TEMPORAL ANALYSIS OF THE EFFECT OF URBANIZATION ON SURFACE RUNOFF IN FOUR NEIGHBOURHOODS IN THE CITY OF UMUARAMA IN PARANÁ, BRAZIL

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ABSTRACT
This paper presents a temporal analysis of the relation between urbanized area growth and changes in the hydrological balance on the studied area, observing alterations in runoff and losses by infiltration in four neighbourhoods located in the city of Umuarama-PR, namely Jardim Bela Vista, Jardim Colibri, Jardim Yonezu and Parque San Remo I and II. This temporal analysis was made from three scenarios, representing the past (2004), the present (2013) and the future (projection), the area was divided into 26 blocks (sub-catchments) and was used the hydrological model SWMM 5:00:22 (Storm Water Management Model) to generate results such as the flow reaching at the receiver rainwater drainage channel, losses of the volume precipitated by infiltration into the soil - using a project precipitation with return period (Rp) of 3 years. The study area was analyzed as a whole and also individually, block by block. This paper draws attention to the issue of urban planning in the growth of cities and their social function, taking into account the identity of the place of study as well as environmental quality.
Keywords: SWMM, urbanization, runoff.

1 INTRODUCTION

One of current models of urban development found in Brazilian's cities, has resulted in an increase in the impermeabilized area and consequent increase of the water loads dumped in the drainage systems, because of the increase of the urbanized area it is natural the impacts occurrence, for example the grow in the runoff, the grow in the sediments production, and the water's quality deterioration.

Otherwise, the surface impermeabilization and the drainage systems construction could result in the frequency and magnitude increase [1], these also could change the rivers characteristics which are inserted in urban areas and even the region's microclimate [2].

In this way, the spring flow of the Pinhalzinho II River located in the city of Umuarama, Paraná – Brazil were constatated with some of these urban's water resources problems, this is one of another afluents of Goioere River. The Pinhalzinho II River is on almost all urbanized area since the 1970s.

This research was developed to understand the correlation between the surface use and occupation in the neighborhoods located in the Pinhalzinho II river's drainage area and the effects in this river. This study has used three different scenarios, each one with different rates of impermeable areas, to observe the effects of runoff in the water body, taking into account the characteristics and peculiarities over the years, following the intensification of urbanization processes.

All of these three scenarios were simulated through the SWMM (Storm Water Management Model), used throughout the world for planning, analysis, design, management and another uses in the urban areas drainage systems [3].

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2 MATERIAL AND METHODS

2.1 Studied area

The study was realized on the neighbourhoods Bela Vista, Colibri, Yonezu, and San Remo I and II, included in the River Pinhalzinho drainage area in the city of Umuarama, Paraná, Brazil (Fig. 1). The studied area is located at coordinates 23º46'36" S; 53º19'11" W, where also are located the urban drainage's receiving channel. The studied area compromises approximately 371.747,21m², in a perimeter of 2.454,73m (Fig. 2). This area was subdivided in 26 sub-catchments that each one corresponds to one block as represented by the Fig. 3.

According to the master plan for the Umuarama city (2006) this area is classified as medium density residential area, which allows the following types of dwellings: single family, single family in series, trade and vicinal services, community uses (teaching and health) as well as permissible institutional housing, condominiums and industrial use.

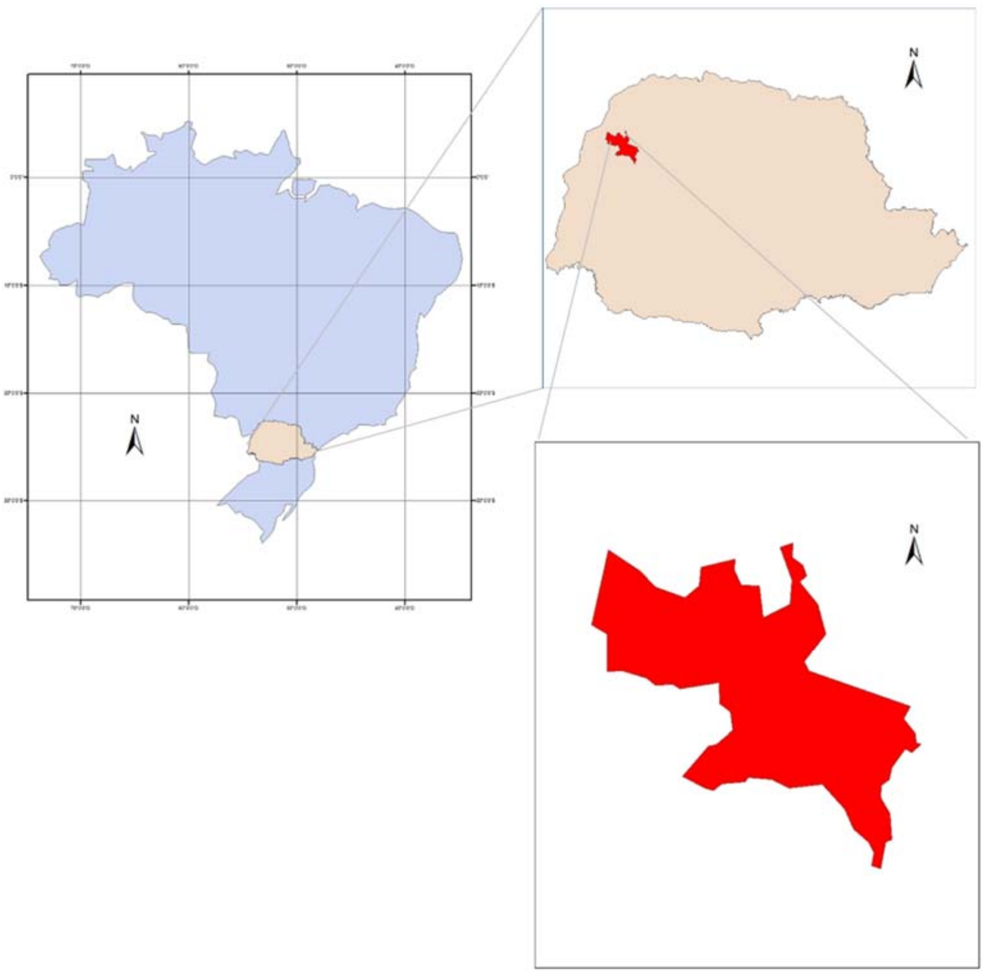

Figure 1: Location of Umuarama City in Brazil.

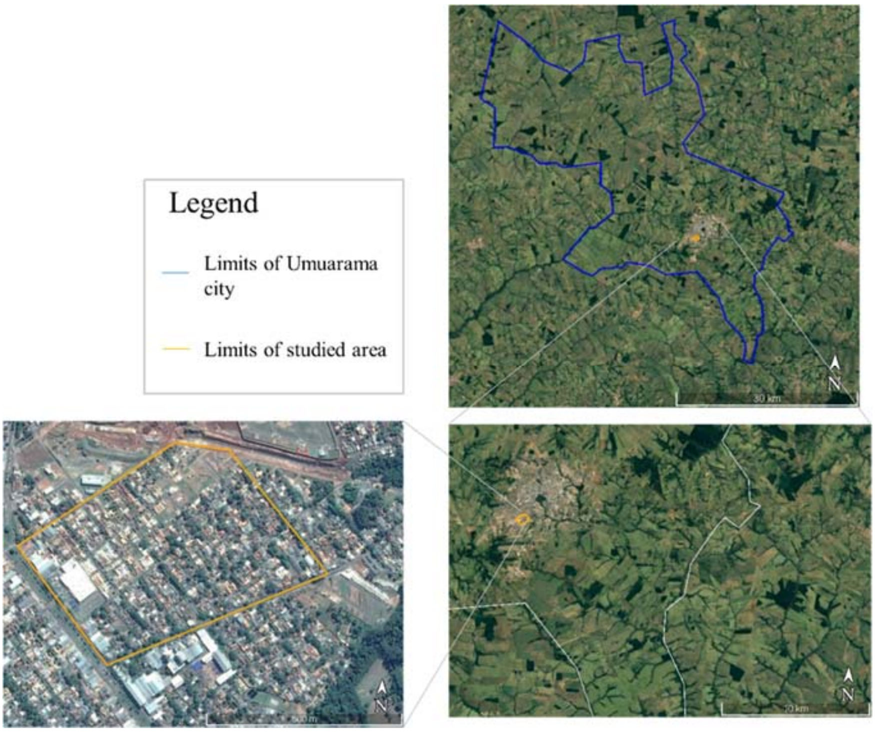

Figure 2: Studied area location.

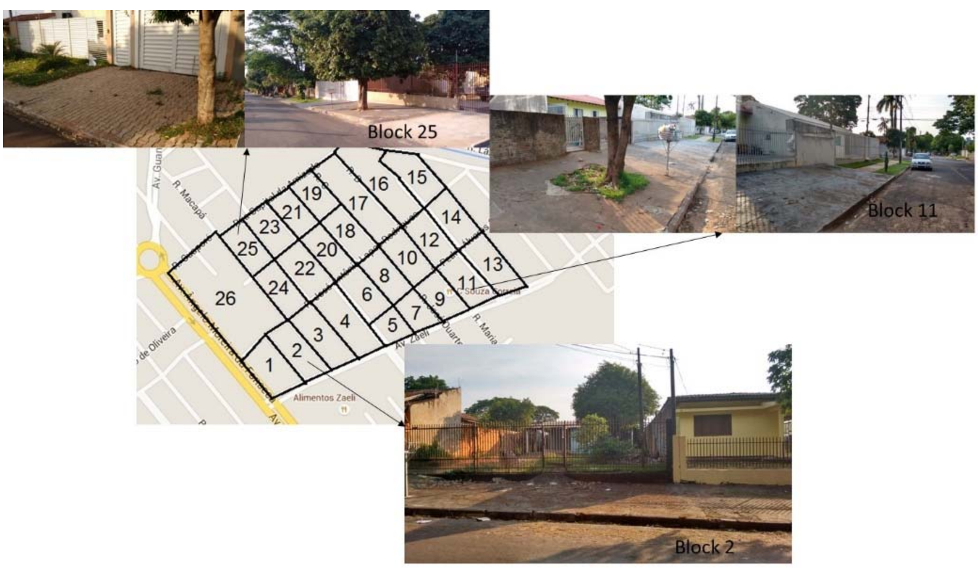

Figure 3: Demonstration of the subdivision and some occupations examples.

The soils are basically composed of latosols, argisols and nitosols. The latosols are divided into Red Latosols with sandy texture (very porous and permeable) and Red Latosols with clayey texture (very porous, friable, markedly drained and very deep). While the argisols, more frequent in medium slopes where the relief is wavy and gently undulating. The nitosols are composed of non-hydromorphic mineral soils, commonly found in medium slopes and gently undulating reliefs [4].

The climate is classified as humid subtropical climate, whose characteristics are humid summer due to the presence of unstable tropical masses, the region is comprised by semideciduous submontane seasonal forest characterized by the occurrence in mountainous regions with average elevations above 400 meters of altitude.

2.2 Survey of project information

For this study was analyzed satellite images given by the software Google Earth Pro, the images were for the years 2013 and 2004, there are used to verify the percentage of impermeable area, to permit the simulation of drainage system for these scenarios.

Each block was measured in its entirely using the ruler tool of Google Earth Pro and then the impermeable areas of each of them were measured using the same tool, generating the comparison for year 2004 and, for the year 2013, whose percentage averages were 69% in 2004 and 89% in 2013.

In addition to these scenarios, a scenario was also established with a projection where all the blocks present a percentage of impermeable area of 99%, assuming that it maintains a population growth in the region and this growth maintains the current tendency to cover up the land surface with waterproof materials, as concrete for example, the great part of the terrain.

The project rain was defined through the IDF curve proposed by Fendrich [5], represented by the eqn (1).

$$i = \frac{1752{,}27\ {R_p}^{0{,}148}}{(t+17)^{0{,}840}} \tag{1}$$

- i is the intensity of the rainfall;
- Rp is the return period of this precipitation (it means the estimated time interval between events of a similar size or intensity); and
- t is the duration time's rainfall.

The return period (Rp) was the recommended on the guidelines for hydraulic and drainage projects in the São Paulo city, which presents the return times according to the type of work, in this case, 3 years. The rainfall durations were 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60 minutes, named "Rain 1" and 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 e 15 minutes, named "Rain 2". The graphic representation of the precipitation (hyetogram) "Rain 1" and "Rain 2" are showed by the Figs 4 and 5.

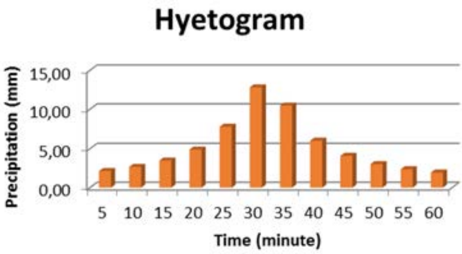

Figure 4: Hyetogram for rainfall "Rain 1".

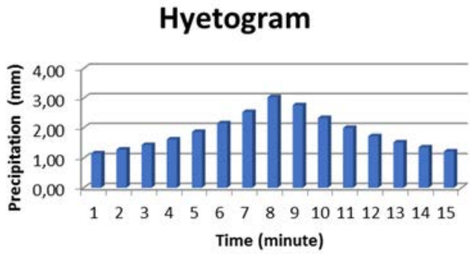

Figure 5: Hyetogram for rainfall "Rain 2".

2.3 SWMM

For simulation in the model SWMM, the model of infiltration used was Green-Ampt and the flow routing was the dynamic wave, the variables employed in this research are displayed at the Table 1.

The runoff was distributed in 2 different outfalls, named "Node 1" and "Node 2" as can possible verify in the Fig. 7. The shape of the receiving channel was considered as trapezoidal, the width was measured by a field tape measure which showed 2.5m between the nodes 1 and 2, and 290m of length, and 4m for width and 195m for length between the node 2 and Exut1. The slope in the channel was 0.5m for each riverside and the deep was 1m.

3 RESULTS AND DISCUSSIONS

This chapter shows the results of the simulation performed by SWMM model. The place studied presents high level impermeability patterns, as could be observed in the thematic maps in the Fig. 8.

Some places have maintained the same pattern of occupancy, so it is possible to observe that the percentages in some blocks have remained.

On the other hand, the blocks which had an intense increase in the percentage of impermeable area probably are due to the occupations that in 2004 did not arrive until these places, but with the course of the years and of the population growth, they began to be parcelled and occupied.

The data presented by the regime "Rain 1" had a greater representatively than those presented by the "Rain 2" regime, due to the more pronounced values.

Table 1: Variables utilized in the simulation.

Variable	Impermeable areas	Permeable areas
N (Manning coefficient)	0.013	0.15
Depression storage (mm)	1.7	3.5
Suction head (mm)	60.96	-
Conductivity (mm/h)	29.972	-
Initial deficit	0.390	-

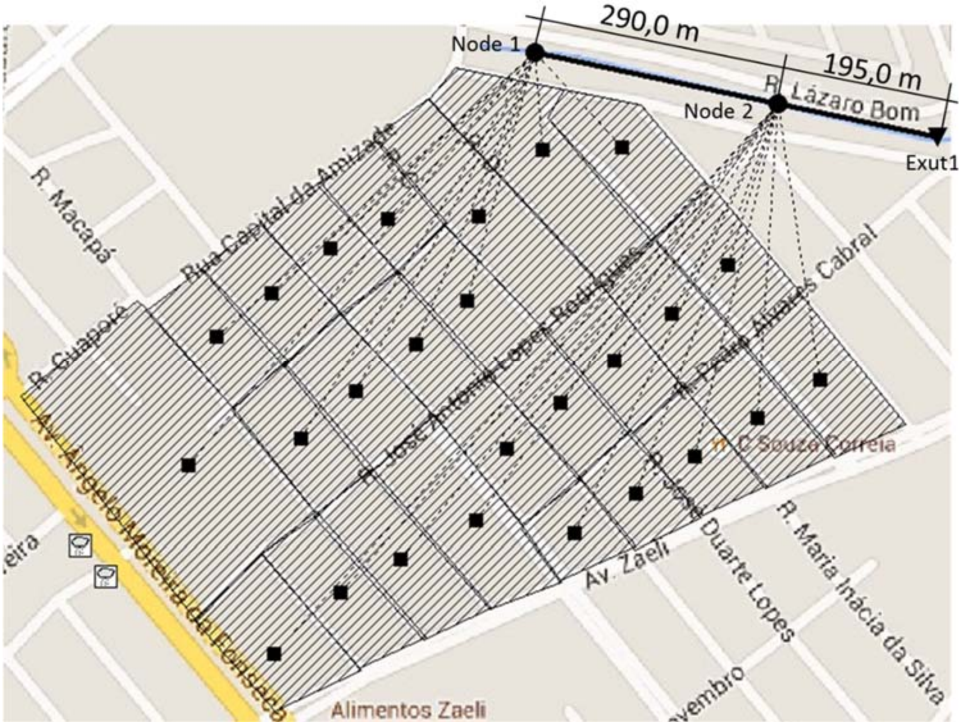

Figure 6: Representation of the simulation project in the SWMM model.

Therefore, only the data generated from the rainfall event "Rain 1" will be used, due to the greater ease to observe the comparisons and results to be discussed. In some moments, graphs and results related to the 30 minutes of this event will be used, since in general, it was the one that presented the highest values.

3.1 2004 scenario

This scenario is characterized by being the smallest percentage of impermeable area. The volume of water drained is approximately 68% of the total volume precipitated, according to Tucci [1], a soil in natural environments, usually drains approximately 10% of the total precipitate, that is, even the scenario with the lowest impermeabilized area, still presents a high percentage of surface runoff.

3.2 2013 scenario

This scenario represents a situation closer to the current one, due to the temporal proximity. There was an increase of about 20% in the average of impervious areas, which represents an area of 74,349.44m².

In this case, a very important point to be raised is that the rate of surface runoff increased proportionally to the increase of impermeable areas in relation to scenario one, because in this case, the runoff was 86% of the total precipitated volume, 18% more than 2004 scenario.

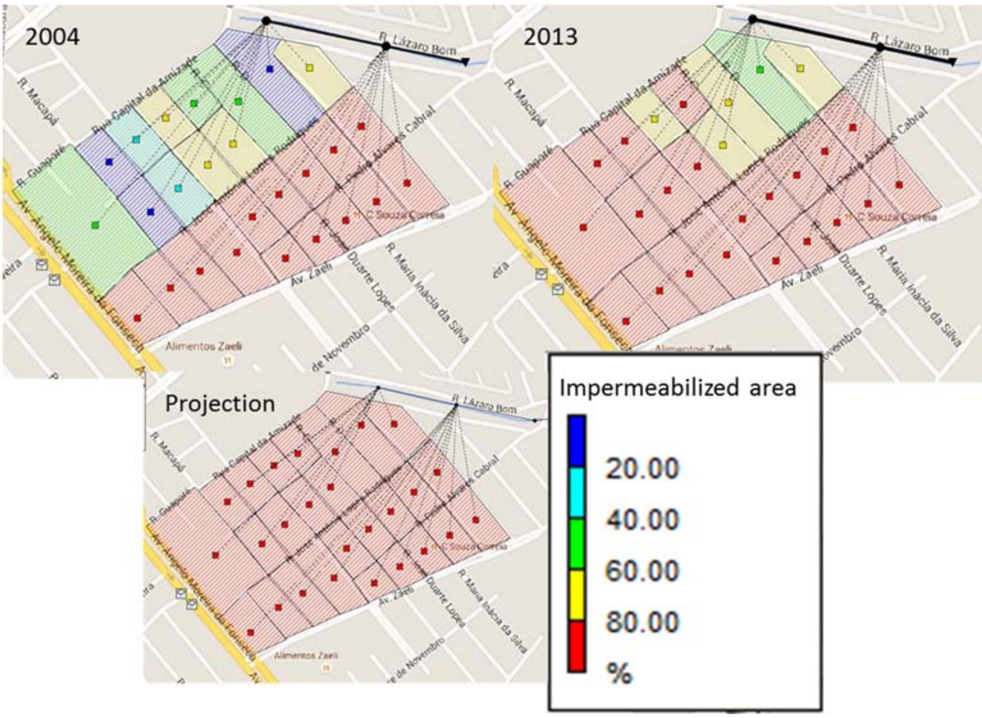

Figure 7: Representation of the impermeabilized area in the three scenarios.

3.3 Projection scenario

The hypothetical scenario with a mean of impermeable2,1 area is 99%, it means, the sites that can be infiltrated will total only 3,717.47m² of the total study area. This projection took into account the possible increase of the occupations of the lots.

The total losses by infiltration and plant interception, quite low, about 20 liters, for a precipitation with a total volume of approximately 2,190L, indicates that the receiving channel will have a fairly high flow.

3.4 Comparison between the scenarios

The comparison between the water balance in these three scenarios is presented in the Table 2.

Table 2: Comparison between the three scenarios water balance.

Water Balance	Volume (m^3)		
	2004	2013	Projection
Total precipitation	2.19	2.19	2.19
Losses for infiltration	0.67	0.26	0.02
Runoff	1.49	1.89	2.13
Final Storage	0.03	0.04	0.04

The runoff and losses are graphically represented by Figs 8 and 9.

In the urban area, there is a drastic difference in the water balance, when compared to the water balance that occurs in the natural environment, mainly because of the strong increase in surface flow. Even if a natural environment is not compared, in this research it was possible to observe this alteration of the water balance related to the urban area growth.

This disparity between the runoff rates in the three scenarios analyzed is mainly due to the large change in percentages of waterproofed area at the study site. This increase in surface runoff can anticipate peak flows, as well as, according to Tucci [1], to increase the average maximum flow rate by six to seven times.

The reduction of water infiltration in the soil can lead to damages such as the decrease in the level of the groundwater by the lack (or decrease) of the feed, while the reduction of losses by plant interception is detrimental because it considerably reduces evapotranspiration rates since the surface of the urban area does not retain water in the same way as the vegetation cover [1].

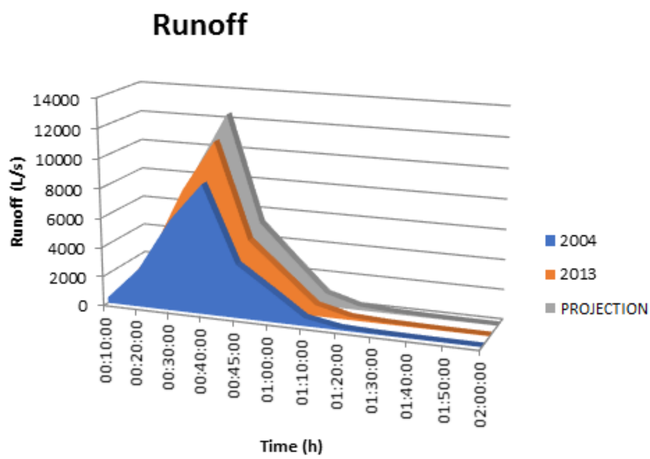

Figure 8: Runoff observed after the simulation.

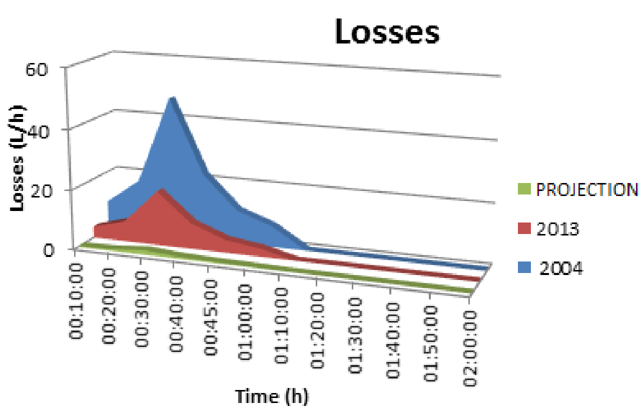

Figure 9: Losses by infiltration and interception observed in the simulations.

4 CONCLUSIONS

The scenarios presented many changes and the consequences of urbanization in a disorderly way or with little effective legislation, can be quite drastic. Even in the situation which had a less modified environment, the results obtained for surface runoff were still high. More effective studies are needed in relation to the consequences that this imbalance in the water balance can cause to the receiving channel, however, it can be assumed that the main ones are sedimentation and erosion, increase of the amount of sediment, increase of the pollution. There is a need for more restrictive legislation and more effectiveness environmental management actions, which stipulates a reasonable value of permeable area in the constructions, that allows a greater infiltration. Thus, the consequences of the increase of the urban area are softened and the city can fulfil its role of quality of life for the population, without very serious damage to the environment where it is inserted.

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