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SOCIOECONOMIC AND ENVIRONMENTAL DETERMINANTS ON THE URBAN POTENTIAL OF THE UNA WATERSHED, IBIÚNA, SP

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ABSTRACT
The study aimed to evaluate the socioeconomic and environmental conditions of Una wathershed, Ibiúna, São Paulo, and identify the potential for urban expansion. Correlation and multiple regression of socioeconomic information from census was fulfilled. (demography, income, education and environmental sanitation) from the selection of census tracts that composes the basin and spatialized with the interpolation of the inverse square of the distance. Together with environmental information derived from mapping the occupation of the basin was obtained urban potential through the multi-criteria analysis by hierarchical analysis process techniques and weighted linear combination. There was an increase of families and literate people, with strong association between the rate of households and the existence of bathroom and septic tank, in addition to the resident rate with the environmental sanitation rates. The most favorable areas for urban expansion they are located north of the wathershed.
Keywords: Urban Growth; Conservation; Environmental planning.

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INTRODUCTION

Wathershed are considered basic units of studies on ecological and economic contexts, becoming a priority for the planning and management of water resources. They are also seen as spatial units of management, and provide various products and services that sustain the human population (RANDHIR and SHRIVER, 2009; MALIK and BHAT, 2014).

Studies carried out in these environments emphasize the understanding of chemical, physical and climatic processes, but approach, to a lesser extent, the research on the urban carrying capacity and the socioeconomic influence on these places (TOLUN *et al*. 2012; FERRARI *et al*., 2013; ROSA, *et al*., 2013; DALTON *et al*., 2014; EUM *et al*., 2014; ARLOS et al., 2015).

The urban growth over the area of wathershed has required special attention, as population growth and urban settlements have increased rapidly and demanded the increasing use of water resources, leading, on the other hand, to water quality degradation, waste discharge, sediment transport, changes in the drainage network and waste accumulation (JAVED *et al*., 2011; JUJNOVSKY *et al*. 2012; BADAR *et al*., 2013; QIN *et al*. 2013; HESTER; CRAMER, 2014; MALIK and BHAT, 2014; MAHESH *et al*. 2015; LOPES; REUSS-STRENZEL, 2015).

Yet knowledge of the socioeconomic status allows us to understand the impact and the characterization of both the population's way of life and the development of activities on natural resources. Socioeconomic studies are carried out in Brazil mostly by the Brazilian Institute of Geography and Statistics (IBGE), which periodically assesses the socioeconomic condition of the country, including territorial areas that make up different wathershed and allow to structure spatially and temporally these information.

To investigate these issues, the application of spatial modeling methods and techniques becomes needed. Among them, Geographic Information System (GIS) and Multi-criteria Analysis (MCA) are techniques that help the analysis, formulation and resolution of problems of spatial decision, contributing to understand how to distribute the socioeconomic characteristics of the territory and plan actions safely (BOSCH *et al*., 2012; RUIZ *et al*., 2012; WANDERSEE *et al*., 2012; BADAR *et al*, 2013; MALIK and BHAT, 2014; LOPES; LOURENÇO; REUSS-STRENZEL, 2016).

The importance of this study lies in the knowledge of socioeconomic aspects, showing the spatial applicability of these information when combined with environmental aspects to trace the urban potential of wathershed, whereas studies in this perspective, although scarce, generate benefits and provide directions for a structured development (JUJNOVSKY *et al*. 2012).

Moreover, considering that the rapid degradation of water resources has impacted the structure and function of wathershed, and that therefore environmental problems should have immediate solutions, it becomes necessary to propose guidelines based on scientific knowledge and to substantiate decision making (RANDHIR and TSVETKOVA, 2011; JUJNOVSKY *et al*. 2012; LOPES, 2014).

The study aimed to evaluate the socioeconomic and environmental conditions of the Una basin, Ibiúna, São Paulo, and to identify the potential for urban expansion, in order to support environmental planning.

METHODOLOGY

Study area

The Una wathershed is located in the municipality of Ibiúna, state of São Paulo, making the tenth Water Resources Management Unit of Sorocaba and Middle Tietê. The basin has approximately 10,000 hectares and represents an important tributary of the Itupararanga reservoir, contributing to the urban water supply of about 1.5 million people that make up the cities of Sorocaba, Votorantim, Mairinque, Alumínio, Ibiúna and São Roque (ROSA *et al*., 2014) (Figure 1).

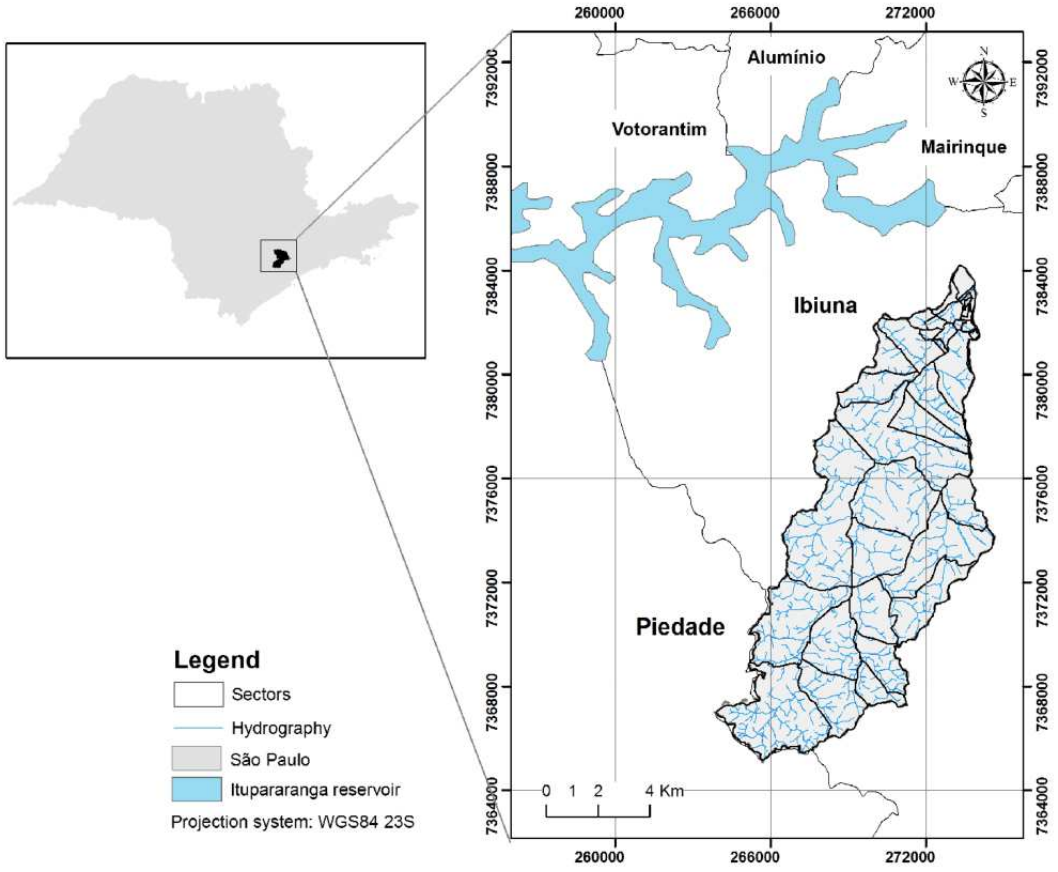


Figure 1: Location of the Una wathershed, Ibiúna, São Paulo, Brazil.

IBGE has defined the territory of the basin in 42 census tracts that are used in the mapping of information that make up the population censuses by the respective institute every ten years, the last being held in 2010 (IBGE, 2010). The basin has a diversified occupation with fragmented Atlantic Forest remnants, agricultural activities, allotments, reforestation and charcoal production, leading to a variety of activities and characterizing the life of the local population.

Materials

To perform the study, the following materials were used: aggregate data on demography, income, education and environmental sanitation, census tract grid of the population censuses of 2000 and 2010, both from the Brazilian Institute of Geography and

Statistics, ArcGIS software, v. 10.2 (ESRI, 2013), Idrisi Selva software (EASTMAN, 2012a) and thematic map of the land use and occupation in the Una wathershed.

Collection and screening of the data of population censuses

It was performed the overlay of the census tract grid of each population census under the borders of the Una basin. Then, the data set of the variables analyzed was drawn to each sector in their respective years, as shown in Table 1.

Table 1: Variables of the socioeconomic aspects analyzed for the Una basin

AREA	VARIABLES
Education	Literate people over five years old
Income	Households without nominal monthly income
	Households with nominal monthly income of 1-2 minimum wages
Demography	Location of industries in urban or rural areas
	Household density
	Resident rate
Environmental Sanitation	Households with water network
	Households with wells and springs
	Households without toilet facilities
	Households with toilet facilities and sewage network
	Households with toilet facilities and septic tank
	Households with collected waste

Data analysis

The temporal assessment of socioeconomic data was performed comparatively by calculating percentage values between the different population censuses. Then the data of the current socioeconomic condition of the basin were normalized into values in the range of 0 and 1, being applied the Pearson correlation matrix, at 5%, and the multiple regression matrix with the aid of Biostat software; household density and resident rate were the dependent variables.

The spatial assessment was carried out by obtaining the centroids of each census tract, using the Feature To Point tool in ArcGIS software and the Join option to link the variables to each centroid. Finally, it was applied the interpolation of the inverse distance weighted using the IDW tool in ArcGis software, using the Spatial Analysis Tool (ESRI, 2013).

Interpolation IDW is considered an accurate technique, which takes into account the spatial dependence of the interpolated values by determining weights, assigned to the points sampled in proportion to the contribution of each neighbor value, depending on the distance, where the radius of each point is determined and the inverse of the square of the distance is calculated. The attribute of an interpolation pixel should be the most similar to its closest point (EASTMAN, 2012b).

The thematic maps of the variables that represent the best socioeconomic conditions and reveal the occupational status of the basin were combined using map algebra, thus generating a unique mapping of the areas with higher socioeconomic status. At this stage, it were combined the thematic maps of household density, resident rate, literate people, households with nominal monthly income between 1 and 2 minimum wages, water network, toilet facilities, sewage network and collected waste.

Potential for urban expansion

The urban potential was assessed by multi-criteria analysis in order to identify the areas with urban settlement capacity over time based on the structured development and the conservation of the basin.

The environmental variables were derived from the mapping of land use and occupation, carried out in previous research, and the combination of the socioeconomic conditions investigated in this study. Each vector variable has been converted into matrix format in Idrisi Selva software; using the stretch function, the criteria were converted into standardized factors on a scale ranging from 0 to 255 scores.

The standardization was carried out in the sense that the inhabitable areas should be close to areas already urbanized, arable, with road network and better socioeconomic structure. Based on the occupancy history, it was estimated that these features induce and facilitate structured urban development in the basin. In contrast, the distance of the vegetation and hydrographic areas was delimited, ensuring the conservation of these features.

Through the Decision Support Tool, Analytic Hierarquich Process techinique (AHP) was applied, establishing importance weights for each factor by a paired comparison matrix constructed with the aid of experts (Table 2). After the calculation of the weights, the consistency level (CL) was carried out to prove the consistency with which the weights have been assigned so that the CL identified in the analysis corresponded to 0.10, being considered acceptable (SAATY, 1977; EASTMAN, 2012b).

Table 2: Comparison matrix with the weights assigned to the factors to identify the potential for urban expansion in the Una wathershed

FACTORS	PAA	PURA	DRN	PSEC	DHYDRO	DVEG	FINAL WEIGHT
PAA	1						0.0970
PURA	7	1					0.3076
DRN	5	1	1				0.2682
PSEC	5	1	1	1			0.2713
DHYDRO	1/7	1/9	1/9	1/7	1		0.0228
DVEG	1/7	1/9	1/7	1/9	3	1	0.0330
							CL = 0.10

Legend: PAA - Proximity to the agricultural area. PURA - Proximity to the urban area. DRN - Distance of the road network. PSEC - Proximity to socioeconomically-structured areas. DHYDRO - Distance of the hydrography. DVEG - Distance of the vegetation. CL - Consistency level.

Finally, Weighted Linear Combination technique (WLC) was applied, combining the factors through the multiplication of each cell or pixel, of each map, by the AHP-derived weight, integrated by means of a weighted average. The result is a continuous mapping of fitness for the proposed objective in which higher scores represent the most favorable areas (LOURENÇO, 1998; EASTMAN, 2012b).

RESULTS AND DISCUSSION

The socioeconomic development of the Una basin can be seen in Tables 3 and 4, where the rates of the studied variables are presented. The household density showed higher increase in the rural area of the basin (7%), while the urban area presented an increase of 5%, totaling an increase corresponding to 466 households. Resident rate was reduced when observing the

last census, showing a decrease of 9% in the urban area and of 7% in the rural area, with a total decrease of 2,649 inhabitants.

The highest demographic and household rates are concentrated in the central and northern regions, getting closer to the urban area of the municipality of Ibiúna, which have flatter reliefs and differ from the upper reaches of the basin, in the southern portion, with more dissected and sloping reliefs.

The education sector increased by 2%, representing an increase of 452 people considered literate, totaling 25,616 literate people in the analyzed period. However, there was a decrease of 0.4% (71 individuals) in the literacy rate in the urban area of the basin, compared with the previous census.

It was also observed an increase of 71% (1,313) of households with income between one and two minimum wages, with a significant increase in the urban area, allowing a distinction in relation to the rural area, since in the previous census, the two sectors had a similar rate. The households that did not show income represent 5% (328).

Table 3: Socioeconomic conditions of the Una wathershed for the period between 2000 and 2010

	Households density		Resident rate		Literate people		Households with income between one and two minimum wages		Households with no income
Year	2000	2010	2000	2010	2000	2010	2000	2010	2010
Urban	5.134	5.368	19.388	17.598	15.450	15.379	960	1.716	222
Rural	3.409	3.641	13.167	12.308	9.734	10.237	900	1.457	106
Total	8.543	9.009	32.555	29.906	25.184	25.616	1.860	3.173	328

Regarding the environmental sanitation, there was an overall improvement in the conditions of households in the basin. As can be seen in Table 4, there was a 20% increase in the rate of households with water abstraction by a distribution network; a decrease of 9% of households with water abstraction by wells and springs; an increase of 50% of households with toilet facilities and sewage network and a decrease of 92% of those which did not have toilet facilities.

Table 4: Environmental sanitation conditions of the Una wathershed for the period between 2000 and 2010

	Households with water network		Households with wells or springs		Households with toilet and sewage network		Households with toilet and septic tank		Households no toilet		Households waste collection	
Year	2000	2010	2000	2010	2000	2010	2000	2010	2000	2010	2000	2010
Urban	4.368	4.977	611	360	2.337	3.532	844	751	40	13	4.782	5.320
Rural	376	709	2.764	2.713	28	22	726	1.135	261	12	1.093	2.787
Total	4.744	5.686	3.375	3.073	2.365	3.554	1.570	1.886	301	25	5.875	8.107

The exception was recorded for households with toilet facilities and septic tank, which showed an increase of 20%. Septic tanks became an alternative to minimize soil pollution when there is lack of sewage collection in the households, but as the number of households with this feature increases, the amount of waste exceeds the absorption capacity of the soil and makes this alternative method infeasible (FOLLMANN and FOLETO, 2013).

Waste collection showed marked improvement in the Una basin, encompassing 90% of households, with an increasing collection rate both in urban and rural areas.

The correlation matrix of the socioeconomic variables can be seen in Table 5, confirming the strong positive correlation between households with literate people, number of residents and income between one and two minimum wages. Although the number of inhabitants presents a decrease, this correlation may be linked to a greater segregation of individuals within the basin, with increased civil construction as the financial capital increases.

Table 5: Linear correlation matrix of socioeconomic variables

	HD	LP	RR	HWN	HWS	HTSW	HTST	HT	HWC	HIMW	HI
HD	1.00	---	---	---	---	---	---	---	---	---	---
LP	0.99	1.00	---	---	---	---	---	---	---	---	---
RR	0.99	0.99	1.00	---	---	---	---	---	---	---	---
HWN	0.65	0.66	0.62	1.00	---	---	---	---	---	---	---
HWS	0.24	0.22	0.26	-0.58	1.00	---	---	---	---	---	---
HTSW	0.39	0.39	0.34	0.75	-0.54	1.00	---	---	---	---	---
HTST	0.19	0.20	0.21	0.02	0.21	-0.31	1.00	---	---	---	---
HT	0.99	0.99	0.99	0.65	0.24	0.39	0.19	1.00	---	---	---
HWC	0.94	0.95	0.93	0.82	-0.04	0.52	0.21	0.94	1.00	---	---
HIMV	0.91	0.92	0.93	0.39	0.48	0.12	0.27	0.91	0.79	1.00	---
HI	0.00	0.00	-0.02	0.17	-0.23	0.26	-0.16	0.00	0.05	-0.10	1.00

LEGEND: HD - Household Density; LP - Literate People; RR - Resident Rate; HWN - Households with Water Network; HWS - Households with Wells or Springs; HTSW - Households with Toilet and Sewage Network; HTST - Households with Toilet and Septic Tank; HT - Households no toilet; HWC - Households Waste Collection; HIMV - Households with Income between One and Two Minimum Wages; HI Households no Income;

Strong and positive correlations were observed between number of literate people, resident rate, households without toilet facilities, households with collected waste and households with income. The correlations showed great importance, given that, as the households and the presence of individuals increase, also increases the demand for sanitation facilities, which, in turn, are claimed from the educational level.

The results also show strong and positive correlations between number of residents, number of households without toilet facilities, households with collected waste and households with income. There is a tendency of correlation between households with water network, toilet facilities and sewage network or collected waste. The results show a strong association between the economic characteristics of the households and their occupants with the sanitation.

There was a lack of correlation between households with no income and the rate of residents in the basin; between water abstraction by wells or springs and the presence of toilet facilities and sewage. These aspects point to the fact that the sanitation condition possibly has a greater association with the public investment in urban infrastructure than with the characteristics of the households.

Through regression analysis, having the variable household as dependent, it was found that at least one of the variables explains the household rate in the basin ($p<0.0001$), being the

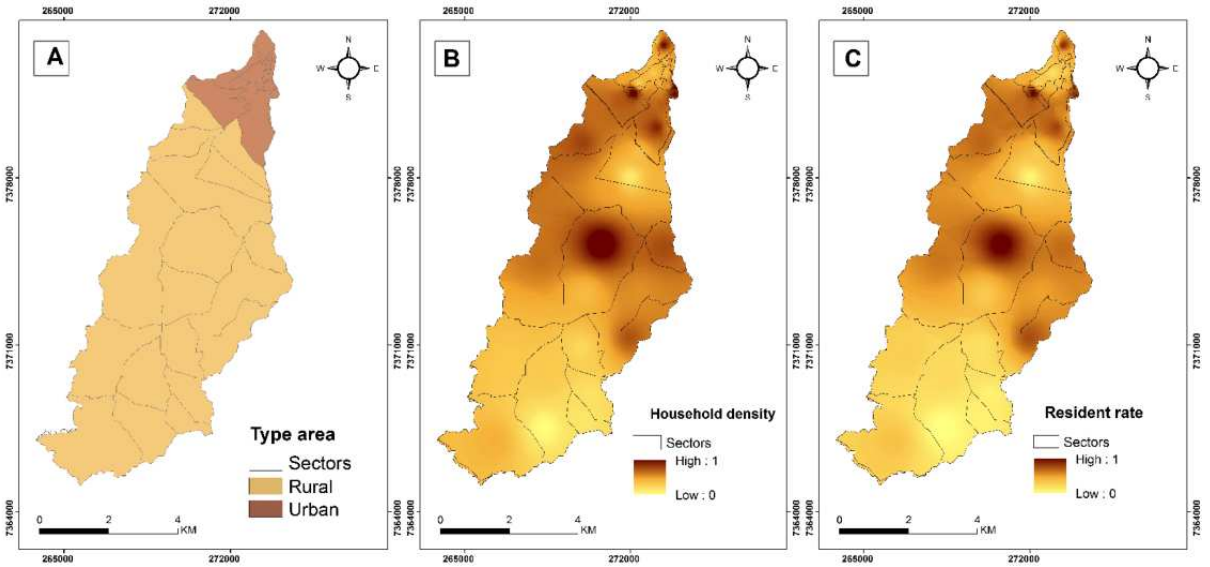
number of households with toilet facilities and septic tank what most explains the increase in household density. This possibility is real; to the extent that households can be built without mandatory implementation of an adequate sanitation system or depending on the location and extension of attendance of the public network, the number of households can be impaired by the absence of these characteristics.

When observing the dependence of the rate of residents in the basin in relation to the other variables, it was found that household density ($p = 0.0123$), literate people ($p<0.0001$), households with water network ($p = 0.0454$), households with wells or springs ($p = 0.0292$) and households with toilet facilities and sewage network ($p = 0.0265$) showed significance to explain the population rate.

The study of socioeconomic variables and the correlation between them has revealed the importance of these analyses in the influence of the anthropic use in wathershed, among them, demography and educational level have shown strong association with soil erosion (BHANDARI et al., 2015). In this sense, the greater the number of households built without adequate condition of housing and of inhabitants without education, the greater the tendency to obtain an environmental degradation to a higher extent. Although there are variables that need improvement in the basin, it was noted that the demands for education and sanitation are improving, and support the increase in local households.

The current socioeconomic characteristics of the Una basin, according to the population census carried out by IBGE in 2010, are spatialized in order to observe the distribution of these conditions in the territory of the studied area. It was observed that the areas with higher density of households, residents and literate people are distributed between urban and rural areas (Figura 2A-D).

Households with no income are distributed mostly in the urban area and in the central part of the rural area of the basin, interspersed with the distribution of households that have incomes between one and two minimum wages and higher population density (Figura 2E-F).



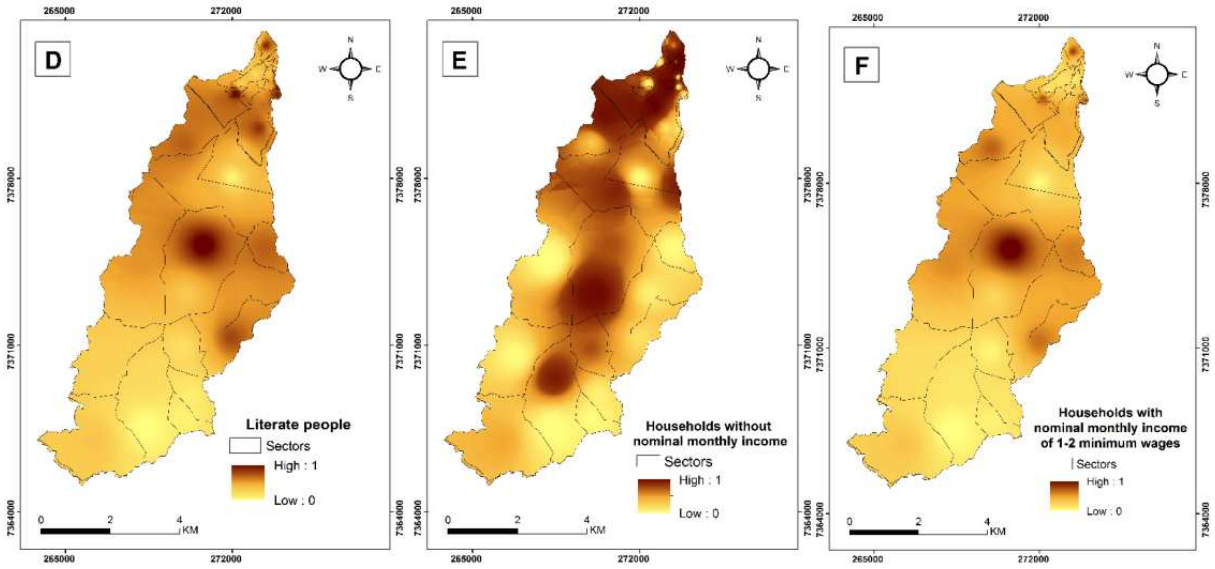
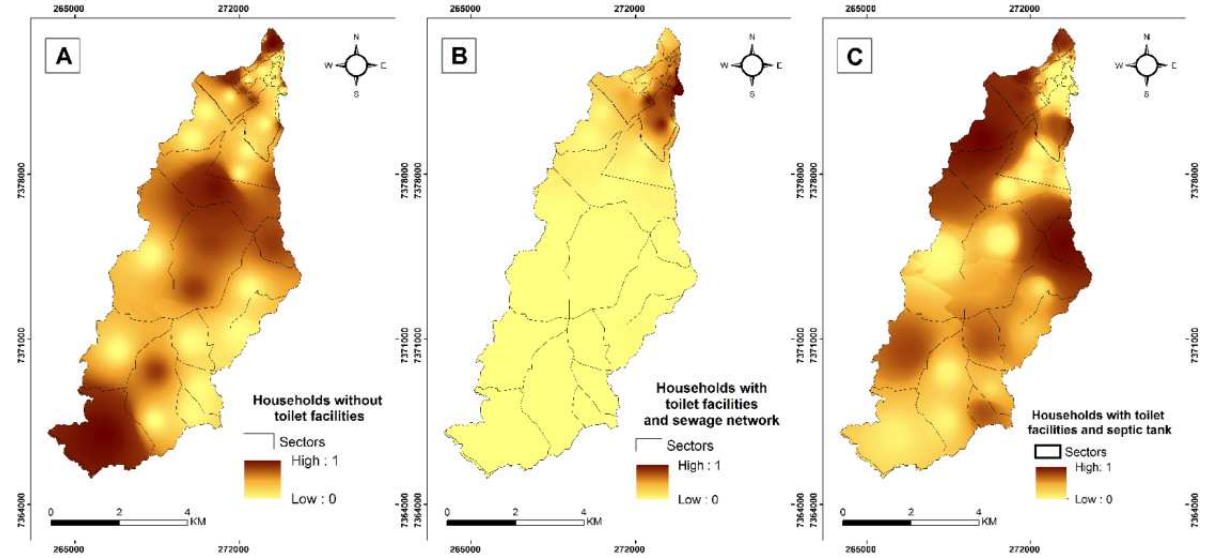


Figure 2: Socioeconomic status of the Una basin. [A] Territory distribution in urban and rural areas. [B] Household density. [C] Resident rate. [D] Literate people. [E] Households without nominal monthly income. [F] Households with nominal monthly income of 1 and 2 minimum wages.

The service extension of the environmental sanitation in the Una basin meets appropriate situations predominantly in the urban area, showing the best distribution rates of attended households. Sanitation rates considered less adequate were distributed throughout the rural area, with the highest rates of households with toilet facilities and septic tank and water abstraction by wells or springs. Waste collection proved to be the most dynamic feature, presenting a collection distribution throughout the basin (Figura 3A-D).



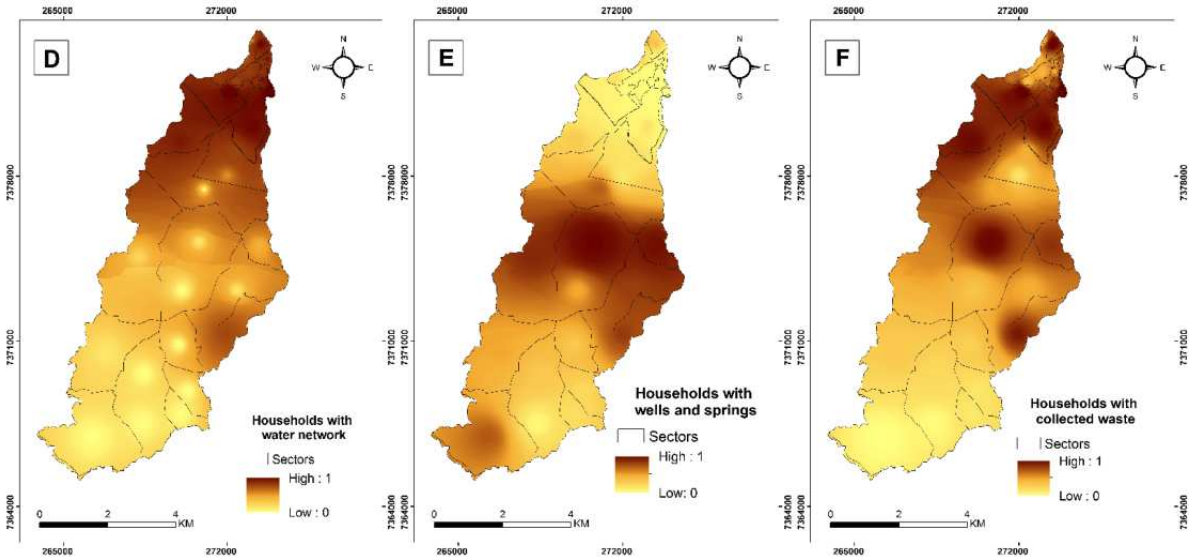


Figure 3: Environmental sanitation condition of the Una wathershed. [A] Households without toilet facilities. [B] Households with toilet facilities and sewage network. [C] Households with toilet facilities and septic tank. [D] Households with water network. [E] Households with wells or springs. [F] Households with collected waste.

The combination of the variables analyzed indicated the north and center of the basin with better socioeconomic conditions. These areas group the urban and rural census tracts, and reinforce the sharp increase in the development of households in the rural area, as noted in the analysis of the population censuses (Figura 4).

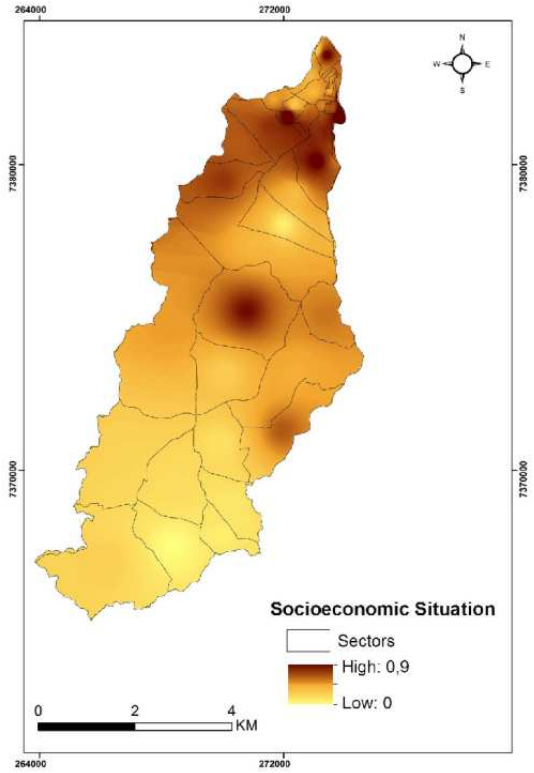


Figure 4: Socioeconomic status of the Una watershed.

Urban potential of the Una basin

The multi-criteria assessment to identify the most suitable areas for urban development indicated the lower course of the Una wathershed with the best scores for urban expansion (Figure 5A). In a similar study, AbuSada and Thawaba (2011) applied the multi-criteria analysis to assess areas suitable for occupation, suggesting that analyses considering socioeconomic and environmental variables, as observed in this study, have better ability to identify safe areas for housing.

The criteria used to map the area indicated that the proximity to areas already urbanized had the greatest importance for its expansion (0.3076), followed by the road network (0.2682), the socioeconomic status (0.2713) and agricultural areas (0.0970) presenting more areas suitable for occupation than vegetated areas (0.0330).

The spatial aggregation of the criteria indicated that the consolidated urban area is a strong criterion for expansion, associated with a developed road network and a structured socioeconomic status, suggesting that the proximity to pre-existing urban areas enables a spreading of new housing structures, in addition to facilitate the expansion of the sewage network (Figura 5B).

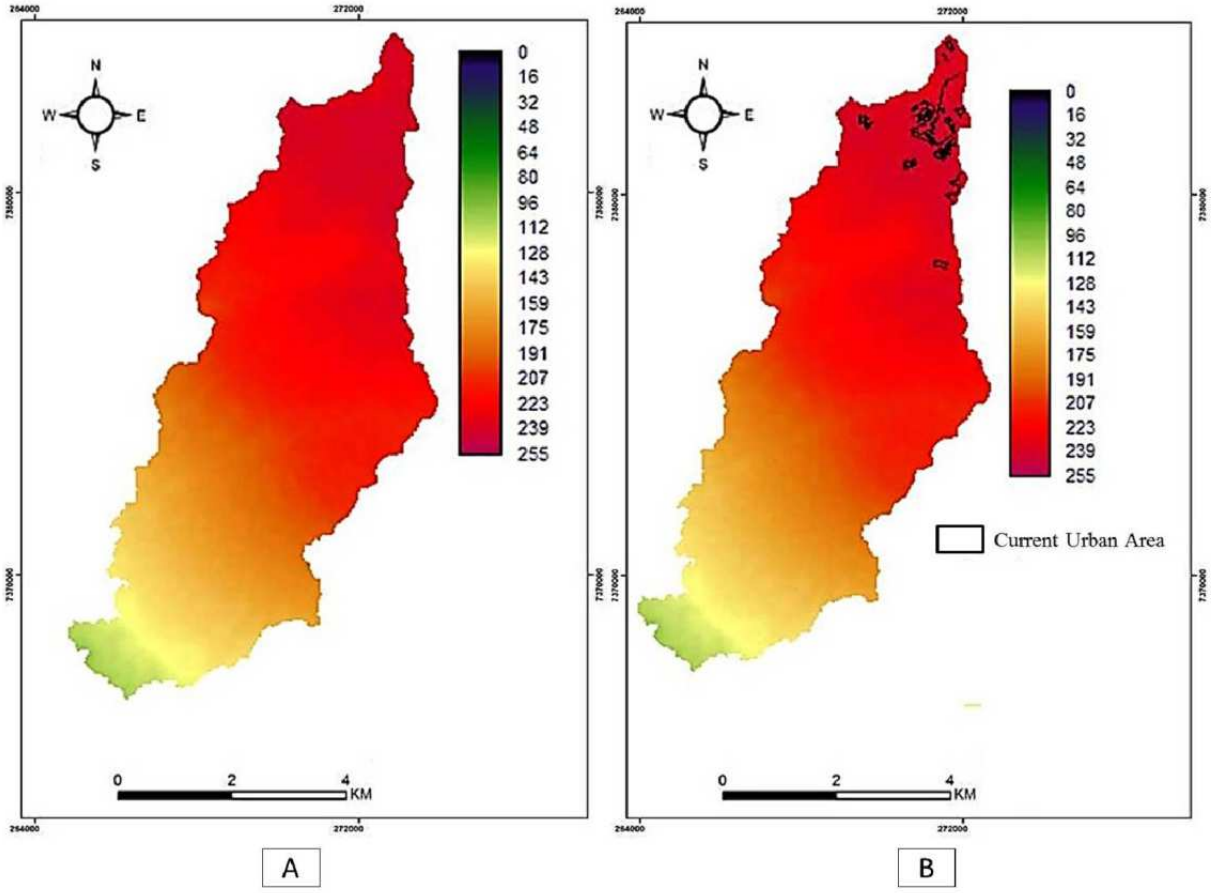


Figure 5: Potential for urban expansion of the Una basin. [A] Suitable areas for urban expansion. [B] Identification of suitable areas with proximity to the current urban area.

The main conflicts in wathershed relate to lack of sanitation, inadequate disposal of solid waste and degradation of water resources, reinforcing the importance of considering the socioeconomic conditions to map the areas that are environmentally safe, as in this study, and to identify socioeconomically-structured areas as a subsidy to urban expansion (CISNEROS *et al*., 2011; GOMES *et al*. 2012; RUIZ *et al*., 2012; QIN *et al*., 2013).

From these aspects, the areas of agricultural use showed to have the potential for such expansion, thus avoiding the areas of native vegetation of the Atlantic Forest, which occur in the basin, to be directed to the goal investigated in this analysis. The hydrography was considered the least important factor (0.0228), justified by the fact that the urban proximity to these areas is associated with a higher water degradation and flood events, moreover, it is important to consider that, regarding the urban water supply, there is no water abstraction over the hydrographic network in the urbanized area, not having proximity as a factor of real importance.

The identification of these areas allows decision making in the long run by governing bodies of the basin, guiding land-use planning of a structured urban growth, in addition to allowing a process of negotiation and discussion with the society about the impacts of using these areas (CISNEROS *et al*., 2011).

The areas with the lowest scores for urban expansion were concentrated in the southern region of the basin, with areas that have greater distance from the current urban area and that house the largest vegetation areas of the basin, although the high level of vegetation fragmentation allows their identification throughout the territory and can foster the construction of recreational and protection areas in order to contribute to the quality of life of residents.

The mapping of potential areas also reinforces the relevance of the use of multi-criteria analysis as a potential tool in order to map urban development in areas of environmental interest, helping public managers in the decision-making process and in reaching the desired goal (ABUSADA and THAWABA, 2011; IOJÃ et al., 2014).

CONCLUSIONS

The analyses showed the importance of considering socioeconomic aspects, combined with other variables, in studies applied to decision making in the planning of wathershed.

In the Una basin, the increase of households and literate people in the period analyzed showed a strong association between household density, number of households with toilet facilities and septic tank, plus the resident and environmental sanitation rates, corroborating the understanding of the dynamics of life of the population. Knowledge of these features and integration with environmental criteria allowed the identification of suitable areas for urban expansion in a safe and sustainable way, the already consolidated urban area being the most important factor for this expansion.

MCA proved to be a practical and flexible technique for selecting areas with high potential for urban expansion in a planned way in the long term, and can be used to adjust the basin to the growth in advance. As the urban growth trend is inevitable and in the Una basin the growth in the last ten years has been significant, the study achieved its goal by indicating areas with capacity to do so.

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