NON-SUSTAINABLE REDUCTION VALUES: A METHODOLOGY TOWARDS A LOW CARBON CITY

INTRODUCTION

Throughout history the biosphere has undergone important structural changes which allowed the modeling of an atmosphere with exceptional biotic features. The biosphere dynamic equilibrium is responsive to several phenomena and processes in which men participate.

Since more than 30 years strong alterations in the integrity of ecological systems have been detected. Since then important meetings have been held: Worldwide Conference on Environment and Development (Stockholm and Rio '92), Assembly on Climate Changes, Meetings of Party Conferences (1995/07).

Once acknowledged the environmental problem, among the key points, "sustainability" can be included in the framework of the human development. Then, several definitions were issued: Thus, the World Committee of Environment and Development has considered it as a way to fulfill the requirements of the present generation without impairing those ones of future generations.

Thus Bariloche Foundation of the Argentine Republic [1] concludes that the above mentioned definition should include an integral development, being able to use natural resources in order to meet the essential needs of people for the present and future generations, improving life quality. This could be achieved in a long time using the maximum potential of ecosystems on the basis of proper technologies and the joint action of people to make fundamental decisions.

Currently, if we analyze worldwide this problem it can be observed that at the beginning of the third millennium something has been done to combat it, though much remains to be done. Overall, quite important contributions have been made in an attempt to solve the problem, but the solutions are still restricted and specific. In addition, results are fragmented, and there is a lack of political responses.

The environmental problem in Latin America was aggravated by: effects of the economy globalization in weak political-institutional states; consolidation and increase of patterns of development and consumption with great social inequity; and also the appearance of unsustainable lifestyles. This context together with the usual urban lack of equilibrium in certain regions (between center and outskirts) led to a precarious habitat [2][3]. All over the world there is an increasing idea, though sometimes uneven, to build up a proper habitat [3][4]. It is clear that the environmental problem goes beyond the ecological dimension.

In Argentina, there has been an increasing interest concerning life quality. Also, those problems related to urban life have been addressed. We must bear in mind that in Argentina 85% of the population live in cities, and urban growth is increasing due to country-city immigration as much as due to a decrease of mortality and increase of birth-rate. This population disparity is notorious in the natural environment where markedly different and unbalanced roles between "donors" and "acceptor systems" are observed.

In this way, it can be inferred that sustainability within the framework of regional urban areas, is far from being achieved, as the diversity of facts present a strong distortion in the immediate and regional environment. It is clear that the word "sustainability" represents a paradigm to be accomplished. Hence, it would be reasonable to analyze the concept of non-sustainability or its degree. Thus, we could determine more accurately the disturbance degree in urban structures, which, in general, have areas of high energy consumption, as well as quantify how far they are from being in equilibrium, and if they are able to improve the region taking into account a wide range of dimensions.

To determine the disturbance degree produced by an urban center where several variables are involved, certain methodologies are required including crucial strategies to analyze common objectives. In this regard, what the Art.41 in the Argentine National Constitution states “Environmental damage has to be primarily repaired” according to the law; is far from its application. The word “repair” is semantically accurate, but practically it is quite difficult due to the large cause/effect diversity, institutions are unaware, lack of cleaning technologies, political-institutional issues, lack of funding, scanty infrastructure and lack of integral methods covering the whole problem.

The present work deals with a way to analyze and consider the urban-environmental situation; it focuses the area of study in order to assess the methodology, without disregarding that limiting can affect the object under study and its bordering conditions. The target area is La Plata district (Figure 1), province of Buenos Aires, Argentina. The aim of such a cut out is to obtain information readily, and to avoid differences arising from different governmental areas. We think that the political-institutional joint action is essential to address problems with those features, but it has not been included here. This work presents results obtained for two scenes, the present and the potential ones. Detailed and global data would accurately describe present diagnoses, which would allow devising good strategies to improve each area damaged.

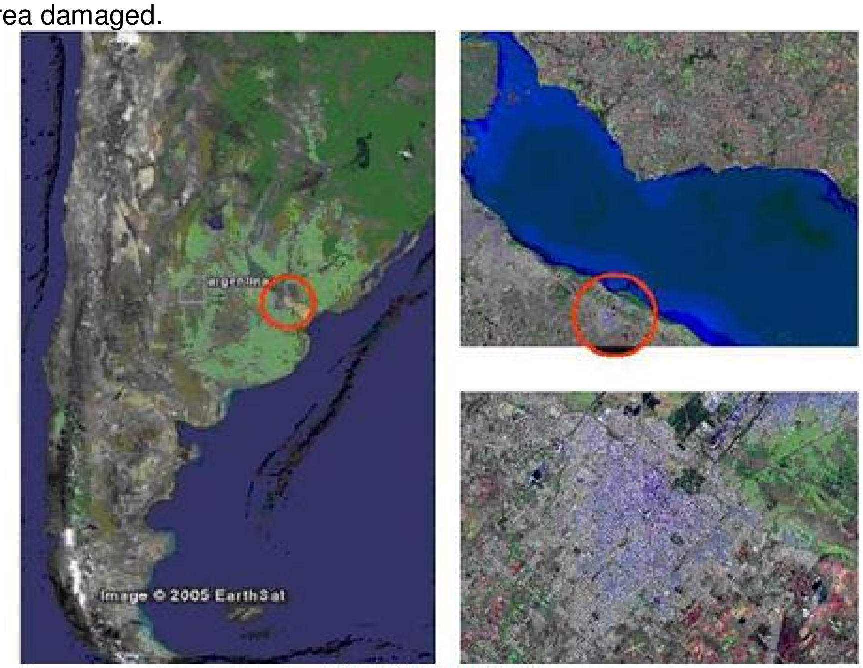


Figure 1. Study area.

METHODOLOGY

Methodology strategies of analysis with the same purpose are involved in this methodology. It is carried out by means of: information systematization, indexes construction, statistical and classification analysis (sample development and data processing), use of geo-referenced systems related to interactions between regions. These various tools allow us to characterize and relate variables, obtain indexes and indicators as well as draw profiles related to energy consumption, air emissions of each pollutant, its source location, and the capacity to mitigate each area according to its forest. The information was obtained from houses surveys (URE-AM and URE-AM II Research projects) [6][7] and origin and destination surveys of the transport system in La Plata city [8]. This methodology allows the processing of a wide range of urban dimensions closely related to basic services associated with life quality. This study was based on the energy demand of this city, determined through sectors and source. It was globally characterized by means of service and infrastructure networks and in particular by the users. For mitigation purposes, present and potential natural absorption sites were evaluated at local and regional level.

Concerning the consumption of urban energy, the material collected up to now allowed us to draw urban maps showing and quantifying energetic density discriminated by sectors (residential, commercial, education, health, transport, etc).

Different energy sources were taken into account (electricity, gas and liquefied and solid fuels) and their units were considered as Tons of Oil Equivalent (TOE). Real consumption for each sector and its use were evaluated; the polluting gas emissions for each energy sector were calculated; and different levels of concentration were geographically localized.

Geographical information system was used to draw maps showing energy and pollution results in the urban network. Those parts of the city were identified as high, medium and low areas of building consolidation, whereas the public and private transport accounted for vehicular density, engine and traffic frequency [9]. Thus, the urban situation based on energy aspects and air pollution, either as a whole or partially, was considered or quantified.

In fact, the available information led us to establish different stages related with the rational use of energy and with different mitigation strategies.

The research projects above mentioned (URE-AM, URE-AM II and Origin and destination of the transport system in La Plata city) allowed us to draw energy consumption patterns, ways of use and pollution, and characteristic profiles for each urban section [10][11][12][13][14][15].

Concerning those rules aimed at mitigating emitted pollutants (e.g CO_2), Art.2 of the Kyoto Protocol deals with carbon-dioxide sequestration technologies as well as novel and advanced technologies which are ecologically rational. This pattern is related to absorption through natural absorption sites of greenhouse effect gases which were not controlled by the Montreal Protocol. This would be part of what the Intergovernmental Panel on Climate Changes named "Strategies of Carbon Management". We are primarily referring to fixation by biological cycle, with relatively fast processes. It is clear that when we say carbon sequestration, we mean to preserve and/or increase the natural reservoirs of terrestrial ecosystems, emphasizing the preservation, forestation and re-forestation in existing sites and/or those ones of potential availability. It is essential to know that these mitigation processes must be part of a strategic plan since forests are temporary natural absorption sites of approximately 20 year atmospheric carbon renewal. Hence, it must be taken into account that the fate of natural absorption sites is to preserve carbon storage.

Consequently, it is important to know the present and potential sequestration capacity with respect to the energetic situation and pollutants emission. It must be pointed out that La Plata city is one of the few cities that were planned since its foundation in 1882, including a large number of parks and gardens. Such a design allowed to make up for changes arisen in the urban systems; this means that the original green area/inhabitant ratio, $14m^2$/ inhabitant in squares and parks has been systematically broken during the last years ($3.41m^2$/ inhabitant and $12.15m^2$/ inhabitant, including sidewalk forest). Anyhow, this city has large green areas as well as a lot of avenues and streets with many trees.

These urban features allow us to present two mitigation strategies using carbon sequestration by means of "biological fixation".

They are: i. The first one takes into account large areas of land covered with trees in either urban or suburban regions; ii. The second one is a potential mitigation analysis to determine which areas are likely to be forested (Public or Private areas).

In the first case, those areas which could be used as natural absorption sites by means of parks and gardens, sidewalks and boulevards, were determined.

Concerning the second one, potential areas to be forested were identified. Their topographical features of each area were also considered, whereas flood plains near the basin of the Rio de la Plata as well as pits and lands without humus, were discarded. Concerning the availability of forest lands, we investigated the most suitable species based on nutrients, carbon fixation level, and development times [16]. In fact, well-managed forestation endeavors would lead to improve and/or establish industry-related endeavors, mainly the private ones. It must be pointed out that in this region there are related industries which raw materials come from distant forests.

Integration through geo-reference, quantification and good featuring of urban areas allowed us to detect those that are highly polluted (gas emissions of any kind, particularly CO_2 of energy origin), as well as forested areas with different absorption capacity. Hence, homogeneous areas with different energy densities, different levels of pollutant concentration, and mitigation areas, could be determined.

The outcoming maps will be used to analyze situations according to different requirements. In brief, this information will feature the non-sustainability degree, rather than the sustainability one in a specific area in order to evaluate present and potential natural or artificial absorption sites so as to devise appropriate strategies to mitigate pollution, and at the same time to increase labor (forestation and management plans) and emerging industries.

The interaction of this complex network would, indeed, adjust the dynamics of urban areas, leading to a better life; thus preservation and improvement of the environment would be achieved.

VARIABLES CONSIDERED, THEIR INSTRUMENTATION.

Among the urban data collected we can mention:

a- Home consumption in relation to different urban consolidations;
b- Public-private health network in relation to energy density complexity;
c- Energy networks (gas and electricity), their supply according to the user;
d- Public and private transport; different types according to energy density;
e- Green areas network (parks) and land to be forested;
f- General information based on a census (urban consolidation, number of houses per block, population, availability of basic services, etc.).

All this information concerning production, localization, energy consumption, building infra-structure, supply of services, etc., was put on the data base.

Statistical programs and Geographic Information Systems (GIS) were utilized. Indexes and specific indicators were obtained; profiles featuring energy density and types of pollutants (CO_2, CO, NO_x, etc.) were drawn. As reference, previous studies carried out in urban services (health and education in the province of Buenos Aires, Argentina) [11][17][10][9], can be mentioned.

Concerning those strategies of “carbon sequestration”, the natural environment and artificial green areas as present and potential natural absorption sites that compensate CO_2 emissions (main cause of the greenhouse effect), were analyzed. This role is mainly fulfilled by green areas with forestation and/or reforestation since these areas constitute large CO_2 natural absorption sites. In Argentina more than 80% of forest species exhibit fast growing, with short rotations; in fact these areas are always taking up the atmospheric CO_2 [16].

Urban and suburban green areas under study can be sorted out: natural areas under control, artificial parks, pasturelands, productive lands and marshlands; all of them play an important role in relation to growth rate, carbon fixation, absorption and emission of gases (CO_2). Overall, controlled forests in the province of Buenos Aires are important CO_2 natural absorption sites. In fact, the balance of carbon dioxide displays an atmospheric CO_2 absorption capacity of 1900 Gg/year [18].

Results were discussed on the basis of energy consumed, pollutants emission, absorption degree. Then, non-sustainability can be evaluated. Different variables will be used to diagnose each situation.

TO SET AN EXAMPLE: DETERMINATION OF NON-SUSTAINABILITY URBAN DEGREE.

Here, the present energy state within the urban area as well as two mitigation programs (present and potential) were evaluated, taking into account the strategy of carbon sequestration using “fixation by the biological cycle”.

FIRST SCENE – PRESENT SITUATION

In order to evaluate energy and pollution, final results of urban and suburban areas were considered by sectors: residential, health, education, transports, commercial, and administration.

Air pollution emissions were considered as energy sources, electric energy (local or regional thermal plant), natural gas, liquefied and solid fuels. Table 1 shows the values for each sector per specific unit.

Integration and overlap of results on theme maps display the distribution of each variable analyzed. Total urban energy consumption corresponds to 460.116 TOE/year, and the integral CO_2 emissions were calculated in 1.078.303.520 Kg/year. As new items are incorporated, results as a whole for each region will be obtained.

Concerning natural absorption sites capacity, this area under study has a significant system of parks (controlled natural areas). Quite a large number of full-grown species are found in these forested areas. According to their development stage, there is approximately 17% decrease of absorption and C fixation compared to young specimens [16].

The other areas (pastureland, productive lands and marshlands) will be incorporated after their analysis, noticing that C and CO_2 fixation and absorption are smaller owing to a woody mass much smaller than the forest one. They have a greater activity during those months with more solar radiation and higher temperature.

Should these areas be extended, a significant variable could be achieved.

Among the species studied, we can mention Coniferae, Eucalyptus sp., Salicaceae which grow in most urban and suburban areas of the region [16]. Table 2 shows the absorption, emission and balance average rates of these species; they will be considered as reference for the total analysis.

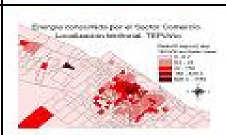
Table 1 Sectors		Reference Variables	Total Energy per sectors TOE /Year	Total Emissions of CO_2 Kg/Year
Residential		TOE / Home. Year 1,76	312.520	662.542.400
Health		TOE / Building.Year 103.9	7.274	15.420880
Education		TOE / Building.Year 4,6	2.317	4.912.040
Commercial		TOE / Building.Year 47,84	54.865	116.313.800
Administration		TOE / Building.Year 47,6	2050	4.346.000
Transport		Total Energy TOE/Year Public Transport 50.090 Private Cars 43.845 Rent Cars 4.153	90.088	274.768.400
TOTAL Energy Consumption. Energy-intensive sectors TOE /Year.			460.116	1.078.303.520

Table 1. Values for each area per specific unit.

Region	Forested Areas (kha)	Anual absorption rates C (Mg.ha^{-1})	Anual emission rates C (Mg.ha^{-1})	Absorption – emission anual balance C (Mg.ha^{-1})	Absorption – emission anual balance C (Gg)
Buenos Aires	144	6,2	2,6	3,6	518,4

Table 2. Absorption and emission average rates of C in Buenos Aires region.

Concerning forestation in La Plata city and its outskirts, there are 662,174 trees in parks, squares, boulevards and sidewalks in the urban center [19].

The areas involved correspond to approximately 715 hectares which distribution is 148.6 hectares in parks and squares, with 18,684 adult specimens; and 567 hectares correspond to sidewalks where 643,490 adult specimens are found. The forestation/surface ratio of the urban area is 79m^2/tree for parks and squares, and 8.8m^2/tree for sidewalks. As to suburban forested green areas there are 415 forested hectares where a wide diversity of trees is found. The total green area under this study corresponds to 1130.6 hectares.

Total consumption within different ranges of energy density, can be displayed in GIS maps. Figure 2 shows the TOE /year distribution in all sectors and in the transport sector. The areas with major density were determined according with consolidation degree and main transport units.

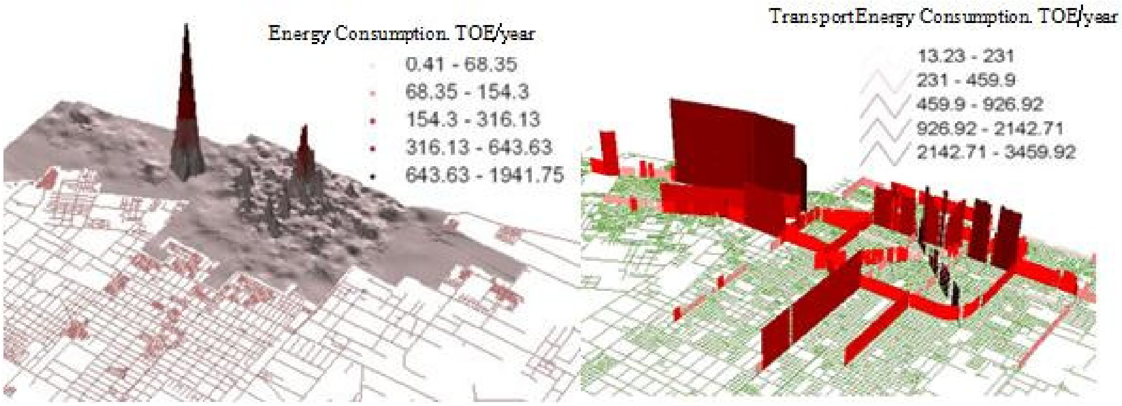


Figure 2. Energy distribution in the study area in TOE/year.

Figure 3 shows the distribution and quantification of CO_2 emissions (Kg/year) produced by the consumed energy in the mentioned areas.

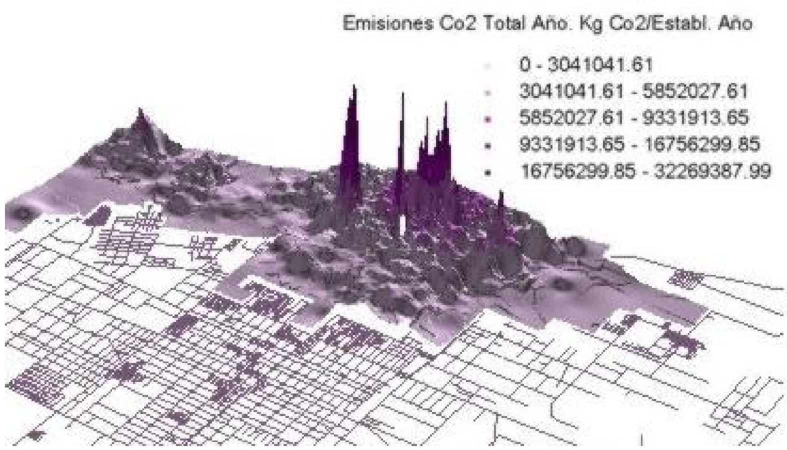


Figure 3. Distribution and quantification of CO_2 emissions (Kg/year) by the energy consumed.

A detailed description of CO_2 emissions in the transport system for this region is shown in Figure 4 [20].

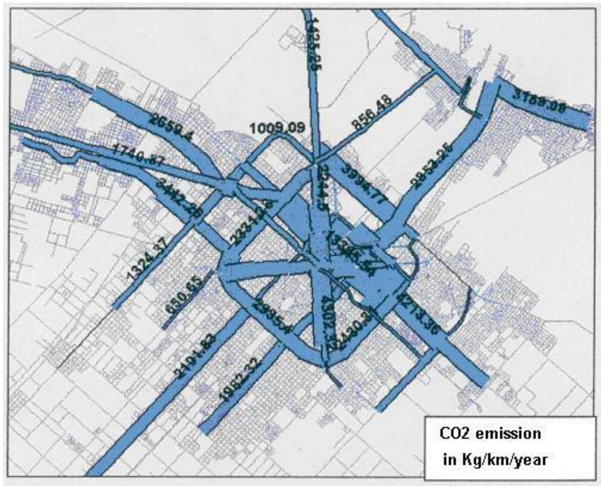


Figure 4. Transport system emissions for the region under study.

Upon the basis of these partial results, the most polluted areas can be envisaged.

As to mitigation, Figure 5 shows CO_2 absorption capacity (Kg/year), and consequently carbon fixation in the urban and suburban green areas.

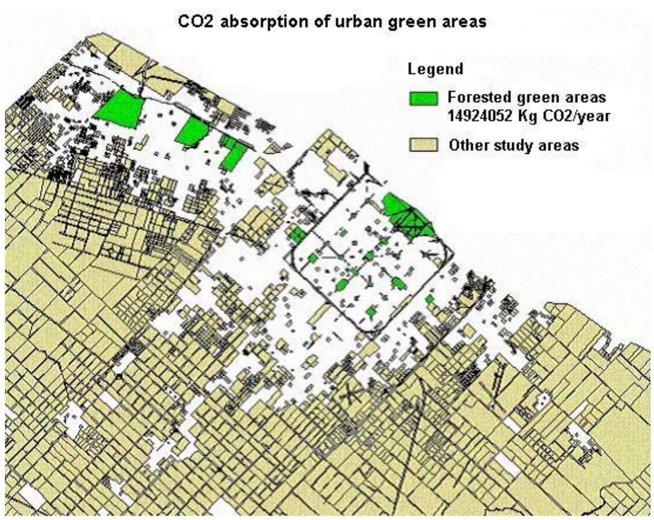


Figure 5. CO_2 absorption capacity (Kg/year) by urban green areas.

In order to evaluate carbon sequestration, the annual balance of C release and absorption in Table 2 (network absorption capacity of 3,600 Kg/hectare/carbon year), was taken into account. Also, all the species and the atomic weight of 44 CO_2 , distributed in 12 of C and 32 of O, as well as the forested area (1,130 hectares) of the region, were included (1). From these calculations, it is drawn that:

$$\therefore CAbsorption \rightarrow 3600kg/ha \times 1130{,}6ha = 4.070.196KgC/year$$

$$\therefore CO_2 Absorption \rightarrow 4.070.196KgC/year \times 44 \div 12 = 14.924.052KgCO_2/year;$$

$$CO_2 Absorption \rightarrow 14{,}9MKgCO_2/year$$

To determine the urban non-sustainability degree (from the energy point of view) we relate absorption capacity of the natural environment (14 MKg of CO_2/year) to emissions associated with urban energy consumption (1.078 MKg/year of CO_2).

Resulting values are summarized in Table 3 where the first partial balance of CO_2 in this region, can be seen. For the first time, the non-sustainability degree of the area under study was measured, showing a temporary percent value of 99.66% (100%-absorption/emission x100).

CO_2 absorption in MKg/year	CO_2 Emission in MKg/year	Non-sustainability degree (100-Absorption/Emission x 100) %
14,9	4416,7	99,66

Table 3. Non-sustainability degree of the area under study (District of La Plata, Buenos Aires).

As other energy items are incorporated within the urban complex, a definite absorption/emission ratio will be assessed.

The obtained value reflects a striking difference between urban areas and the natural environment, triggering a strong lack of equilibrium between “donor” and “acceptor” systems.

SECOND SCENE. POTENTIAL SITUATION.

To evaluate the second scene we considered the potential absorption of new natural absorption sites. Then, we analyzed the areas to be forested using well-adapted species, hence a better time/absorption ratio. The district of La Plata has 58,484 hectares of available land. In this paper we include the intensive productive horticultural sector with around 6134 Ha (nowadays these areas are being turned into residential urban areas, with an intermediate forestation potential). Figure 6 shows the available areas in which the Rio de La Plata basin, as well as pits, and rubbish dumps, were discarded.

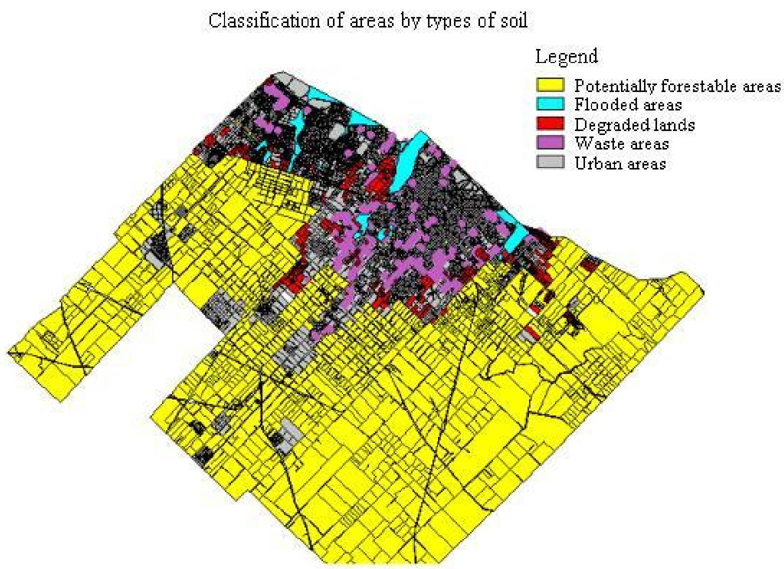


Figure 6. Forest land availability of La Plata district. (2nd scene – Potential situation).

Data in Table 1 were considered in order to devise an integral strategy between the local authorities, production sectors, and the inhabitants, to obtain C fixation wisely.

Concerning production, forestation is an attractive endeavor, which would either favor or improve some industries such as construction, furniture, paper, sawmills, packing cases, etc. It must be pointed out that this province has certain factories which raw material comes from distant forest regions. If industry is the target of forestation, we must take into account that once started plantation, the useful land would correspond to the potential land calculated for an annual period of approximately 10 years, at an annual fixation rate around 21,9 and 12 Mg/ha per year (Coniferae and Salicaceae) for young specimens. As regards extraction for the industrial processing, rotation should be regulated according with species growth, C fixation, and deforestation demand.

Despite these benefits, we must bear in mind that the available useful land for C fixation would be reduced in relation to the rotation rate. Given a rate of 1/3 (1/3 plantation, 1/3 growth, and 1/3 adult stage), the useful land for C fixation would be around 2/3 of the potential land calculated.

In brief, for the second scene we determined a C fixation average of 16,950 Kg/ha per carbon year (young specimens), and a potential land of 38,989 ha (2/3 of the useful potential land).

$$\therefore CAbsorption \rightarrow 16.950 kg/ha \times 34.900 ha = 591.555.000 KgC/year$$

$$\therefore CO_2 Absorption \rightarrow 591.555.000 KgC/year \times 44 \div 12 = 2.169.035.000 KgCO_2/year;$$

$$\therefore CO_2 Absorption \rightarrow 2.169{,}035 MKgCO_2/year$$

Values calculated are summarized in Table 4 where the potential resource compared with the present ones of the region is shown.

Scene	CO_2 Absorption in MKg/year	CO_2 Emission in MKg/year	Non-sustainability degree (100-Absorción/Emisión x 100) %
Present	14,9	1078,3	98,62
Potential	2169,035	1078,3	-101,15

Table 4. Potential resource of the region.

A definite absorption/emission ratio will be achieved after incorporating all the involved parts. It is clear that "the biological fixation of carbon" strategy could reverse the present situation of non-sustainability, improving the relationship between "donor services" and "acceptor services". It must be noted that conservation and reduction of energy have not been ruled yet neither in the present scene nor in the potential scene. Undoubtedly this fact would improve the absorption/emission ratio; thus the non-sustainability degree would be much lower.

On the other land, the climate dynamics related to the predominating wind frequency should be also considered to determine accurately those areas that have a strong demand of absorption. In summer, winds blow primarily from N and E, whereas in winter they come from NE, NW, S, SE and SW. In consequence, the area considered as potential would play a significant role as natural absorption site in both seasons.

This situation evidences that it is crucial to establish rules within the region, so neighboring districts or towns could also carry out sanitation policies, compensating differences from one region to another.

The problem has been clearly depicted; it is part of our daily life, though the government action is still scanty. To understand this problem it is essential to get a better relationship between the environment and the inhabitants, promoting actions to reverse critical situations such as unemployment, pollution. In fact, the government must know that "positive action is better than rhetoric", since in certain cases, risk could be irreversible.

CONCLUSIONS

In terms of efficacy, the analysis of converging methodologies allowed us to perform a satisfactory study. This cross sectional study allowed us to determine and quantify those areas with homogenous and overlapping problems.

The spatial analysis of indexes and profiles, in this case, consumption-pollution led us to determine those areas of energy with high consumption, and consequently high pollution.

Different situations will be diagnosed on the basis of different variables and requirements.

Non-sustainability degree rather than the sustainability one will be inferred by collecting results from each sector.

Should these factors operate in this system, then a number of important issues could be addressed to counterbalance big differences existing between the urban and the natural environment. Yet, the no-mitigation of such differences makes this region vulnerable of irreversible damage.

Taken as a whole, structural modifications are likely to be carried out to achieve a wise use of regional resources. In brief, we are able to evaluate the true non-sustainability degree of this region and to devise helpful strategies in overcoming the challenge of living in a lower carbon city.

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Carlos A. Discoli; Irene Martini; Dante A. Barbero.

Instituto de Investigaciones y Políticas del Ambiente Construido (IIPAC), Grupo de Investigación Nº1, Facultad de Arquitectura y Urbanismo, Universidad Nacional de La Plata.
Calle 47 N°162. CC 478 (1900) La Plata, Buenos Aires, Argentina.
Consejo Nacional de Investigaciones Científicas y Técnicas, CONICET.
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Phone -fax: O54-0221-4236587/90. Int. 254.
e-mail:discoli@rocketmail.com;irene_martini@yahoo.com.ar;dantebarbero@yahoo.com.ar .