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# Ecosystem Services Assessment in Rio de Janeiro:

## The case of Guerenguê River's Sub-basin in Jacarepaguá's Watershed.

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# Ecosystem Services Assessment in Rio de Janeiro: The case of Guerenguê River's Sub-basin in Jacarepaguá's Watershed.

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*"Everyone in the world depends completely on Earth's ecosystems and the services they provide…"*

Millennium Ecosystem Assessment 2005a

## Summary

Urban sprawl that started on 1970s in the Jacarepaguá's Lowlands deeply affected its sensitive environment. It leads to several problems, among those, reduction of human well-being. In 1996, a catastrophe reached the area. Erosion and flooding affected many people. Nowadays, the place still has several populated flood prone areas and landslide risky areas. The absence of sewage collection, green spaces and the irregular occupation of environmental protected areas result in a region that is characterized by visual, air and water pollution. The depletion of ecosystem services leads the area to a low life quality status.

The main objective of this research is to investigate the ecosystem services that could be provided by Guerenguê River's Sub-basin in Rio de Janeiro. To do so, the methodology adopted included, in-depth interviews, secondary data analysis, and observation, based on qualitative and quantitative data. The framework of analysis was based on ecosystems services.

Ecosystems Services are those ecosystem processes that provide directly or indirectly benefits to human life, therefore, influencing human well-being. Humans depend on nature to get food, water and materials to an uncountable number of activities. These resources depend on ecosystems processes (Millennium Ecosystem Assessment, 2005a). However, according to the Millennium Ecosystem Assessment (2005a), humans have changed the ecosystems like never before in history affecting their own well-being. Under business as usual, environment depletion tends to increase unless the full value of ecosystem services is taken into account.

The main findings of this study were the land uses present in the Sub-basin of Guerenguê River, its ecosystems services, actions to improve and the ecosystem services that could be provided by the restored sub-basin. The conclusions rely on the finding of the most important and urgent actions to be taken and recommendations like a production of a clearer research direction and integrated approach by the decision and policy makers.

## Keywords

Ecosystem services assessment, wetland, watershed management, sustainable development, flooding

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# Chapter 1: Introduction

## 1.1 Background

How much nature worth? What nature offers to humans and what is its value? In fact, human being depends on nature to get food, water and materials to an uncountable number of activities. These resources depend on ecosystems processes. Those ecosystem processes that provide directly or indirectly benefits to human life are called Ecosystems Services and are strongly related to human well-being (Millennium Ecosystem Assessment, 2005a). However, according to the Millennium Ecosystem Assessment (2005a), humans have changed the ecosystems like never before in history affecting their own well-being. Under business as usual, environment depletion tends to increase unless the full value of ecosystem services is taken into account.

In this thesis, the ecosystems services present in the Sub-basin of Guerenguê River in Rio de Janeiro will be assessed according to the different land uses adopted in the region. Moreover, the identification of ecosystems services that could be provided by a restored wetland will also be assessed based on actions to enhance it and on the historical background of the region. The selection of this area is based on its strategic location for the city expansion Logit (2011).and historical urban sprawl according to de Barros (2001).

This study brings awareness about the importance of human interference in ecosystem services and its consequences. More than that, according to Millennium Ecosystem Assessment (2005a) these actions have deep impacts on human well-being. According to what is stated on the Millennium Ecosystem Assessment (2005a) people need nature and its processes to live. However, many of these services are damaged by human actions resulting in losses to the whole society.

## 1.2 Problem Statement

Urban sprawl that started on 1970s in the Jacarepaguá's Lowlands deeply affected its sensitive environment (de Barros 2001). It leads to several problems, among those, reduction of human well-being to some people. In 1996, a catastrophe reached the area. Erosion and flooding affected many people. Nowadays, the place still has several populated flood prone areas and landslide risky areas (Miguez 2007 and Municipality GeoRio Map of landslide susceptibility). In addition, the absence of sewage collection, green spaces and the irregular occupation of environmental protected areas result in a region that is characterized by visual, air and water pollution. The depletion of ecosystem services leads the area to a low life quality status.

## 1.3 Research Objective

The main objective of this research is to investigate the ecosystem services that could be provided by Guerenguê River's Sub-basin in Rio de Janeiro. For this purpose, the specific objectives are:

- Identify the land uses present in the Sub-basin of Guerenguê River
- Analyze the ecosystem services available in Guerenguê River's Sub-basin in its current situation
- Identify possible actions to restore the sub-basin
- Investigate the potential ecosystem services of restored Guerenguê River's sub-basin

## 1.4 Research Question

In order to achieve the objectives of this research, research questions where formulated. The main research question is:

What are the ecosystem services that could be provided by restored Guerenguê River's sub-basin in Rio de Janeiro?

To answer the main question, the specific questions are:

1. What are the land-uses present in Guerenguê River's Sub-basin in Rio de Janeiro?
2. What are the ecosystem services available in the specified sub-basin?
3. What actions can be taken to restore the sub-basin?
4. What are the potential ecosystem services of a restored Guerenguê River's Sub-basin in Rio de Janeiro?

## 1.5 Significance of the Study

The significance of this work relies on the importance of the selected area, the worldwide accepted framework adopted and on its possibility to be used as reference for other similar areas. The area selected as a case study is part of a strategic region for urban expansion of the city of Rio de Janeiro. In addition, several studies show the relation of ecosystem services and human well-being (Millennium Ecosystem Assessment 2005a). However, the area of Guerenguê River Sub-basin developed in a very unsustainable way as it will be presented along this work. Carrying out an ecosystem services assessment, is possible to identify critical areas where actions are of extreme importance to the maintenance of life quality and even, life safety in what it concerns to natural hazards. Moreover, this analysis and results serve as an example for other areas of the region if considered specific local data.

The area where Guerenguê River's Sub-basin is located is a strategic area of the city of Rio de Janeiro. This is where the Pilot Urban Plan of Lúcio Costa designated the 'New Metropolitan Centre' (Costa, 1976). This area is also where one of the most important historical monuments of the region is located: 'Colonia Juliano Moreira'(Tardin 2008). Recently, the area also became part of an important project of transport system expansion: the implementation of the highways and Bus Rapid Transit System Transolímpica and Transcarioca for the Olympic Games of 2016 (Logit 2011).

Even with all importance of the area, uncontrolled urban sprawl deeply affected its local environment and consequently, human well-being. This study tackles the different types of land uses and their environmental aspects, by an analysis framework that is strongly related to human well-being: Ecosystem Service Assessment (Millenium Ecosystem Assessment 2003). With this framework, is possible to relate the need of environmental restoration in degraded areas from the perspective of human being. It can also direct decision making in prioritizing actions that would bring important benefits not only related to life quality, but also, to life safety. This is the case of ecosystems services of natural hazard and erosion protection. They protect against flooding, erosion and landslides. These events have already affected the area and some areas are still under risk (Miguez 2007 and Municipality GeoRio Map of landslide susceptibility).

To finalize the importance of the current study is possible to state that the achieved results and based on the characteristics of the sub-basin analysed, this work can be generalized to a wider arena. Adaptations are necessary to each case but these results repeat within themselves and the same happens if compared with other areas. The importance of generalization, even

with restrictions, relies on the fact that solutions for similar areas can be further developed based on this work.

## 1.6 Scope and Limitations

The scope of this work can be described in three ways: the area of the case study, the analytical framework and the time available. The area studied corresponds to Guerenguê River's Sub-basin which is located in the west part of city of Rio de Janeiro as better described further in this thesis. The framework to guide the research is based on ecosystem services presented on Millennium Ecosystem Assessment (2005b). The time available to do the research is short if considered the diversity and amount of data to be collected. The timetable is available in the Annex 4 Time Scheduling. According to Millennium Ecosystem Assessment (2003) the application of Ecosystems Services Assessment is highly data intensive and requires detailed and in depth assessments by various specialists. The topic is also quite new and because of that not a lot of data is available yet. Studies like 'Portland's Green Infrastructure: Quantifying the Health, Energy, and Community Livability Benefits' (City of Portland Bureau of Environmental Services 2010) and 'An Integrated Wetland Assessment Toolkit: A guide to good practice' (eds. Springate-Baginski, Allen & Darwall 2009) show some of these difficulties and limitations in assessing watersheds' ecosystems benefits.

The main limitations of this research are related to the time available and the data to be collected. Collection of data presents difficulties related to its diversity, format, availability and quantity. Ecosystem services assessment demand a large diversity of data recorded along a period of time. Ecosystems and its services usually overlap and that brings another difficulty to the achievement of the objectives of this research (Millennium Ecosystem Assessment 2003). There are several categories of data to be collected and each of them are part of long term studies. Some examples are: biological, climatological, environmental quality, geographical and cultural among others. Biological data required include species, amount of them, natural process of nutrients etc. Climatological data to be included are changes in temperature, precipitation etc. Geographical data like type of soil, vegetation and hydrology, susceptibility to erosion, flooding among others are also required. Moreover, cultural data related to heritage, identity, tourism, personal feelings, among others, are also necessary. This great diversity demands a lot of time to collect the data and also to analyze them. The fact that ecosystem services assessment is quite new approach also brings us to a problem which is related to the format that the data is collected is not in the format required to analyze it. It leads to limitations of time to organize them or even the impossibility to use the data. Many times, the data required is even not available. It is the case for example of air quality. No data about the air quality in the region could be found. In short, the amount of data collected would require much more time to be analyzed than what is available.

Other limitations are related to interviews and observations. The plan described in the item 3.3 Sample Size and Selection of starting contacting specialists from the Federal University of Rio de Janeiro that could indicate contacts in the municipality did not work because of one of the biggest strikes of the history of the university was happening during the period of time of field work and still is while this thesis is written. Once the municipality specialists were reached, another difficulty arose due to the fact they did not want to go through the interview guidelines. On the other hand, they suggested other contacts and secondary data. To interview dwellers and do observations on site, some difficulties were found and were related to the distance of the site, the existence of irregular settlements under the control of drug traffic and time constraint. To get respondents it is necessary to go several times in the location and count on their availability to participate in the research. Some dwellers were asked to be

interviewed but each of them had different reasons to do not participate or did not have the profile required to fill the criteria necessary. Only a dweller had the willingness to participate and matched with the profile required.

Based on the limitations of the research is possible to conclude that the data collection and the data analysis demand much more time to provide a more complete study. However, within its constraints, it was possible to achieve the objectives proposed in this thesis.

# Chapter 2: Literature Review

## 2.1 Introduction

In this chapter, several interrelated concepts and theories will be explored in order to provide a base to this research. The main source of these theories relies on the Millennium Ecosystem Assessment Reports due to their great combination of worldwide researchers and scientists. In order to sew up what are Ecosystem Services, concepts like ecosystem, biodiversity and human well-being are tackled as much as their interrelations. To continue building the conceptual framework, drivers of change in ecosystem and its services will be also addressed. After that, concepts of ecosystem value and valuation approaches will be cited. To conclude this literature review, ecosystem services related to wetlands will be discussed.

### 2.1.1 Millennium Ecosystem Assessment

The Millennium Ecosystem Assessment was a four-year international work program (from 2001 to 2005) called by the United Nations to "assess the consequences of ecosystem change for human well-being and the scientific basis for actions needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being" (Millennium Ecosystem Assessment 2005a, Preface p. v).

According to the Millennium Ecosystem Assessment Reports "everyone depends on nature and ecosystem services for a decent, healthy and secure life" (Millennium Ecosystem Assessment 2005a, Preface p. v). In the last decades, due to the crescent demand for food, water and energy, humans have changed the ecosystems like never before in history. This has reduced nature's capability to provide the services needed by human being.

The need for change of human actions is stated on Millennium Ecosystem Assessment report as indispensible to guarantee not only the Millennium Development Goals to reduce poverty, hunger and disease but to reduce climate change, vulnerability to natural disasters and maintain water supply, among others.

### 2.1.2 The Economics of Ecosystems and Biodiversity (TEEB)

The Economics of Ecosystems and Biodiversity was a study requested by G8+5 Environment Ministers to assess the economics of biodiversity loss in the globe. Their reports are available since 2008. It was found by them that the investments in healthy ecosystem are important not only to reduce poverty but to enhance climate change mitigation and adaptation. They also highlight the importance of considering ecosystem services values by markets due to its high economic importance to every stakeholder. The absence of market prices for ecosystem services leads to decisions that depreciate these services and, consequently, human well-being. Several tools are provided in their reports to advice policy makers. (The Economics of Ecosystems and Biodiversity 2009a)

## 2.2 Ecosystem Services

### 2.2.1 Ecosystem

The definition adopted by the Millennium Ecosystem Assessment of Ecosystem is the one used by the Convention on Biological Diversity stated on Rio Declaration on Environment and Development by United Nations in 1992: "a dynamic complex of plant, animal and micro-organism communities and their nonliving environment interacting as a functional unit" (United Nations 1992: Article 2 in Millennium Ecosystem Assessment 2003 p.51). It is based on several studies about the theme since 1938 when an initial scientific definition was made by Arthur Tansley.

Ecosystems have different scales and different levels of interactions. In a big scale, the biosphere of the planet is an ecosystem composed of several ecosystems that interact with each other. In well-defined ecosystems, the level of ecosystem interactions across its boundaries is weaker than interactions among its elements. It means that ecosystems can have their limits determined but they also overlay each other composing the environment.

### 2.2.2 Biodiversity

Biodiversity is strongly related to ecosystems. Its definition to the present work is the same as in United Nations Report: "the variability among living organisms … and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (United Nations 1992: Article 2 in Millennium Ecosystem Assessment 2003 p.51). Therefore, it is possible to conclude that not only the diversity of species is important for the interactions in their own ecosystem but also the diversity of ecosystems itself.

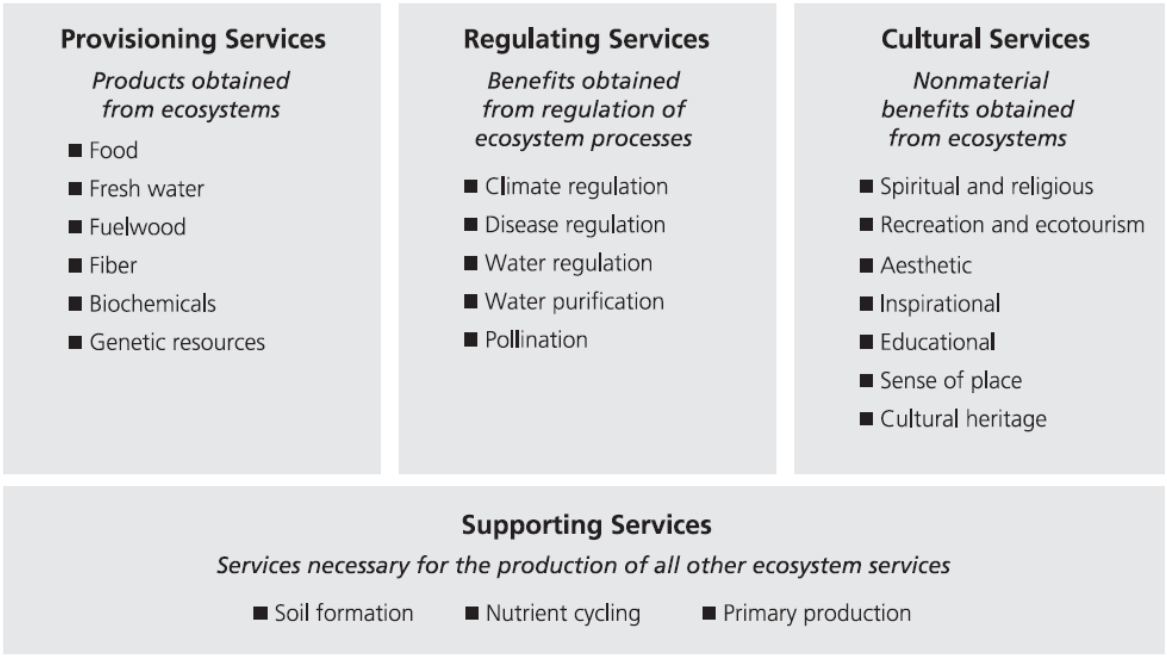
### 2.2.3 Ecosystem Services

The definition used by the Millennium Ecosystem Assessment is that "ecosystems services are the benefits that people obtain from ecosystems." (Millennium Ecosystem Assessment 2003, p.53). That is because ecosystems have processes and conditions made by their own species (Daily 1997b:3 in n Millennium Ecosystem Assessment, 2003, p.53) and, as long as human being is part of ecosystems, it influences its processes and conditions but also benefit from it. More than that, these processes and conditions generate products that are beneficial for humans. These goods and services are ecosystem services.

As mentioned before, biodiversity plays an important role in the maintenance of ecosystem. Studies show that biodiversity's changes, affect the function of ecosystems (Schulze and Mooney 1993; Loreau et al. 2002 in Millennium Ecosystem Assessment 2003, p. 60). In The Economics of Ecosystems and Biodiversity (TEEB) for Policy Makers Chapter 4, Integrating Ecosystem and Biodiversity Values into Policy Assessment, is said that the biodiversity crisis is caused by the unsustainable growth and the undervaluation of ecosystem services due to lack of comprehension of its long-term economic benefits.

In order to be assessed, Ecosystem Services can be grouped in different ways. In this study we use the same classification as Millennium Ecosystem Assessment which is made by functions even though some overlapping occurs.

**Figure 1 Ecosystems Services**




Source: Millennium Ecosystem Assessment 2003 p.57

**Box 1: Types of Ecosystem Services**

Provisioning Services: Products provided by ecosystems to human being.

Regulating Services: Ecosystem processes produce a regulation which is beneficial and in some cases indispensable for humans.

Cultural Services: Nonmaterial benefits that depend on each culture or person.

Supporting Services: Services needed to the maintenance of ecosystems that affects humans in long term or indirectly.

Source: Millennium Ecosystem Assessment 2005a, Preface p.vi

According to Millennium Ecosystem Assessment, a multi-sectorial approach is indispensable to assess ecosystems services. Each ecosystem service should have its condition, supply and interactions analyzed. It is also important to bind it in time and space. Analyze ecosystem condition is to assess how well it is and how this ecosystem performs in provide certain service. There are several methods and measures to assess it in order to know its value. With this evaluation is possible to manage them in a sustainable way. It means to manage maintaining and conserving the ecosystems for future generations.

## 2.3 Ecosystems and Human well-being – Ecosystem Approach

By understanding that humans are part of ecosystems, Ecosystem Approach links human well-being with the environment. According to the Convention on Biological Diversity, Ecosystem Approach is defined as "a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way" (Millennium Ecosystem Approach 2003, p.52).

According to the Millennium Ecosystem Assessment human well-being has several definitions (Alkire 2002 in Millennium Ecosystem Assessment 2003, p.73) and most of them include:

- Basic material needs for a good life
- Freedom
- Health
- Personal security
- Good social relations

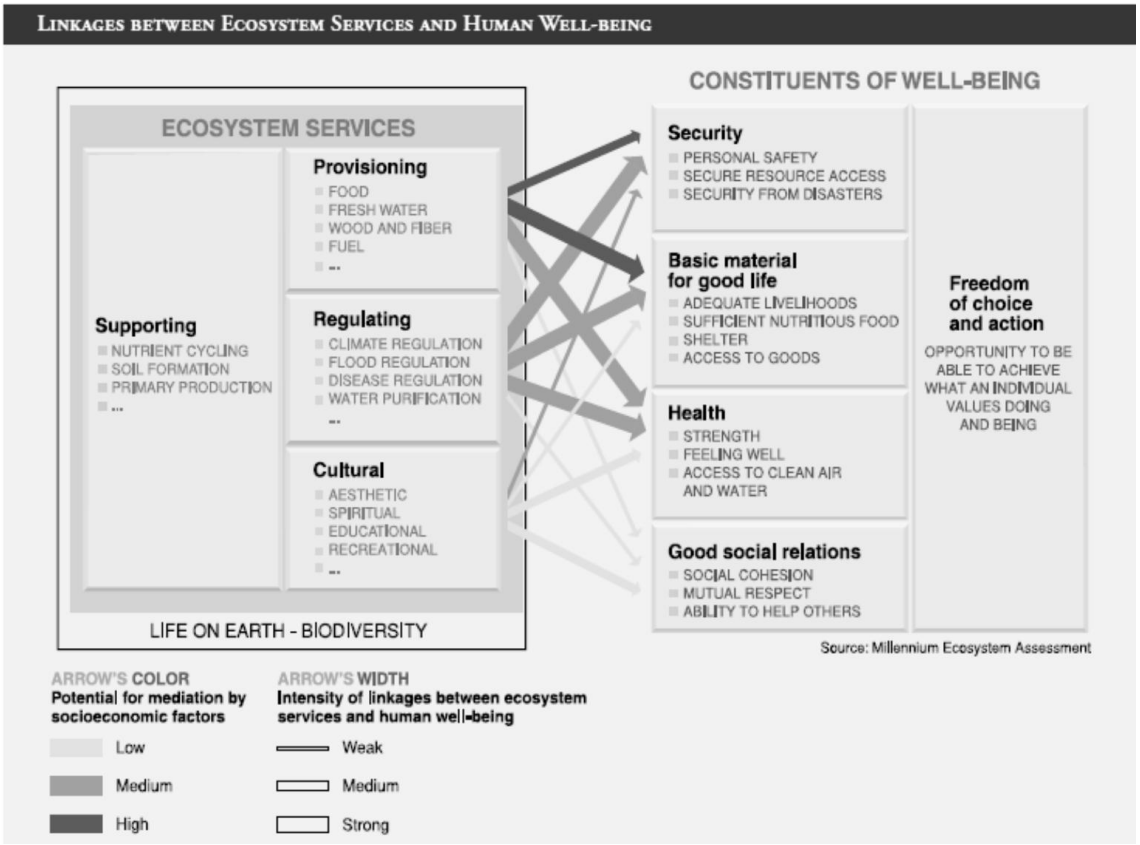
Physical, social, psychological and spiritual fulfillment conditions are provided by all these together. A major privation of these elements can be stated as poverty. Poverty is defined as "the pronounced deprivation of well-being" by World Bank in the World Development Report 2000/01 (Millennium Ecosystem Assessment 2003, p.74).

Relating these items with what is provided by ecosystem services is possible to realize that many of them are offered by ecosystem services. Therefore, the condition of the ecosystem is important to the maintenance of the provision of these services. Livelihood sustainability, biodiversity are part of its maintenance.

Livelihood sustainability has three aspects that include environmental and social contexts. According to the Department for International Development in Sustainable Livelihoods Guidance Sheets from 1999 in Millennium Ecosystem Assessment 2003, cooperation and recovery, maintenance or enhancement of livelihood capabilities and assets is the first aspect. The second is enhancement or no diminishment of other's livelihoods in the social context and the third one is no depletion of ecosystems that can damage livelihoods and well-being of others. The three aspects refer to the present and future times. Biodiversity supports and is supported by all these.

In the graph, Ecosystem Services are clustered in four groups: Supporting, Provisioning, Regulating and Cultural. On the right part of the graph, the constituents of well-being are grouped in 5 groups: Freedom of choice and action, Security, Basic material for good life, Health and Good Social Relations. According to the graph, different ecosystem services have different 'potential for mediation by socioeconomic factors' and are classified by low, medium and high, increasing the tone of the color as higher it is. The thickness of the arrows indicates the 'intensity of linkages between ecosystem services and human well-being'. It is possible to visualize that the Regulating and Provisioning Ecosystem Services have more intense linkages with Security and Basic Material for good life and Health. The Provisioning Services have more 'potential for mediation by socioeconomic factors' on Security and Basic material for good life.

**Figure 2: Linkages between Ecosystem Services and Human Well-being**




Source: Millennium Ecosystem Assessment 2005a, Preface p.vi

## 2.4 Drivers of Change in Ecosystem and their Services

As mentioned before, human being depends on natural assets and services to live. Each people, nation or company have their own standards of needs. The level of demand and hence the level of interference on ecosystems are defined by specific actors. According to Millennium Ecosystem Assessment (2003), these decision makers are pushed by Global Driving forces as demographic; economic; sociopolitical; science and technology; cultural and religious; physical, biological and chemical. These drivers of change can affect ecosystems and its services directly or indirectly, with more or less intensity, in a shorter or longer term, at local, regional and (or) global level and generate positive or negative externalities.

Direct effects are more clearly at the local level where people activities alter the condition and the capacity of ecosystems services, motivated by any of the identified driving forces. Indirect effects can happen regionally, even when the drivers are outside an ecosystem. They can be for example private companies, composed by individuals and communities, that basically motivated by personal gains, take collective decisions for local, national and global business.

Decisions made by people affect more at the local level as actions taken by public and private decision makers affect the ecosystems at regional level (municipal, provincial and national level) and international level (globally). As long as public decisions are basically motivated to unit well-being for nations, sub-national units, supra-national units and trading communities, each level can have more than one ecosystem and therefore, some decisions regarding to that should consider to be taken over level borders.

These informations are important to understand the forces that are involved in the relation of human being and ecosystems. There are so, endogenous drivers of decision-making at the regional level like: institutions; service and commodity prices and markets; technology development; macroeconomic policy. And exogenous drivers like: changes in land use and cover patterns; development in basic science; ecosystem characteristics. All these influence the valuation of ecosystems according to Millennium Ecosystem Assessment (2003).

## 2.5 Concepts of ecosystem value and valuation approaches

In Pricing Nature by Hanley and Barbier (2009) it is mentioned that when ecosystems clearly started to disappear was when policy makers begging considering how environmental decision-making and human welfare were affected by these losses. A number of scientists, among them economists and ecologists produced several inter-disciplinary assessments emphasizing that goods and services from ecosystems needed to be "valued' (Daily 1997, Heal et al. 2005, Millennium Ecosystem Assessment 2005a, Pagiola et al. 2004, World Resources Institute 2001 in Hanley and Barbier 2009).

In the Millennium Ecosystem Assessment (2003) is stated that as long as humans benefit from ecosystem services, they have economic value. Ecosystems can be valued differently according to different ways to understand it. Some concepts are utilitarian (anthropocentric) and non-utilitarian. Non-utilitarian approach complements or counter-balance utilitarian approach.

Use values are those related to direct and indirect services and therefore have economic value. However, non-use values, related to bequest and existence services, are also valued by societies and are based on preference. Several times, cultural services related to community identity and sociocultural values of ecosystems go beyond preference.

The importance to valuate ecosystems according to the Millennium Ecosystem Assessment (2003) is based on the common reasons to undertake it. They are:

- "to assess the overall contribution of ecosystems to social and economic well-being
- To understand how and why economic actors use ecosystems as they do and
- To assess the relative impact of alternative actions so as to help guide decision-making" (Millennium Ecosystem Assessment 2003)

Part of the total wealth of nations and flow benefits come from its ecosystems. However, national total income calculated through the conventional systems of accounts does not capture many ecosystem values because they are not traded. More than that, depletion or appreciation values are usually not taken into account. This way, the state of well-being has its indications wrongly stated what can lead to wrong decisions. Therefore, more adequate indicators are important to guarantee well-fare, sustainable use, inter-temporal allocation of natural resources and for intergenerational equity according to Millennium Ecosystem Assessment (2003).

Still as stated by Millennium Ecosystem Assessment (2003), it is also important to undertake valuation of ecosystems to understand why and how ecosystems are used by human being the way it is done. Individuals, public and private behavior and choices are guided by market. Ecosystem services are not usually priced what leads to an unsustainable use of resources. The availability of information about the value of the services provided by ecosystems is therefore important for decision makers. That leads us to the third common reason to undertake ecosystems valuation where ecosystem management regimes can be compared and selected more adequately.

Hanley and Barbier (2009) states that the main reason to do ecosystem valuation is usually important for land use policies in order, for instance, to determine in an area how much of its ecosystem should be conserved or converted to other use. Reports by The Economics of Ecosystems and Biodiversity (2009a, 2009b) agrees with this point of view because it says

that by knowing the value of ecosystems services and consequently the value of ecosystems because without ecosystem there is no service provided, more cost-efficient decisions can be resulted and inappropriate trade-offs can be avoided.

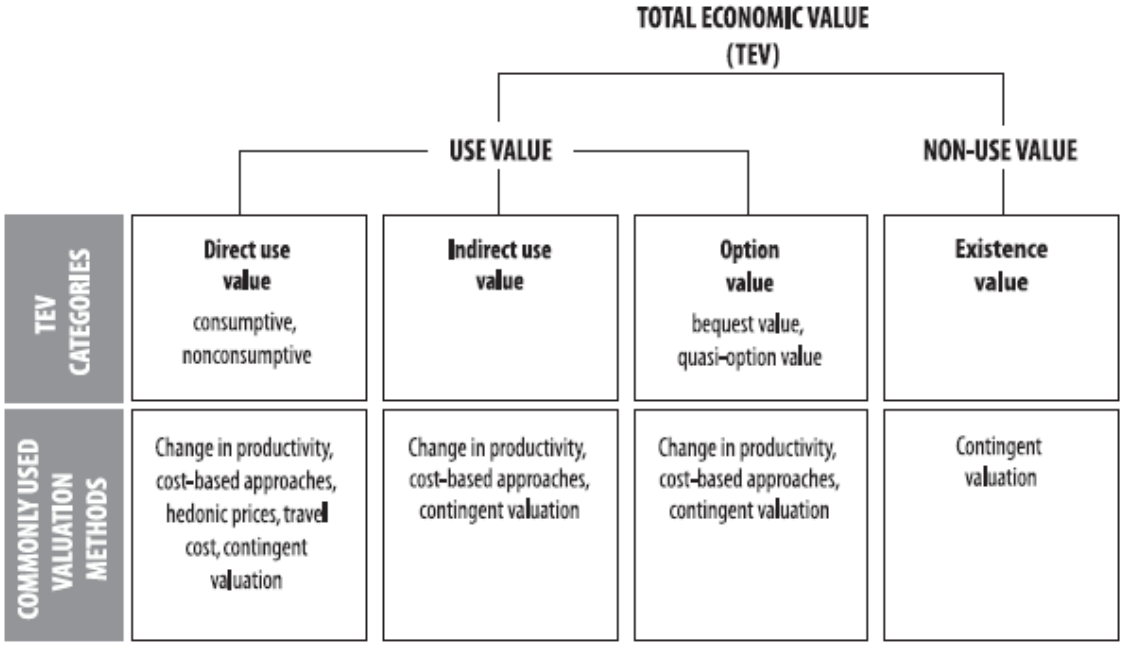
### 2.5.1 Economic Valuation Techniques

Total Economic Value is a "framework for looking at the utilitarian value of ecosystems" (Millennium Ecosystem Assessment 2003, p.132). In the guide produced by the Department for Environment, Food and Rural Affairs, UK (Defra) entitled 'An introductory guide to valuing ecosystem services' (2007) several valuation methods are listed:

- Revealed Preference Methods: Market prices; Averting behavior; Productions functions approach; Hedonic pricing; Travel cost method; Random utility models.
- Stated Preference methods: Contingent valuation; Choice modeling;
- Cost based approaches: Opportunity cost; Cost of alternatives/substitute goods; Replacement cost method (also known as shadow project costs)

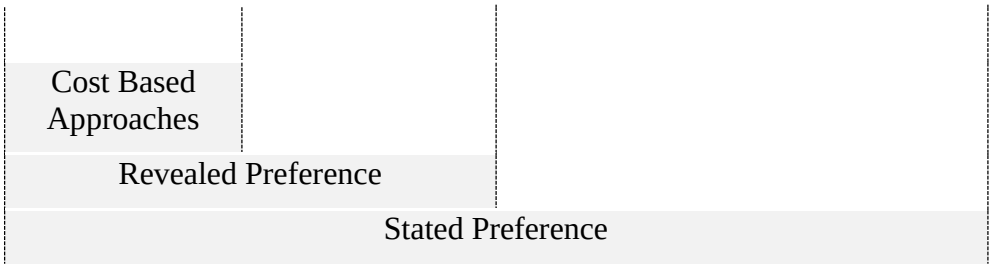
The most common used methodologies are shown in the figure bellow.

**Figure 3: Total Economic Value**




Source: Millennium Ecosystem Assessment 2003, p.132

**Figure 4: Valuation Approach**




Adapted by the Author 2012 from Defra (Department for Environment, Food and Rural Affairs, UK) entitled 'An introductory guide to valuing ecosystem services' (2007) – Type of Valuation Approach related to the type of use.

There is a special type of approach called Benefits Transfer Approach that, according to Millennium Ecosystem Assessment (2003), this approach estimates values in one context in order to estimate it in a different context. For this estimation any method can be used. To be reliable and valid some conditions must be followed: the commodity or service under valuation must be identical in both sites and the affected population must have the same characteristics. It can also be developed by values of similar ecosystems from other studies according to The Economics of Ecosystems and Biodiversity (2009a). It is very useful when the valuation process have constraints about information and resources. It must be done carefully due to wide changes even among similar ecosystems. Therefore TEEB adds to the conditions related to reliability and validity mentioned in Millennium Ecosystem Assessment (2003) that the sources of information should be reliable as referred by The Convention on Biodiversity Decision VIII/26.

There are some reasons that limit monetary valuation. The main reasons are, first of all, it is an expensive procedure due to its costs and required expertise and second, values can vary over time due to market changes like scarcity or demand that are increasing every year as stated by The Economics of Ecosystems and Biodiversity (2009a).

## 2.6 Wetlands

The definition of wetlands adopted by the Millennium Ecosystem Assessment Synthesis Report 'Ecosystems and Human well-being: wetlands and water' (2005b) is the one from the 'Ramsar Convention on Wetlands' where wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres" (Article 1.1 of the Convention text in Millennium Ecosystem Assessment 2005b, p. v). This definition includes so the inland wetland of rivers as long as these are temporarily flooded area.

Wetlands provide several ecosystem services and is considered by Millennium Ecosystem Assessment that its wise use is "the maintenance of their ecological character within the context of sustainable development, and achieved through the implementation of ecosystem approaches." (Ramsar 2005 in Millennium Ecosystem Assessment 2005b, p. v)

According to Millennium Ecosystem Assessment (2005b), wetlands all over the world were destroyed or degraded in the last century and they are still being depleted. The result is that more and more people are vulnerable to floods, droughts, erosion, fish scarcity among others services like water purification, tourism, recreation, etc. These are some services provided by wetlands however the pressures over it are enormous.

Unconverted wetlands offer so many benefits to human being that its value is usually higher than converted land if taken into account marketed and non-marketed economic benefits. Resiliency improvement is a viable method for both adaptation and mitigation of climate change effects.

### 2.6.1 Wetland degradation

Population growth and unsustainable economic development are the primary indirect drivers of loss and degradation of wetlands. The direct ones "include infrastructure, development, land conversion, water withdrawal, pollution, overharvesting and overexploitation, and the introduction of invasive alien species" (Millennium Ecosystem Assessment 2005b, p. 4). More than that, economic drivers like lack of information and market distortions also contribute to the depletion wetlands.

In Millennium Ecosystem Assessment Synthesis Report 'Ecosystems and Human well-being: wetlands and water' (2005b), some scenarios are made and for all of the four presented, the demand for ecosystems services will increase by 2050 and land use continues to be the main driver of the depletion of wetlands. It means that restoration and conservation of wetlands is urgent.

### 2.6.2 Ecosystem services provided by wetlands

The following tables include the ecosystem services provided by wetlands with its related magnitude and "examples of hydrological-ecological relationships at different river flows that support ecological character of wetlands and their services" (Millennium Ecosystem Assessment 2005b, pp. 31-33).

**Table 1: Relative magnitude (per unit area) of ecosystem services derived from different types of wetland ecosystems**

**Table 3.1. Relative Magnitude (per Unit Area) of Ecosystem Services Derived from Different Types of Wetland Ecosystems** (Derived from C19 Table 19.2, C20 Table 20.1)

Scale is low •, medium ●, to high: ⬤; not known = ?; blank cells indicate that the service is not considered applicable to the wetland type. The information in the table represents expert opinion for a global average pattern for wetlands; there will be local and regional differences in relative magnitudes.

| Services | Comments and Examples | Permanent and Temporary Rivers and Streams | Permanent Lakes, Reservoirs | Seasonal Lakes, Marshes, and Swamps, Including Floodplains | Forested Wetlands, Marshes, and Swamps, Including Floodplains | Alpine and Tundra Wetlands | Springs and Oases | Geothermal Wetlands | Underground Wetlands, Including Caves and Groundwater Systems |
|---|---|---|---|---|---|---|---|---|---|
| **Inland Wetlands** | | | | | | | | | |
| **Provisioning** | | | | | | | | | |
| Food | production of fish, wild game, fruits, grains, and so on | ⬤ | ⬤ | ⬤ | ⬤ | • | • | | |
| Fresh water | storage and retention of water; provision of water for irrigation and for drinking | ⬤ | ⬤ | ● | • | • | • | | ⬤ |
| Fiber and fuel | production of timber, fuelwood, peat, fodder, aggregates | ● | ● | • | ⬤ | ● | • | • | |
| Biochemical products | extraction of materials from biota | • | • | ? | ? | ? | ? | ? | ? |
| Genetic materials | medicine; genes for resistance to plant pathogens, ornamental species, and so on | • | • | ? | • | ? | ? | ? | ? |
| **Regulating** | | | | | | | | | |
| Climate regulation | regulation of greenhouse gases, temperature, precipitation, and other climatic processes; chemical composition of the atmosphere | • | ⬤ | • | ⬤ | • | • | • | • |
| Hydrological regimes | groundwater recharge and discharge; storage of water for agriculture or industry | ⬤ | ⬤ | ● | ● | • | • | | • |
| Pollution control and detoxification | retention, recovery, and removal of excess nutrients and pollutants | ⬤ | ● | • | ● | • | • | | ● |
| Erosion protection | retention of soils and prevention of structural change (such as coastal erosion, bank slumping, and so on) | ● | • | • | ● | ? | • | | • |
| Natural hazards | flood control; storm protection | ● | ⬤ | ⬤ | ● | ● | • | | • |
| **Cultural** | | | | | | | | | |
| Spiritual and inspirational | personal feelings and well-being; religious significance | ⬤ | ⬤ | ● | ● | • | ● | • | • |
| Recreational | opportunities for tourism and recreational activities | ⬤ | ⬤ | ● | • | • | • | • | • |
| Aesthetic | appreciation of natural features | ● | ● | • | ● | • | • | • | • |
| Educational | opportunities for formal and informal education and training | ⬤ | ⬤ | ● | ● | • | • | • | • |
| **Supporting** | | | | | | | | | |
| Biodiversity | habitats for resident or transient species | ⬤ | ⬤ | ● | ● | • | • | • | • |
| Soil formation | sediment retention and accumulation of organic matter | ⬤ | • | ● | ⬤ | • | ? | ? | |
| Nutrient cycling | storage, recycling, processing, and acquisition of nutrients | ⬤ | ⬤ | ⬤ | ⬤ | • | • | ? | • |
| Pollination | support for pollinators | • | • | • | ● | • | • | | |

Adapted by the Author 2012 from Millennium Ecosystem Assessment 2005b, pp. 31-33

**Table 2: Examples of hydrological-ecological relationships at different river flows that support ecological character of wetlands and their services**

**Table 3.2. Examples of Hydrological-Ecological Relationships at Different River Flows That Support Ecological Character of Wetlands and Their Services** (Derived from C19.2, C20.2)

| Flow Component | Ecological Role |
|---|---|
| Low (base) flows<br>*Normal level:* | provide adequate habitat space for aquatic organisms<br>maintain suitable water temperatures, dissolved oxygen, and other chemical conditions, including salinity<br>maintain water table levels in floodplain and plant soil moisture<br>provide drinking water for terrestrial animals<br>keep fish and amphibian eggs suspended<br>enable passage of fish to feeding and spawning areas<br>support hyporheic organisms (living in saturated sediments) |
| Low (base) flows<br>*Drought level:* | enable recruitment of certain floodplain plants<br>purge invasive, introduced species from aquatic and riparian communities<br>concentrate prey into limited areas to the benefit of predators |
| Higher flows<br>(small flood pulses) | shape physical character of river channel, including availability and heterogeneity of different biotopes (such as riffles, pools) and microhabitats<br>restore normal water quality after prolonged low flows, flushing away waste products, pollutants, and proliferations of nuisance algae<br>maintain suitable salinity conditions in estuaries<br>prevent encroachment of riparian vegetation into the channel<br>aerate eggs in spawning gravels, prevent siltation of cobble interstices<br>determine size of river bed substrata (sand, gravel, cobble, boulder) |
| Large floods | provide fish migration and spawning cues<br>provide new feeding opportunities for fish and waterbirds<br>recharge floodplain water table<br>maintain diversity in floodplain forest types through prolonged inundation (plant species have differing tolerances for flooding) and their natural regeneration processes<br>control distribution and abundance of plants on floodplain<br>trigger new phases of life cycles (such as insects)<br>enable fish to spawn on floodplain, provide nursery area for juvenile fish<br>deposit nutrients on floodplain<br>maintain balance of species in aquatic and riparian communities<br>create sites for recruitment of colonizing plants<br>shape physical character and habitats of river channels and floodplain<br>deposit substrata (gravel, cobble) in spawning areas<br>flush organic materials (food) and woody debris (habitat structures) into channel<br>purge invasive, introduced species from aquatic and riparian communities<br>disburse seeds and fruits of riparian plants<br>drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes)<br>provide plant seedlings with prolonged access to soil moisture<br>drive floodplain productivity |

Source: Millennium Ecosystem Assessment 2005b, p. 38

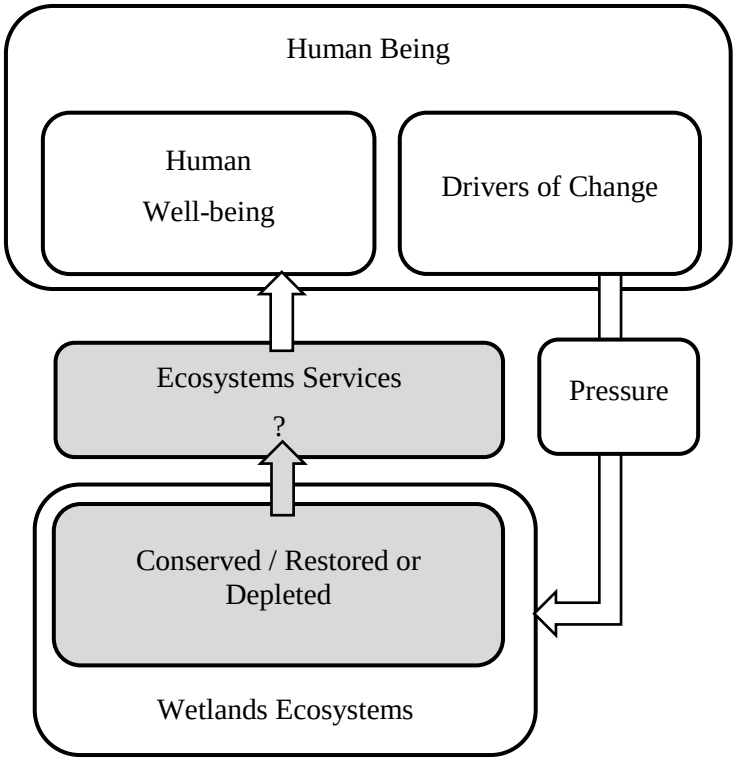
## 2.7 Conclusion

Ecosystem Services are those services provided by ecosystems to human beings such as fresh water, wood, fish, flooding protection among several others. Wetlands are special ecosystem because it provides several services and have several overlapping with other ecosystems. However, these ecosystems are under pressure of human action. These pressures change ecosystems affecting not only its fauna and flora, but human well-being. It is even possible to monetize the cost of the lack of ecosystem services. To do so, ecosystem services identification and analysis should be done beforehand. This is the scope of this research as shown on the conceptual framework.

## 2.8 Conceptual Framework

The conceptual framework was formulated based on the relationship of the studied theories and aim to situate the present study in the existing theoretical context. The graph below shows these relations and the highlighted boxes are part of the theories that concern to the scope of this study.

**Figure 5: Conceptual Framework**




Source: Author 2012

Human being is, at the same time, those who put pressure over wetlands ecosystems and those which well-being is affected by its consequences. Pressure results in a depleted, conserved or restored wetland ecosystem. The state of the ecosystem will influence its ecosystem services provision that, consequently, impacts on human well-being. The present work focuses on the wetlands ecosystems of Gurenguê River Sub-basin and its ecosystem services based on the research question presented on item 1.4 Research Question, in order to achieve the objective presented in the item 1.3 Research Objective.

# Chapter 3 – Research Design and Methods

In this chapter, research design and methods are explained. The type of research is described in this introduction and more details about the research design and methods are explored along the chapter. Further, research approach and techniques are portrayed as much as the operationalization of the research questions necessary to direct the data collection methods and analyses that are described in the end of the chapter. The operationalization is followed by the sample size and selection which in the case of this research is more related to the in-depth interviews with dwellers and specialists. Moreover, validity and reliability are tackled and, as mentioned before, this section is conclude with information about data collection and data analyses description.

This research has characteristics of exploratory, descriptive and explanatory. Exploratory because it looks for understanding what is the present situation of the specific area based on a specific framework. It is descriptive because it describes past and actual situation. Moreover, it is also explanatory because it compares different times in the history of the case study: past, present and future. In order to achieve its objectives, the research will be conducted as explained in this chapter.

## 3.1 Research Approach and Techniques

### 3.1.1 Approach

The approach of this research is both qualitative and quantitative. Both types of data are necessary to achieve the objectives and answer the research questions. It is clear in the operationalization the need of both approaches.

### 3.1.2 Techniques

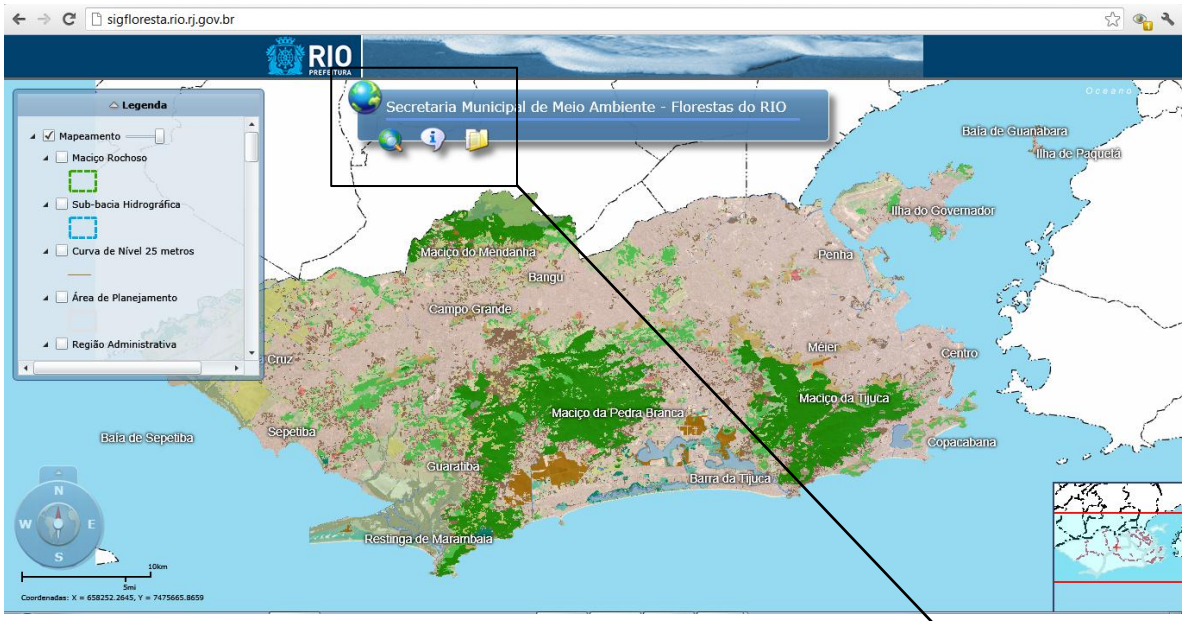
The techniques used in the research were Case Study Single Holistic, analyses of existing data bases, in-depth interviews and observation. The technique of case study in this thesis is based on the typical characteristic of the occupation and its consequences in the watersheds in the city of Rio de Janeiro. The case of Guerenguê River's Sub-basin can be used as representative of the situation of most watersheds in the city. The research mainly consisted of analysis of existing data bases. However, to get access to that and to validate them, in-depth interviews and observations were necessary. In depth interviews were also used as a mean of clarification of the data collected and enrichment by inclusion of different perspectives from the situation.

## 3.2 Operationalization: variables, indicators

The operationalization that guided the research to answer the main question is based on ecosystem service approach. A brief explanation of this process will be made in this section however, the full operationalization is provided in the Annex 1 including a summary of research method, data type, data collection methods and data source.

To assess ecosystem services, land use must be identified beforehand according to the reference study by Tianhong L. et al 2010 'Variations in ecosystem service value in response to land use changes in Shenzhen'. For that purpose and to answer the first specific research question (1), consultations with specialists from the municipality were necessary in order to identify the existence and possibility of use of this data. The municipality, through the Environmental Bureau, has the assessment of all land use and vegetation of the city available online on the interactive website http://sigfloresta.rio.rj.gov.br/:

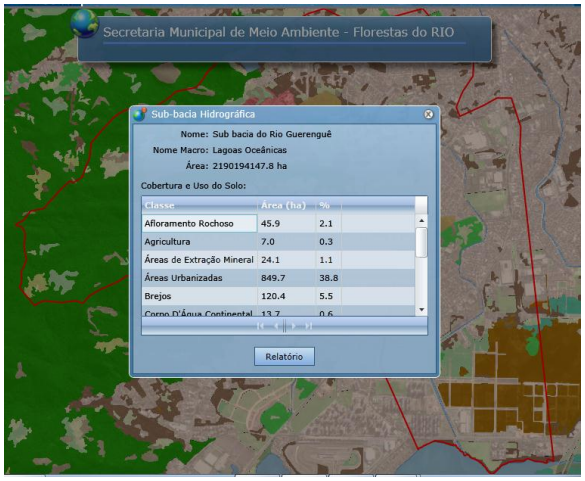
**Figure 6: Municipality Website with land uses and vegetation: sigfloresta.rio.rj.gov.br**

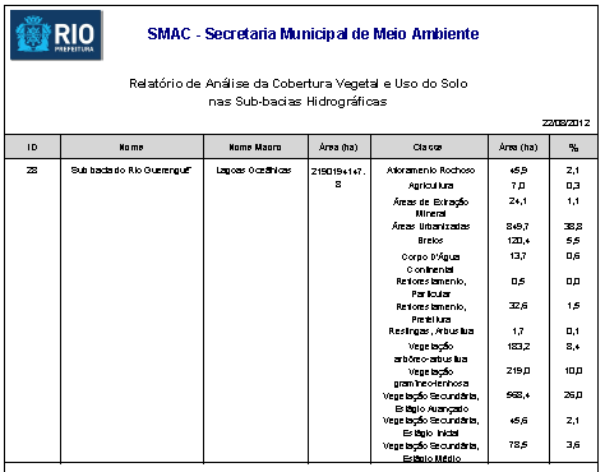



Adapted by the author in 2012 from http://sigfloresta.rio.rj.gov.br/

In the left box, is possible to choose which items will be displayed. In the consult button is also possible to use special filters. In this case, Guerenguê River's Sub-basin was selected. That is shown surrounded by a red line. It also shows the Area and the percentage of each land use and in the sub-basin. The report can be generated and printed or saved. Other information is also available in this website like the assessing process used by them.


**Figure 7: Acquiring reports from municipality website sig.floresta.rio.rj.gov.br**




Adapted by the author in 2012 from http://sigfloresta.rio.rj.gov.br/

After that, based on the concept of Ecosystems Services of wetlands, variables and indicators, adapted from the Millennium Ecosystem Assessment (2005b), were used to operationalize the data collection for the last two specific research questions (2 and 3). The data collection of these items was made by observation on site, consults with specialists from the municipality and dweller interview.

## 3.3 Sample Size and Selection

The selection of people to participate on this research is purposive selected based on the fact that the in-depth interviews in this case aim to collect data and not to precede a quantitative analysis. Moreover, specialists would be providers of spoken information, reports and academic works but also indicating other specialists due to the great number of disciplines involved in an ecosystem service assessment. Dwellers are also important group of respondents due to their daily contact with the situation in the region. Interviewees were selected based on some criteria as described further.

The selection of specialists was mainly related to their contact with the area and the issue. It was expected to contact academic specialists with published work in the sector or about the region. Specialists from the municipality were also required due to a more practical approach to the questions involved. To reach the targeted group of specialists a plan was developed. The plan was to start contacting specialists from the Federal University of Rio de Janeiro where some specialists are known and can provide direct contacts in the municipality due to its partnership in developing strategies for the city.

To interview dwellers some criteria were adopted like house located in all the different identified land uses, years living in the region being 10 years or more preferable and being a community leader or representative. Some difficulties were expected and were related to the distance of the site, the existence of irregular settlements under the control of drug traffic and time constraint. To get respondents it is necessary to go several times in the location and count or their availability to participate of the research. It is also ideal that staff from the municipality join the field trip and indicate community leaders.

The creation of an interview approach strategy, the limitation of selection of interviewees, the prediction of difficulties and solutions were important to direct the research period. Interviewees will be described in the chapter 4, item 4.2 Description of the Sample. The list with people that were contacted is available in the Annex 6.

## 3.4 Validity and Reliability

### 3.4.1 External Validity

As explained earlier in this chapter, Guerenguê River's Sub-basin presents similar characteristics of other sub-basins in the city, therefore working as good representative of other areas. Even though, it cannot be statistically generalized because each watershed part will have different forces interacting with the phenomenon affecting its results.

### 3.4.2 Internal Validity

To guarantee the internal validity, different ways to measure the same variables were made. This triangulation was made by analysis of several secondary data and interviews in order to cross check the results. Whenever possible, alternative interpretations based on different theories and point of view were also considered.

### 3.4.3 Reliability

To guarantee reliability and maximum transparency to the research, its process is well described in this chapter and additional information about its constraints is also provided. A

database of all collected data before process this and the description of how it will be analyzed are also available in the annex 5.

## 3.5 Data collection methods

The data collection methods include:

1. Research of secondary data on data basis, documents, reports, literature and maps
2. Research of primary data is based on interviews and observations including photos and films

It is important to observe that the main results from the interviews with specialists were the access to secondary data and recommendation to other specialists contact. Therefore, no transcription of these interviews was necessary to be done. However, some important information and cross check of secondary data results were also provided during the interviews and are included along the text.

More details about data collection view annexes with operationalization, interview guidelines and time scheduling.

## 3.6 Data analysis methods

The data analysis methods for this research consisted on the review of the data found and, supported by literature, the achievement of the research objective and conclusion.

- Land use data were provided by the municipality through the website http://sigfloresta.rio.rj.gov.br/. (specific question 1)
- To analyze the ecosystem services available on the site based on its current land use (specific research question 2) the framework of ecosystem service approach was used as analytical method.
- The identification of possible actions to restore the sub-basin (specific research question 3), were made through the analysis of secondary data and in-depth interviews.
- and on the ecosystems services of a restored watershed (specific question 4) the framework of ecosystem service approach was used as analytical method.
- To investigate the ecosystem service of a restored watershed (specific question 4) the framework of ecosystem service approach was used as analytical method. In addition, an approach based on its history, current situation and analysis of possible actions to its restoration was carried out including, as much as possible, a correlation with a past period in time. This historical approach is based on theories where the study of 'natural' ecosystem state is used as a parameter of ecosystem restoration (Jackson & Hobbs 2009).

# Chapter 4: Research results and analysis

## 4.1 Description of the case

### 4.1.1 Location

**Figure 8: Brazil in the world**

**Figure 9: State of Rio de Janeiro in Brazil**

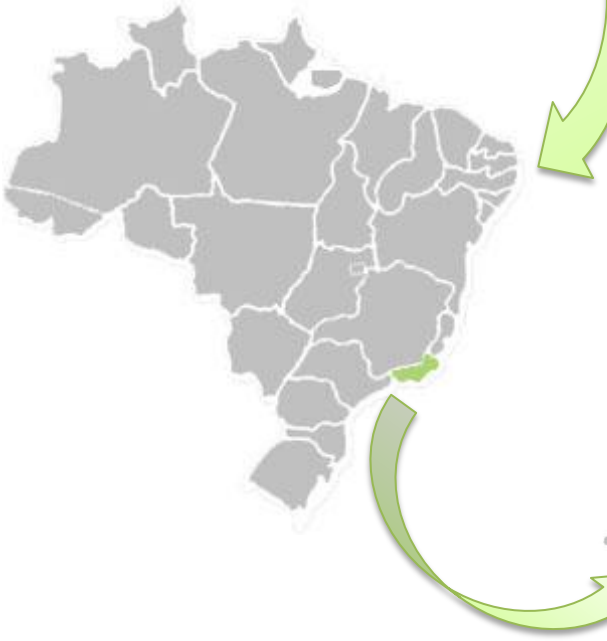
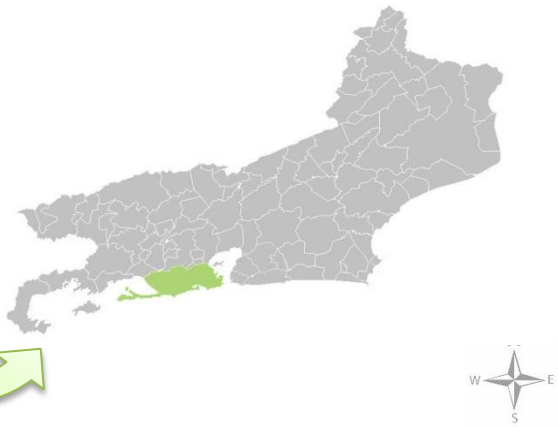
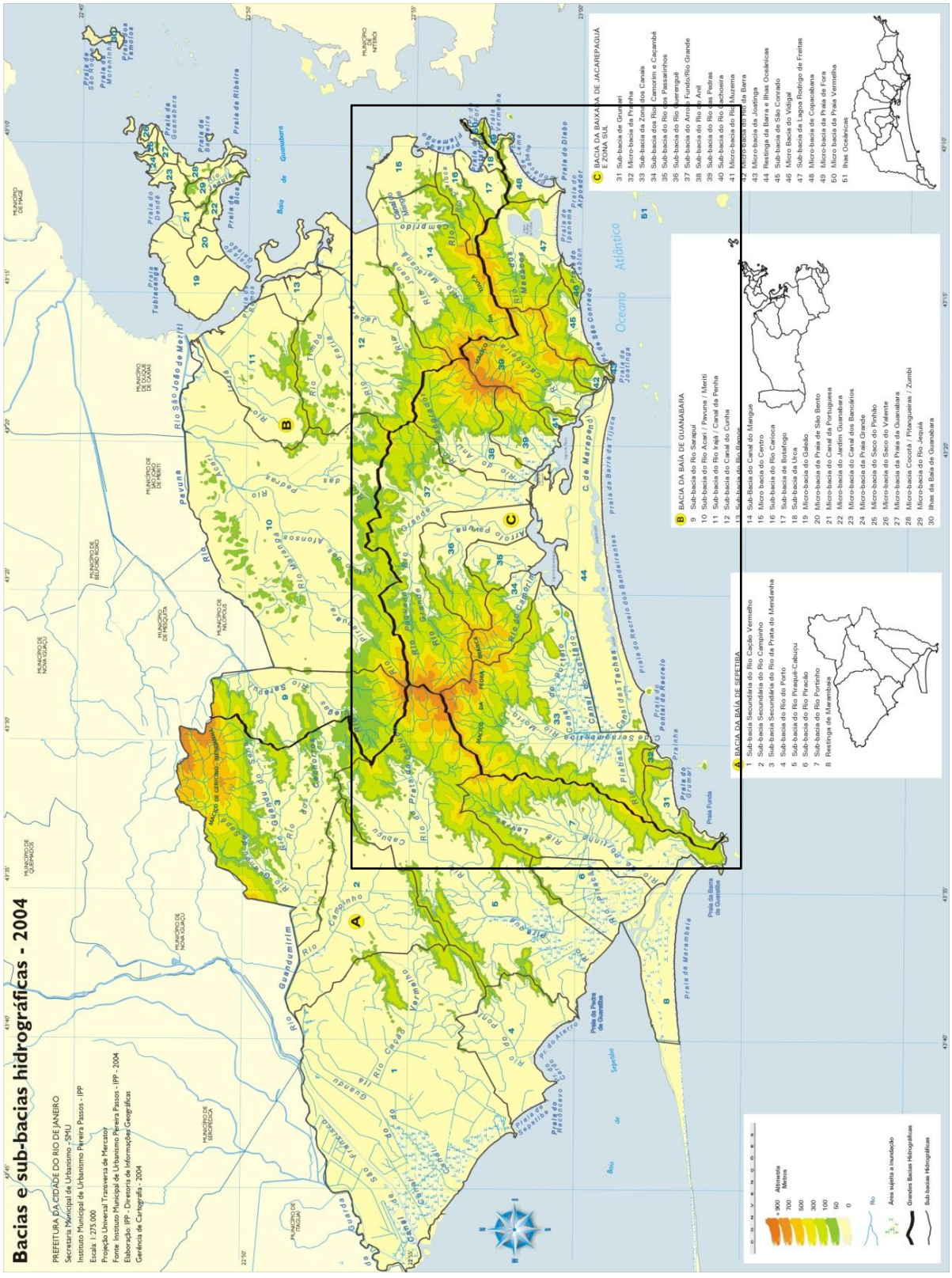


**Figure 10: City of Rio de Janeiro in the State of Rio de Janeiro**




Adapted by the Author from Google Maps 2012

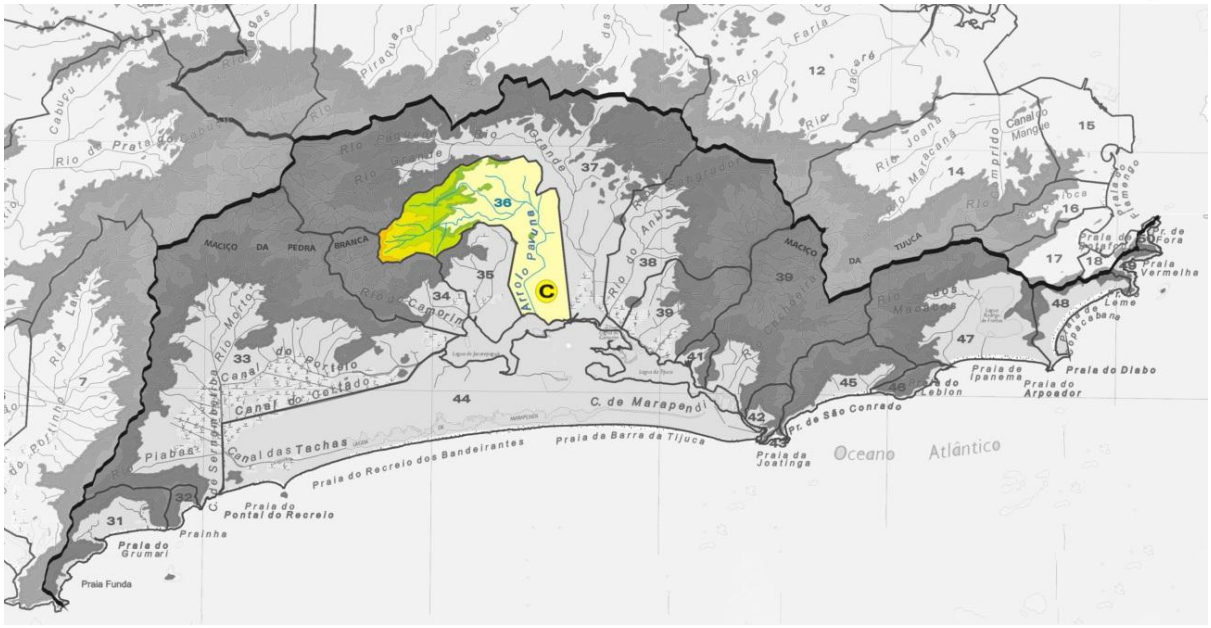
**Figure 11: Rio de Janeiro and its watersheds**




Source: Municipality website 2001-2011

The Sub-basin of Guerenguê River is located in the center part of the Basin of Jacarepaguá's Lowlands and South Area. Jacarepaguá's Lowlands are located in the West Zone of the city. It is part of XVI Administrative Region with the same name. The Sub-basin of Guerenguê River has an area 2190.2ha (Source: Municipality Environmental Bureau) including parts of three neighborhoods: Jacarepaguá, Curicica and Taquara.

**Figure 12: Sub-basin of Guerenguê River in the Basin of Jacarepaguá's Lowlands and South Area**




Adapted by the author from Municipality website 2001-2011

### 4.1.2 Description of the site

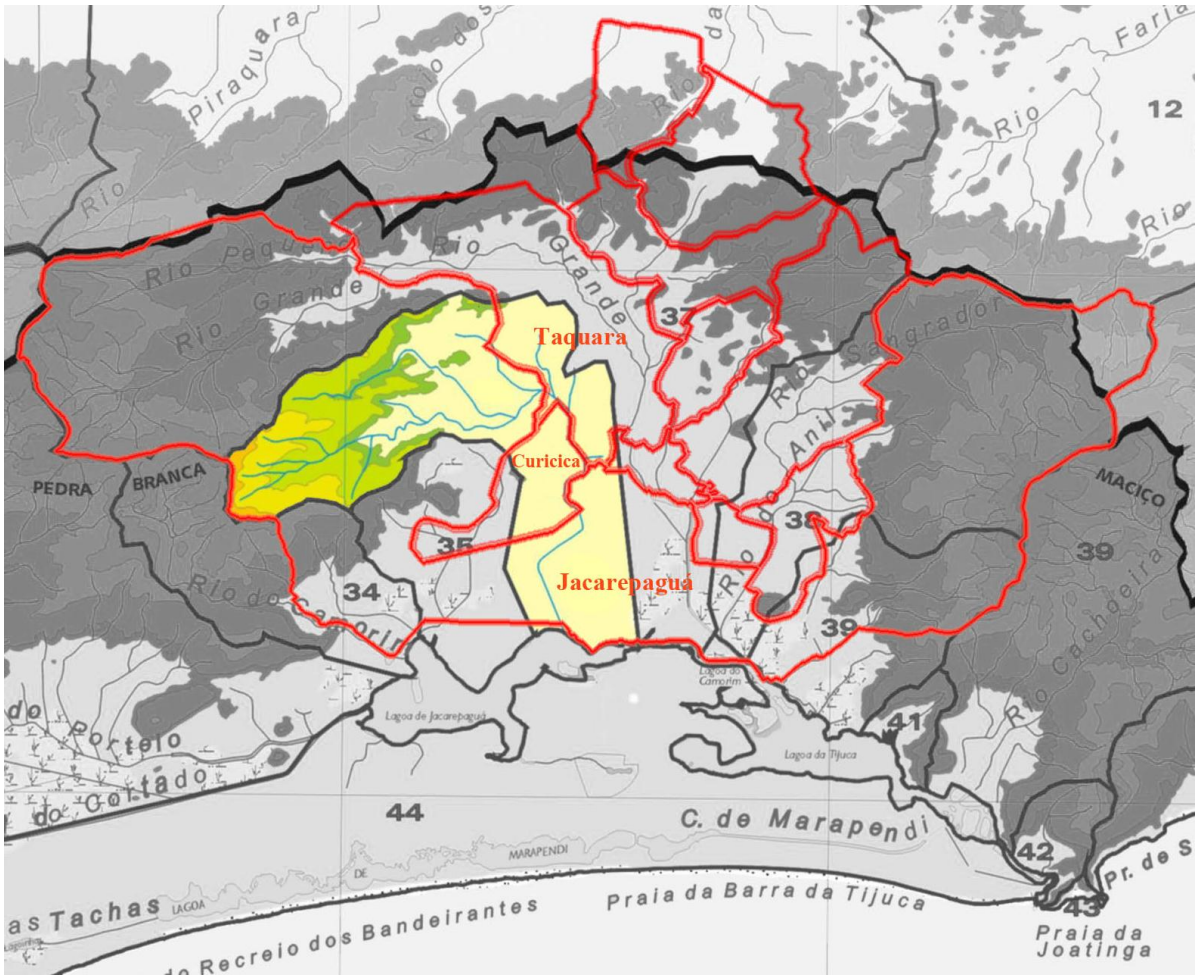
Guerenguê River's Sub-basin has some clear limiting elements. On its south part it is limited by Camorin Lagoon. To north, it is limited by Pedra Branca Massif. On the massif, the springs of rivers Monjolo, Areal and Engenho Novo are located. They join in a single river that gives the name of the sub-basin, Guerenguê. Further, this river will be called Arroio Pavuna and finally outfall in Camorin Lagoon.

**Table 3: Guerenguê River's Sub-basin's rivers and its extensions**

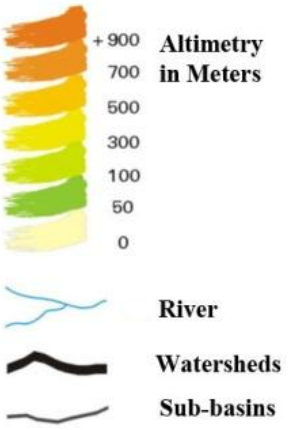
| River | Extension (km) |
|---|---|
| **Guerenguê** | 2.3 |
| **Monjolo** | 2.0 |
| **Areal** | 4.7 |
| **Arroio Pavuna** | 3.5 |
| **Córrego do Engenho Novo** | 4.7 |

Source: Municipality website 2001-2011

**Figure 13: Guerenguê River's Sub-basin and Neighbourhoods from XVI Administrative Region of Jacarepaguá**




Adapted by the Author 2012 from Municipality website 2001-2011



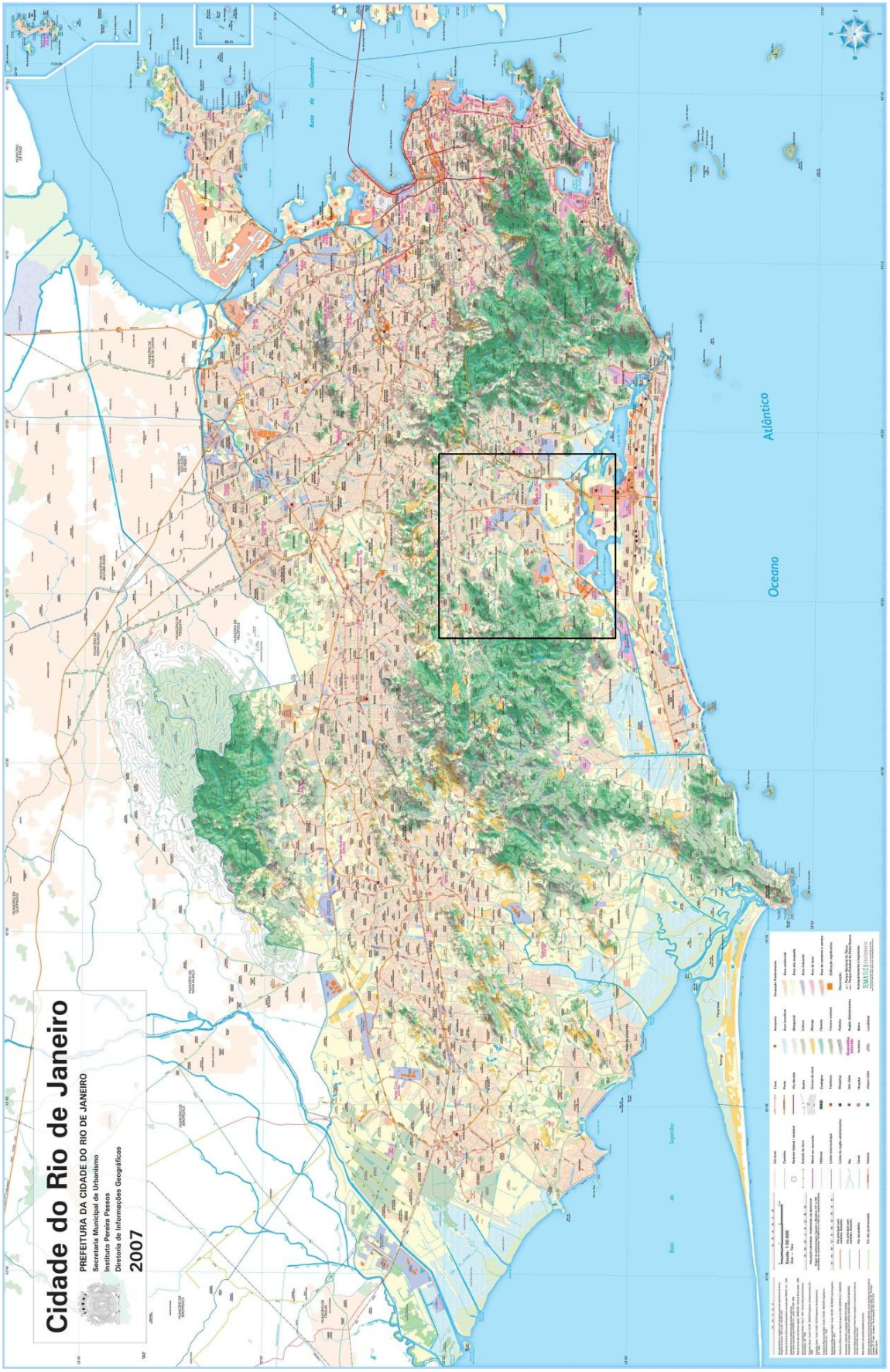

The red lines show the neighbourhoods that are part of XVI Administrative Region of Jacarepaguá. The three neighbourhoods highlighted, Jacarepaguá, Curica and Taquara are those under the influence of the Sub-basin of Guerenguê River.

In this map is also possible to see the topography of the region. Most of the sub-basin is located between 0 and 50 m above the see level and the highest part of the Massif are to the west part and can reach until 700m high. Areas above 100 m in the City of Rio de Janeiro are Environmental Protected Areas.

The Climate in the City of Rio de Janeiro is Tropical and the micro-climate of the region has its characteristics with high temperatures and well defined wet and dry seasons. Most part of the year, it is very humid with maximum air humidity reaching 88% on summer and 65% on winter. Its mean annual temperature is 23.5$^{o}$C and mean annual evaporation reaches 700mm (Tardin 2008).

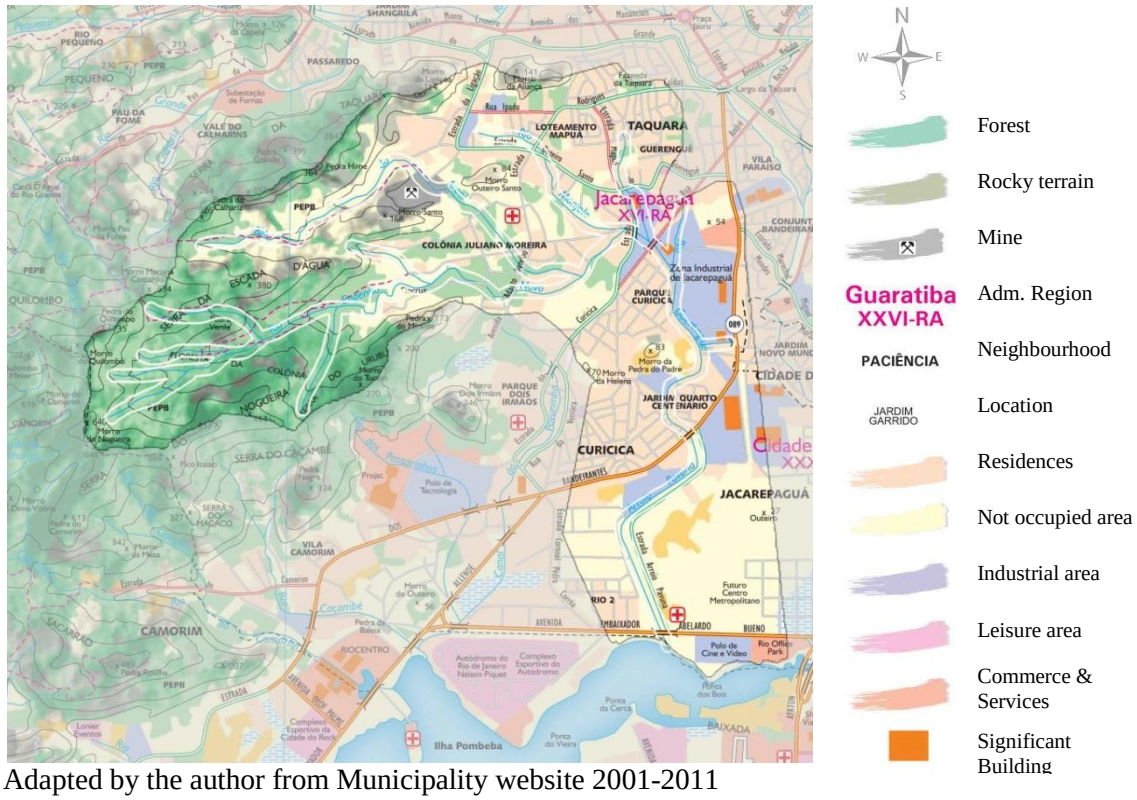
Types of vegetation present in the area will be defined in the item 4.3.1.1 of Land Uses Classification.

**Figure 14: Land Use map of the city of Rio de Janeiro 2007**




Source: Municipality website 2001-2011

**Figure 15: Detail of land use map with Guerenguê River's Sub-basin highlighted**



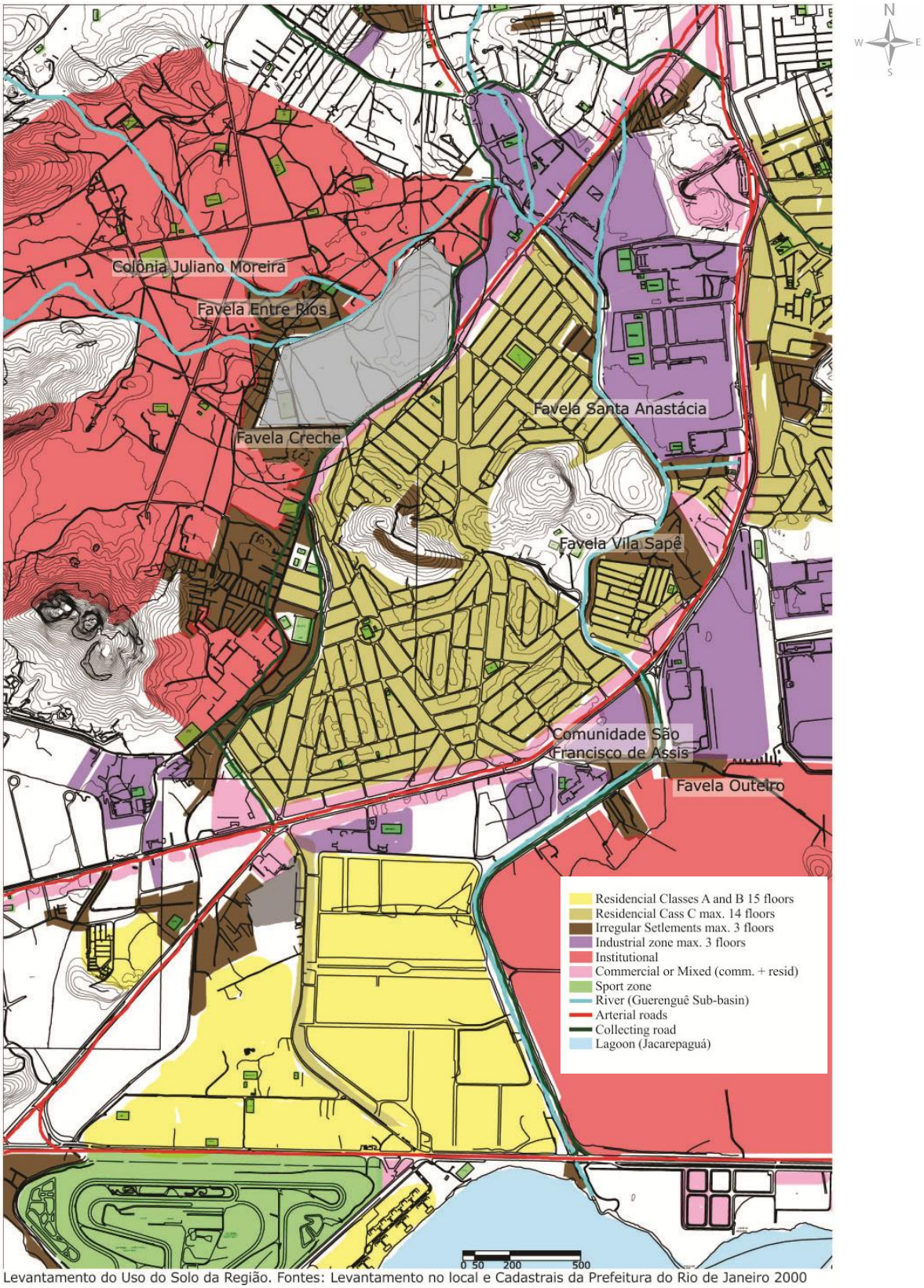

Adapted by the author from Municipality website 2001-2011

**Figure 16: Satelite Image with Guerenguê River's Sub-basin highlighted**


Adapted by the author from Google Maps 2012

It is possible to see from the land use maps presented and satelite images that the area has many densely urbanized areas, expansion areas and vegetation in the hilly area. A more detailed map and description of the land uses and vegetation will be provided in the section 4.3.1.1 of Land Use Classification.

**Figure 17: Detailed Land use map of the urbanized area of Guerenguê River Sub-basin**




Levantamento do Uso do Solo da Região. Fontes: Levantamento no local e Cadastrais da Prefeitura do Rio de Janeiro 2000

Adapted by the author in 2012 from Ezequiel 2007

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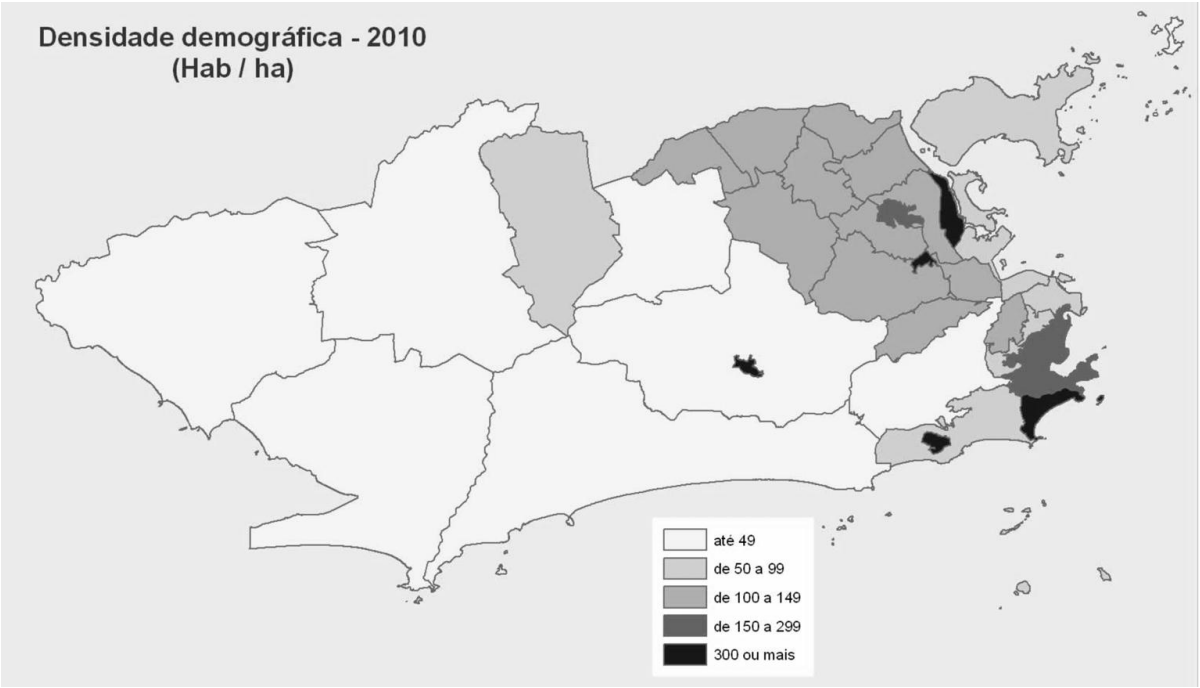
Estimated Population in the Sub-basin of Guerenguê River:

**Figure 18: Demographic density of the City of Rio de Janeiro**




Adapted by the author from Municipality website 2001-2011

According to municipality data (Municipality of Rio de Janeiro, 2001-2011) the density in the region is of maximum 49 inhabitants per hectare and the area of sub-basin is of 2190.2ha. Based on this data, an estimated number of Guerenguê River's Sub-basin is around of 107,320 inhabitants.

**Table 4: Number of houses from irregular settlements occupying the riparian area of rivers of Guerenguê River's Sub-basin**

| Irregular Settlements | Total of Residences | Residences on the wetland |
|---|---|---|
| Comun. S. F. de Assis | 259 | 80% = 208 |
| Creche | 568 | 5% = 28 |
| Entre Rios | 452 | 10% = 46 |
| Outeiro | 169 | 10% = 17 |
| Santa Anastácia | 381 | 50% = 191 |
| Vila Sapê | 888 | 10% = 89 |
| | | Total = 579 units |

Source: Morei 2000

Adapted by the author in 2012 from Ezequiel 2007

### 4.1.3 History of Jacarepaguá's Lowlands

**Figure 19: Photo from Jacarepaguá's Lowlands from the Tijuca's Massif**

Source: Ezequiel 2007

Before the arrival of Portuguese to Brazil in 16th century, indigenous population used to live in the area. The first allotments of this region were donated by Estácio de Sá in 1565, required by the "Council of City's Founders" and by Jesuits. Later, the area was donated to Salvador de Sá suns. Part of it, later on, was also donated to Benedictines. The heritage continues though out several succession lineages (Gonçalves 1999 in de Barros 2001).

On 17th century, sugar cane mills were implemented in the region. For some centuries the region had several disperse villages that developed around farm's main buildings. Connection with the city center was difficult so the region remain isolated. Some churches, residences and farm's main buildings with characteristics of this period can still be found there (de Barros 2001).

After the collapse of sugar cane industry the area remain isolated. Large properties start to dismember in smaller ones. It increases the population in the area and more activities like services, jobs and handcrafting attract more and more people (Viana 1992 in de Barros 2001).

With the beginning of the cycle of coffee, vegetation from the massifs was replaced by coffee crops. In 1843 a plague affected the crops and in 1844 a great drought reached the city. It was caused by the replacement of forest to coffee crops in the massifs. Minister Almeida Torres at that time decided that a reforestation should be made. In 1861 Tijuca's Forest was created managed by Major Manuel Gomes Archer. He and 6 slaves reforest around 16.000 sq.m with 100.000 trees from his own farm (de Barros 2001).

After the cycle of coffee production was over, Jacarepaguá remain unoccupied and its fauna and flora could reasonably regenerate (Vianna 1992 in de Barros 2001). According to Leitão

(1999 in de Barros 2001), lowlands started to be drained since the 1940s by the government and by the land owners based on health and property values.

In the beginning of 20th century, Jacarepaguá became a neighbourhood and people were stimulated to occupy the region when the access by tram became possible. The area was a great source of agriculture products, fishes, crabs, crocodiles, wood and firewood. These materials were collected, used and sold by people in a proportion that already called the attention of Corrêa (1932 in de Barros 2001) who warned about the indiscriminate use of these resources, highlighting the possibility of erosion, flooding and species reduction.

In 1930s, the areas along the beach were allotted creating the neighbourhoods of Barra da Tijuca and Recreio dos Bandeirantes. The access to these neighbourhoods were made though the north part of Jacarepaguá until 1950s and 1960s when important accesses roads were built connecting these regions with the city centre (de Barros 2001).

According to de Barros (2001), in 1960s the area started to be urbanized with sanitation facilities, rectification of rivers, drainage of wetlands and opening of channels. A channel connecting Marapendi Lagoon to Tijuca Lagoon, completely changed the environment of Marapendi Lagoon. It was transformed from lake with fresh water to a lagoon with brackish water. The riparian vegetation changed from marsh to mangrove.

In the same decade, architect Lúcio Costa, who designed in the decade before the pilot plan for Brasília, was requested to elaborate a pilot urban plan to organize the occupation of Jacarepaguá lowlands. Jacarepaguá's Lowlands include all area between the massifs (Pedra Branca and Tijuca) and the beach. The Pilot Urban Plan for Barra da Tijuca and Jacarepaguá Lowlands was approved in 1969 by the Decree number 42, from 23/06/69 (de Barros 2001).

**The Pilot Urban Plan for Barra da Tijuca and Jacarepaguá Lowlands**

The main objective of this urban plan was to determine guidelines for the occupation of the area, preserving its environment. Lúcio Costa looked for a way to combine the unavoidable urbanization keeping its natural characteristics ensuring this way life quality. The breadth and wide spaces preservation were considered, resulting in a plan for urbanization of only half of Jacarepaguá Lowlands (de Barros 2001).

**Table 5: Pilot Urban Plan for Jacarepaguá's Lowlands' areas**

| Area and occupation limitations according to the established legislation and physical characteristics. | |
|---|---|
| **Jacarepaguá Lowlands** | **Sq. km.** |
| Total area | 160 |
| Land area | 147 |
| Inland water bodies | 13 |
| 'non aedificanti' areas (land occupation limits based on legislation) | 65 |
| Potentially urban area | 82 |

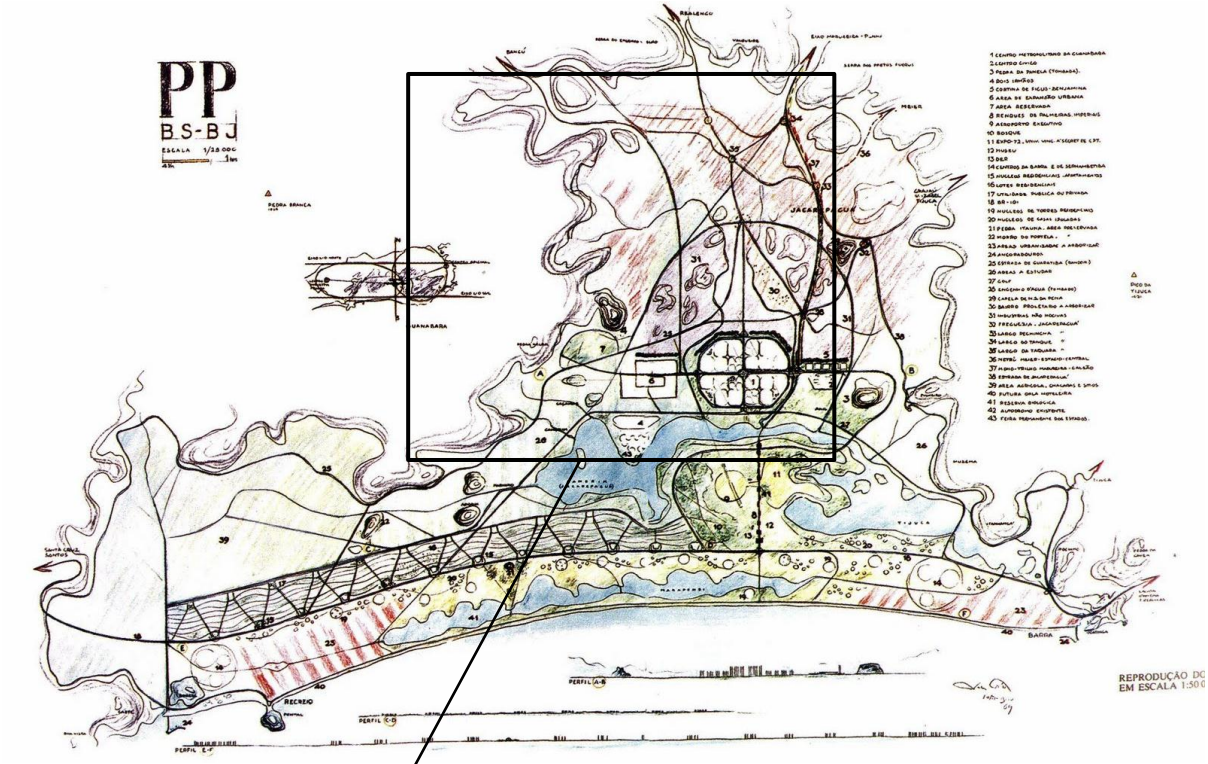
Source: de Barros 2001

The area was divided in 46 sub-zones with different land parceling criteria, land use, intensity of use, buildings types, heights etc. It is described in the Decree number 324;76 latter on complementing edited legislation (de Barros 2001).

The project included integrated green areas, preferably preserved in its natural state and the donation of special environment interest areas to create public parks. The preservation of natural monuments like the small hills was based on its importance to the environment and landscape of the area (de Barros 2001).

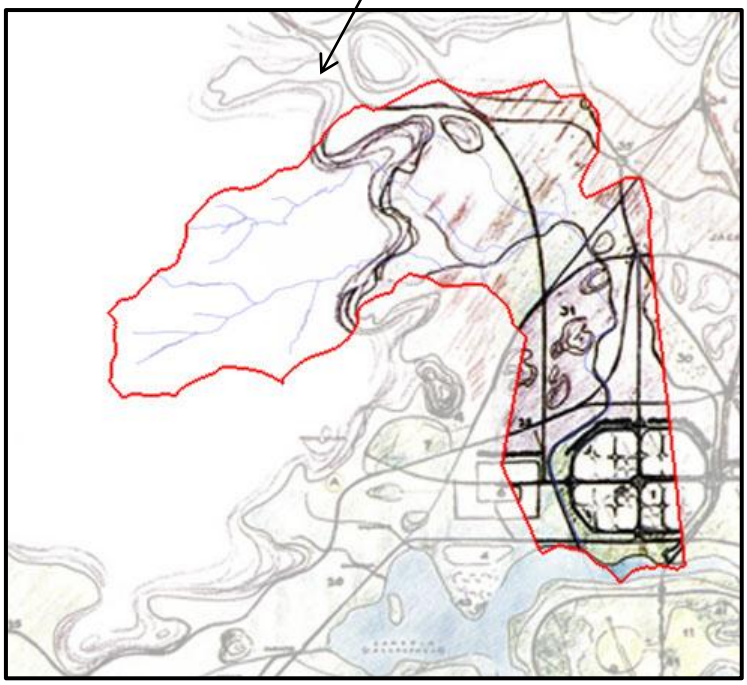
Lucio Costa also emphasizes that this area became the new metropolitan center benefited by space, industrial areas access, labor force availability and plenty of area for residences. Fiscal incentives were given to the industry to allocate in the designated are according to the urban plan. Mainly chemical/pharmaceutical, electrical, mechanical and metallurgical industries settled in the area (de Barros 2001).

**Figure 20: Pilot Urban Plan for Jacarepaguá's Lowlands and Barra da Tijuca by Lúcio Costa 1969**




Source: Costa 1976

**Figure 21: Detail of the plan highlighting Guerenguê River Sub-basin**



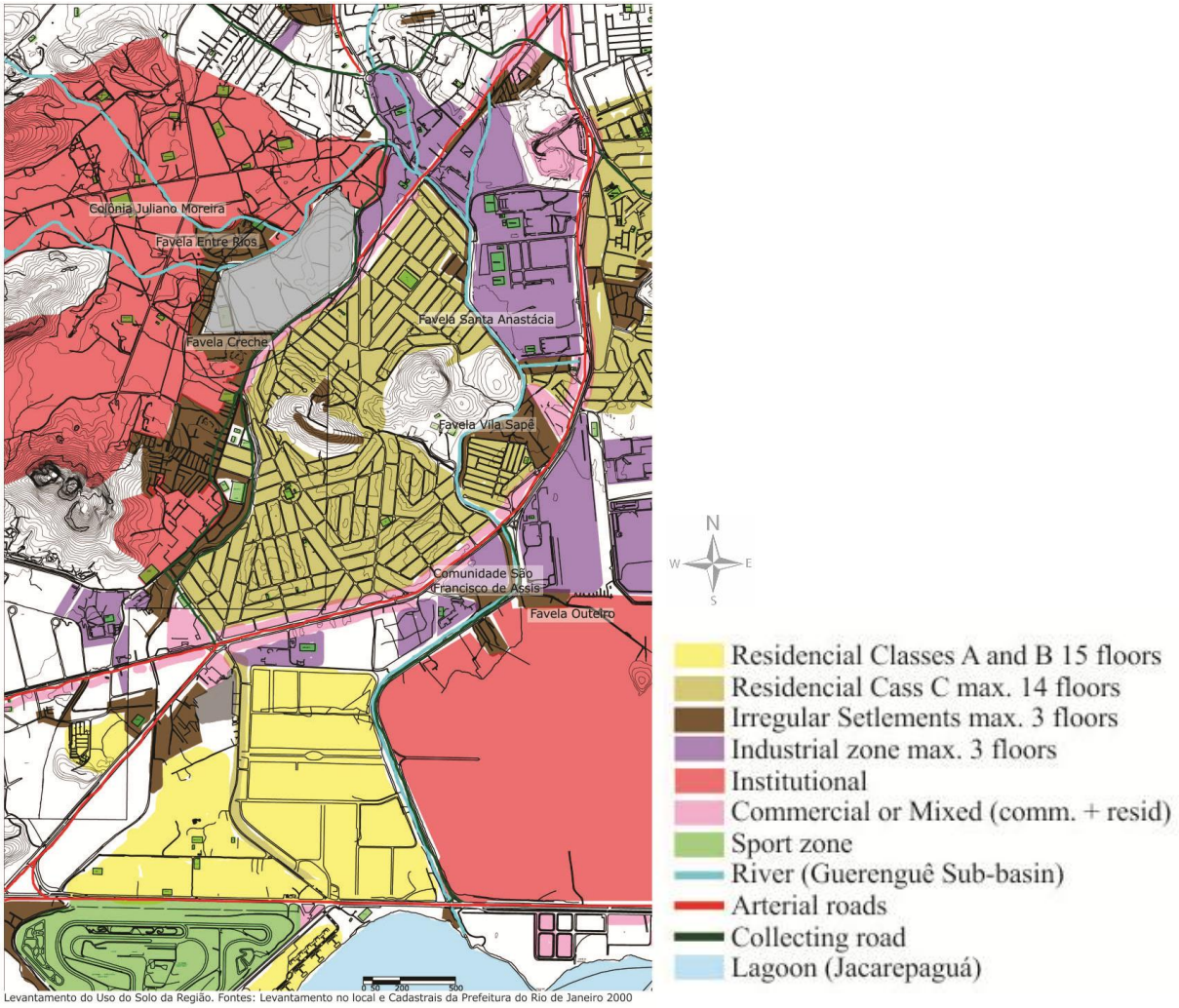
Adapted by the Author 2012

It is possible to observe that the importance of the Guerenguê River Sub-basin in this plan by the location of the 'new metropolitan region'. Most Part of it is in this sub-basin. According to this plan, residences expansion areas are located to west of Arroio Pavuna and above that, the location of industrial area, very clearly specified by Lúcio Costa as no harmful ones.

## After the pilot urban plan

Comparing the project with the actual situation is possible to see that most part of the designed area for no harmful industries is now occupied by industries is now occupied by low income and middle income neighborhoods without sewage infrastructure and almost without green areas.

**Figure 22: Land use map of the region of Gurenguê's River Sub-basin, 2007**




Adapted by the author in 2012 from Ezequiel 2007

According to de Barros (2001), in 1970s, the first gated communities were built with educational, leisure and commercial facilities included in its area. 'Riocentro' and area for large events and conferences and a speedway were implemented in the region by the government. The existing slums from the area started to grow in the same years due to the increasing demand of construction workers. This generates the big social contrast between poverty, social exclusion and the high economic level pattern of the gated communities.

The area was changing its economic life pattern based on agriculture to another one based on industry, commerce and services attracting people, labor force, transport and communication systems and infrastructure. The area became so productive in the provision of goods, services, leisure and landscape that became self-sufficient. This way, its inhabitants did not have the need to look for services and activities in other neighborhoods but the opposite was happening, people that live in other neighborhoods were attracted by the services provided there (de Barros 2001).

The construction of other highway ‘Linha Amarela` (Yellow Line) in 1997 increased the investments and floating people in the region from the north part of the city. Companies also migrated to the area attracted by the infrastructure provided by the nucleus creating internationally recognized corporative nucleus. That brings even more investments (de Barros 2001).

According to de Barros (2001), population growth did not follow a sustainable model resulting in negative impacts to the environment and people’s quality of life. The index of consumption of environmental resources have being higher than its recovery capacity.

The creation of legislation to guide land use regarding ecosystems preservation has shown inefficient. Sanitation, transport system, social equity and environmental protection are still under evaluation in order to be put in equilibrium (de Barros 2001).

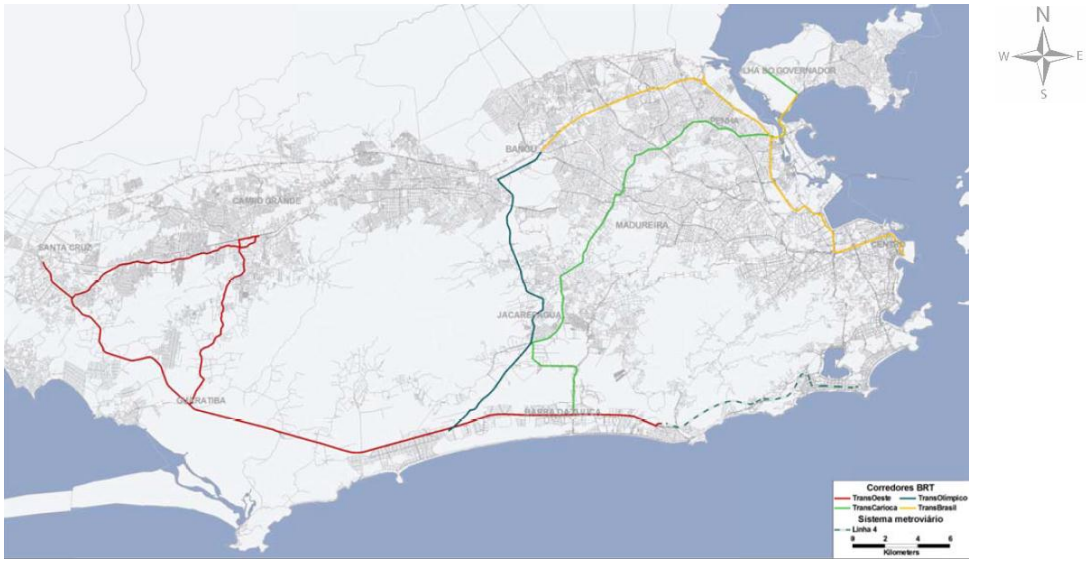
De Barros highlight that the urbanization of the area was characterized by several irregularities, highlighting those related to irregular construction, irregular land occupation, sand extraction from dunes and from lagoons and rivers, emissions of sewage, residues, sediments among others. The environmental quality in the region is shown by the pollution in its water bodies, traffic jam, emerging zoonosis, environmental heritage degradation.

**2012**

The area still presents all these contrasts and recently the area will be affected by several new activities. In 2007, XV Pan-American Games, held in Rio de Janeiro, brought new urban equipments to Jacarepaguá like the Pan-American Village along the Camorin lagoon conformed and now used as gated community and the Sport Complex City of Sports beside the existing International Speedway Nelson Piquet.

Rio de Janeiro will again host international sports events like the Soccer World Cup that will happen in Brazil in 2014 and the Olympic Games 2016 in the city. Due to the size of an event like Olympic Games, several structural constructions will be necessary in the transport system. Therefore, the Sub-basin of Guerenguê River will receive two more highways, the ‘Transolímpica’ and ‘Transcarioca’. The project is still controversial due to large quantity of housing relocation necessary for its construction.

**Figure 23: Primary plan of new highways and BRTS in Rio de Janeiro**




In blue ‘Transolímpica’ in green ‘Transcarioca’

Source: Logit 2011

Along with that, gated communities are constantly growing in the region. A project of sewage treatment for the area is also under construction since 2001 and is scheduled to be ready in 2031 (CEADE website). In interviews with specialists was possible to know that there is a project from the housing department under development in the historical area called Colônia Juliano Moreira.

Another important project going on is of the dredging, rectification and channelization of rivers by Rio-Águas (Watershed Management Bureau) in the whole city. It is divided by groups and the Sub-basin of Guerenguê River is part of the second group of watersheds to be treated according to specialists.

## 4.2 Description of the sample

As described in the item 3.3 Sample Size and Selection, the selection of specialists was mainly related to their contact with the area and the issue. It was expected to contact academic specialists with published work in the sector or about the region. Specialists from the municipality were also required due to a more practical approach to the questions involved. To reach the targeted group of specialists a plan was developed, however, some adaptations were necessary due to some constraints faced during field work. The initial plan was to start contacting specialists from the Federal University of Rio de Janeiro where some specialists are known and have contacts in the municipality. However, one of the biggest strikes of the history of this university was happening at that time and by the moment this thesis is being written, strike continues. It made difficult the access to these specialists even after some contact trial through e-mail, telephone and even by visiting the university. The decision was then, to go to straight to the municipality and try a direct approach. In the first times, difficulties related to time availability and absences due to external work by the specialists made the process slower. After trying in different departments, some meetings were possible to be arranged. In this way, a lot of data could be collected and other contacts indicated. The list of contacts was so large that it was not possible with the time available, talk with all of them. Latter contacts with academic specialists happened but field work time was already over.

To interview dwellers, as described in the item 3.3 Sample Size and Selection, some criteria were developed like house location in the different identified land uses, years living in the region being 10 years or more preferable and being a community leader or representative. Some difficulties were found and were related to the distance of the site, the existence of irregular settlements under the control of drug traffic and time constraint. To get respondents it is necessary to go several times in the location and count or their availability to participate of the research. It is also ideal that staff from the municipality join the field trip and indicate community leaders. Due to time constraints of the research and by the municipality staff, only one visit to the site was possible to be done but even though, the presence of municipality staff. In this visit, some dwellers were asked to be interviewed but each of them had different reasons to do not participate or did not have the profile required to fill the criteria necessary. Only a dweller had willingness to participate and matched with the profile required.

## 4.3 Presentation and Analysis of Results

### 4.3.1 Land Uses in Guerenguê River's Sub-basin

#### 4.3.1.1 Land Uses Classification

The data bellow is based on the documentation available on the municipality website of land use monitoring sig.floresta.rio.rj.gov.br.

**Table 6: Land Uses Classification**

| Type | Classification | Typology | Specification | Abbreviation |
|---|---|---|---|---|
| **Athropic Areas** | Non-agricultural | Urbanized Areas | - | Au |
| | | Exposed Soil | - | Se |
| | | Mineral extraction area | - | Aem |
| | Agricultural | Agriculture | - | Ag |
| | | Arboreous-shrubby vegetation | - | Ve |
| | | Reforestation | Municipality | R |
| | | | Private | Rp |
| | | Grassy-woody vegetation | - | Vg |
| **Natural Vegetation Area** | Forest Formation Area | Ombrophilous Forest | Dense montane | Dm |
| | | | Dense sub-montane | Ds |
| | | | Dense of lowlands | Db |
| | | Secondary Vegetation | Initial level | V1 |
| | | | Intermediate level | V2 |
| | | | Advanced level | V3 |
| | Campestral | Rocky outcrop | - | Afr |
| | Primary formations | Restingas | Herbaceous | Re1 |
| | | | Shrubby | Re2 |
| | | | Woody | Re3 |
| | | | Sandy | Re4 |
| | | Mangroves | - | Man |
| | | Saline fields | - | Cs |
| | | Marsh | - | Br |
| | Continental water bodies | Continental water body | - | CaC |
| | | Beaches | - | Pr |

Source: Municipality report from Municipality website sig.floresta.rio.rj.gov.br 2012

The legal parameters for defining th emapping classes, scale 1:10,000 are present in the following legislations: Law Number 11,428 from 22 December 2006, and regulates the use and protection of native vegetation from Atlantic Forest Bioma and give other providences; Decrete Number 6,660, from 21 November 2008, that regulate instruments of the previous law; CONAMA Resolution Number 06 from 4 May 1994, that establish definitions and measurable parameters to the analysis of ecological succession of Atlantic Forest in the State of Rio de Janeiro, and CONAMA Resolution Number 388 from 26 February 2007 that regulate resolutions validity that define primary vegetation and secondary vegetation in its initial, medium and advanced stages of regeneration of Atlantic Forest with objectives stated on article 4$^{th}$ paragraph 1$^{st}$ of law 11,428 of 22 December 2006.

Beyond pertinent legislation, the land use and vegetation mapping from the city of Rio de Janeiro legend had as background information, the Technical Manual of Brazilian Vegetation (IBGE 1992), the Technical Manual of Land Use (IBGE 2006) and Land Use and Vegetation Mapping from the City of Rio de Janeiro (Rio de Janeiro Environmental Bureau 1999).

The Classes Legend for Natural Vegetation and Anthropic Areas is found as follows:

**Athropic Areas**

- Non-agricultural
    - Urbanized Areas (Au)

In this class were considered intensive use areas, structured by edifications and road system, where predominant artificial superficies non-agricultural are located. In this category are included built area, road, services and transport area, energy, communications and associated terrains, areas occupied by industries, industrial and commercial complexes and institutions that, in some cases are isolated from urban areas. Urbanized areas can be continuous, where nonlinear vegetation areas are exceptional, or not continuous, where vegetated areas occupy more significant areas.

    - Exposed Soil (Se)

In this class were considered intensive use areas, structured by edifications e road system, where predominant artificial superficies non-agricultural. Are included in this category built area, road area, services, and transport, energy, communications and relating terrain, areas occupied by industries, industrial complex and commercial and institutions that, in some cases are isolated from urban areas. Urbanized areas can be continuous, where nonlinear vegetation areas are exceptional, or not continuous, where vegetated areas occupy more significant areas.

    - Mineral extraction area (Aem)

Activity that include mineral substances extraction areas, like mining and mines.

- Agricultural
    - Agriculture (Ag)

In this class, were included every and any cultivating system. Cultures with short or medium cycle duration that, after production, leave the area available to new plantation, e also permanent cultures that have long cycle and allow susceptible harvesting, with no need of new planting every year. This category include farming cultures, vegetables, fruit, aromatic, ornamental and culinary and small fruit species.

    - Arboreous-shrubby vegetation (Va)

In this mapping unity were included valleys and slopes with or without fruity species, besides sites and corrals, with the presence of native and exotic species.

    - Reforestation (R and Rp)

Plantation or formation of green massifs with native forest species or exotic. In this definition there is no distinction between areas previously occupied with forest species or not because reforestation include every area with forest species no mattering its environment. Plantation can be heterogeneous, homogeneous and mixed. In the delimitation of this class, were considered the limits present in the reforestation file provided by Environmental Bureau if Rio de Janeiro as supporting data and classified as Reforestation (R) and other areas as Private Reforestation (Rp)

    - Grassy-woody vegetation

This class includes the predominantly herbaceous vegetation with rare shrubs and subshrubs less developed and / or complete absence of trees. Displays cover country formed by a grassy carpet in some areas with exposed soil, with few woody plants, stunted, occupying areas where the original vegetation has been removed by various practices, including burning, for implementation of different types of use.

**Natural Vegetation Area**

According to IBGE (2006), natural vegetation comprises a set of grassland and forest structures, including forests and grasslands or changed until spontaneous secondary forest formations, shrub, herbaceous and / or woody, grassy, in different successional stages of development, spread over different geographical environments and situations.

The forest formations in its broad meaning include arboreal formations in the case of the municipality of Rio de Janeiro, are arboreal formations of the Dense Forest (forest structure with continuous top cover). These formations have characteristic vegetation of the area more humid tropical, with an annual dry period between 0 to 60 days, consisting of phanerophytes perennial plants. In the area of occurrence of this type of vegetation, rainfall is well distributed during the year, with the annual average of 1,500 mm.

Rain Forest yet, is divided based on altimetrical tracks, which are reflected in different physiognomies: Montana Rain Forest, Sub-Montana Rain Forest and Lowlands Rain Forest.

- Forest Formation Area
  - Rain Forest
    - Montana (Dm)

The environment where this class occurs is restrict to Medanha Alkaline Massif over 500m until the board with the city of Nova Iguaçú.

- Sub-Montane (Ds)

The environment where this class occurs are located between 50m and 500m high in Medanha Alkaline Massif, on slopes and valleys with well conserved remaining vegetation.

- Lowlands

  - Secondary Vegetation

Vegetation that grows after the overthrow of primary forests. Brazilian term that refers to any type of vegetation that grows after forests overthrow. These forests are those that have already suffered some kind of human intervention, with three stages in the succession process - initial, intermediate and advanced, according to CONAMA Resolution No. 06/1994 where we have:

- Initial level (V1)

Herbaceous / shrub physiognomy, open or closed cover, with the presence of species predominantly helophytic plants, woody plants, when they occur, have average DBH of 5 cm and height up to 5 m.

- Intermediate level (V2)

Shrub / tree physiognomy, trees with DBH ranging from 10 to 20 cm and average height ranging from 5 to 12 meters;

- Advanced level (V3)

Arboreal physiognomy with mean DBH of 20 cm and height exceeding 20 m.

  - Campestral
    - Rocky outcrop (Afr)

In this class were delimited visible rock fragments in the images used in this study and which were positioned at the same level or above ground level in and in any topographic position (elevation).

- Primary formations
  - Restingas

Restingas are coastal ecosystems, physically determined by soil conditions (sandy soil) and by the marine influence, having recent sedimentary origin (beginning of the Quaternary period), where the species living there (flora and fauna) have mechanisms to support the physical dominant conditions as salinity, extremes temperatures, strong wind presence, water shortages, unstable soil, strong and direct sunlight. The vegetation over restinga is under intense pressure from human occupation and consequent change of the original landscape, which complicates its conservation. The different ecosystems that make up the vegetation on the restinga are fragile environments due to the nature of its poor soil, composed of unconsolidated sand and, in many areas, with a considerable degree of salinity (LabTrop, 2010).

- Herbaceous (Re1)

It is an herbaceous plant formation, interspersed with fractions of exposed soil (sand), usually in dune habitat.

- Shrubby (Re2)

These are formations composed both by herbaceous vegetation as for shrub vegetation, presenting different density levels. Normally it compound an environment transition between purely herbaceous resting and woody.

- Woody (Re3)

These are forest formations that also present different density levels.

- Sandy (Re4)

These are areas occupied by dunes or exposed sandy soils fractions very close to the sea or channels with marine influence.

  - Mangroves (Man)

These are coastal ecosystems that occur in the transition between environments, terrestrial and marine, throughout the tropical and subtropical regions, suffering direct influence of the tidal regime. They consist of typical woody plant species, beyond micro and macro algae, adapted to the wide range of salinity and able to colonize predominantly unconsolidated substrate.

  - Saline fields

These are relatively flat areas located between mangrove and Restinga formations (in all its variations) that have periods of marine flooding, followed by drying ups.

  - Marsh (Br)

These are fragments of swampy areas that are extremely vulnerable to the condition of permanent soil waterlogging.

- Continental water bodies
  - Continental water body (Cac)

Natural and artificial water bodies and that are not of marine origin, such as rivers, canals, lakes and freshwater ponds, dams, weirs, etc.

  - Beaches (Pr)

Beaches are open field sites with little or no vegetation, associated with the margins of the ocean.

#### 4.3.1.2 Mapping of land uses in Guerenguê River's Sub-basin

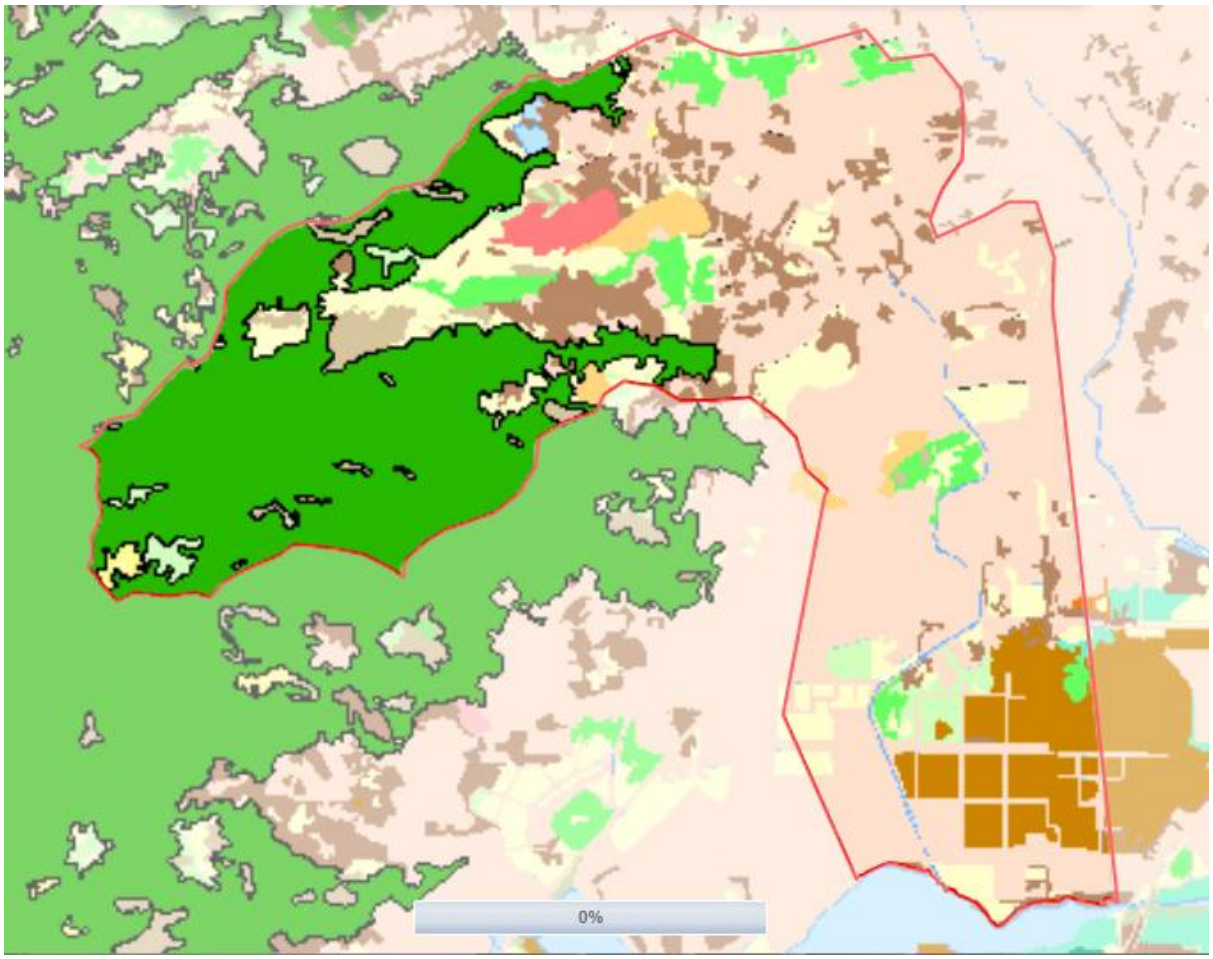
According to the reports available on Municipality website sigfloresta.rio.rj.gov.br, Guerenguê River's sub-basin has an area of 2190.2 ha that can be classified as follows:

**Table 7: Mapping of land uses from Sub-basin of Guerenguê River**

| Type | Classification | Typology | Specification | Area (ha) | % |
|---|---|---|---|---|---|
| **Athropic Areas** | Non-agricultural | Urbanized Areas | - | 849.7 | 38.8 |
| | | Exposed Soil | - | 0 | 0 |
| | | Mineral extraction area | - | 24,1 | 1,1 |
| | Agricultural | Agriculture | - | 7,0 | 0,3 |
| | | Arboreous-shrubby vegetation | - | 183.2 | 8.4 |
| | | Reforestation | Municipality | 32.6 | 1.5 |
| | | | Private | 0.5 | 0.0 |
| | | Grassy-woody vegetation | - | 219.0 | 10.0 |
| **Natural Vegetation Area** | Forest Formation Area | Ombrophilous Forest | Dense montane | 0 | 0 |
| | | | Dense sub-montane | 0 | 0 |
| | | | Dense of lowlands | 0 | 0 |
| | | Secondary Vegetation | Initial level | 45.6 | 2.1 |
| | | | Intermediate level | 78.5 | 3.6 |
| | | | Advanced level | 568.4 | 26.0 |
| | Campestral | Rocky outcrop | - | 45.9 | 2.1 |
| | Primary formations | Restingas | Herbaceous | 0 | 0 |
| | | | Shrubby | 1.7 | 0.1 |
| | | | Woody | 0 | 0 |
| | | | Sandy | 0 | 0 |
| | | Mangroves | - | 0 | 0 |
| | | Saline fields | - | 0 | 0 |
| | | Marsh | - | 120.4 | 5.5 |
| | Continental water bodies | Continental water body | - | 13.7 | 0.6 |
| | | Beaches | - | 0 | 0 |

Source: Municipality report from sig.floresta.rio.rj.gov.br 2012

**Figure 24: Land Use and Vegetation of Guerenguê River's Sub-basin**




Adapted from municipality website sig.floresta.rio.rj.gov.br 2012

**Table 8: Land use and vegetation legend**

| Type | Classification | Typology | Specification | Abbreviation |
|---|---|---|---|---|
| Athropic Areas | Non-agricultural | Urbanized Areas | - | Au |
| | | Exposed Soil | - | Se |
| | | Mineral extraction area | - | Aem |
| | Agricultural | Agriculture | - | Ag |
| | | Arboreous-shrubby vegetation | - | Ve |
| | | Reforestation | Municipality | R |
| | | | Private | Rp |
| | | Grassy-woody vegetation | - | Vg |
| Natural Vegetation Area | Forest Formation Area | Ombrophilous Forest | Dense montane | Dm |
| | | | Dense sub-montane | Ds |
| | | | Dense of lowlands | Db |
| | | Secondary Vegetation | Initial level | V1 |
| | | | Intermediate level | V2 |
| | | | Advanced level | V3 |
| | Campestral | Rocky outcrop | - | Afr |
| | Primary formations | Restingas | Herbaceous | Re1 |
| | | | Shrubby | Re2 |
| | | | Woody | Re3 |
| | | | Sandy | Re4 |
| | | Mangroves | - | Man |
| | | Saline fields | - | Cs |
| | | Marsh | - | Br |
| | Continental water bodies | Continental water body | - | CaC |
| | | Beaches | - | Pr |

Adapted from municipality website sig.floresta.rio.rj.gov.br 2012

### 4.3.2 Ecosystems Services Related to the Land Uses of Guerenguê River's Sub-basin

In this section, an analysis of the ecosystems services available in the specific sub-basin will be made and a correlation with the current land uses will be described. Moreover, a matrix presents a summary of the contribution of each land use to the provision of ecosystem services.

**Provisioning**

- Food

Food provision by ecosystem services includes all edible products collected from nature and agricultural products.

  - Fish

No data about the existence of fish in the Sub-basin of Guerenguê River in recent time was found. The possibility of fish consumption is strongly related to the water quality of the water bodies. Rivers' water quality, in its turn, is related to land use, urbanization type and level and sewage infrastructure. The data collected about these factors related to the existence of fish in the sub-basin are presented in this section.

As described in the item 4.3.1 about proportion of land uses in the region, large part of Guerenguê River's Sub-basin is densely urbanized. In addition, no sewage collection is available in the area. A sanitation project for the region is under construction since 2001 but its conclusion is scheduled to 2031 (CEDAE website). For this reason and based on specialists interviews, most of the area remains without sewage collection system. Supplementary, studies show that the water quality of the two downstream rivers of the sub-basin, Guerenguê and Arroio Pavuna, have indicators comparable to sewage (Miguez 2007). This study will be described in more details under the item 'fresh water service'.

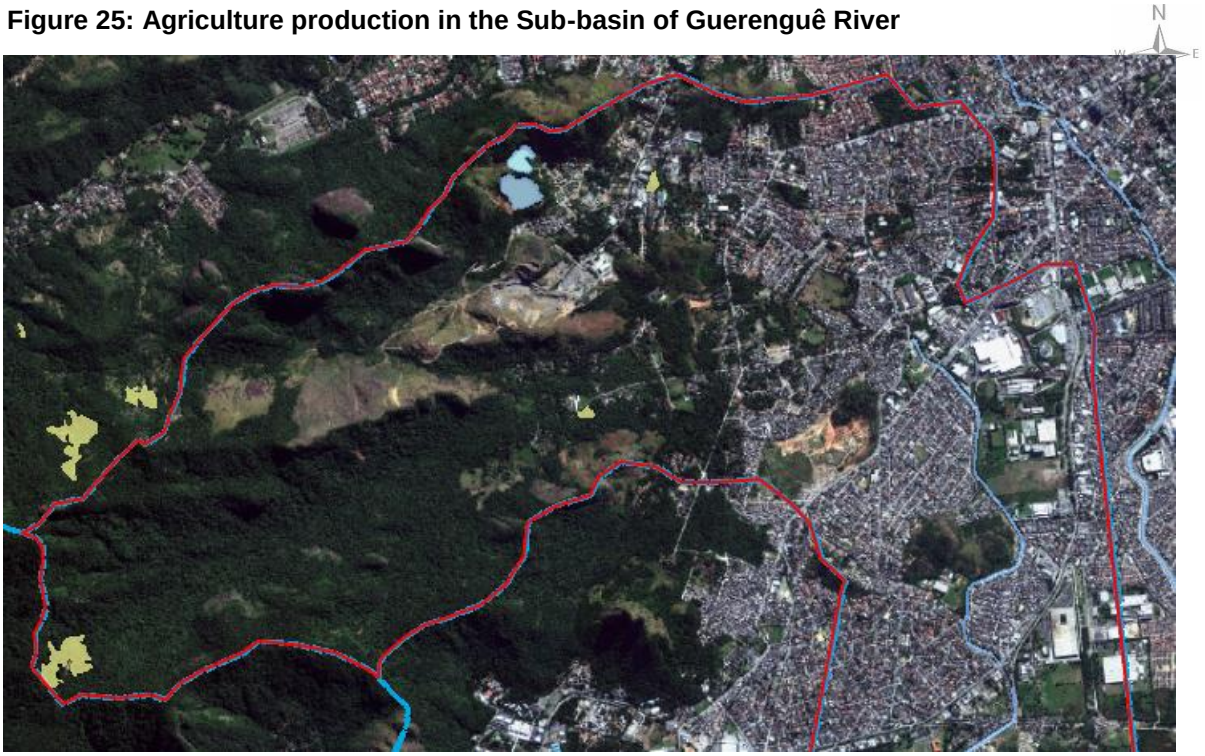
It is stated by Miguez (2007) that wetland ecosystems suffer environmental impacts because of pollution. Life from these ecosystems can be seriously harmed by the chemical, physical and biological changes caused by pollution. Fish can die if turbidity, temperature, pH, dissolved oxygen, ammonia and organic matter indicators change. According to de Barros (2001) the process called eutrophication cause death of fish. People can also be affected if in contact with polluted rivers.

Based on the facts that this is a densely urbanized area, with several irregular settlements especially along the rivers, without sewage collection and with the results for the water quality analysis (Miguez 2007), it is possible to conclude that there is no possibility of fish consumption in the rivers Monjolo, Guerenguê and Arroio Pavuna, Still according to Miguez (2007) people should avoid contact with these rivers' water otherwise they are under risk of contamination. It is confirmed by the interview with the specific dweller. The possibility of finding fish in the upstream of the less urbanized rivers exists. However, no data could be found about that.

  - Agriculture products

Only two sources provided information regarding agriculture production nowadays in Guerenguê's River Sub-basin: an interviewed dweller and the municipality. The municipality data strict to the quantification in the land use map and area report but no further detail was provided. In the image below, the red line limit the northern part of the sub-basin and inside this area is possible to identify in yellow, the only 3 areas where agriculture was identified. They correspond to 7.0 ha or 0.3% of the total area of the sub-basin. It is possible to see other yellow marked areas by they belong to neighbor watersheds as they are located outside the red lines limit region.

**Figure 25: Agriculture production in the Sub-basin of Guerenguê River**



Source: municipality website sig.floresta.rio.rj.gov.br 2012

In the interview with the specific dweller, she says that most of people have no time or the dedication needed to grow agriculture products. However, she mention that people from the communities, including her plant trees and collect their fruits for self-consumption.

It is possible to conclude that agriculture production in the Sub-basin of Gurenguê River not expressive.

- Fresh Water

In order to know if the sub-basin provides the ecosystem service of fresh water provision in its current state, studies about its water quality were collected. The study, the results and results interpretation are described in this section. Further details like water collection points, results for water quality analysis and parameters are available on Annex 7.

The study coordinated by Miguez in 2007, was requested by the municipality and it is one of the documents provided by Rio-Águas, the municipality organ responsible for the watersheds management in Rio de Janeiro, when requested about the water quality of the Guerenguê River's Sub-basin.

The study highlight that Rio de Janeiro has a historical population growth. As the population grow, also grow the built area in the city and the demand for infrastructure and environmental resources. However, the fast urban grow in Rio does not match with the infrastructure expansion. The growth pressure, then, fall over environment. The extensive use of water bodies as sewage and solid waste collectors make they lose their self-recovery ability and the water quality decrease (Miguez 2007).

As mentioned on item of fish provision service, pollution causes severe impacts on ecosystems. Water quality of rivers and lagoons are also important to the life conditions of the population. Depreciation of water quality increases the problem of fresh water resource scarcity. Groundwater can be contaminated and turn unfeasible its use for human supply. If a flooding event of a contaminated river or lagoon reaches the population, public health problems increase by the possibility of contamination.

According to the studies coordinated by Miguez (2007) and to the land use analysis, large part of Guerenguê River's Sub-basin is composed of areas with high density, high population and industrial indexes. Urban sprawl advancement in this area cause severe impacts on water and air quality and population's life quality. The upper part of this sub-basin has low density and cause relatively low environmental impacts. The middle part is densely urbanized, including industries and a road with intensive traffic called 'Avenida dos Bandeirantes'. This area generates high environmental impacts due to the discharge of high levels of solid waste, sewage and industrial liquid discharge and also airy emissions from vehicles and industries. The runoff of this densely urbanized area also ends in its waterways. The final part of Guerenguê River has its natural course modified by canalization. It pass through medium and medium-high level of gated communities and several irregular settlements.

There are interconnected elements that influence each other and the superficial water quality. They are: climate, lithology of the region, the surrounding vegetation, the aquatic ecosystem and human being. The climate factors are the distribution of rainfall, temperature and winds in the region. It influences soil erosion, rocks decomposition and the type of vegetation existing in the area. Therefore, water analysis can show different composition levels of minerals and organic matter based on the types of soil, rocks and vegetation. Living organisms in the water regulate the aquatic ecosystem based on the feeding chain that involves several elements and organisms. According to Miguez (2007), the biggest changes in water composition comes from the anthropic actions. Organic effluents from urban sewage, synthetic components from industries, fertilizers and pesticides from agriculture and heavy metals are discharged in rivers that, for many years, are used as rejects deposits.

Through the analysis of several parameters, water quality analysis can, according to Miguez 2007, provide several indicators that influence life quality as can be observed in the table below:

**Table 9: Water quality parameters and their known effects**

| Pollutants | Characterization Parameters | Effluent Type | Effects |
|---|---|---|---|
| **Suspended Matter** | Total suspended matter | Housing<br>Industries | Aesthetic Problems<br>Sludge Deposition<br>Pollutants' absorption<br>Pathogens' Protection |
| **Floating Matter** | Oil and greases | Housing<br>Industries | Aesthetic Problems |
| **Biodegradable organic matter** | BOD | Housing<br>Industries | Oxygen consumption<br>Death of fishes<br>Septic conditions |
| **Pathogens** | Coliforms | Housing | Hydro transported Diseases |
| **Nutrients** | Nitrogen<br>Phosphorus | Housing<br>Industries | Excessive growth of algae<br>Fish toxicity<br>New-borns diseases (nitrates) |
| **No biodegradable composts** | Pesticides<br>Detergents<br>Other | Agricultural<br>Industries | Toxicity<br>Foam<br>Oxygen Transfer reduction<br>No biodegradability<br>Bad smell |
| **Heavy Metals** | Specific Elements (arsenic, cadmium, chromium, mercury and zinc) | Industries | Toxicity<br>Sewage biological treatment inhibition<br>Ground water contamination |

| | | | |
|---|---|---|---|
| **Inorganic solved matter** | Total solved matter<br>Electrical conductivity | Reused | Excessive Salinization<br>Losses to agriculture (irrigation)<br>Plants toxicity (some ions)<br>Soil permeability problems (Sodium) |

Translated from Miguez 2007 p.95

As stated by Miguez (2007), water quality analysis includes three approaches: physical, chemical and biological. Domestic sewage contains 0.1% of dissolved and suspended organic matter and 99.9% of water. The presence of substances that affect water characteristics are the physical impurities. Organic substances and soluble inorganic substances are the chemical impurities. Live being released together with human waste are the biological impurities. Turbidity and deposit of mud can be affected by suspended matter. Color, smell and temperature can also be influenced that substances that together with suspended matter are the Physical impurities. Chemical impurities are proteins, fats, hydrates' carbon, phenols and by a series of artificial substances, fabricated by man like detergents for example. The most important mineral substances are nutrients (nutrients and phosphorous), sulphur, heavy metals and toxic components. Bacteria, virus, fungus, helminths, and protozoan are examples of biological impurities. If they cause diseases they are called pathogenic.

In several visits to the area, the team could identify through observation that the rivers of the sub-basin are very susceptible to mainly receive pollution from domestic sewage. In order to confirm that, surface water from some points of the rivers of the Sub-basin of Guerenguê River were collected and submitted to laboratorial tests. The specific collection points and results are available in the Annex 7. Below, the interpretation of the results of water quality tests is presented according to Miguez (2007):

*Solid Matter*

Based on the amount of solid matter sewage can be classified in weak, medium or strong. This classification is used to determine extension and control needed by treatment units. According to this table, the classification of sewage which is launched on Guerenguê River is weak sewage.

*Color and turbidity*

Color and turbidity determine the level of deterioration of the sewage. Grey color indicates fresh sewage, black color, indicates an advanced decomposition stage. Close to Bandeirantes Road, the color is grey and closer to the lagoon is black. It is related to the fact that the fresh sewage is found in the most populated dense area with low or none infrastructure.

*BOD*

Results of BOD around 100 and 400 mg per litter are usually the results of domestic sewage. Variations from 15.5 and 166 mg per litter were found on the collected samples. Points P2 (Monjolo River) and P4 (Guerenguê River) presented superior value to 100mg per litter. Point P5 (Arroio Pavuna) had 75mg per litter, result lower than the previous point, P4 (maximum point), maybe due to the collection from the superficial layer of the water (it was avoided to collect the mud deposited on the bottom). According to these results the water of Rivers Monjolo and Guerenguê can be classified as weak sewage.

*Nitrogen and Phosphorus*

Jordão & Pessoa (2005) in Miguez (2007) warn that even though it is possible to characterize the organic matter by the tests of nitrogen, these are practically not used anymore to this porpoise, being substituted by BOD determination.

The concentration of nitrogen, under its several ways (ammonia, nitrites and nitrates), indicates the age of the swage or its stabilization according to the demand of oxygen. Nitrites are very unstable in the sewage and easily oxidize to nitrates form. Nitrates are the final stage of stabilization and can be utilized by algae or other plants to generate protein. Its presence indicates an old pollution. It rarely exceeds 1.0 mg per litter on sewage or 0.1 mg per litter in surface waters (Jordão & Pessoa 2005 in Miguez 2007). In the case of the analysed samples, the biggest value found were 0.02 mg per litter on P3 and P4 that belongs to Guerenguê River.

*COD*

The values found on the samples vary from 31 to 218 mg per litter. The highest value was found on sample collection point P4 (Guerengê River) where BOD was also the highest. By these results it is really possible to state that the biggest amount of discharges is from domestic sewage.

The relation COD/BOD indicates industrial discharge less easily biodegraded. Typically COD varies from 200 and 800 mg per litter on domestic sewage, with mean of 400mg per litter and keep around 1.7 and 2.5 times BOD values.

*Biological Characteristics*

*Total Coliforms*

Raw sewage contains from 106 to 109 NMP/100ml of total coli. Results of P1, P2 and P3 were 105 NMP/100ml of total coli, while points P4, P5 and P6 have results of 106 NPM/100ml of total coli. It means that all samples presented values of raw sewage or very close to it.

*Faecal Coliforms*

Raw sewage presents around $10^5$ to $10^8$ NMP per 100ml of faecal coli. Points P1, P2 and P3 presented values of $10^5$ NMP per 100ml of faecal coli and points P4, P5 and P6 presented results of $10^6$ faecal coli. All samples presented values of raw sewage.

As a conclusion, water test result analysis for the sub-basin indicates not only the contamination of the waterways but mainly that this contamination is so high that the rivers area classified as weak sewage and cannot be used by humans in its actual state.

- Fiber and Fuel
    - Fiber and Fuel Production

Data about fiber and fuel production where only found related to the past of the region and will be described further, in order to answer the third sub research question. To answer this question, no fiber and fuel production is available at the present moment in the sub-basin.

- Biochemical

The only data found about extraction of materials from these area is based on the interview with a dweller that say that most of people in the region use plants and fruits of the region for medicinal porpoises. Here is her statement: “We use ‘aroeira’ to reduce inflammations, erva de santa maria (used to have a lot, but not so many have left), Eucalyptus for sinusitis, fruits (guava for constipation, passion fruit to relax).”

- Genetic Material

No data direct related to Genetic Material Ecosystem Service could be found however, it is believed that the existence in the region of protected areas of Atlantic Forest makes this type of service possible in the region.

**Regulating Services**

- Climate Regulation

According to de Barros (2001) and Miguez (2007), climate is responsible for the formation of the local environment of Jacarepaguá and that the same happens on the other way round, local environment affects the climate. The paragraphs below show how it happens in the region where the Sub-basin of Guerenguê River is located.

The influence of the climate, according to Miguez (2007), happens through the distribution of rainfall, temperature and winds. de Barros (2001) states that the climate in the lowlands is hot tropical climate. Dry and wet seasons are well defined. The area has light breeze alternated with strong winds seasons. According to Miguez (2007), climate also influences on the type of vegetation and, in this case, the humid climate display abundant vegetation. De Barros (2001) adds that the constant winds in the region were responsible for the formation of 'restingas' ecosystem'. She also states that lagoons, rivers and artificial channels are important elements of the region and that lagoons' hydrodynamic is linked with tides, rivers, rains and winds.

Local environment characteristics can also influence climate and are mainly related to land use. Forested areas present lower temperatures, lower index of air pollution and larger capacity to rainy water absorption then urbanized areas. According to Miguez (2007) some remarkable characteristics of the city, like the increasing demographic growth, the concentration of built areas, the asphaltic paving and the industrial areas can cause changes in the local climate like indicators of air temperature. He also says that the area is characterized of polluted air by the intense vehicles traffic.

It is possible to conclude that the climate regulations capacity in the region of the sub-basin is reduced by the high levels of land use change and intense vehicles traffic reduces its.

- Hydrological regimes

According to de Barros (2001) the lowlands are cut by lagoons, rivers and artificial channels. On the massifs are located the headsprings of the rivers that flow into the lagoons. The hydrodynamic of the lagoons are linked with the tides, rivers, rains and winds. The lagoons are 'Jacarepaguá', 'Tijuca', 'Camorim', 'Marapendi' and 'Lagoinha'. They have 13 sq.km in total and perimeter of 60km. Corrêa (1932 in de Barros 2001) states that, these lagoons had clean and fresh water with rich fauna also in its margins. Several islands were crated in the lagoons as a result residue deposition from dredging of shells to the industry.

Miguez (2007) says that due to the high elevation above the sea level of the lines that separate the watersheds and the deep slopes in these high elevations, several rivers have a torrential flow, bringing large flows in a short period of time. On the lowlands, where is very urbanized, these water ways deeply decrease their slope, providing large flooding under an intense rainfall.

- Groundwater recharge and discharge

According to de Barros (2001), deforestation exposed the soil and, without vegetation, the rain water could not infiltrate specially in the sloppy areas. The sandy areas of 'Restinga's Ecosystem' are covered by characteristic vegetation that avoid contribute to soil permeability promoting ground water recharge what is important to the maintenance of region water bodies. These vegetation is almost not found anymore in the region.

- Storage of water to agriculture or industry

There are no data related to the storage of the waters form this watershed for any reason. Moreover, there are several problems related to water quality of water bodies. Groundwater

can be contaminated and turn unfeasible its use for human supply. Depreciation of water quality increases the problem of fresh water resource scarcity.

It is possible to conclude that hydrological regimes in the region are compromised by land use change and water pollution.

- Pollution control and Detoxification
  - Nutrients excess and pollution retention, recovery and removal

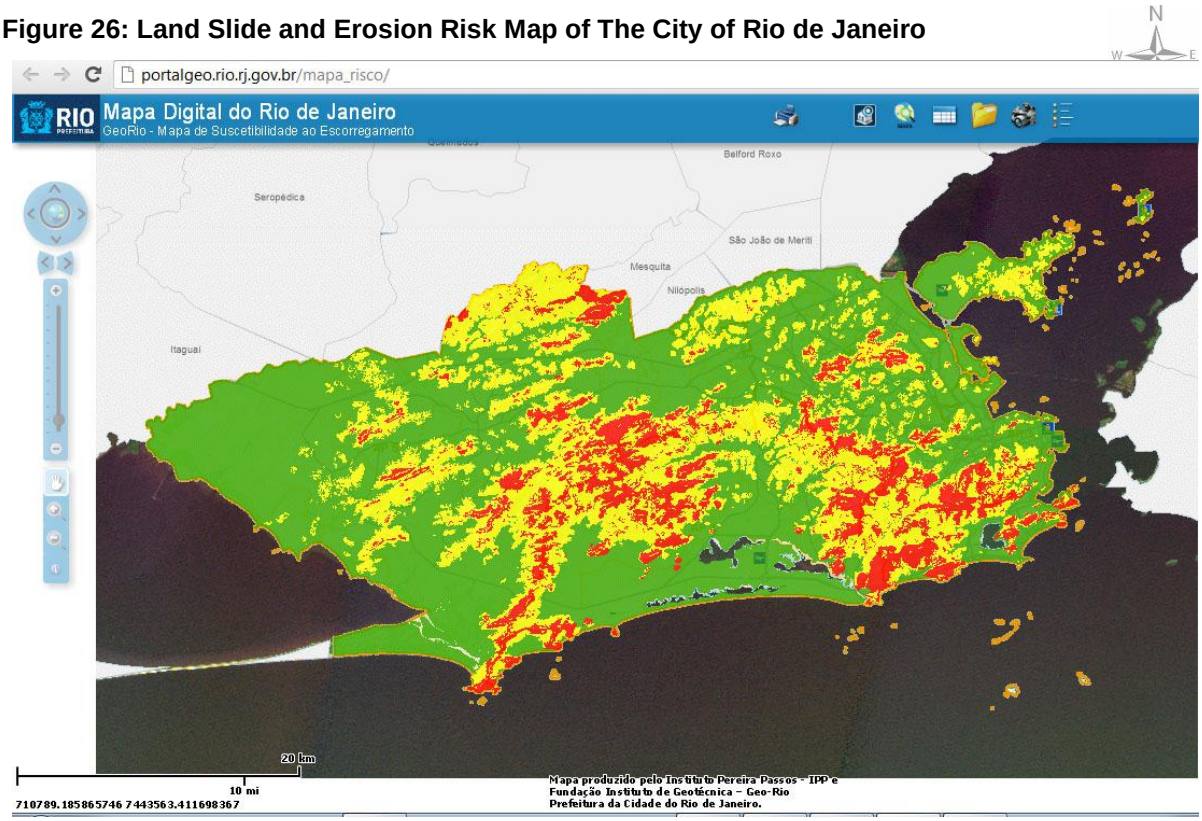
According to Miguez (2007), water bodies of Guerenguê River's Sub-basin receive large quantity of sewage, waste and pollution. The area is also known by its large quantity of traffic what also affects the air quality. There are several areas where vegetation do not exist what also reduces the capacity of environment to retain, remove and even filtrate pollution.

Data collected about water quality presented in the item fresh water of this thesis revealed that the amount of nutrients discharged in its rivers is bigger than its natural recovery capacity what requires a sewage treatment. It mainly comes from domestic sewage due to lack of sewage collection system in this densely urbanized region (Miguez 2007).

- Erosion Protection
  - Retention of Soils
  - Prevention of Structural changes

The Sub-basin of Guerenguê River is susceptible for erosion according to the study of the municipality "Landslide Susceptibility Mapping" and to past events. The most alarming areas are located in Pedra Branca Massif due to the amount of soil that can slide from the sloppy region. Smaller erosion points are located along the rivers especially in those areas with less riparian vegetation according to observation on site and interviews. Some areas have already being reforested by municipality cooperation projects together with surrounding communities in order to avoid landslides.

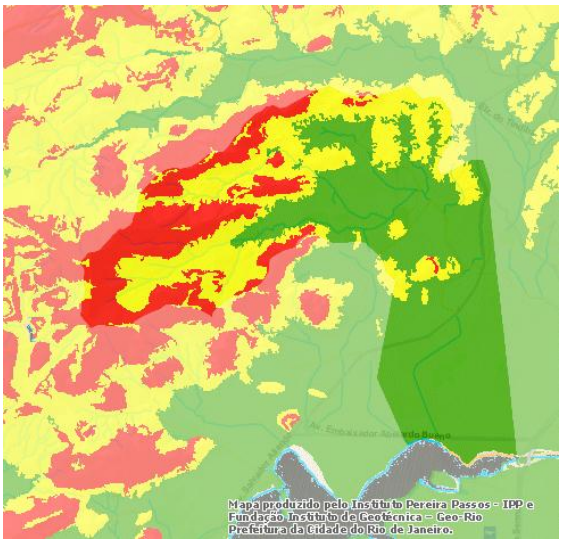
**Figure 26: Land Slide and Erosion Risk Map of The City of Rio de Janeiro**




Source: municipality website portalgeo.rio.rj.gov.br 2012

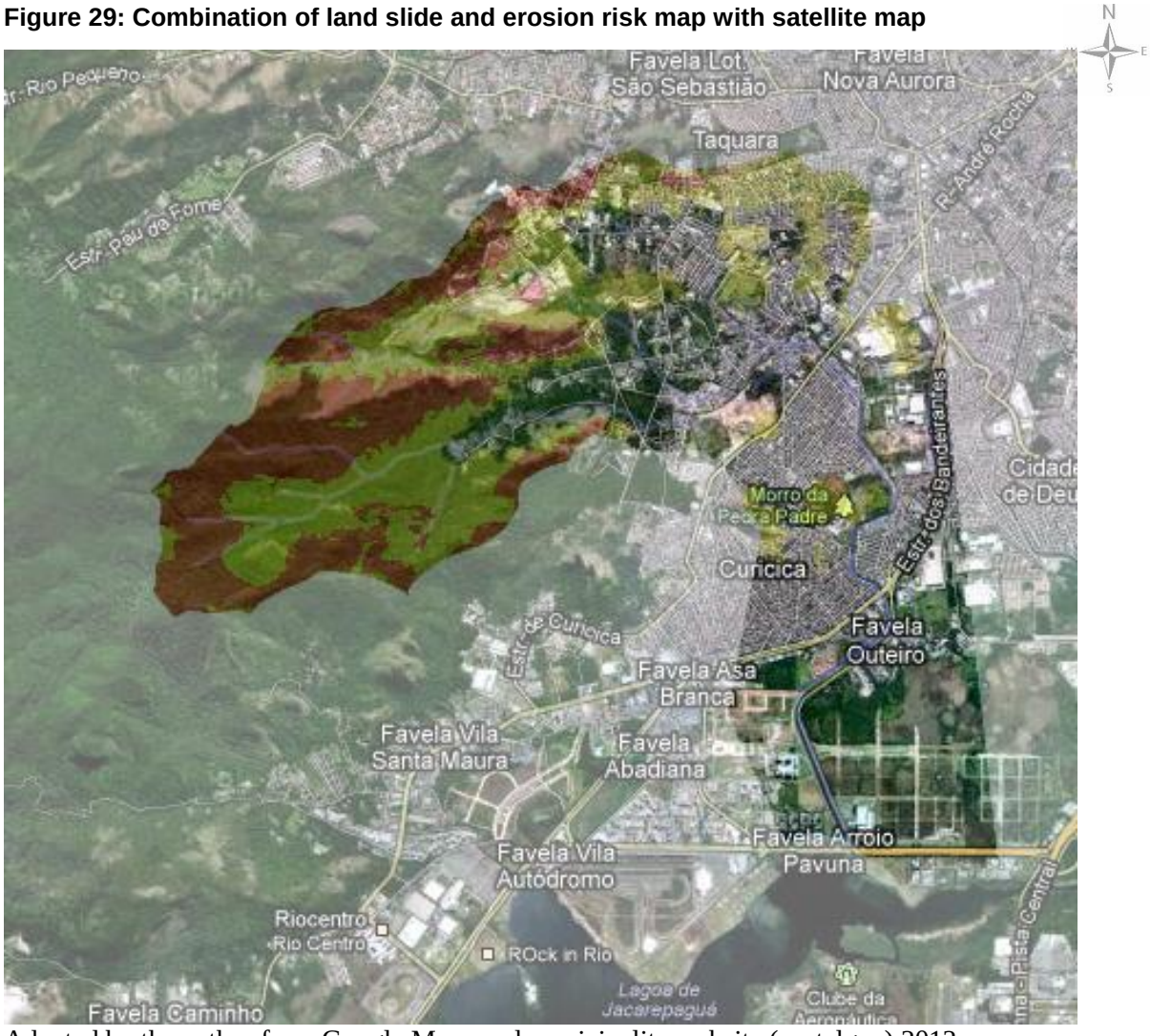
**Figure 27 Satelite view Sub-basin Highlighted**


**Figure 28: Risky areas Sub-basin Highlighted**




Adapted by the author from Google Maps and municipality website (portalgeo) respectively 2012

**Figure 29: Combination of land slide and erosion risk map with satellite map**




Adapted by the author from Google Maps and municipality website (portalgeo) 2012

The most serious landslide event happened in 1996 when on the arrival of a cold front, an abnormal quantity of rain reach Jacarepaguá, 304mm against 20mm in the city center (Miguez 2007). This rain caused flooding in the lowlands of Jacarepaguá and landslides in the higher parts. A vast volume of soil and large blokes of rocks were dragged downhill, silting in the river channels and increasing flooding in massive proportions.

The highest parts of Pedra Branca Massif presents a steep slope shape. It facilitates erosion and sediments dragging even with vegetation. Vegetation protect, improve infiltration by driving and absorbing it. The animals that compose forest ecosystem also reduce pressure over soil (de Barros 2001)

The reforestation project of the municipality works in specific locations based in some criteria: low income communities organized by community associations in the immediate surroundings of the deforested area, deforested area must have a marked slope, must be an Environmental Preservation Area (APA – Área de Proteção Ambiental) under pressure of irregular occupation, surrounding areas of Conservation Units, watersheds' flood prone areas.

Urban reforestation program aim to recover and protect urban forests based on a partnership with the communities that surround these areas. It was created in 1984 in the Social Development Municipality Bureau (SMDS – Secretaria Municipal de Desenvolvimento Social) in order to improve infrastructure in low income communities in task force regime. It moved to payed task force and the reforestation were also included in these improvements in 1986, having its first project done in Jaracarepaguá in 1987 in Morro de São José Operário. In 1994 it became under control of CRA, Coordinating Board of Environmental Conservation and Recuperation (Coordenadoria de Conservação e Recuperação Ambiental). It is present in 100 communities, around 800 dwellers covering more than 1,800ha with more than 5 million planted trees.

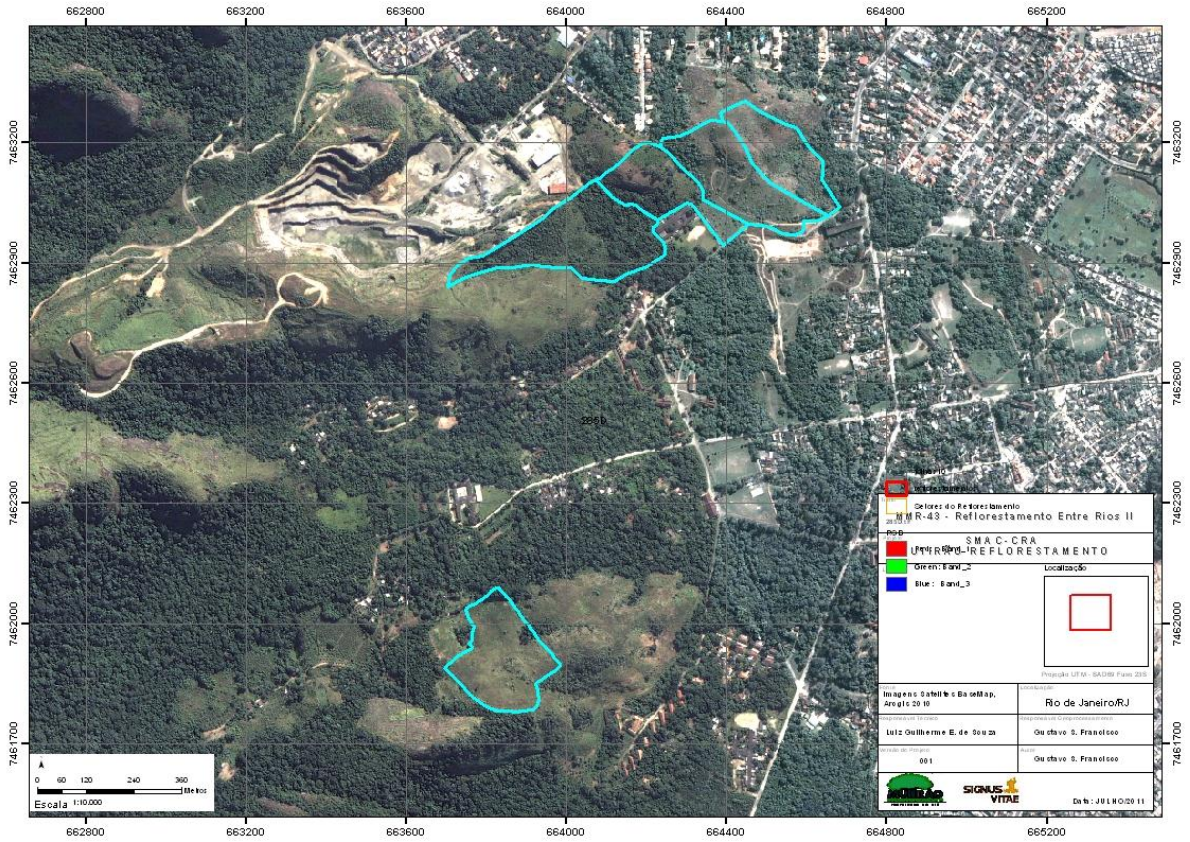
The Municipality offer training programs and all the material and plants needed. Around 150 species of trees are used, most of them from Atlantic Forest Ecosystem. The collection of seeds are made from 2,500 registered trees selected based on the maintenance of biological diversity of the reforestation. The trees grow in 5 different nurseries around the city and produce around 1,000,000 trees per year.

The importance of reforestation according to them is that forests in sloppy areas stabilize the soil and the reduction of erosion and sediments dragging that cause siltation in water bodies therefore avoiding flooding. It presents vast results related to life quality, not only for the risk reduction and by the work opportunity for the local communities but it also brings awareness and environmental protection for wider parts of the city.

The difficulties faced by this project are mainly related to risk of fire and drug traffic present in some communities (municipality, 2008).

A reforestation project located in the Sub-basin of Guerenguê River is located in maps above:

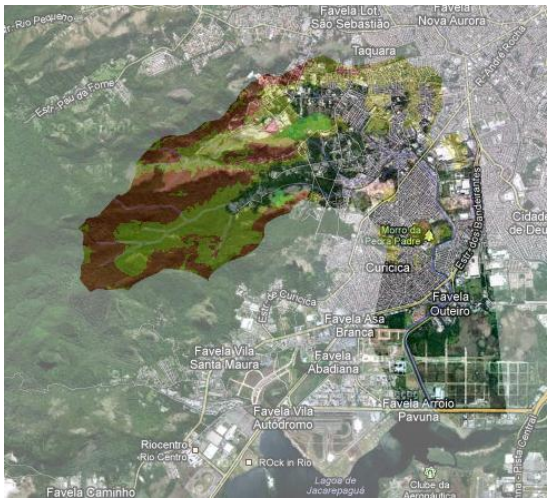
**Figure 30: Municipality Reforestation Map in the area of Guerenguê River's Sub-basin**




Source: Municipality, Reforestation sector 2012

**Figure 31 Municipality Reforestation Areas**


**Figure 32 Combination of risk and reforestation**




Adapted by the author from Google Maps and Municipality (portalgeo and Reforestation) 2012

It is possible to conclude that several parts of the sub-basin are susceptible to erosion and landslide. Some, due to the geographical situation and other due to deforestation. Some areas are in the communities and are harder to prevent based on reforestation projects due to its dense urbanization.

- Natural Hazards
    - Flood Control and Storm Protection

As mentioned in previous items of this chapter, the climatological and geographical conditions of Jacarepaguá Watershed contribute to the existence of flood prone areas. The combination of these conditions with intensive and fast urban sprawl increases the flooding vulnerability of the region. The flood prone areas were identified in Miguez work (2007) and are presented in a map and a matrix.

Miguez (2007) explains that the rivers from Jacarepaguá Watershed present a torrential flow due to the steep slopes of the high massifs of Pedra Branca and Tijuca. Under intense rainfall, common in the rainy season of the local climate, these rivers carry a large amount of water in a short period of time. The high level of urbanized area reduce the possibility of infiltration and expose dwellers to the risk of flooding. It is also confirmed in de Barros work (2001).

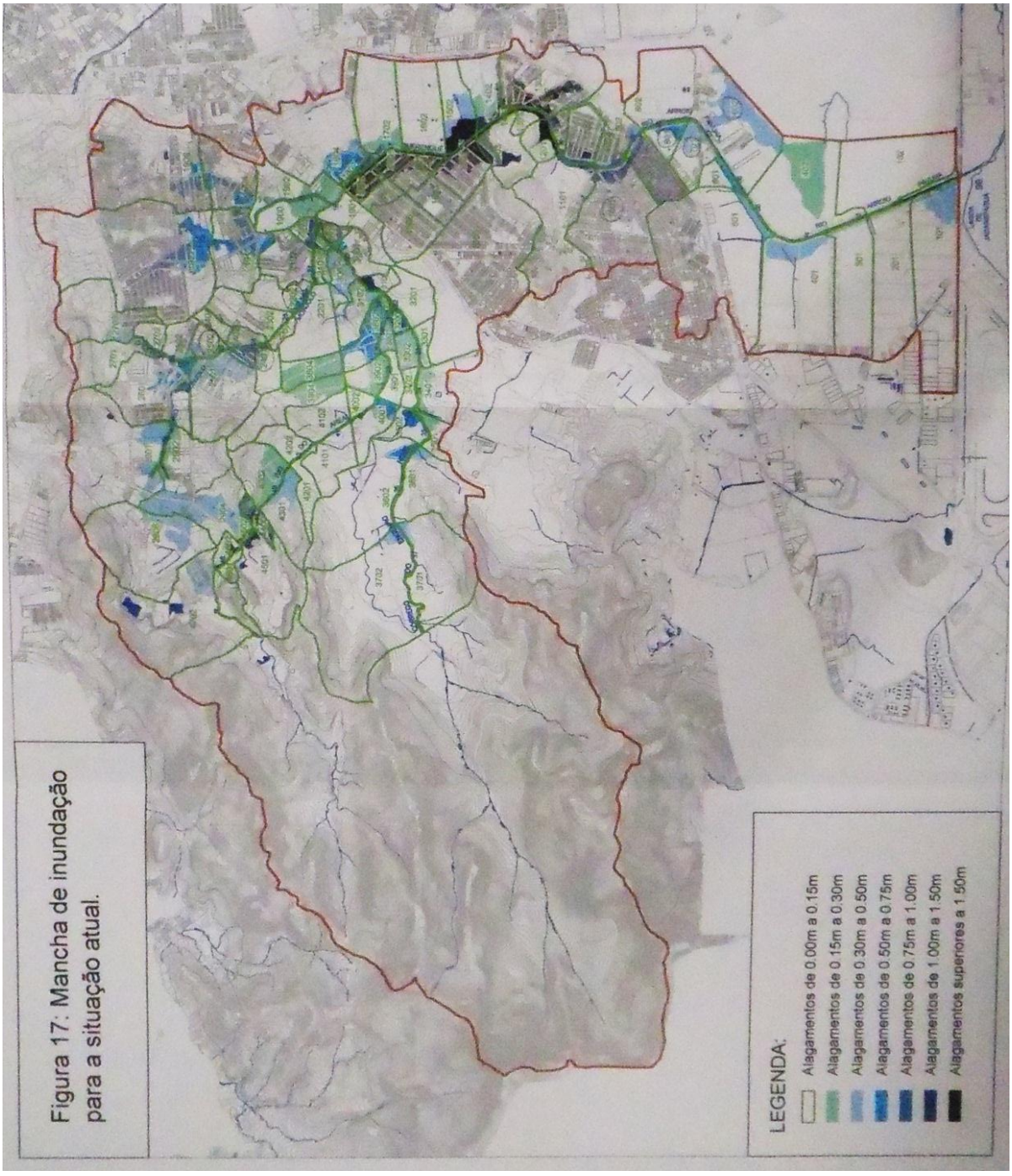
Other important, according to Miguez (2007) factor that increase flooding possibility is river's channel reduction. It can be caused by natural and manmade reasons like siltation, solid waste launching, occupation of riparian areas of rivers and constructions. All these problems can be found in Jacarepaguá Watershed.

With the heavy rains from 13 February 1996, rivers' levels increased and houses irregularly built in its riparian area were affected. On 14 February 1996, in only 8 hours, 200mm of rain fell over the area driving this place to a destruction scenery. Large rock blokes and large amount soil reduced rivers' channels, even flattening some, worsening the situation (Miguez 2007). It is important to mention also that flooding of polluted water bodies causing also, public health problems.

The intensification of urbanization generates, as expected, more flooding. Planning in advance is always the best solution for sustainable development. Diffuse pollution control practices also works as rain water runoff solutions and can also contribute to reduce flooding. However the only action in this sense that could be observed was the relocation of one irregular settlement. After the flooding of 1996, the work force made was to reconstruct bridges, rain water galleries and rectification of rivers.

The map and the matrix above show the flood prone areas based on lagoons high tide and 20 year rain scenary. According to Miguez (2007), the area affected by flooding is alarming. It affects not only the riparian areas but also areas far from the water bodies. Are affected, not only irregular, but also, regular urbanization areas. The most vulnerable group though, is of irregular occupations along the rivers.

**Figure 33: Flooding depth in the actual situation**




Source: Miguez 2007

**Cultural**

- Spiritual and Inspirational
    - Personal feeling and well-being

Most of the data found about personal feeling and well-being is based on life quality and life conditions in the region. It is highlighted in the studies found that irregular occupation of riparian areas, conversion of green area in densely urbanized area with dense traffic, increase the vulnerability to flooding, water quality degradation, reducing, in this way, well-being.

According to Miguez (2007), it is considered that the achievement of a better quality of life, environmental quality is determining factor. Waters contamination and in the atmosphere that compromised flora, fauna and life quality. People from Guerenguê River's Sub-basin is suffering of sever influences on the water and air quality and in population's life quality.

De Barros (2001) study, investigates the importance of the community participation in local sustainable development. She focuses on environmental and life quality. It is emphasized by her that the pilot urban plan for the region made by the Architect Lúcio Costa in 1960s, intended to develop Jacarepaguá region preserving the integrity of the local ecosystem, this way, ensuring quality of life. However, the model was not fully followed, causing impacts on ecosystems and on people's life quality.

The pollution of the water bodies cause death of fishes causing losses to fisherman and their quality of life. According to de Barros (2001), high levels of air, noise and visual pollution, climate change, urban chaos and several other effects that are present in the region compromise population life quality.

In the theoretical framework developed in this study shows the relation of ecosystem services and human well-being. The data collected says that the situation in the region is compromising life quality and consequently human well-being.

- Religious Significance

No data about religious significance could be found for the area.

It is possible to conclude with the data available that cultural service in the region is very reduced.

- Recreational
    - Tourism

Tourism in the region is not so explored now but there are several attractions that could be in use. They are not that attractive due to the not pleasant urban environment as described in this work. De Barros (2001) mention a study from UNDP (United Nations Development Program) and IPEA (Institute for Applied Economy Researches) and the Municipality of Rio de Janeiro that emphasizes that the fastened occupation of this area are causing laky system degradation, compromising the touristic profile of the region.

- Recreational

It is mentioned by Miguez (2007) that the polluted water of the water bodies of the region cannot be used for leisure activities and it also compromises activities in the surroundings due to reduction of attractive environment for those.

It is possible to conclude with the data available that recreational service in the region is very reduced.

- Aesthetic
    - Identity and Contemplation

Many aesthetic aspects can be compromised in the actual situation of the sub-basin. According to Miguez (2007), direct sewage discharge, insufficient solid waste collection and dense urbanization without green areas distribution depreciate the aesthetic ecosystem service provision. The heavy traffic also contributes to air and noise pollution. It was possible to observe in the local that air conditions are worsened by the soil exposure along some roads. It reduces the landscape and contemplation activities.

It was not possible to find people appreciating the natural features in the urbanized areas. In some areas is possible to see garbage spread along and inside the rivers, sewage being discharged, the lack of maintenance of the public space. The green areas that also compose the sub-basin are more pleasant but irregular occupation and environmental degradation are always contrasting with natural environment.

The area where an irregular settlement was removed from the riparian areas of Arroio Pavuna and where middle and middle-high class gated communities are expanding a little landscape treatment were provided with grass, palm trees and bromelias a fence made of wood and plans as the pictures show. A single cyclist was found there. Even though the natural vegetation was not recovered, the images show the aesthetic potential of the region and the contrast with the other side of the river that lacks care.

When visiting one of the houses along the Arroio Pavuna, it was possible to see how some dwellers deal with the river. Sewage and garbage are direct discharge on it as shown in the photos. In the interview with the specific dweller, the river is now just sewage. She express more identity by the past state of the river, with clear water and sandy soil. She complain that the landscape treatment gave to the area is not natural, and she does not identify herself with that type of vegetation in that area. She mention that this is a high class style that has no relation with the local identity.

Miguez (2007) says that leisure activities on the surroundings of the stream are prejudiced because the environment lose its aesthetic attraction due to the siltation of its channels, the exacerbated proliferation of algae and macrophytes (when in an advanced stage of eutrophication) and the bad smell from the domestic sewage that mix with the river's waters. It is mention by him that the implementation of sewage and more efficient solid waste collection systems and recovery of riparian areas would improve a lot the aesthetic local condition.

De Barros (2001) states that the laky system to where most part of the rivers from Jacarepaguá flows, presents an unique beauty scenery and demands special environmental care. She also states that the history of the area presents high importance to natural and cultural heritage. In Lúcio Costa's pilot urban plan included the integration of green areas preferably preserving its natural state, preservation of natural monuments like small hills based on the landscape importance for the region. By local visits is possible to see that small hills and some natural vegetation were really preserved, but not in the proportion and distribution necessary to guarantee aesthetic features in the whole area. Many parts of the sub-basin lack of contemplation possibility.

It is possible to conclude with the data available that aesthetic service in the region is very reduced.

- Educational
    - Educational and training

De Barros (2001) study, focus on community participation on the implementation of sustainable development. Miguez (2007) agree saying that the success of the implementation of non-structural measures like, land use planning, street swapping and solid waste collection,

illegal pipes connection control, depends very much on participation and awareness of people.

It was interesting when visiting the area, the contrast between identity and environmental protection. By interviewing the dweller that lives downstream, in the limit to the lagoon, she mentions that she cannot live without the nature she has around here there. However, the area has no sewage collection so her sewage is directly discharged in the water bodies of the sub-basin. She argues that everybody is doing the same, and wonder why her community should be removed if several gated communities also discharge their sewage there. This shows the lack of information related to awareness and environmental protection. She also believes that it is important to the whole education of her daughter that she grows close to nature. It is true that the region has no sewage collection so it is also political problem. According to de Barros (2001) politicians would only take environmental friendly actions if demanded by the population.

It is possible to conclude with the data available that educational service in the region is very reduced.

**Supporting**

- Biodiversity
    - Habitat for resident or transient species

No data could be found about the actual condition of biodiversity in the region, especially about its fauna. As mentioned before, the water bodies of Guerenguê River's Sub-basin are much compromised in terms of aquatic life. The lack of integration of green areas is also observed and reduce the possibility of migration of species and provision of habit for them. The only area where this appropriate habitat for resident or transient species are located in the massifs.

According to de Barros (2001), it find birds like garças (egrets), socós (herons), maçaricos (kingfishers), marrequinhas, irerês, frangos d'água and colheiros mainly in the lagoons of the region. Crocodile Caiman latirostris (Jacaré de papo amarelo) is now very rare due to chasing and ecosystem pollution. According to Côrrea (1932 in de Barros 2001), at that time, fauna was much richer than today.

Miguez (2007) states that the historical population growth, urbanization and industrialization, changed and is still changing widely Rio de Janeiro original environmental aspect. These modifications in land use, water and atmosphere, compromises flora fauna and life quality. De Barros (2001) agrees and add biodiversity the affected items. According to her, if degradation continues like this, not a lot will be left soon.

It is possible to conclude with the data available that biodiversity provision was much higher in the past.

- Soil Formation
    - Sediment retention and accumulation of organic matter

Soil formation as an item of ecosystem services, is mostly related to the hability of nature by its natural process transform organic matter and sediment in a fertile soil. It is also related to the its hability of sediment retention. As mentioned before, the area has natural characteristics and suffered several anthropic actions that made it susceptible to erosion and sediments transport by the rivers' waters, instead of sediment retention. It is possible to say that sediment retention and accumulation of organic matter is very present in the massif forest. The area along the lagoon is composed by mangrove but most of it is deteriorated. Mangrove is characterized by a very fertile and wet soil, rich fauna and flora. It was possible to observe

that not only dwellers are responsible for the removal of mangrove along the lagoon, also private and municipality contractors neglect the importance of these rich ecosystems by building in these areas.

- Nutrients Cycling
    - Storage, recycling, processing and aquisition of nutrients

The deforestation exposed the soil and, without vegetation, the rain water could not infiltrate. Forest elements regulate the impact of rain on the soil through its vegetation, animals and its natural drains reducing its pressure over the soil. Without the vegetation facilitates erosion and consequently river and lagoons siltation. The nutrients recycling process are interrupted and the soils lose its fertility (de Barros 2001).

All the feeding chain is sustained based on the content of present nutrients and, consequently, these concentrations regulate the ecosystem productivity. A well-defined daily cycle influences on the variation of pH of water, the same happens with the concentrations of carbonates and calcium bicarbonate, for example, due to the process of production and consumption of $CO_2$. Aquatic plants use nutrients dissolved in the water. Algae make photosynthesis consuming $CO_2$ from the water liberating $O_2$. The anthropic action over the aquatic environment is maybe the responsible for the biggest changes in the water composition (Miguez 2007).

It is possible to conclude with the data available that nutrients cycling service is almost null in the urbanized areas.

- Polination
    - Support for pollination

Due to lack of integration among the few green areas the only possible area to find that is in the forest of massifs. However, it is possible to conclude that green areas provide that service and the lack of these green areas in a great extension of land reduces the possibility of providing support for pollination.

Table 10, below, shows a summary of the findings of this section.

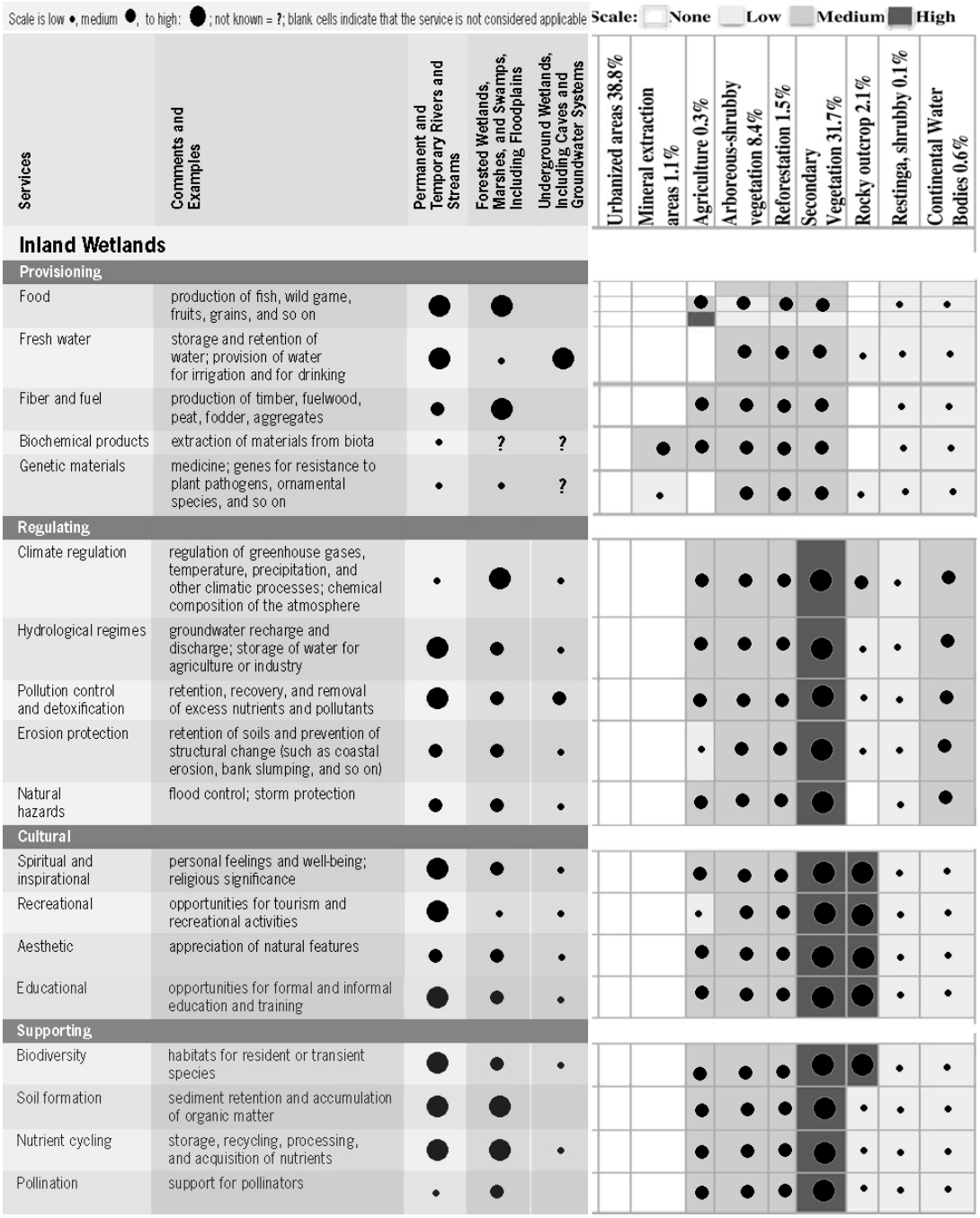
**Table 10: Contribution to Ecosystem Service by land use. Scale: None Low Medium High**

| Variables | Indicators | Urbanized areas 38.8% | Mineral extraction areas 1.1% | Agriculture 0.3% | Arboreous-shrubby vegetation 8.4% | Reforestation 1.5% | Secondary Vegetation 31.7% | Rocky outcrop 2.1% | Restinga, shrubby 0.1% | Continental Water Bodies 0.6% |
|---|---|---|---|---|---|---|---|---|---|---|
| **Provisioning** | | | | | | | | | | |
| **Food** | Fish | | | | | | | | | |
| | Fruits | | | | | | | | | |
| | Agriculture products | | | | | | | | | |
| **Fresh water** | Water quality | | | | | | | | | |
| **Fiber and Fuel** | Fiber and fuel production | | | | | | | | | |
| **Biochemical products** | Extraction | | | | | | | | | |
| **Genetic Material** | Availability | | | | | | | | | |
| **Regulating** | | | | | | | | | | |
| **Climate regulation** | GHG, Temperature, Precipitation<br>Other climate processes | | | | | | | | | |
| **Hydrological regimes** | Ground water recharge and discharge<br>Storage of water | | | | | | | | | |
| **Pollution control and detoxification** | Nutrients excess and Pollution: Retention, Recovery, Removal | | | | | | | | | |
| **Erosion protection** | Retention of soils<br>Prevention of structural changes | | | | | | | | | |
| **Natural hazards** | Flood Control<br>Storm protection | | | | | | | | | |
| **Cultural** | | | | | | | | | | |
| **Spiritual and inspirational** | Personal feeling and well-being<br>Religious Significance | | | | | | | | | |
| **Recreational** | Tourism<br>Recreation | | | | | | | | | |
| **Aesthetic** | Identity<br>Contemplation | | | | | | | | | |
| **Educational** | Education<br>Training | | | | | | | | | |
| **Supporting** | | | | | | | | | | |
| **Biodiversity** | Habitat for resident or transient species | | | | | | | | | |
| **Soil formation** | Sediment retention<br>Accumulation of organic matter | | | | | | | | | |
| **Nutrient cycling** | Storage, recycling, processing and acquisition of nutrients | | | | | | | | | |
| **Pollination** | Supports for pollination | | | | | | | | | |

Source: Author 2012

In order to compare the magnitude of services provided by the land uses of Guerenguê River's Sub-basin to the magnitude provided by conserved wetland ecosystem, the Table 1 from Millennium Ecosystem Assessment (2003) and Table 10 with the findings of the specific sub-basin were adapted generating Table 11 as shown below. From Table 1, only those wetland ecosystems related to the specific sub-basin were selected: Rivers, Forested Watersheds and Groundwater system. Guerenguê River's Sub-basin findings now are presented in Table 11 using the same symbols as those adopted by Millennium Ecosystem Assessment (2003) to represent the magnitudes of service provision, black circles with different sizes.

**Table 11 Comparison between ecosystem services of types of wetlands and Gurenguê River's Sub-basin land uses.**




Adapted and produced by the author in 2012 from Millennium Ecosystem Assessment 2005b

### 4.3.3 Actions to restore and potential Ecosystem Services of a restored Guerenguê River's Sub-basin

In order to achieve these research objectives and answer the relevant questions, an historical approach (Jackson & Hobbs 2009), current situation and suggestions of actions for improvement based on the data collected will be presented to each indicator of ecosystem service. The potential restoration based on each action on the provision of Ecosystem Services in the Sub-basin of Guerenguê River, will be related, if possible, to a certain period of its history.

**Provisioning**

- Food
  - Fish

*Historical Background*

It is estimated in the studies of de Barros (2001) that since the sugar cane production started in 17$^{th}$ century in the lowlands of Jacarepaguá, the residues were discharged in the rivers and already contributing to siltation and death of fishes. In her work, she refers to Corrêa (1932) who already warn that deforestation and indiscriminate fishery activities were damaging water bodies and its ecosystem. Afterwards, with the growing urban sprawl that began after 1969, when the Pilot Urban Plan designed by Lúcio Costa was approved, environment was extremely affected, according to her, in a no turning back way. This pollution affected aquatic life and fisherman's life quality.

*Actions*

As confirmed by Miguez (2007), water bodies from Guerenguê River Sub-basin suffer mainly of domestic sewage pollution. This pollution affects the aquatic ecosystem and the provision of fish. He highlights the need of an integrated approach in the region in order to recover the water quality in the sub-basin's rivers. The first measure should be the implementation of sewage collection and treatment system in order to avoid raw sewage discharge in the water bodies. These are under construction since 2001 but the endings of works are only for 2031. Other measures that would help water quality improvement and consequently fish provision improvement are the preservation of the remaining riparian vegetation, the recovery of the destroyed riparian vegetation and a more efficient solid waste management.

*Historical Relation*

The historical background combined with the already suggested measures to recover the water quality in the region, it is possible to visualize that after the implementation of sewage collection in all the region, even in the low income communities, a scenery of fish provision ecosystem service similar to 17th century or earlier, before the sugar cane production started or at least from 1960s, before urban sprawl could be presented in the region.

  - Fruits

*Historical Background*

Not many of data about fruit provision could be found. De Barros (2001) says that before the arrival of Portugueses, indigenous communities collect products from the native vegetation but nothing specific about fruits. The interviewed dweller that lives there since she was born,

in 1978, states that nowadays she consumes fruits from her backyard and mentions that mangrove fruits used to grow there naturally and now it is necessary to cultivate.

The existing vegetation might provide some fruits. However, considering the high urbanization level of the region and the conventional approach from the city of Rio de Janeiro, fruits for consumption would come from agriculture. Therefore, this indicator of food provision is considered in this work of minor weight to the local ecosystem service.

- Agriculture

*Historical Background*

Indigenous population that lives in the region before the arrival of Portugueses to Brazil already had agriculture production proportional to their culture and population (Drummond 1997 in de Barros 2001). The development of agriculture in the area is dated from 17$^{th}$ century sugar cane started to be produced there. Afterwards, coffee started to be produced in the highlands. These productions were made in a way the exploited the soil at it maximum, causing droughts that affected the crops themselves. The lowlands had a more diversified agriculture. After the plague of 1843 and the drought of 1844 the production of coffee was reduced and Jacarepaguá remain unoccupied. This period recovered a lot of its fauna and flora. In the beginning of 20$^{th}$ century Jacarepaguá was source of natural and agriculture products. In 1969 the pilot urban planning of Lúcio Costa was approved and since then, the land use change and occupation increased highly. The area changed its agricultural economic patterns to industrial, commercial and services. Only few parts are still remaining or used for agriculture production.

Nowadays, agriculture occupy only 0,3% of the region according to land use map produced by the municipality. According to Millennium Ecosystem Assessment for Wetlands (2005b) the importance of wetlands for provision of food ecosystem service is of high magnitude. That includes fish, fruits and agriculture products. However, the benefits to human being provided by agriculture production in this region seems to be of secondary importance. It is warned by Miguez (2007) that agriculture can contribute to water bodies' contamination by pesticides and fertilizers. He suggests as well that the recuperation of local natural ecosystem is of high importance.

On the other hand, urban agriculture is new trend in the fields of city resilience in terms of sustainability (Chen 2012). Techniques of roof gardens with agriculture production are considered a way to reduce GHG emisions avoiding long distance transportation of food from rural areas, as a structural measure for rain water absorption helping reduce flooding problems and of climate regulation in urban heat islands. However, paint houses in the high income class, terrace to low income houses and roofs are the most common roof top occupation in Rio de Janeiro. On paint houses, high income class can enjoy more space and have a private leisure area. Terraces for the low income are not only seen as a leisure area but also a possible area for house expansion. Roofs are widely used for indoor climate regulation.

*Actions*

Two possibilities are then open to increase agriculture in the region, free lands agriculture implementation or green agricultural roofs. Both options seem to be quite unrealistic for Guerenguê River's Sub-basin characteristics but should not be discarded.

*Historical Relation*

It can't be compared to any period in history if considering that this is now an urbanized and not rural area.

- Fresh water

*Historical Background*

Jacarepaguá urban occupation changed very much the water quality of the region. According to Magalhães Corrêa (1932 in de Barros 2001) the lagoons, that are part of its water system had clean and fresh water with rich fauna also in its margins. Since then, man has changed the local ecosystem severely. Still in de Barros (2001) work is possible to find that 'Marapendi' lagoon used to be composed by fresh water but after the construction of the channel with the same name in the end of 1960s connecting this lagoon to 'Tijuca' lagoon, it has now brackish water. The previously existing marsh vegetation close to the margins was converted into mangrove vegetation. Mangrove is nowadays, according to municipality data, null in the region.

The 'Restinga's Ecosystem' contribute to soil permeability promoting ground water recharge when it rains which levels are important to the maintenance of region water bodies. According to the land use found in the region, very few have left of this important ecosystem to ground water recharge and consequently to water provision. In the region, restinga represents only 0,1% of the area of Guerenguê River Sub-basin.

The great drought of 1844 made the government reforest Tijuca's Massif and creates, in 1861, 'Tijuca' Forest. It was an important step to guarantee water provision in the region. Nowadays, only secondary forests are found and represents 31,7% of the sub-basin area. Anthropic areas of shrubs, grassy-wood and reforestation correspond to 19,9% and natural march vegetation 5,5% are also present in the region.

The growing urban sprawl that started in 1970s in the region without the need proportion of sanitation increased so much organic matter in the water bodies in a way that environment could not manage to recover. The urbanization of the area was characterized by several irregularities, highlighting those related to irregular construction, irregular land occupation, sand extraction from dunes and from lagoons and rivers, emissions of sewage, residues, sediments among others.

Nowadays, fresh water system in the region is provided by CEDAE. Its source is not from the region. It depends of an enormous infrastructure system that brings water for human consumption from Guandú Water Treatment Plan.

*Actions*

It is possible to conclude that deforestation and waste discharge in the water bodies are the main reasons to weak fresh water provision in the area. As mentioned in the item fish provision, a sewage collection and treatment is under development in Jacarepaguá to be ready in 2031. The full implementation of this system in the sub-basin is crucial to its water bodies' quality.

*Historical Relation*

Considering that sewage is not discharged in the rivers in the future, the use of this water for human consumption is not possible without provision of treatment. However, other uses of fresh water would improve incredibly life quality in the region by providing for instance aesthetic benefits, leisure and fishing. The benefits are also related to land value and to all

types of ecosystem services. In this way, it presents high level of importance to the region. If compared to a previous time in local history, would be around 1960s.

- Fiber and Fuel

*Historical Background*

In 17th century the region started to be producer of sugar cane. Fiber and fuel at that time were abundant in the forests. To clean the terrain and introduce sugar cane culture forests were burnt. The same happened to coffee production latter on. Moreover, sugar cane industrial production demanded high quantity of firewood and that was also collected from the remaining forests. It was estimated that to produce 1kg of sugar, 15kg of firewood was necessary. In the beginning of 20th century, Corrêa (1932 in de Barros 2001) mention that the area was a great source of wood and firewood being collected, used sold by people. He also mentions that handcraft industry exploited these materials from protected areas. Going further in history, an interview with the selected dweller from the region since 1978, the use of fiber of 'tabôa' was common around 20 years ago. According to her, it is extinct nowadays.

No recommendation about fiber and fuel production in the area was found. It does not seem to be a common feature of the region. The vegetation in the area seems to have other more important use for its forests which is of erosion and flooding prevention and fresh water provision. The possibility of use its trees for fiber and fuel production seems not possible due to the need of Atlantic forest preservation and environmental protection area.

- Biochemical Products

*Historical Background*

The extraction of materials from the region is known since before Portugueses arrive in Brazil. Indigenous population extract several materials from the ecosystem. Extraction of sand from dunes, lagoons and rivers is also known in the region when urbanization started in 1960s. The area has a mineral extraction area nowadays that occupy 1,1% of the sub-basin area. The interviewed dweller mention that she and other people from community use some plants for medicinal proposes.

Extraction of biochemical products form the region seems to be viable under no damaging proportion.

**Regulating**

- Climate regulation
  - Temperature and precipitation

*Historical Background*

Jacarepagua is composed by lowlands and highlands with peaks higher than 1.000m above the sea level. The south of lowlands used to be completely flooded in the beginning of 20th century (Corrêa 1932 in de Barros 2001). At that time, the region was provider of natural materials (de Barros 2001). The pilot urban project of Lúcio Costa from 1969, integrated

urban and natural features however in the urban expansion was characterized by several irregularities, especially irregular land occupation in 1970s.

Indicators of climate regulation in the region are mainly related to its land use. Forests and water bodies contribute to climate amenities and show that they are more adaptable to climate changes circumstances. Densely urbanized areas increase temperatures, air and water pollution and are not adapting to climate change situations. As the research results show, the sub-basin has all the problems of a dense urban area that affect, not only the environment, but human-being.

*Actions*

Several changes were suggested by specialists like the recovery of riparian vegetation that helps in climate regulation. A result might be a combination of urbanized area with green corridors along the rivers. Other green areas or rain water harvesting could also contribute.

*Historical Relation*

It is hard to compare to any of cited period of time due to the new approach suggested.

- Hydrological Regimes
  - Ground water recharge and discharge

*Historical Background*

The historical background of Jacarepaguá shows that the first problem with ground water recharging and discharging was in 1844 when a severe drought affected Tijuca's Massif due to replacement of forest to coffee crops. A reforestation of the Massif was made and in 1861 Tijuca's Forest was funded. This fact brought the awareness of the need of forests around the springs and the conservation of these forests are possible to see in the massif of Pedra Branca where the springs of the sub-basin are located. Since 1970s local environment was completely changed in the lowlands from an agricultural to densely urbanized area. Many vegetation that contribute to ground water recharge was converted to build area and pollution contribute to ground water contamination.

*Actions*

As mentioned before, the implementation of sewage collection and treatment system is the first need of the area. Secondly, the protection and recovery of riparian vegetation is great importance to water bodies' conservation.

*Historical Relation*

This is a scenery that does not refer to any period of time.

  - Storage of water

No data was found about storage of water in the region.

- Pollution control and detoxification
  - Nutrients excess and Pollution: Retention, Recovery, Removal
    - Pollution

*Historical Background*

The levels of pollution beyond the recovery capacity of the region become crucial from 1970s on. Retention, recovery and removal of nutrients excess in the local environment are mainly related to water quality levels and solid waste management. The levels in Guerengue river and Monjolo are of weak sewage. In this case, rivers cannot recover its water quality by natural process being sewage treatment necessary. Other pollutants are those that affect air quality.

*Actions*

Most of natural areas before city expansion are now converted to an unsustainable urban area. Sewage treatment and implementation of more efficient solid waste collection and green areas in the urbanized sub-basin were some of the measures appointed by Miguez (2007) that would help reduce pollution in the sub-basin.

*Historical Relation*

These measures might bring back the ecosystem provision from beginning of 1970s when occupation was still in the beginning and the pressure over ecosystem was lower, however, in a more sustainable way.

- Erosion Protection
  - Retention of Soils and Prevention of Structural Changes

*Historical Background*

Corrêa, in 1932, already predicted the need of environmental care in order to avoid natural disasters (de Barros 2001). It was common to deforest slopes for banana tree planting what is not recommended because it destroy the vegetation of inland wetlands what causes damages to water bodies, erosion and flooding risk. The deforestation exposed the soil and, without vegetation, the rain water could not infiltrate. Forest elements regulate the impact of rain on the soil through its vegetation, animals and its natural drains reducing its pressure over the soil. The absence of vegetation facilitates erosion. (de Barros 2001). In 1996, after a heavy rain reached the region, large rock blokes and vast volume of soil came down from the slopes (Miguez 2007). In the municipality maps, some areas are still considered of medium and high risks for erosion. Some of these areas were already part of reforestation project. The interviewed dweller confirmed that some areas along the rivers also suffer from erosion.

*Actions*

Some solutions suggested by Miguez (2007) are the protection and recovery of riparian vegetation. However, many areas with erosion risk are occupied making difficult to recover it in a sustainable way. Other solutions should be taken into consideration in order to recover the erosion protection.

*Historical Relation*

If other solutions are taken into consideration to restore ecosystems in order to avoid erosion it could be probably related to the period from before deforestation started in 17$^{th}$ century.

- Natural Harzard
  - Flood control and Storm Protection

*Historical Background*

The deep slope of some areas of the massifs, where the rivers come from, facilitates erosion and sediments transport by the river's waters. Combined with the anthropic erosion, due to its intense urbanization, makes the area susceptible to constant flooding (de Barros 2001). Deforestation of the area started on 17th century with the sugar cane production. The south area of Jacarepaguá's lowlands is a flat and low area that used to be completely flooded in 1930s according to Corrêa (1932 in de Barros 2001). Since the he emphasizes that the vegetation, especially in the sloppy areas should be preserved in order to avoid that, in the rainy season, with tropical rains, the rainy water, not retained in the hilly area, cause flooding in the lowlands. Also, the action converting slope forests and riparian vegetation to banana trees planting, damages to water bodies, erosion and flooding risk. As mentioned by de Barros (2001), the intense urbanization started from 1970s on and according to Miguez (2007), the biggest tragedy faced in the area was in 1996 when erosion and flooding deeply affected local inhabitants.

*Actions*

According to Miguez (2007) the intensification of urbanization generates, as expected, more flooding. Planning in advance is always the best solution for sustainable development. Some measures suggested by him reduce rainwater runoff working in a combined way on flooding control. They are the same as the measures for erosion protection.

*Historical Relation*

The period of time in history that these actions might lead is the same as item erosion protection.

## Cultural

The identified actions for cultural ecosystem services are common to all services of this section. Therefore, firstly, historical background of all cultural ecosystem services is stated. Secondly the identified actions to this type of ecosystem service are presented. For this type of service, historical relation is not applicable.

*Historical Background*

- Spiritual and inspirational
    - Personal feeling and well-being

It is possible to see in Corrêa's work (1932 in de Barros 2001) the importance the natural environment of Jacarepaguá has for him. According to Miguez (2007), environmental quality is a determining factor to the achievement of a better life quality. When Lúcio Costa designed the pilot urban planning for the region he was definitely considering these factors. However, visits to site show a different scenario. Moving to the upstream from the outfall, contrasts between gated communities, low income settlements, gardens, chaotic traffic, pollution and forests bring as much different feelings as its diverse is the local landscape. The feeling of these views is combined with insecurity feeling due the existence of traffic and urban violence in the region even in forested areas.

    - Religious Significance

No data about religious significance in the area was found apart from the existence of historical churches in Jacarepaguá Watershed.

- Recreational
    - Tourism

The historical heritage of the area related to sugar cane and coffee are not explored in the region. The single attraction of the area is the environmental protected area of Pedra Branca Massif. A study from UNDP (United Nations Development Program), IPEA (Institute for Applied Economy Researches) and the Municipality of Rio de Janeiro, emphasizes that the fastened occupation of this area are causing laky system degradation, compromising the touristic profile of the region.

    - Recreation

According to Miguez (2007), water pollution of the streams ends up in the no utilization of it by the population because the risks of contract a disease is high. Also, the leisure activities on the surroundings of the stream are prejudiced because the environment loses its aesthetic attraction and the smell from the domestic sewage that mix with the river's waters. Also, the area has very few leaisure options, only some sport fields and squares, and Pedra Branca Massif.

- Aesthetic
    - Identity and Contemplation

As mentioned before, the aesthetic characteristics of the area are very compromised by pollution and urban sprawl. The aesthetic features of the region were very emphasized by de Barros (2001), Corrêa (1932 in de Barros 2001) and Lúcio Costa according to de Barros (2001). As requested in the urban plan of 1969, the rocky crops were preserved. The forested area above 100m in Pedra Branca Massif is also preserved by the environmental protection area. Some historical heritage remaining from rural past, survive among road infrastructure and urban settlements and should be preserved (Tardin, 2008) like the area of 'Colônia Juliano Moreira'. They are part of the identity and remain as possible contemplation areas.

- Educational
    - Education and Training

Data that can be related to that could be cited the reforestation program. At the same time it promote environmental recovery it also provide awareness and build capacity to the surrounding communities. According the interviewed dweller, it is important for her to grow her child in contact with nature. No more data could be found.

*Actions*

Considering the preservation of the already identified landscape features like the forests and rocky crops, the implementation of the traditional solutions of sewage collection and treatment would already increase a lot the aesthetic condition of the area according to Miguez (2007). Other measures like preservation and recovery of riparian vegetation and improvement of solid waste collection can also contribute to all cultural services. The preservation and recuperation appropriate management of the historical area of 'Colonia Juliano Moreira' is also important to these services, according to Tardin (2008).

*Historical Relation*

Historical relation does not apply in this section.

**Supporting**

The identified actions for supporting ecosystem services are common to all services of this section. Therefore, firstly, historical background of all supporting ecosystem services is stated. Secondly the identified actions to this type of ecosystem service are presented. For this type of service, historical relation is not applicable.

*Historical Background*

- Biodiversity

It is clear that biodiversity in the region was enormous before 17th century when sugar cane production started. In 1932, Corrêa was already worried with deforestation and hunting activities. The drainage of the area started in 1940s according to Leitao (1999 in de Barros 2001). Other example of human impact on local nature is the conversion of Marapendi lagoon from fresh to brackish water completely changing the ecosystem. The pollution of water bodies and deforestation made several species disappear from the sub-basin or drastically reduce. The original forest has gone and now only secondary vegetation are available, especially on the massif where more preservation is found.

- Soil formation
  - Sediment retention and accumulation of organic matter

This type of service can only be found in the massifs.

- Nutrient Cycling

This service started to be degraded in 17th century with the beginning of sugar cane production. Before that, indigenous agriculture included land crop rotation avoiding that the nutrients of the land where lost. The deforestation that happened since then, exposed the soil and, the nutrients recycling process are interrupted and the soils lose its fertility (de Barros 2001). The urbanization converted most part of Guerenguê River's Sub-basin and in these areas nutrient cycling does not exists.

*Actions*

For the preservation of biodiversity is important to preserve the existing green areas, recuperation of riparian vegetation, and creation of green corridors. For the biodiversity of aquatic life is sewage treatment is also of extreme importance. These solutions also apply to soil formation on nutrient cycling and even pollination about what no data could be found.

*Historical Relation*

Loss of biodiversity and green areas many times cannot be recovered to a past level if urban area is preserved there. Therefore it is not possible to compare to any specific time in the past.

To conclude the presentation of results for this specific research question, a compilation of the actions proposed and the possible ecosystem services that can be enhanced by them are organized in a matrix below. The table also shows the possible period in history to which the ecosystem improvement can be related.

**Table 12: Ecosystem Service Provided by Restored Guerenguê River's Sub-basin based on specific actions and time of reference**

| Variables | Indicators | Actions | | | | |
|---|---|---|---|---|---|---|
| | | sewage collection and treatment system | riparian vegetation recovery | solid waste management | Architectural restoration and preservation | Free land or green roof agriculture |
| **Provisioning** | | | | | | |
| **Food** | Fish | 17th / 1960s | | | | |
| | Fruits | | | | | - |
| | Agriculture products | | | | | |
| **Fresh water** | Water quality | 1960s | | | | |
| **Fiber and Fuel** | Fiber and fuel production | | | | | |
| **Biochemical products** | Extraction | | | | | |
| **Genetic Material** | Availability | | | | | |
| **Regulating** | | | | | | |
| **Climate regulation** | GHG, Temperature, Precipitation<br>Other climate processes | | - | | | |
| **Hydrological regimes** | Ground water recharge and discharge<br>Storage of water | - | | | | |
| **Pollution control and detoxification** | Nutrients excess and Pollution: Retention, Recovery, Removal | 1970s | | | | |
| **Erosion protection** | Retention of soils<br>Prevention of structural changes | | 17th | | | |
| **Natural hazards** | Flood Control<br>Storm protection | | | | | |
| **Cultural** | | | | | | |
| **Spiritual and inspirational** | Personal feeling and well-being<br>Religious Significance | - | | | | |
| **Recreational** | Tourism<br>Recreation | | | | | |
| **Aesthetic** | Identity<br>Contemplation | | | | | |
| **Educational** | Education<br>Training | | | | | |
| **Supporting** | | | | | | |
| **Biodiversity** | Habitat for resident or transient species | - | | | | |
| **Soil formation** | Sediment retention<br>Accumulation of organic matter | | | | | |
| **Nutrient cycling** | Storage, recycling, processing and acquisition of nutrients | | | | | |
| **Pollination** | Supports for pollination | | | | | |

Source Author 2012

In order to provide a better visualization of the relation of the actions possible results to the magnitude of ecosystem service provided by conserved wetlands, the table below was adapted.

**Table 13 Comparison between ecosystem services of types of wetlands and Guerenguê River's Sub-basin actions**

| Scale is low •, medium ●, to high: ●; not known = ?; blank cells indicate that the service is not considered applicable | | | | | Actions | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Services | Comments and Examples | Permanent and Temporary Rivers and Streams | Forested Wetlands, Marshes, and Swamps, Including Floodplains | Underground Wetlands, Including Caves and Groundwater Systems | sewage collection and treatment system | riparian vegetation recovery | solid waste management | Architectural restoration and preservation | Free land or green roof agriculture |
| **Inland Wetlands** | | | | | | | | | |
| **Provisioning** | | | | | | | | | |
| Food | production of fish, wild game, fruits, grains, and so on | ● | ● | | | | | | - |
| Fresh water | storage and retention of water; provision of water for irrigation and for drinking | ● | • | ● | | | | | |
| Fiber and fuel | production of timber, fuelwood, peat, fodder, aggregates | ● | ● | | | | | | |
| Biochemical products | extraction of materials from biota | • | ? | ? | | | | | |
| Genetic materials | medicine; genes for resistance to plant pathogens, ornamental species, and so on | • | • | ? | | | | | |
| **Regulating** | | | | | | | | | |
| Climate regulation | regulation of greenhouse gases, temperature, precipitation, and other climatic processes; chemical composition of the atmosphere | • | ● | • | | - | | | |
| Hydrological regimes | groundwater recharge and discharge; storage of water for agriculture or industry | ● | ● | • | - | | | | |
| Pollution control and detoxification | retention, recovery, and removal of excess nutrients and pollutants | ● | ● | ● | | | | | |
| Erosion protection | retention of soils and prevention of structural change (such as coastal erosion, bank slumping, and so on) | ● | ● | • | | | | | |
| Natural hazards | flood control; storm protection | ● | ● | • | | | | | |
| **Cultural** | | | | | | | | | |
| Spiritual and inspirational | personal feelings and well-being; religious significance | ● | ● | • | | | | | |
| Recreational | opportunities for tourism and recreational activities | ● | • | • | | | | | |
| Aesthetic | appreciation of natural features | ● | ● | • | | | | | |
| Educational | opportunities for formal and informal education and training | ● | ● | • | | | | | |
| **Supporting** | | | | | | | | | |
| Biodiversity | habitats for resident or transient species | ● | ● | • | | | | | |
| Soil formation | sediment retention and accumulation of organic matter | ● | ● | | | | | | |
| Nutrient cycling | storage, recycling, processing, and acquisition of nutrients | ● | ● | • | | | | | |
| Pollination | support for pollinators | • | ● | | | | | | |

17th / 1960s

1960s

1970s

17th

Adapted and produced by the author in 2012 from Millennium Ecosystem Assessment 2005b

# Chapter 5: Conclusions and recommendations

In this chapter, conclusions of this study are presented. It starts with a quick retrospective of the research purpose. Afterwards, discussions about the findings regarding the research questions are presented. Moreover, recommendations related to policies and methodology are discussed. Finally, future research directions are given followed by a final conclusion.

The problem statement presented in the chapter 1 of this thesis shows a relation between losses of human well-being and losses of ecosystem services in the Sub-basin of Guerenguê River. Based on that, the purpose of this study was to identify the ecosystem services that could be provided with the restoration of this watershed.

## 5.1 Discussion

In order to answer the main research question of what are the ecosystem services that could be provided by restored Guerenguê River's Sub-basin in Rio de Janeiro, this research was carried out based on four specific questions. This section presents a discussion regarding the findings based on these questions.

*Discussion regarding Land Uses in Guerenguê River's Sub-basin*

The identification of the land-uses present in the selected sub-basin was answered by the collection and presentation of data provided by the Municipality website sig.floresta.rio.rj.gov.br. This website has an updated database of land uses and vegetation cover of the city of Rio de Janeiro. It provides maps and reports with the area and percentage of each identified land use in the sub-basin. The map and the report are available in the item 4.3.1 Land Uses in Guerenguê River's Sub-basin. The importance of identify land uses is related to the theory of Millennium Ecosystem Assessment (2003) presented in session 2.4 Drivers of Change in Ecosystem and their Services. There is mention that land uses, among other factors, influence the importance given to ecosystems by human being. The identification of the land uses and vegetation are also important to answer the specific research question 2 regarding to what ecosystem services are available in the Gurenguê River's Sub-basin.

*Discussion regarding ecosystem services available in the specified sub-basin*

The analysis of the present ecosystem services in Guerenguê River Sub-basin is based on the land uses identified with the previous question and on the ecosystem service assessment. Supported by the findings presented in the item 4.3.2 Ecosystems Services Related to the Land Uses of Guerenguê River's Sub-basin, a matrix, table 10, was developed to identify the magnitude of provision of ecosystem services of each land use identified. This gives the answer to question 2. In this matrix, table 10, is possible to identify those land uses which contribution is none, low, medium or high to the ecosystem services. By these results, it is possible to conclude that some land uses are not providing any ecosystem service. This is the case of the urbanized areas. It is very warning because the lack of some ecosystem services like erosion and flooding protection expose people to risks and reduce their well-being. Other land uses, like secondary vegetation, highly provide ecosystems services, like those mentioned above, preserving this way, resilience and well-being. This relationship between

ecosystems services and human well-being was discussed in the literature review (Millennium Ecosystem Assessment, 2005a) and was reinforced by other authors like de Barros (2001) and Miguez (2007) in the presentation and analysis of data collected.

After the identification of the magnitude of each land use found in the Sub-basin of Guerenguê River, a relation to the theoretical framework was made by a comparison with table 1 that shows wetland ecosystems services magnitude provision by types of wetlands (Millennium Ecosystem Assessment 2005b). As stated in the history of the region, Guerenguê River's Sub-basin was composed of wetlands. Nowadays, according to the findings, only few remain from its wetlands and its waterways suffer of degradation. The comparison between table 1 and table 10, results in table 11. From table 1, only those types of wetlands related to Guerenguê River Sub-basin were selected: Rivers, Forested Wetlands and Ground water systems. By comparing the magnitudes from both tables is possible to see that most of land uses present in the analysed sub-basin are not providing ecosystem services or provide less than its possibility if compared to table 1.

Moreover, the percentage of land uses also influence the provision of ecosystem services. The extreme reduction of certain ecosystems compromises the provision of service by them. This is the case of restinga ecosystem that represents only 0.1% of the total sub-basin's area nowadays. The most significant land uses according to its size are urbanized areas that correspond to 38.8% of the land use in Gerenguê River's Sub-basin and secondary vegetation that occupies 31.7% of the this sub-basin. Both are contrasting in the provision of services. The urbanized areas do not offer any ecosystem services while secondary vegetation provides them in a large quantity and in a high magnitude. However, secondary vegetation is concentrated in the higher part of the sub-basin and the urbanized area in the low part. By these results is possible to conclude the need of integration among these land uses in order to provide ecosystem services in the urbanized area as well.

*Discussion regarding actions that can be taken to restore the sub-basin*

The actions that can be taken to enhance ecosystem service provision in the area were identified based on suggestions made by specialists both in interviews and secondary data. Those actions are:

- Sewage collection and treatment
- Riparian vegetation recovery
- Improvement in solid waste collection
- Architectural restoration and preservation
- Free land or green roof agriculture

*Discussion regarding the ecosystem services that could be provided by the sub-basin*

Finally, in order to answer the specific question 4 and the main research question about potential ecosystem services of restored Guerenguê River's Sub-basin, an historical approach combined with the actions identified in the previous question was made. The historical background combined with actions and its possible results lead, in most of the cases, to an ecosystem service provision related to a certain period of time in history. All these are tackled in the presentation of the research findings and are summarized in a matrix, table 12. Table 12 shows which ecosystem services are improved by certain action and, whenever it is possible, to which period of history of the area the enhancement is related to. According to it, it is possible to get to some conclusions based on each action:

Sewage collection and treatment would have high impacts on provision of fish and fresh water to similar levels of 1960s. It would also improve regulating services of pollution control and detoxification to levels like in 1970s and also hydrological regimes. Moreover, it would improve Cultural and Supporting Ecosystem Services.

Riparian vegetation recovery actions help in fish and fresh water provision to levels like in 1960s. This is the only action that tackles all the other services from Regulating, Cultural and Supporting Ecosystems Services being classified therefore as the most promising action.

Improvement in solid waste management collection might improve fish and fresh water provision as much as pollution control and detoxification. Also reaches cultural services.

Architectural restoration and preservation might improve the most the cultural services and urban agriculture would only improve agriculture products provision in the case of Guerenguê River's Sub-basin.

The Ecosystem Services of Fiber and Fuel, Biochemical Products and Genetic Material are not demanded in Guerenguê River's Sub-basin and therefore are not considered by the actions proposed.

Moreover, in order to relate the findings to the theories, table 13 compares table 12 (actions to improve ecosystem service provision in the specific sub-basin, ecosystem services improved and historical time relation) to table 1 (magnitude of ecosystem services provided by different types of wetlands presented in chapter 2 of theoretical framework). The wetland types that are related to Guerenguê River's Sub-basin selected from table 1 provide ecosystem services in different magnitudes. In Table 12, different actions enhance different ecosystem services. A possible way to prioritize actions is by comparing the ecosystem services tackled by them with the magnitudes that can be reached. It can be visualized in table 13.

Based on this study is possible to conclude that the actions that are more beneficial and important are sewage collection and treatment, riparian vegetation recovery and improvements on solid waste collection. The ideal is that these actions happen in an integrated way in order to complement each other. In this way it would also increase the provision of ecosystems services and consequently well-being. It is important to highlight that the implementation of sewage collection and treatment is already under construction. However, its conclusion is predicted to the year 2031.

To finally conclude and fully answer the main research question, the ecosystems services that could be provided of restored Guerenguê River's Sub-basin, are highlighted in the right part of table 13 and its magnitude can be compared in the left part of the same table based on its wetland type. It means that, according to this study, almost all ecosystems services could be provided by Guerenguê River's Sub-basin except fiber and fuel, biochemical products and genetic material. The reason why these ecosystems services were not tackled is based on the fact that no related data could be found or even that they are not applicable to the area. This conclusion, although, is dependent on the adoption of the already mentioned actions, preferably taken in an integrated way.

## 5.2 Recommendations

### 5.2.1 Recommendations Regarding Policies

*Integration*

As we could see in the presentation of the data collected, many have already being studied about the region, and many have already being suggested to the region. However, the identified actions that could enhance ecosystem services in the Sub-basin of Guerenguê River can be better successful if implemented with three types of integration: integration among the actions, integration among sub-actions and integration among governmental departments (interviewed specialists, de Barros 2001 and Miguez 2007). Both integration among actions and sub-actions depend on integration among governmental departments.

Firstly, integration among actions refers to an overall improvement of ecosystem services provision on the specified sub-basin by the achievement of more benefits. For instance, the most beneficial actions according to the findings of this research are sewage collection and treatment, rivers' riparian vegetation recovery and solid waste collection improvement. These three actions support each other's results and increase the provision of ecosystem services as presented in the findings. To secure the integration among the actions, government sectors should also work in an integrated way as the implementation of these actions are carried out by different departments (interviewed specialists, de Barros 2001 and Miguez 2007).

Moreover, each action demands sub-actions that also depend on different government sectors. For instance, a sub-action necessary to the recovery of river's riparian vegetation regards to land use change in some areas along the rivers. It might be responsibility of the housing department in combination with other bureaus. Another sub-action is the reforestation of these areas which depends on the reforestation department and the parks and gardens department. Other sub-actions are also necessary to implement it and, as those already presented here, depend on different government departments (interviewed specialists, de Barros 2001 and Miguez 2007). That is why integration among sub-actions and among government sectors is necessary in each action.

To conclude policy recommendations regarding integration, three types of integration are suggested: integration among actions, among sub-actions and among government departments (interviewed specialists, de Barros 2001 and Miguez 2007). It improves the enforcement capacity of the government and increases quantitatively and qualitatively the benefits.

*Ecosystem Services as a Common Assessment Framework among Government Departments*

Problems related to policy enforcement and not integrated approach can be caused by the absence of a common assessment framework among the government departments. In order to avoid these problems, the use of Ecosystem Service Assessment as a way to evaluate urban environment quality is recommended.

There are legislations regarding the occupation of river's riparian area that apply to the area but are not being fully enforced and are interpreted in different ways among government departments. According to the Brazilian Forest Code (Law number 4.771/65 edited by Law number 7.803 from 18/07/1989 and under change nowadays), the width of river's riparian area protection (APP – Permanent Protected Area) is of 30 meters for rivers up to 10 meters wide like those from Guerenguê River's Sub-basin. Another law regarding land use (Law

number 6.766/79) do not allow occupation in the area of 15 meters to each side of river`s margins. Both laws` paragraphs regard the preservation of water bodies. The area related to land use legislation (Law number 6.766/79) is considered by the watershed management department, Rio-Águas, as an area important mainly to the maintenance of rivers regarding to machinery access (interviewed specialist). On the other hand, to the Municipal Environmental Bureau, these protected areas are also important to avoid flooding (interviews and Miguez 2007). However, what is possible to see in the region is that these areas are, in many cases, occupied by irregular settlements showing that these laws are not being fully enforced.

The literature review of this study refers to publications from the Millennium Ecosystem Assessment. These works established scientific bases for actions necessary to sustainable development focused on policy relevant questions (Millennium Ecosystem Assessment 2005a). Based on ecosystem service approach, these wetlands provide several benefits to human being (Millennium Ecosystem Assessment 2005b). The adoption of this framework by the municipality as a way to measure these benefits can bring a common approach among the departments and improve the enforcement of these laws by the creation and enforcement of common policies regarding the existing legislation.

*Prioritization of Actions*

A compilation of urgent actions for the Sub-basin of Guerenguê River are included in this work and presented showing its benefits magnitudes (Table 13 Comparison between ecosystem services of types of wetlands and Guerenguê River's Sub-basin actions). The analysis of these actions through ecosystem services framework might help policy makers and decisions makers to prioritize those actions that might bring more well-being to the population. The same can be done to other areas.

*Planning*

According to all studies used as reference or source of data, interventions are necessary in areas like Guerenguê River's Sub-basin in order to guarantee human well-being. Moreover, studies and legislations should be made prior occupation and be enforced according to the recommendation of specialists and literature like from Miguez (2007). This is also presented in Chapter 4 of research results and analysis, when answering the specific question 3 regarding actions to restore the sub-basin. It is stated by Miguez (2007) that the best solution to avoid natural hazards is planning.

### 5.2.2 Recommendations Regarding Methodology

Ecosystems services framework has recently attracted more attention (Montes et al 2010) however ecosystem services assessment requires large amount of data (Millennium Ecosystem Assessment 2003). It causes difficulties to get the data requested, demand different types of information and specialists consultations and demands a significant amount of work in order to organize the data in the framework. Therefore the recommendation is that the ecosystem assessment framework comes together with clear data collection and analysis guidelines. This would make this framework even more used worldwide and more reliable in terms of results.

## 5.3 Future Research Directions

This research can be used as a reference to similar works even though it had some constrains during its production as stated in the section 1.6 Scope and Limitations. It is also possible that Guerenguê River Sub-basin ecosystem service assessment be deepening in order to include those data that for any reason was not available. With the achieved results and based on the characteristics of the sub-basin analysed, this work can also be generalized to a wider arena. Many results found to Guerenguê River's Sub-basin also apply for other sub-basins in the region, especially those derived from Pedra Branca Massif. Adaptations are necessary to each case like land uses identification and water quality analysis. These research items have to be carried out to each sub-basin.

## 5.4 Conclusions

Based on the theoretical and conceptual framework and on the findings of this research is possible to confirm that humans are degrading wetland ecosystems, affecting the provision of ecosystem services and therefore affecting the human well-being in Guerenguê River's Sub-basin.

Urbanization causes environmental impacts and at the same time offers facilities to human being. However, the studies used to collect data emphasize that planning considering the environment preservation is essential, not only for its fauna and flora but also for human well-being. The equilibrium between urban and natural is the key to sustainable development. If the ecosystems that provide services to humans are not maintained, the losses happen in unaccountable sectors. Unsustainable urban occupation can cause losses in biodiversity, economic, aesthetic, etc. The framework of analysis based on ecosystem services exposes the situation from the perspective of human being. It is an analytical way to present what humans are losing by degrading their own environment.

This study, based on the problem statement regarding the diminishing of well-being in Guerenguê River's Sub-basin due to reduction of wetland ecosystem services provision, looked for ecosystem services that could be provided by this watershed. It is possible to conclude that different land uses provide different ecosystem services in the area influencing human well-being. Moreover, actions are necessary to restore the sub-basin and the provision of ecosystem services. Therefore, ecosystems services that could be provided by Guerenguê River's Sub-basin were identified and presented. To finalize, recommendations regarding policies, methodologies and future research directions were made.

## Bibliography


Ballinas, M. P. 2011, Ecosystems services assessment of the Magdalena River Basin, as means for ecosystem-based adaptation in Mexico City, MSc. Thesis, Erasmus University, Rotterdam.

Barbier E. B. & Hanley N. 2009, *Pricing Nature: Cost-Benefit Analysis and Environmental Policy*, Edward Elgar Publishing, Cheltenham/Northampton.

CEDAE, 2012, CEDAE [Homepage of CEDAE] Available: http://www.cedae.com.br/ [2012, 23 August].

Chen S. 2012, 'Civic agriculture : towards a local food web for sustainable urban development', *APCBEE Procedia*, vol.1, pp. 169-176

City of Portland Bureau of Environmental Services 2010, Portland's Green Infrastructure : Quantifying the Health, Energy, and Community Livability Benefits, Entrix, Portland

Costa, L. 1976, *Pilot urban plan for urbanization of the Lowlands among Barra da Tijuca, Pontal de Sernambetiba and Jacarepaguá (Plano-piloto para urbanização da Baixada compreendida entre a Barra da Tijuca, o Pontal de Sernambetiba e Jacarepaguá)*, Municipality of Rio de Janeiro, Rio de Janeiro

de Barros, S. C. M. 2001, *Sustainable development and community participation: an exploratory study of the environmental conflicts in Barra da Tijuca area (Desenvolvimento Sustentável e participação comunitária: um estudo exploratório dos conflitos ambientais na área da Barra da Tijuca)*, MSc. Thesis, IBGE, Rio de Janeiro

Department for Environment Food and Rural Affairs 2007, An Introductory guide to valuing ecosystems services, Crown, London

Ezequiel, L.F. 2007, *Sustainable Urban Planning in Curicica: When rivers and houses are harmonized (Urbanismos sustentável em Curicica : Quando rios e casas harmonizam-se)* [Homepage of Faculty of Architecture and Urban Planning of the Federal University of Rio de Janeiro, Media Library of final projects] [Online]. Available: http://www.fau.ufrj.br/MEDIATECA/2007%202/052.htm [2012, 29 July].

Jackon, S.T & Hobbs, R. J. 2009, 'Ecological Restoration in the Light of Ecological History', *Science Magazine*, vol. 325, no. 5940, pp. 567-569

Logit 2011, *Report 1 – Updating of Transport network, transport zoning revision, actual matrix of tranports and demand models – Actual Situation. Studies and Basic Project for the implementation of corridor Transcarioca sector Penha-Galeão Aiport (Relatório 1 – Atualização da Rede de Transporte, Revisão do Zoneamento de Transporte, Matriz Atual de Transportes e Modelos de Demanda – Situação Atual. Estudos e Projeto Básico para Implantação do corredor Transcarioca Trecho Penha-Aeroporto Galeão)*, Logit, São Paulo

Miguez, M.G. 2007, *Study for the environmental recovery and integrated control of flooding and hydrologic pollution in the sub-basin of Rivers Guerenguê / Arroio Pavuna, Jacarepaguá – RJ (Estudo para recuperação ambiental e controle integrado de enchentes e poluição hídrica na sub-bacia do Rio Guerenguê / Arroio Pavuna, Jacarepaguá –RJ)*, Report to the Municipality of Rio de Janeiro, COPPETEC, UFRJ, Rio de Janeiro

Millennium Ecosystem Assessment 2003, Ecosystems and Human Well-being: Framework for assessment, Island Press, Washington

Millennium Ecosystem Assessment 2005a, Ecosystems and Human Well-being: Synthesis, Island Press, Washington

Millennium Ecosystem Assessment 2005b, Ecosystems and Human Well-being: Wetlands and Water Synthesis, World Resources Institute, Washington

Montes C., Gómez-Baggethun E., Lomas, P. L. & de Groot R. 2010, 'The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes', *Ecological Economics*, vol. 69, pp. 1209–1218

Municipality of Rio de Janeiro 2008, Reforestation Taskforce 20 years (Multirão de Reflorestamento 20 anos), Municipality of Rio de Janeiro, Rio de Janeiro.

Municipality of Rio de Janeiro, 2001-2011- copyright, Armazém de Dados [Homepage of Armazém de Dados]. Available: www.armazemdedados.rio.rj.gov.br [2012, 23 August].

Municipality of Rio de Janeiro, 2009 - copyright, GEORIO [Homepage of GEORIO]. Available: http://obras.rio.rj.gov.br/index.cfm?arquivo_estatico=1541.htm [2012, 23 August].

Municipality of Rio de Janeiro, 2009 - copyright, Watershed Management Bureau (Subsecretaria de Gestão das Bacias Hidrográficas) [Homepage of Rio-Águas]. Available: http://obras.rio.rj.gov.br/index.cfm?arquivo_estatico=1542.htm [2012, 23 August].

Municipality of Rio de Janeiro, Digital map of Rio de Janeiro, GeoRio – Map of landslide susceptibility (Mapa Digital do Rio de Janeiro, GeoRio – Mapa de Suscetibilidade ao Escorregamento) [Homepage of GeoRio]. Available: http://portalgeo.rio.rj.gov.br//ipp_viewer/?config=config/georio/escorrega.xml [2012, 23 August].

Municipality of Rio de Janeiro, Municipality Environmental Bureau (Secretaria Municipal do Meio Ambiente – Florestas) [Homepage of Municipality Environmental Bureau]. Available: sigfloresta.rio.rj.gov.br [2012, 23 August].

Springate-Baginski, O., Allen, D. and Darwall, W.R.T. (eds.) 2009, *An Integrated Wetland Assessment Toolkit: A guide to good practice*, Gland, Switzerland: IUCN and Cambridge, UK: IUCN Species Programme. xv+144p.

Tardin, R. 2008, *Free spaces: System and Territory Design (Espaços Livres: Sistema e Projeto Territorial),* 7Letras, Rio de Janeiro

The Economics of Ecosystems and Biodiversity 2009a, The Economics of Ecosystems and Biodiversity for National and International Policy Makers – Summary: Responding to the value of Nature, Welzel+Hardt, Wesseling

The Economics of Ecosystems and Biodiversity for Policy Makers preliminary drafts chapters available for download. The Economics of Ecosystems and Biodiversity 2009b, The Economics of Ecosystems and Biodiversity for National and International Policy Makers – Summary: Responding to the value of Nature, Chapter 4: Integrating ecosystem and biodiversity values into policy assessment [Homepage of TEEB], [Online]. Available: http://www.teebweb.org/Portals/25/Documents/TEEB%20for%20POLICYMAKERS%20Chapter%204.pdf [2012 June 10]

Tianhong L., Wenkaia L. & Zhenghanb Q. 2010, 'Variations in ecosystem service value in response to land use changes in Shenzhen', *Ecological Economics*, vol. 69, pp. 1427-1435

# Annexes

## Annex 1 Operationalization: variables and indicators

| **What are the ecosystem services that could be provided by restored Guerenguê River's sub-basin in Rio de Janeiro?** | | | |
|---|---|---|---|
| **Specific Question** | **Variable** | **Indicator** | **Details** |
| **1. What are the land-uses present in Guerenguê River's sub-basin in Rio de Janeiro?** | Land-use type | View Mapping Classification | **Research Method:** Qualitative / Quantitative<br>**Data Source:** Municipality<br>**Data Collection Methods:** Interviews Reports<br>**Data Type:** Secondary |
| **2. What are the ecosystem services available in the specified sub-basin?** | View Ecosystem Services operationalization | View Ecosystem Services operationalization | View Ecosystem Services operationalization |
| **3. What actions can be taken to restore the sub-basin?** | | | |
| **4. What are the potential ecosystem services of a restored Guerenguê River's sub-basin in Rio de Janeiro?** | | | |

Source: Author 2012

For the specific research question 1 the matrix of mapping classification is provided below:

**Table 14 Land uses and vegetation mapping classification**

| Type | Classification | Typology | Specification | Abbreviation |
|---|---|---|---|---|
| **Athropic Areas** | Non-agricultural | Urbanized Areas | - | Au |
| | | Exposed Soil | - | Se |
| | | Mineral extraction area | - | Aem |
| | Agricultural | Agriculture | - | Ag |
| | | Arboreous-shrubby vegetation | - | Ve |
| | | Reforestation | Municipality | R |
| | | | Private | Rp |
| | | Grassy-woody vegetation | - | Vg |
| **Natural Vegetation Area** | Forest Formation Area | Ombrophilous Forest | Dense montane | Dm |
| | | | Dense sub-montane | Ds |
| | | | Dense of lowlands | Db |
| | | Secondary Vegetation | Initial level | V1 |
| | | | Intermediate level | V2 |
| | | | Advanced level | V3 |
| | Campestral | Rocky outcrop | - | Afr |
| | Primary formations | Restingas | Herbaceous | Re1 |
| | | | Shrubby | Re2 |
| | | | Woody | Re3 |
| | | | Sandy | Re4 |
| | | Mangroves | - | Man |
| | | Saline fields | - | Cs |
| | | Marsh | - | Br |
| | Continental water bodies | Continental water body | - | CaC |
| | | Beaches | - | Pr |

Source: Municipality website sig.floresta.rio.rj.gov.br

**Table 15: Operationalization of Ecosystems Services to answer specific question 2, 3 and 4**

| **Variables** | Indicators | Research Method: **Qualitative / Quantitative** Data Type: **Primary and Secondary** | |
|---|---|---|---|
| | | **Data Collection Methods** | **Data Source** |
| **Provisioning** | | | |
| Food | Fish | Literature Reports Observation Interviews | Literature Municipality Dwellers Specialists |
| | Fruits | | |
| | Agriculture products | | |
| Fresh water | Water quality | | |
| Fiber and Fuel | Fiber and fuel production | | |
| Biochemical products | Extraction | | |
| Genetic Material | Availability | | |
| **Regulating** | | | |
| Climate regulation | GHG, Temperature, Precipitation<br>Other climate processes | | |
| Hydrological regimes | Ground water recharge and discharge<br>Storage of water | | |
| Pollution control and detoxification | Nutrients excess and Pollution:<br>Retention, Recovery, Removal | | |
| Erosion protection | Retention of soils<br>Prevention of structural charges | | |
| Natural hazards | Flood Control<br>Storm protection | | |
| **Cultural** | | **Research Method:** Qualitative **Data Type:** Primary and Secondary | |
| | | **Data Collection Methods** | **Data Source** |
| Spiritual and inspirational | Personal feeling and well-being<br>Religious Significance | Literature Reports Observation Interviews | Literature Municipality Dwellers Specialists |
| Recreational | Tourism<br>Recreation | | |
| Aesthetic | Identity<br>Contemplation | | |
| Educational | Education<br>Training | | |
| **Supporting** | | **Research Method:** Qualitative / Quantitative **Data Type:** Primary and Secondary | |
| | | **Data Collection Methods** | **Data Source** |
| Biodiversity | Habitat for resident or transient species | Literature Reports Observation Interviews | Literature Municipality Dwellers Specialists |
| Soil formation | Sediment retention<br>Accumulation of organic matter | | |
| Nutrient cycling | Storage, recycling, processing and acquisition of nutrients | | |
| Pollination | Supports for pollination | | |

Source: Author 2012

## Annex 2 Instruments: Interview Guidelines

| **2 What are the ecosystem services available in the specified sub-basin?** | | |
|---|---|---|
| **Interview Guideline 2 A - Dwellers** | | |
| **Variables** | **Indicators** | **Questions** |
| Basic Data | | 1. How long do you live here?<br>☐Less than 5 years<br>☐6 to 10 years<br>☐10 to 15 years<br>☐16 to 20 years<br>☐More than 20 years |
| **Provisioning** | | Qualitative / Quantitative Information |
| Food | Fish | 2.<br>a. Have you ever seen fish in this river?<br>☐Yes<br>☐No<br>b. If Yes, what type of fish? _____<br>c. Do you consume or sell this fish?<br>☐Yes<br>☐No<br>d. Was there any change in the quantity of fish since when you live here?<br>☐Increased<br>☐Reduced<br>☐ |
| | Fruits | 3.<br>a. Are there fruits in this wetland?<br>☐Yes<br>☐No<br>b. If yes, what type of fruits? _____<br>c. Do you consume or sell these fruits?<br>☐Yes<br>☐No<br>d. Was there any change in the quantity of fruits since when you live here?<br>☐Increased<br>☐Reduced |
| | Agriculture products | 4. Is there agriculture production in this wetland?<br>☐Yes<br>☐No<br>a. If yes, what type of products? _____<br>b. Do you consume or sell these products?<br>☐Yes<br>☐No<br>c. Was there any change in the quantity of production since when you live here?<br>☐Increased |

| | | |
|---|---|---|
| | | ☐Reduced |
| Fresh water | Water quality | 5.<br>a. Have you notice any change in the water quality since when you live here?<br>_____<br>b. If yes, how do you describe the water before and after the change?<br>_____<br>6. How do you use the water? (You can mark as much squares as you need to answer this question. If possible, describe other use or uses you do on the line beside the option "Other")<br>☐Do not use<br>☐Bath<br>☐Drink<br>☐Garbage<br>☐Sewage<br>☐Transport<br>☐Other: _____ |
| Fiber and Fuel | Fiber and fuel production | 7.<br>a. Do you, or anyone you know use woods from this wetland for anything?<br>☐Yes<br>☐No<br>b. If yes, who? _____<br>c. For what purpose? _____ |
| Biochemical products | Extraction | 8.<br>a. Do you or anyone you know use anything from this wetland to produce biochemical products?<br>☐Yes<br>☐No<br>b. If yes, who? _____<br>c. For what purpose? _____ |
| Genetic Material | Availability | - |
| **Regulating** | | Qualitative / Quantitative Information |
| Climate regulation | GHG<br>Temperature<br>Precipitation<br>Other climate processes | 9. How do you classify the air quality here in comparison to other parts of the city?<br>☐Worse<br>☐The Same<br>☐Cleaner<br>10. How do you classify the Temperature here in comparison to other parts of the city?<br>☐ Warmer<br>☐The Same<br>☐Colder<br>11. How do you classify the frequency precipitation here |

| | | |
|---|---|---|
| | | in comparison to other parts of the city?<br>☐ Less frequent<br>☐ The same<br>☐ More frequent<br>12. How do you classify the intensity of precipitation here in comparison to other parts of the city?<br>☐ Less intense<br>☐ The same<br>☐ More intense |
| Hydrological regimes | Ground water recharge and discharge<br>Storage of water | 13. What happens here when it rains? (You can mark as much squares as you need to answer this question.)<br>☐ Flooding<br>☐ The soil absorb the water<br>☐ The water goes to the river<br>☐ The river overflow<br>☐ Erosion<br>☐ Landslide |
| Erosion protection | Retention of soils<br>Prevention of structural charges | |
| Natural hazards | Flood Control<br>Storm protection | |
| Pollution control and detoxification | Nutrients excess and Pollution:<br>Retention<br>Recovery<br>Removal | Vide questions 5 and 9 |
| **Cultural** | | Qualitative Information |
| Spiritual and inspirational | Personal feeling and well-being<br>Religious Significance | 14. What kind of other importance have this area for you? (You can mark as much squares as you need to answer this question. If possible, describe other significance on the line beside the option "Other")<br>☐ Personal felling<br>☐ Well-being<br>☐ Religious<br>☐ Identity<br>☐ Contemplation<br>☐ Education<br>☐ Training<br>☐ Other _____<br>☐ None of the above |
| Aesthetic | Identity<br>Contemplation | |
| Educational | Education<br>Training | |
| Recreational | Tourism<br>Recreation | 15. Are there tourists here?<br>☐ Yes<br>☐ No<br>16.<br>a. Does anyone use this wetland as recreational area?<br>☐ Yes<br>☐ No<br>b. If yes, who? _____<br>c. What do they do? _____ |

| **Supporting** | | Qualitative / Quantitative Information |
|---|---|---|
| Biodiversity | Habitat for resident or transient species | 17. What animals do you know that exists here? _____<br>18. What vegetation exist here? _____<br>19. Is there sedimentation here? _____<br>20. Is there accumulation of organic matter here? _____ |
| Soil formation | Sediment retention Accumulation of organic matter | |
| Nutrient cycling | Storage, recycling, processing and acquisition of nutrients | |
| Pollination | Supports for pollination | |

**2. What are the ecosystem services available in the specified sub-basin?**

**3. What actions can be taken to restore the sub-basin?**

**4. What are the potential ecosystem services of a restored Guerenguê River's sub-basin in Rio de Janeiro?**

| **Interview Guideline 2B, 3 and 4 - Specialists** | | |
|---|---|---|
| **Variables** | **Indicators** | **Questions** |
| **Provisioning** | | Please, relate your answers to data as much as possible |
| Food | Fish | 1.<br>a. Are there fishes in that sub-basin?<br>☐ Yes<br>☐ No<br>b. If yes, what type of fish? _____<br>c. Was there any change in the quantity of fish since the land use change started?<br>☐ Increased<br>☐ Reduced<br>d. Why? _____<br>e. Which period it might have happened?<br>☐ Less than 5 years<br>☐ 6 to 10 years<br>☐ 10 to 15 years<br>☐ 16 to 20 years<br>☐ More than 20 years<br>2. Considering the wetland restoration, what would be the potential of fish availability in the sub-basin? _____ |
| | Fruits | 3.<br>a. Are there fruits in this wetland?<br>☐ Yes<br>☐ No<br>b. If yes, what type of fruits? _____<br>c. Was there any change in the quantity of fruits since land use change started?<br>☐ Increased<br>☐ Reduced<br>d. Why? _____<br>4. Considering the wetland restoration, what would be the potential of fruits availability in the sub-basin? _____ |
| | Agriculture products | 5. Is there agriculture production in this wetland?<br>☐ Yes<br>☐ No<br>a. If yes, what type of products? _____<br>b. Was there any change in the quantity of production since land use change started?<br>☐ Increased<br>☐ Reduced<br>c. Why? _____<br>6. Considering the wetland restoration, what would be the potential for agriculture production in the sub-basin?<br>_____ |

| | | |
|---|---|---|
| Fresh water | Water quality | 7.<br>a. Is there any change in the water quality since land use change started? _____<br>b. If yes, how do you describe the water before and after the change? _____<br>8. How is this water used? (You can mark as much squares as you need to answer this question. If possible, describe other use or uses you do on the line beside the option "Other")<br>☐ Do not use<br>☐ Bath<br>☐ Drink<br>☐ Garbage<br>☐ Sewage<br>☐ Transport<br>☐ Other: _____<br>9. What is the potential water quality if the wetland is restored?<br>10. What are the potential uses if the wetland is restored?<br>_____ |
| Fiber and Fuel | Fiber and fuel production | 11.<br>a. Is anyone using the wood from the wetland?<br>☐ Yes<br>☐ No<br>b. If yes, who? _____<br>c. For what purpose? _____ |
| Biochemical products | Extraction | 12.<br>a. Are the products from this wetland used to produce biochemical products?<br>☐ Yes<br>☐ No<br>b. If yes, who? _____<br>c. For what purpose? _____<br>13. What is the potential if restored? _____ |
| Genetic Material | Availability | 14.<br>a. Are the products from this wetland containing important genetic Material?<br>☐ Yes<br>☐ No<br>b. If yes, are they being used?<br>☐ Yes<br>☐ No<br>c. How? _____<br>d. By who? _____<br>15. What is the potential if restored? _____ |

| **Regulating** | | |
|---|---|---|
| Climate regulation | GHG<br>Temperature<br>Precipitation<br>Other climate processes | 16. Is there data available about:<br>a. GHG<br>b. Temperature<br>c. Precipitation<br>d. Other climate process<br>17. How do you classify the air quality here in comparison to other parts of the city?<br>☐ Worse<br>☐ The Same<br>☐ Cleaner<br>18. How do you classify the Temperature here in comparison to other parts of the city?<br>☐ Warmer<br>☐ The Same<br>☐ Colder<br>19. How do you classify the frequency precipitation here in comparison to other parts of the city?<br>☐ Less frequent<br>☐ The same<br>☐ More frequent<br>20. How do you classify the intensity of precipitation here in comparison to other parts of the city?<br>☐ Less intense<br>☐ The same<br>☐ More intense<br>21. What is the potential if restored? |
| Hydrological regimes | Ground water recharge and discharge<br>Storage of water | 22.<br>a. How the hydrological regimes work in this region related to ground water recharge and discharge?<br>b. What about storage of water?<br>c. What are the differences among the different types of land use related to this?<br>23. What is the potential if restored? |
| Erosion protection | Retention of soils<br>Prevention of structural charges | 24. In each land use type:<br>a. How is the erosion classified related to retention of soils?<br>b. What about erosion prevention?<br>25. What is the potential if restored? |
| Natural hazards | Flood Control<br>Storm protection | 26. How the following types of land use works for flood control and storm protection?<br>(To be identified in the first part of field work)<br>27. What is the potential if restored? |
| Pollution control and detoxification | Nutrients excess and Pollution:<br>Retention<br>Recovery<br>Removal | 28. How does it work in each land use type in this region?<br>29. What is the potential if restored? |

| | | |
|---|---|---|
| **Cultural** | | |
| Spiritual and inspirational | Personal feeling and well-being<br>Religious Significance | 30. In each of the land use how are these items included? Any other to add? (please describe and explain)<br>a. Personal feeling<br>b. Well-being<br>c. Religious<br>d. Significance<br>31. What is the potential if restored? |
| Aesthetic | Identity<br>Contemplation | 32. In each of the land use type, are these items included? Any other to add? (please describe and explain)<br>a. Identity<br>b. Contemplation<br>33. What is the potential if restored? |
| Educational | Education<br>Training | 34. In each of the land use type, are these items included? Any other to add? (please describe and explain)<br>a. Education<br>b. Training<br>35. What is the potential if restored? |
| Recreational | Tourism<br>Recreation | 36. Have this area potential for Tourism and Recreation? (please describe and explain)<br>37. Are there any projects related to that?<br>38. What is the potential if restored? |
| **Supporting** | | |
| Biodiversity | Habitat for resident or transient species | 39. What animals exists here and what are their population?<br>_____ |
| Soil formation | Sediment retention<br>Accumulation of organic matter | 40. What vegetation exists here and what are their population?<br>_____<br>41. Is there sedimentation here?<br>_____ |
| Nutrient cycling | Storage, recycling, processing and acquisition of nutrients | 42. Is there accumulation of organic matter here?<br>_____<br>43. What about the Nutrient cycling?<br>_____ |
| Pollination | Supports for pollination | 44. What about pollination?<br>_____<br>45. What is the potential if restored?<br>_____ |

Source: Author 2012

## Annex 3 Transcription of interview with dweller

| **2 What are the ecosystem services available in the specified sub-basin?** | | |
|---|---|---|
| **Interview Guideline 2 A – Dweller Rio Arroio Pavuna (daughter of Community Leader)** | | |
| **Variables** | Indicators | Questions |
| Basic Data | | 1. How long do you live here?<br>☐ Less than 5 years<br>☐ 6 to 10 years<br>☐ 10 to 15 years<br>☐ 16 to 20 years<br>☐ **More than 20 years** |
| **Provisioning** | | Qualitative / Quantitative Information |
| **Food** | Fish | 2.<br>a. Have you ever seen fish in this river?<br>☐ **Yes, When I was a kid (from 34 to 25 years ago)**<br>☐ No<br>b. If Yes, what type of fish?<br>**Robalo, Tainha, Saveio, river shrimp**<br>c. Do you consume or sell this fish?<br>☐ **Yes, When I was a kid, we used to fish, consume and even had a restaurant with**<br>☐ No<br>d. Was there any change in the quantity of fish since when you live here?<br>☐ Increased<br>☐ **Reduced. Today It is not possible to see or consume fish from the river.** |
| | Fruits | 3.<br>a. Are there fruits in this wetland?<br>☐ **Yes**<br>☐ No<br>b. If yes, what type of fruits?<br>**Specific from mangrove and Banana, Cane, Mango, Jamelão, Avocado, Acerola, Pitanga, Cajú, Coco, Guava, Passion fruit (this one used to exist here naturally, now only if you plant it)**<br>c. Do you consume or sell these fruits?<br>☐ **Yes, Consume.**<br>☐ No<br>d. Was there any change in the quantity of fruits since when you live here?<br>☐ Increased<br>☐ **Reduced** |
| | Agriculture products | 4. Is there agriculture production in this wetland?<br>☐ Yes<br>☐ **No. It demands too much care and time.** |

| | | |
|---|---|---|
| | | a. If yes, what type of products? _____<br>b. Do you consume or sell these products?<br>☐ Yes<br>☐ No<br>c. Was there any change in the quantity of production since when you live here?<br>☐ Increased<br>☐ Reduced |
| **Fresh water** | Water quality | 5.<br>a. Have you notice any change in the water quality since when you live here?<br>☐ **Yes**<br>☐ No<br>b. If yes, how do you describe the water before and after the change?<br>**Before we used to swim, to fish. The water was clean and the ground was of sand. The water body was smaller but when the city started to grow here, the water body grew up and we could navigate.**<br>**Today I don't even touch the water. It is pure swage and rotten. The ground is now full of mud. We don't navigate on it anymore.**<br>6. How do you use the water? (You can mark as much squares as you need to answer this question. If possible, describe other use or uses you do on the line beside the option "Other")<br>☐ **Do not use**<br>☐ Bath<br>☐ Drink<br>☐ Garbage<br>☐ Sewage<br>☐ Transport<br>☐ Other: _____ |
| **Fiber and Fuel** | Fiber and fuel production | 7.<br>a. Do you, or anyone you know use woods from this wetland for anything?<br>☐ Yes<br>☐ **No. Not anymore but in the past we used 'taboa' to handcrafting. Today it is extinct here.**<br>b. If yes, who? _____<br>c. For what purpose? _____ |
| **Biochemical products** | Extraction | 8.<br>a. Do you or anyone you know use anything from this wetland to produce biochemical products? |

| | | |
|---|---|---|
| | | ☐ **Yes**<br>☐ No<br>b. If yes, who? **Our community, me, my mother.**<br>c. For what purpose? **We use 'aroeira' to reduce inflammations, erva de santa maria (used to have a lot, but not so many have left), Eucalyptus for sinusitis, fruits (guava for constipation, passion fruit to relax).** |
| **Genetic Material** | Availability | - |
| **Regulating** | | Qualitative / Quantitative Information |
| **Climate regulation** | GHG<br>Temperature<br>Precipitation<br>Other climate processes | 9. How do you classify the Temperature here in comparison to other parts of the city?<br>☐ Warmer<br>☐ The Same<br>☐ **Colder because of the trees and the proximity to the lagoon.** |
| **Hydrological regimes** | Ground water recharge and discharge<br>Storage of water | 10. What happens here when it rains? (You can mark as much squares as you need to answer this question.)<br>☐ **Flooding**<br>☐ **The soil absorb the water**<br>☐ The water goes to the river<br>☐ The river overflow<br>☐ **Erosion, on the other side**<br>☐ Landslide |
| **Erosion protection** | Retention of soils<br>Prevention of structural charges | |
| **Natural hazards** | Flood Control<br>Storm protection | |
| **Pollution control and detoxification** | Nutrients excess and Pollution:<br>Retention<br>Recovery<br>Removal | Vide questions 5 and<br>11. How do you classify the air quality here in comparison to other parts of the city?<br>☐ Worse<br>☐ The Same<br>☐ **Cleaner, but it has worsened with so much traffic** |
| **Cultural** | | Qualitative Information |
| **Spiritual and inspirational** | Personal feeling and well-being<br>Religious Significance | 12. What kind of other importance have this area for you? (You can mark as much squares as you need to answer this question. If possible, describe other significance on the line beside the option "Other")<br>☐ **Personal felling**<br>☐ **Well-being**<br>☐ Religious<br>☐ **Identity**<br>☐ **Contemplation**<br>☐ **Education**<br>☐ Training<br>☐ **Other – It should have gardens with local vegetation not with palm trees. We also have meetings to bring awareness about not throw** |
| **Aesthetic** | Identity<br>Contemplation | |
| **Educational** | Education<br>Training | |

| | | |
|---|---|---|
| | | **garbage in the river and lagoon.**<br>☐ None of the above |
| **Recreational** | Tourism<br>Recreation | 13. Are there tourists here?<br>☐ Yes<br>☐ **No**<br>14.<br>a. Does anyone use this wetland as recreational area?<br>☐ **Yes**<br>☐ No<br>b. If yes, who? **Community**<br>c. What do they do? **Rent a boat from a dweller and go to the lagoon. We also do our own parties to the whole community.** |
| **Supporting** | | Qualitative / Quantitative Information |
| **Biodiversity** | Habitat for resident or transient species | 15. What animals do you know that exists here? **Fishes (Robalo, Tainha, Saveio) , Shrimps (River Shrimp), Red Crabs, Snakes (boa constrictor, jararaca, Coral Sanke) Crocodiles, Birds (Cranes), Capybara**<br>16. What vegetation exist here? **Mangrove**<br>17. Is there sedimentation here? **All I know is that the river soil used to be of sand and now it is made of mud.**<br>18. Is there accumulation of organic matter here? **Yes. Sometimes a lot of algae (gigoga) appear here and the dwellers remove.** |
| **Soil formation** | Sediment retention<br>Accumulation of organic matter | |
| **Nutrient cycling** | Storage, recycling, processing and acquisition of nutrients | |
| **Pollination** | Supports for pollination | |

Source: Author 2012

## Annex 4 Time Scheduling

| Step | Date | Month |
|---|---|---|
| Research proposal submission | 29 June | June |
| Field work | Check Specific Scheduling | July |
| Colloquium | 3 August | August |
| First Draft Final Thesis Submission | 20 August | |
| Deadline Final Thesis Submission | 09 September | September |
| Thesis Defense | 12 September | |

**Table 16: Field work time scheduling**

| Specific Question | Source | July (field work) | | | |
|---|---|---|---|---|---|
| | | Week 1<br>2-6 | Week 2<br>9-13 | Week 3<br>16-20 | Week 4<br>22-27 |
| 1. What are the land-uses present in Guerenguê River's sub-basin in Rio de Janeiro? | Observation | Photos and on site | | | |
| | Secondary data | Mapping | Municipality Report | | |
| 2. What are the ecosystem services available in the specified sub-basin? | Observation | Photos and on site | | | |
| | Secondary data | Municipality Reports Literature | | | |
| | Interviews | Dwellers | Specialists | | |
| 3. What actions can be taken to restore the sub-basin? | | | Specialists | | |
| 4. What are the potential ecosystem services of a restored Guerenguê River's sub-basin in Rio de Janeiro? | Observation | Photos and on site | | | |
| | Secondary data | | | Municipality Reports Literature | |
| | Interviews | | Specialists | | |

## Annex 5 List of Collected Data and its operationalization

**Table 17: Data Collected**

| Number of Reference | Title | Source | Source of |
|---|---|---|---|
| **1** | Mapeamento da cobertura vegetal e do uso das terras no município do Rio de Janeiro no ano de 2010 | SMAC (Environmental Bureau of Rio de Janeiro) sigfloresta.rio.rj.gov.br | Mapping Report of Vegetation<br>Land use |
| **2** | Relatorio de Analise da Cobertura Vegetal e uso do solo nas sub-bacias hidrograficas – Sub-bacia do Rio Guerengue | | Table with the percentage of types of vegetation and land use in the sub-basin of Guerengue River |
| **3** | Map of Report | | Description of vegetation and land use of Guerengue River Sub-basin |
| **4** | Reforestation Task Force Project | SMAC (Environmental Bureau of Rio de Janeiro) Reforestation | Reforestation of risky areas nearby poor communities in the region. |
| **5** | Desenvolvimento Sustentavel e participacao comunitaria: um estudo exploratorio dos conflitos ambientais na area da Barra da Tijuca (2001) | Master Thesis of Environmental Bureau of Rio de Janeiro Staff | Local Ecosystem (Fauna and Flora)<br><br>Historical Evolution |
| **6** | Estudo para recuperacao ambiental e controle integrado de enchentes, poluicao hidrica na Bacia do Rio Guerengue / Arroio Pavuna, Jacarepagua – RJ (2007) | Rio-Aguas (Watershed Management Bureau) | Water quality indicators (also related to aquatic life)<br><br>Flood prone areas |
| **7** | Cartografia de Risco Quantitativo a Escorregamentos em Setores de Assentamentos Precarios na Cidade do Rio de Janeiro – Plano Municipal de reducao de risco | Geo-Rio (Geotechnical Institute of the City of Rio de Janeiro) | Erosion risky areas |
| **8** | Book:Espacos Livres: Sistema e Projeto Territorial | Author: Raquel Tardin | Historical Development<br>Cultural importance |
| **9** | Municipality Data | Municipality website: http://www.armazemdedados.rio.rj.gov.br/ | Maps, Data of Temperature, Precipitation, Inhabitants etc. |
| **10** | Interviews | Dweller | Ecosystem Services in their point of view |
| | | Specialists | Local characteristics and events<br>Secondary data<br>Local plans |

Source: Author 2012

**Table 18: Operationalization of data**

According to the list of secondary sources above, the data source is indicated below. For all items, interviews contribute and so it is not listed (10).

| Ecosystem Services operationalization | | | |
|---|---|---|---|
| **Variables** | **Indicators** | **Research Method:** Qualitative / Quantitative **Data Type:** Primary and Secondary | |
| | | **Data Collection Methods** | **Secondary Source** |
| **Provisioning** | | | |
| **Food** | Fish | Literature Reports Observation Interviews | 5, 6 |
| | Fruits | | 5 |
| | Agriculture products | | 5 |
| **Fresh water** | Water quality | | 6 |
| **Fiber and Fuel** | Fiber and fuel production | | 5 |
| **Biochemical products** | Extraction | | 5 |
| **Genetic Material** | Availability | | 5 |
| **Regulating** | | | |
| **Climate regulation** | GHG, Temperature, Precipitation<br>Other climate processes | Literature Reports Observation Interviews | 9 |
| **Hydrological regimes** | Ground water recharge and discharge<br>Storage of water | | 5, 6 |
| **Pollution control and detoxification** | Nutrients excess and Pollution:<br>Retention, Recovery, Removal | | 5, 6 |
| **Erosion protection** | Retention of soils<br>Prevention of structural charges | | 5, 6, 4, 7 |
| **Natural hazards** | Flood Control<br>Storm protection | | 5, 6 |
| **Cultural** | | | |
| **Spiritual and inspirational** | Personal feeling and well-being<br>Religious Significance | Literature Reports Observation Interviews | 5, 6, 8 |
| **Recreational** | Tourism<br>Recreation | | |
| **Aesthetic** | Identity<br>Contemplation | | |
| **Educational** | Education<br>Training | | |
| **Supporting** | | | |
| **Biodiversity** | Habitat for resident or transient species | Literature Reports Observation Interviews | 5 |
| **Soil formation** | Sediment retention<br>Accumulation of organic matter | | 5, 6 |
| **Nutrient cycling** | Storage, recycling, processing and acquisition of nutrients | | 6 |
| **Pollination** | Supports for pollination | | |

Source: Author 2012

## Annex 6 Contacts

**Dweller Interviewed**
Nadja Dazzi, Arroio Pavuna Community

**Academic specialists consulted**

Ana Lucia Britto (Ph.D. Environment and Urban Planning - Researcher and Professor UFRJ - PROURB)
André Lucena (Environment Economist - COPPE)
Camilo Michalka (Environmental Engenering - UFRJ)
Lucia Maria Sá Antunes da Costa (Ph.D. Researcher and Professor UFRJ - PROURB)
Raquel Tardin (Ph.D. Researcher and Professor UFRJ – PROURB)
Rita de Cássia Martins Montezuma (PhD Researcher and Professor Geography PUC)
Roberto Shaeffer (Ph.D., Energy Planning - COPPE)
Vera Regina Tângari (Ph.D. Researcher and Professor UFRJ – PROARQ)

**Municipality specialists**

SMAC (Environmental Management Bureau)
Brasiliano Vito Fico (Manager of territorial monitoring)
Mauro Luiz Salinas do Rosário (Geographer)
Roberto Bastos Rocha (Environmental Protection Manager)
Rômulo M. Madeira (Reforestation)
Suzana Claudia Monteiro de Barros (Master Thesis Author)

Rio-Aguas (Watershed Management Bureau)
Mônica Santiago Montenegro (Manager Jacarepaguá Watershed)
Morvan Barreto Nobre (Watershed Manager)

Geo Rio
Brandao (Geologist)

## Annex 7 Water quality analysis data (Miguez 2007)

Water quality analysis variables:

COD – Chemical Oxygen Demand

BOD – Biochemical Oxygen Demand

NT - Total Nitrogen (ammonia, nitrite, nitrogen)

TSS – Total Suspended Solids

FSS – Fixes Suspended Soilids

VSS – Volatile Suspended Solids

**Table 19: Location of Sample Collecting Points for water quality analysis**

| Code | Location of Sample Collecting Points |
|---|---|
| **P1 Pte 1** | Engenho Novo River, in Areal |
| **P1 Pte 2** | Engenho Novo River, in Areal |
| **P2** | Monjolo River |
| **P3** | Guerenguê River, downstream of the junction of Monjolo and Engenho Novo Rivers |
| **P4** | Guerenguê River, close to Coca-Cola Factory |
| **P5** | Arroio Pavuna – Bridge of Avenida dos Bandeirantes close to Castor Street |

Translated from Miguez 2007 p. 96

**Table 20: Water quality analysis results**

| **Sample from 02/04 – Processed on 03/04** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameters** | | P1 Pte1 | P1 Pte2 | P2 | P3 | P4 | P5 |
| **mg/l** | COD | 31.2 | 31.2 | 156 | 171.6 | 218.4 | 156 |
| | BOD | 19.6 | 15.5 | 123.5 | 78.5 | 166 | 75.7 |
| | $NH_4$ | 0.6 | 0.38 | 5 | 5 | 7 | 2 |
| | Nitrite | Nd | nd | nd | 0.02 | 0.02 | 0 |
| | NT | - | - | - | 19.2 | - | 18.6 |
| | Total Phosphorous | - | - | - | - | - | 3.8 |
| | TSS | 12 | 2 | 33 | 33 | 61 | 63 |
| | FSS | 6 | 1 | 11 | 10 | 22 | 26 |
| | VSS | 6 | 1 | 22 | 23 | 39 | 37 |
| **PtCo** | Color | 37 | 57 | 148 | 139 | 155 | 203 |

Translated from Miguez 2007 p. 96

**Table 21: Typical characteristics of solids on gross sewage, mg/l (*)**

| Solid Matter | Strong Sewage (mg/l) | Medium Sewage (mg/l) | Weak Sewage (mg/l) |
|---|---|---|---|
| **Total Solids** | 1.160 | 730 | 370 |
| **Total Suspended Matter** | 360 | 230 | 120 |
| **Volatile Suspended Matter** | 280 | 175 | 90 |
| **Fixed Suspended Matter** | 80 | 55 | 30 |
| **Total Dissolved Sollid** | 800 | 500 | 250 |
| **Volatile dissolved Solid** | 300 | 200 | 105 |
| **Fix Dissolved Solid** | 500 | 300 | 145 |
| **Depositing Solids** | 20 | 10 | 5 |
| **(*) S. Sedmenting, ml/l** | | | |

Translated from Miguez 2007 p. 101

**Table 22: Typical values for organic weight on sewage**

| Solid Matter | Strong Sewage | Medium Sewage | Weak Sewage |
|---|---|---|---|
| **COD** | 800 | 400 | 200 |
| **BOD, 5d, 20$^{o}$C** | 400 | 200 | 100 |
| **Total Nitrogen** | 85 | 40 | 20 |
| **Organic Nitrogen** | 35 | 20 | 10 |
| **Free Ammonia** | 50 | 20 | 10 |
| **Nitrite, $NO_2$** | 0.10 | 0.05 | 0 |
| **Nitrates, $NO_3$** | 0.40 | 0.20 | 0.10 |
| **Total Phosphorous** | 20 | 10 | 5 |
| **Organic Phosphorous** | 7 | 4 | 2 |
| **Inorganic Phosphorous** | 13 | 6 | 3 |

Translated from Miguez 2007 p. 99