Environmental Impact of Urban Settlements in Brazil: The Case of Water Treatment

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Abstract

The objective of the present work is to estimate an IPAT model of the impact of urban settlements in the collected sewage volume of each urban center above 50000 people in Brazil between 2001 and 2004. The relationship between environment – development – population is the main aspect the authors pretend to highlight, because of the complex challenge the underdeveloped countries face in order to reconcile different objectives such as economic growth, development, and sustainable use of the environmental resources. Within some research agendas in urban and environmental studies is surprising not to find the impact of the urban settlements in the water resources availability as a topic of interest, despite of the potential problems this item could represent in the future of world societies, besides the classical public health approach. The authors are aware of the limitations of the present model, nevertheless, they believe that such a research would help to understand, from another point of view, the complexity of the use of water resources in a developing country such as Brazil. Even though, Brazil has the highest supply of water resources around the world, it does not mean that a better use of such resources and an improvement in policy making cannot be established as a goal. The data was collected from several sources: socioeconomic data comes from IBGE (Brazilian statistical bureau)'s website and environmental data was collected from SNIS (National System of Sanitary Information) which belongs to the Brazilian Ministry of Cities. The methodological framework uses a panel data methodology for unbalanced panel. The socioeconomic profile of some cities was determinant in the environmental impact of such cities. The socioeconomic profile was reflected by the population size itself. The other component of the economic profile was GDP per capita for every locality in the universe of the research. The functional form of the estimation was logarithmic – logarithmic in order to recognize the non linearity of the relationships between the variables; some control variables are used as well. The more developed cities show a wider impact. Even though, it is less than proportional, perhaps because of the lack of water treatment in many small cities in the country side. Nevertheless, the per capita impact was lower in the bigger ones. The future policies should address the importance of correct collection of sewage in order to protect the water for future human consumption, but also for reducing the impact this consumption pattern causes.

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Introduction

The interaction between human beings and their environment became a concerning issue for society as those interactions began to threaten the future of human life itself. One of the most important thinkers interested in this issue was Robert Malthus in his famous text “*An essay on the principles of population”*, where the importance of the availability of natural resources for human activities was highlighted.

Since then, the debate about the environmental issue has grown considerably. According to Price (1998), the arguments used in the debate are more sophisticated, even if their core aspects remain: On one hand are those who consider that the resources available will be, unavoidably completely exhausted, limiting in this way the size of human population; on the other, are those who believe that technological improvements may avoid the exhaustion of these resources, preventing the reduction of human population.

Nevertheless, some researchers disagree with this reductionist insight of the debate about population and environment, giving new arguments that try to explain the interactions between human beings and their environment. For example, the discussion about security and environment proposed by Obrien (2006), where she tried to understand how human activities over the environment can affect the security that social organization provides to human beings.

From a different point of view a discussion regarding the relationship between population, development, and environment, emerges in which the main point is to evidence that these three topics are complementary (MARTINE, 2007). Within this conceptual framework, an important issue is the impact that cities –as a way of space appropriation by a great part of the world’s population- have over the environment their survival depends on.

Some research has been done trying to measure the impact human settlements have over crop lands, and their availability in the long run as a matter of food security (FISCHER ET AL, 1997).

Another kind of impact being studied is the one that poverty causes over the environment. Particularly, matters about the relation between wealth distribution and environmental damages are being studied, allowing considerations about the consequences of certain consumption patterns and life styles over the environment, as well as how certain practices can reduce those impacts and even reduce the incidence of poverty in some circumstances (SWINTON ET AL, 2003).

In the discussion about environment, population, and economics, the lack of studies about the availability of water resources is remarkable, except when regarded as a potential public health problem, that is, when it causes diseases and other side effects over people's quality of life (REDMAN AND JONES, 2005).

This paper seeks to study the impact that urban settlements have as forms of social organization and spatial appropriation over the environment they relate to. In this sense, to question the commonly held assumption that cities represent a threat to the conservation of natural resources, as they represent a large demand of such resources. However, it is also recognized that cities do concentrate a large part of current production and consumption in the world (MARTINE, 2007).

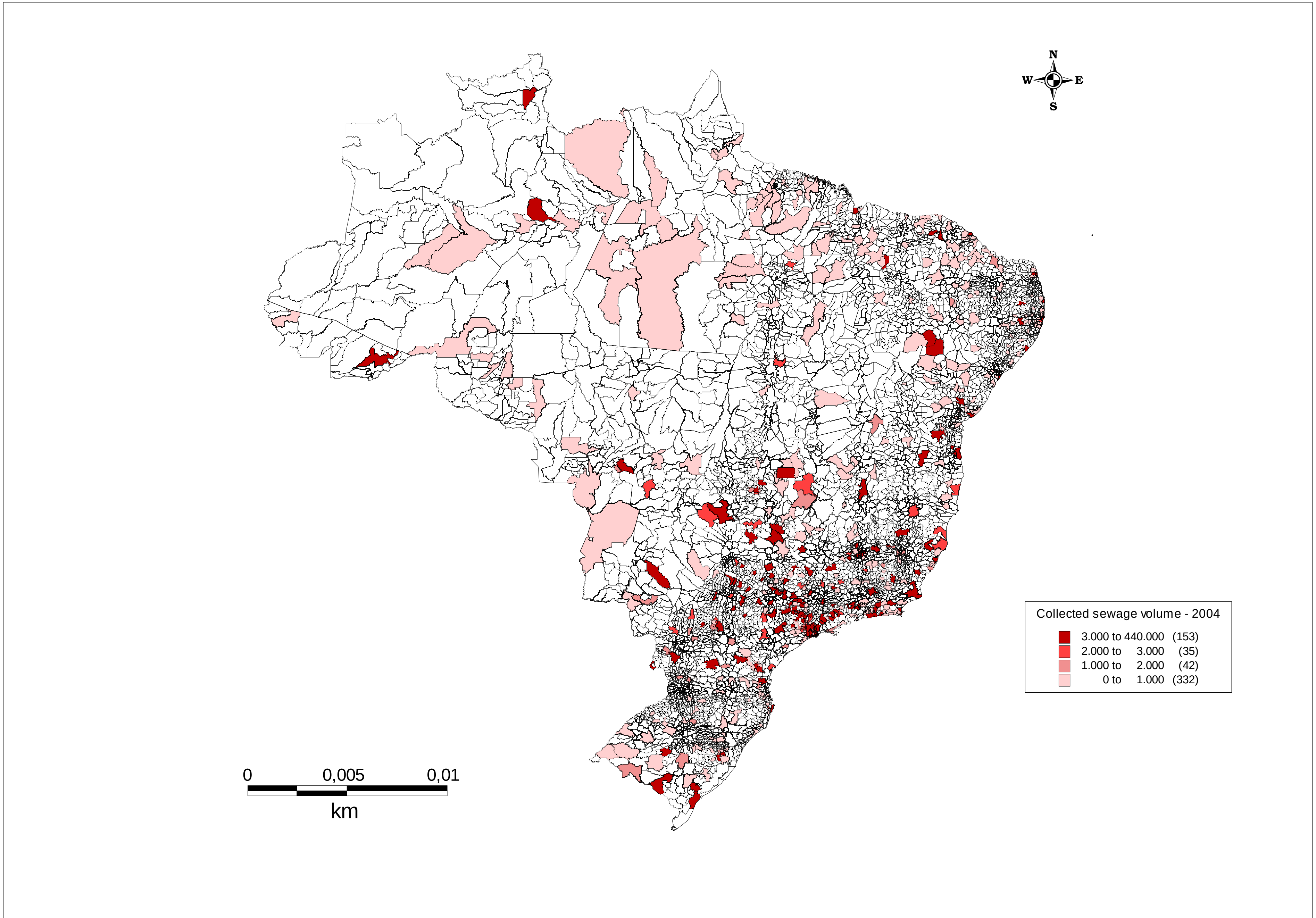
The growing use of natural resources in urban settlements poses a risk for their future availability. The present work uses the volume of sewage produced by urban settlements with over fifty thousand inhabitants in Brazil as a measure of the amount of consumption and waste of resources that this type of spatial appropriation and social and economic organization generates. An analysis of the amount of water collected in the sewage network might help establish the degree to which urban societies take advantage of their water resources. It might also allow a better understanding of the impact of cities and the corresponding social and economic relations that take place in them over the environment that makes such organization possible.

Since only part of water collected through the sewage system undergoes a treatment for being disposed to the natural environment, this variable makes a good indicator of the effects of cities over natural resources due to their consumption patterns and production processes. In fact, on average, between 2001 and 2004, the ratio of volume of sewage that received treatment over the volume of sewage collected, was between 60 and 68% for Brazilian municipalities with over fifty thousand inhabitants. In other words, over 30% of the water being used by these cities is returned to the environment as polluted water, generating a large impact over future availability of water resources.[3]

[3] This data was collected and calculated by the authors based on the National System of Sanitary Information (SNIS) from Brazilian Ministry of Cities.

FIGURE 1

Collected Sewage Volume (1000 m^3/year). 2004



Source: Authors' elaboration based on SNIS data.

Figure 1 shows us the volume of collected sewage in each Brazilian city with over fifty thousand inhabitants for the year 2004[4]. The spatial pattern observed, as it would be expected, follows the Brazilian urbanization pattern, which indicates that the larger cities would generate a bigger volume of sewage.

This work does not pretend to engage in the debate over the existence of a limit on the natural resources available and its impact over the continuity of present forms of social organizations. Instead, it seeks to evidence how certain behaviors in specific social organizations as urban settlements that are apparently posing risks for future availability of resources, might, surprisingly represent, an efficient use of natural resources. As such, large cities could be considered as strategies for sustainability.

Using IPAT methodology (Impact = Population X Affluence X Technology), the present work pretends to establish the impact of population, affluence and technology over water resources in Brazil. The latter is measured as the volume of collected water through the sewage network in Brazilian cities with over fifty thousand inhabitants for the 2001-2004 period. The next section presents the model; the third section contains some methodological considerations. Finally, after showing the results, some final considerations are introduced.

The IPAT model

The IPAT model was initially proposed by Ehrlich and Holdren in the early seventies. The model tries to measure the impact of human activity over some natural resource. It considers that consequences of human actions over the environment are the result of the size of the population as well as their production and consumption styles.

The equation of the model can be written as I(mpact) = P(opulation) X A(ffluence) X T(echnology), which shows that human effects over the environment, (I), are product of population size and distribution (P), the affluence or wealth (A), measured as *per capita* GDP or consumption level, and of technology (T), represented by the unitary production level or the efficiency of production.

The focused impacts on IPAT models are those of long-lasting consequences. The environmental degradation considered occurs in long and continuous time periods, even

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[4] The year 2004 was chosen in this figure due to the bigger availability of data in this year. The cities in white are those with less than fifty thousand inhabitants or those that do have more than fifty thousand inhabitants but data was not available.

if some events, such as oil spills and leaks, could have some considerable impacts over the environment in the short tem. (MCNICOLL, 2005)

The model considers that populations affect the environment not only because of their size, distribution, and growth rates, but also because of the particular habits of each social group. These effects are not independently generated; in fact, they are strongly related, making the functional form specific.

If the population, the way of life, and the technology were totally independent, it would be plausible to consider an additive relation among those variables over the resource use. Nevertheless, this is not a reasonable hypothesis, given the fact that more complex interactions among the variables exist.

People use of resources varies with available technology, but also with consumption standards, traditions, and other social variables, that, when considered in the interaction with the environment, generate some important interrelationships between human activities and the impacts themselves. (MCNICOLL, 2005)

The non-linearity of environmental relations must be seriously considered as estimation problems arise because of this. For that reason, it is highly recommended not to assume elasticities of one, and not to reduce into a linear model the complex interactions within the actual variables and their respective impacts (MCNICOLL, 2005)

Despite of the offered advantages given by the simplicity of the model (simple linear form and use of easily available variables), there are some arguments against the IPAT formulation. Commoner (1991) and Raskin (1995) argued that technological changes are more significant than population or affluence as determinants of pollution levels. Hynes (1993) emphasizes that beliefs and human behaviors are omitted from that formulation; Turner et al (1995), suggest that intensity of environmental change is strongly correlated with poverty rather than affluence, specially in developing regions. Another concerning issue is the application scale of the model: according to Turner et al (1995), the model is applicable to global environmental changes, but, when it is used to regional or local analysis, it ignores the impact of external factors.

Notwithstanding, despite of the limitations of IPAT models, they provide a useful tool for understanding the human impact over specific natural resources. They allow, for instance, to differentiate the factors included by the contexts or development levels. Among the work that uses IPAT formulation we found Commoner (1991), Raskin (1995), Dietz and Rosa (1994), and DeHart e Soulé (2000).

The present work pretends to distance itself from the Malthusian debate, which reduces the discussion to the limited scope of the resources, or, through technological improvements, to its lack of boundaries. On the contrary, the use of an IPAT model, is linked to the idea that the protection of the environment requires more efficient production technologies, less waste, and finally a stable size of world population (HINRICHSEN e ROBEY, 2000).

Methodological Considerations

The present model, as mentioned before, belongs to the IPAT model family, which has a multiplicative functional form, in order to comprehend the complex relations that exist between socio-economic and socio-environmental factors. Because of this characteristic, a log-log formulation was chosen. The log-log transformation allows us to use the classical linear model in accordance to the multiplicative functional form of the independent variables.

The model was estimated by *POLS* (Pooled Ordinary Least Squares), fixed effects, and random effects. Some control variables were included in order to control for the inherent heterogeneity of Brazilian municipalities and also to reduce the problem of lack of information for some cities in some years (*attrition*).

Table 1 presents the variables used in the estimation and their respective sources. The dependent variable, related to the environmental impact, is the volume of collected sewage, defined by the National System of Sanitary Information, SNIS for the Portuguese acronym, from the Brazilian Ministry of Cities, as the "annual volume of sewage collected in the sanitarian system (generally, considered as being from 80% to 85% of the volume of consumed water in the sewage served area)"[5], measured in thousands of cubic meters per year (1000 m^3 / year).

The independent variables are the city's population size (P), *per capita* GDP (A), and industrial participation in the added value of the city's GDP (T). As control variables

[5] Authors' free translation from the official document in Portuguese.

the extension of sewage system[6] and the mean practiced tariff of water and sewage were included[7].

TABLE 1

Variables Used in the Model

IPAT MODEL VARIABLE	VARIABLE USED	SOURCE
ENVIROMENTAL IMPACT (I)	Collected Sewage Volume	SNIS – Ministry of Cities
POPULATION (P)	City's Population size	Brazilian Statistical Bureau IBGE
AFFLUENCE (A)	GDP *per capita*	Brazilian Statistical Bureau IBGE
TECHNOLOGY (T)	Industrial Participation in the City's GDP	Brazilian Statistical Bureau IBGE
-	Sewage Network Extension (control variable)	SNIS – Ministry of Cities
-	Mean Practiced Tariff of Water and Sewage (control variable)	SNIS – Ministry of Cities

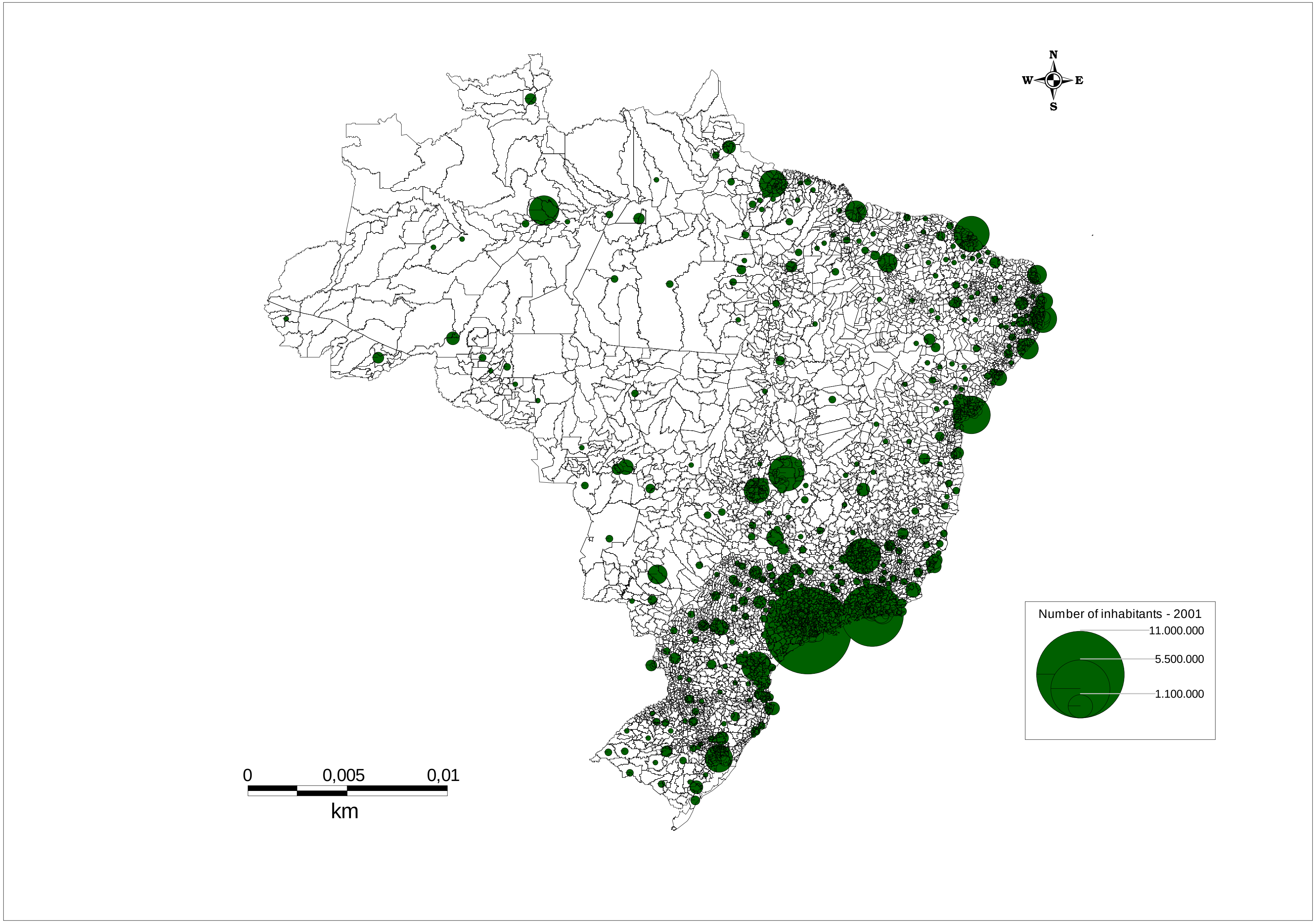
The period under consideration begins in 2001 and ends in 2004. The period was chosen because of the limited availability of some data. All series presented many holes, and in order to solve the attrition problem, the period was restricted.

[6] The extension of sewage system is defined by the SNIS as "Total length of sewage network, including collect networks, collectors and interceptors, and excluding intra-properties branches and impulsion line of pump system, operated by service provider at the end of the year" (Authors' free translation from the official document in Portuguese), measured in kilometers. .

[7] The indicator of mean practiced tariff is given by the ratio between the direct operational revenue of water and sewage over the total invoiced volume of water and sewage. The chosen indicator includes the networks of water and sewage because both of them are considered by the consumer in his choice of optimal consumption level.

FIGURE 2

Urban settlements over fifty thousand inhabitants in Brazil 2001



Source: Authors' elaboration based on IBGE data.

The sample analyzed is made of Brazilian cities with a population larger than fifty thousand inhabitants in the year 2001, according to the Brazilian Statistical Bureau (IBGE) (Figure 2). The sample selection is justified as big urban settlements are places where the relations between human beings and natural resources are more intense, as a matter of the wider productive and reproductive activities that take place in those scenarios; in Brazil, particularly, this happened mainly in the coastal area, due to the pattern of urbanization in the country, usually given from the coast to the continent.[8] Furthermore, the lack of some data from SNIS for municipalities with a small number of inhabitants evidences the difficulty of working with these geographical units and the need of the enlargement of information systems for the regions located far away from the largest urban centers.

Estimation and results

More than just allowing for the temporal analysis of several cross section data, the panel data analysis permits the control for non-observed heterogeneity in these units and a greater amount of data, helping reduce colinearity as well as allowing more variability among the independent variables. As a result, there is more efficiency and more degrees of freedom in the estimation.

In this particular case, colinearity is a problem among the independent variables, even if this colinearity is not severe (which would turn the estimation impossible). An analysis of correlation between the regressors shows that, the use of four temporal periods reduces the colinearity between them (compared with only one cross section). This justifies the use of panel data in this work. Table 2 shows the correlations between the regressors for the four time periods considered.

TABLE 2

Correlation matrix between regressors

	ln(population)	ln(GDP per capita)	ln(industrial participation)	ln(network)	ln(tariff)
ln(population)	1,00				
ln(GDP per capita)	0,21	1,00			
ln(industrial participation)	0,10	0,58	1,00		
ln(network)	0,47	0,28	0,23	1,00	

[8] About Brazilian urbanization, see Santos (1993)

ln(tariff)	0,01	0,21	0,07	-0,22	1,00

Source: Authors' elaboration.

Among the main difficulties found in panel data estimation are the measurement errors, and the attrition problem (inexistence of data for cross section units in some time periods). These problems can led to biased estimations, compromising the model interpretation.

In the data used, a lack of information problem was noticed for the SNIS variables. This problem concerns, mainly, the small municipalities all over the country and specially those from the states of Minas Gerais and São Paulo[9]. The strategies used for minimizing the attrition problem were 1) including some dummy variables in the regressions in order to control for the states of São Paulo and Minas Gerais attrition problems.

First, Pooled Ordinary Least Squares – POLS – was estimated for the present model. Table 3 displays information about the results of the POLS estimation. The first column presents the simple estimation, the second one, the White robust estimation, and the third uses also White robust estimation but weighting by the number of observations of each cross section. The robust estimation of standard errors was necessary, after the high autocorrelation showed by the residuals[10].

TABLE 3

POLS estimations results

Dependent variable: Ln (collected sewage volume)

	(1)	(2)	(3)
Ln(population)	0.133**	0.133	0.133
	(0.054)	(0.101)	(0.155)
Ln(GDP *per capita*)	0.280***	0.280***	0.280**
	(0.079)	(0.084)	(0.133)
Ln(industrial participation)	-0.100	-0.100	-0.100

9 Among the municipalities with more than fifty thousand inhabitants, the state of Minas Gerais corresponds to 12.7% of missing data for "collected sewage volume", 13.6% of missing data for "sewage network extension", and 11.5% for "mean practiced tariff of water and sewage". For the state of São Paulo, these values are 13.5%, 13.8%, and 11.5%, respectively.

10 In order to test for autocorrelation of residuals, the original model was regressed including as independent variable the first lagged residuals to test the significance of this parameter. The lagged variable was significant at 1% level, indicating the presence of serial autocorrelation. The standard errors of this regression were estimated by White matrix, so the test is robust to heteroskedasticity. Furthermore, the test is not dependent of strict exogeneity between the regressors and the residuals. No test was made for heteroskedasticity of residuals because, if this is a problem of the sample, it is already corrected by the robust estimation of standard errors.

	(0.106)	(0.095)	(0.149)
Ln(network)	1.169***	1.169***	1.169***
	(0.015)	(0.033)	(0.050)
Ln(tariff)	-0.019	-0.019	-0.019
	(0.098)	(0.071)	(0.095)
MG	0.054	0.054	0.054
	(0.140)	(0.135)	(0.185)
SP	0.207*	0.207	0.207
	(0.111)	(0.164)	(0.259)
2002	- 0.120	- 0.120	- 0.120*
	(0.128)	(0.120)	(0.069)
2003	- 0.353***	- 0.353***	- 0.353***
	(0.125)	(0.123)	(0.128)
2004	- 0.376***	- 0.376***	- 0.376***
	(0.123)	(0.122)	(0.110)
Constant	- 2.190**	- 2.190	- 2.190
	(0.916)	(1.470)	(2.297)
Observations	1304	1304	1304
R2	0.90	0.90	0.90

Obs.: Standard Errors in parenthesis

* significant at 10%; ** significant at 5%; *** significant at 1%

Source: Authors' elaboration

The only variable of IPAT model that was significant after POLS estimation was GDP *per capita*: a 1% increase in the GDP *per capita* indicates an increase in 0.28% of polluted water. The coefficient of population was significant in the first estimation, but lost that significance after the robust estimations. The technology variable, was not significant in any estimation. The parameter of the control variable "sewage network extension" was significant in the three cases.

By using this method for estimating the model, the existence of economies of scale regarding urban settlements evidences the impact over the environment that this type of social organization involves. The main contribution of this paper is to establish that an increase in population in cities causes a less than proportional impact over the environment. In other words, increases in population has a less-than-one elasticity over water resources. Therefore, the concentration of economic activities in large urban settlements might actually be helping reduce the environmental impact that such increases in production through increases in population might have outside cities.

The 2002 year dummy passed from not significant to significant after the robust estimation, indicating that the human impact over the water resources was modified, becoming less intense than in the year 2001. This means that, if no autocorrelation of residuals is considered, the time dimension seems to affect the estimated relation.

Moreover, the year's dummies indicate that, on average, the impact over water resources decrease over time. This issue will be considered later, when some commentaries will be proposed including the results of the other estimations.

When the existence of non-observed heterogeneities is suspected in the cross section residuals, the estimation by fixed and random effects is considered as an option. This could be the case in the estimation showed in Table 3, because the sample of Brazilian municipalities is very heterogeneous, and a series of cultural, political, and historical characteristics could affect the dependent variable and are not being considered as independent variables in the model.

The fixed and random effect estimation allows to deal with the non-observed effects in the regression. In the case of fixed effects, it is assumed that, the non-observed effect are correlated with the regressors for each cross-section. On the other hand, in the random effects estimation, the non-observed component is considered as a random variable, independent from the regressors.

An inherent problem of fixed effects estimation is the small variability of independent variables in the period studied. In this case, the estimations by fixed effects might be inaccurate, given the difficulty to make the difference between the effect of these variables and the non-observed effect (WOOLDRIDGE, 2002). Furthermore, the estimation by fixed effects does not allow the use of variables that are constant in time, because the effect of these variables would be eliminated as well, with the non-observed effect (WOOLDRIDGE, 2002). The absence of the control dummies for the states of Minas Gerais and São Paulo in the fixed effects estimation, means that the attrition problem would not be reduced, compromising the confidence of the estimative.

TABLE 4

Fixed effect estimation results

Dependent variable: Ln(Collected sewage volume)

	(1)	(2)	(3)
Ln(population)	1.572	1.572	1.572
	(1.095)	(1.134)	(1.209)
Ln(GDP per capita)	0.093	0.093	0.093
	(0.197)	(0.186)	(0.194)
Ln(industrial participation)	0.144	0.144	0.144
	(0.218)	(0.148)	(0.165)
Ln(network)	0.697***	0.697***	0.697***
	(0.025)	(0.133)	(0.147)
Ln(tariff)	-0.188*	-0.188	-0.188

	(0.109)	(0.159)	(0.161)
Constant	-15.982	-15.982	-15.982
	(12.132)	(13.290)	(14.210)
Observations	1304	1304	1304
R2	0.50	0.50	0.50

Obs.: Standard Errors in parenthesis
* significant at 10%; ** significant at 5%; *** significant at 1%

Source: Authors' elaboration

Table 4 presents the regression estimates with fixed effects. None of the IPAT model variables were significant in any of the three estimations. Only the control variable "Sewage collection network" was significant in all the three cases. The estimation of standard errors by the Newey – West matrix is justified by the result obtained in the test of auto – correlation of residuals: when regressed over their own lags, the parameter was significant at 1%, confirming the serial auto – correlation[11].

TABLE 5

Random Effects Estimation Results

Dependent variable: Ln(Collected sewage volume)

	(1)	(2)	(3)
Ln(population)	0.520***	0.520***	0.520***
	(0.096)	(0.197)	(0.200)
Ln(GDP per capita)	0.293***	0.293**	0.293**
	(0.109)	(0.127)	(0.137)
Ln(industrial participation)	0.177	0.177	0.177
	(0.144)	(0.122)	(0.136)
Ln(network)	1.005***	1.005***	1.005***
	(0.017)	(0.061)	(0.075)
Ln(tariff)	-0.347***	-0.347***	-0.347***
	(0.090)	(0.116)	(0.133)
MG	0.333	0.333	0.333
	(0.244)	(0.284)	(0.275)
SP	0.857***	0.857***	0.857***
	(0.197)	(0.306)	(0.310)
Constant	-6.613***	-6.613**	-6.613**
	(1.449)	(2.871)	(2.886)
Observations	1304	1304	1304
R2	0.50	0.50	0.50

Obs.: Standard errors in parenthesis
* significant at 10%; ** significant at 5%; *** significant at 1%

Source: Authors' elaboration

[11] As in the POLS estimation, the heteroskedasticity problem was solved by the robust estimation.

Table 5 reports the results of random effects estimation. In this case, the parameters of the IPAT model variables, referring to population and affluence were significant. Here, the variable that seems more important for explaining sewage production is population: an increase of 1% in population size, indicates an increase of 0.52% in the collected sewage volume. In the case of GDP *per capita*, this value is 0.29%. The technology variable was not significant in any of the estimations. In fact, this variable does not seem to explain the dependent variable.

Opposite to the results found in the POLS estimation, population size seems to have greater effects over sewage production than GDP per capita. This result evidences the need to understand both variables as main factors in the determination of the use of water resources.

Production processes and population size have a significant role when analyzed together due to the complementary nature of their relationship established not only by classic economic theory but also in the different interactions that they imply for social organization.

When first considered, increases in population size would have a more than proportional impact over the environment, mainly because, although production is carried out by only a small part of the population, it has an effect as a whole through the consumption patterns entailed in their current habits, norms and life styles. Hence, when considering population, one can establish a direct and an indirect effect. However, analyzing these two impacts independently clearly show the tendency that was previously exposed regarding the efficiency in the use of resources of concentration in urban settlements. This result could mean that concentration in cities might help reduce the impact that individuals might pose over the environment.

The control variables were statistically significant: the collected sewage volume grows with the sewage collection network, showing the same results as in the other estimations, and decreases with the tariff value. When regarding the state dummies, the one corresponding to São Paulo, was significant in the three cases while the Minas Gerais one was not. The parameter indicates that São Paulo is 85% above the mean of the country in the sewage collection volume.

The fact of São Paulo having more than a fifth of Brazilian population, as well as around a third of the Brazilian GDP, makes its impact more intense and significant as a whole, than the other states, in particular, Minas Gerais which also has a big attrition problem. Nevertheless, the difference in the parameters of both state control variables would mean that the impact that São Paulo causes, is much larger and important than that from the state of Minas Gerais.

Again, the autocorrelation test of residuals rejected the null hypothesis, justifying the robust estimation of standard errors. However, this did not affect the significance of the parameters. A Hausman test was made in order to compare the fixed and random effects models which did not reject the null hypothesis that both of them are not statistically different from one another, so random effects was chosen because it's estimates are more consistent.

The random effects model allowed for the use of control variables to reduce the attrition problem. Moreover, it did not have the estimates compromised with the low variability of the data. Notwithstanding, a hypothesis of random effect estimation is that the non – observed effects must be random variables, not correlated with the regressors. If we consider that cultural, historical, and political characteristics do not present a systematic correlation standard with the independent variables in the model, the fixed effects estimation is preferable, because its results are more consistent than the POLS ones.

Discussion

Commonly, cities are branded as locus of great environmental problems due to the massive use of resources that their existence entails, but also, due to the important changes they produce in their surroundings. The emblematic example of the former situation is the atmospheric contamination caused by pollution coming from vehicles and industries. At this point, it is important to point out that the city has also been considered as a successful form of social organization and spatial appropriation as it has been able to continuously provide better conditions for its settlers and to concentrate nearly half of the world's population (UNITED NATIONS, 2006 in MARTINE, 2007) This is not a coincidence since those improvements are more effectively and efficiently adopted in urban settlements as the agglomeration of people reduces transaction costs (JACOBS, 1969; PRED, 1966). The efficiency in the dissemination of new productive techniques or new forms of social organization can also be translated to the environmental field when considering the form of spatial appropriation and social organization entailed in large urban settlements. The environmental effects are also characterized by this type of *efficiency* as the per capita impact decreases in large urban settlements as opposed to smaller ones.

The present work evidences this kind of "efficient" impact as the results obtained when measuring the impact of demographic and economic variables evidence a certain degree of economic efficiency. As the environmental impact over water resources is less than proportional to increases in the variables formerly mentioned, the hypothesis of environmental efficiency in Brazilian urban conglomerations is supported.

At this point, it is important to mention that econometric results must be understood as partial approximations that allow the authors to gain some insight into a situation. The empirical results are not to be thought of as conclusive remarks for demonstrating the hypothesis. On the contrary, the authors are aware that the empirical results help formulate more and better questions and further the analysis and reflection upon the subject. As a consequence, the authors consider that the issue that goes beyond the actual empirical results of the present work is the relationship between cities as specific forms of spatial appropriation and the development of productive processes that allow for an efficient use of available resources in terms of sustained economic development, appropriate living conditions for its settlers. Certainly, this isn't a minor challenge. It requires the coordination of the proper authorities in diverse fields, since as was mentioned before, the complementary nature of these areas is the key to understanding the problem and generating effective solutions without sacrificing development in any of the other fields.

In a developing country like Brazil, that owns a great part of the world's water resources, the approach of this work is particularly relevant as policymaking is still a subject that requires further development, specially regarding the execution of broad strategies that address the different levels and fields that make up the problem.

The task of developing effective and efficient cities in terms of economic development and environmental sustainability requires the improvement of reliable information systems and an institutional strengthening that establish an appropriate framework for policymaking, which should address the way to a better use of available resources by urban settlements. We do not attempt to support the argument of a indiscriminate or uncontrolled growth of small cities. On the contrary, such institutional and information system enlargement would permit the achievement of the efficiency levels in the use of natural resources observed in large cities by carrying out appropriate strategies according to the size of such cities.

Such strategies should incorporate the specific characteristics of the natural resources available to those cities. In that way, the development process established for those cities could have a reduced impact over the environment and the natural resources available without jeopardizing the social and economic development of those settlements.

Even though the sustainable development of the settlements still in development process is being addressed by policy makers, the reduction of the impacts being caused by large urban settlements should be considered as well. Although the latter show a greater degree of efficiency than the small urban settlements, the environmental impact of these settlements is undeniable and requires rapid strategies for its reductions.[12]

Therefore, as shown, spatial appropriations can have different types and dimension of impacts over the water resources they depend on. However, it becomes necessary to establish utilization patterns and standards for the available resources in the process of appropriation in order to lengthen their availability without disturbing current use of social groups benefiting from them.

Final considerations

In the present work, we tried to estimate the impact of human activities over water resources for Brazilian municipalities from 2001 to 2004. The estimation by random effects seemed to be more adequate to the present model.

According to this estimation, population is the variable that has more effect over water pollution, followed by GDP per capita. Therefore, the importance of a controlled size of population in relation to natural resources must be highlighted.

The importance of GDP per capita as a determinant of water use clarifies the need for establishing more efficient uses of water such as modes of production whose waste rates tend to zero.

For further research, it is important to consider the cultural habits when thinking about sustainable use of resources and the preservation of the last pure water reserves. Same importance has the Government and his investments in water treatment, which allows used water for being reused and not disposed into the water corps, seeing that this is a increasingly scarce resource around the world.

Finally, this work corroborates the need for inclusion of natural resources into the discussion about economic development, given that, in the estimated models, the

[12] The current state of the Tietê and Pinheiros rivers in the city of Sao Paulo and the Guanabara Bay are good examples of the large impacts that mega-cities have over the water resources available to them.

availability and quality of such resources are influenced by economic and population variables. In the same way, the mode of production which guarantees human life on earth depends on natural resources. This interdependent relation identifies a problem that will become more important in the research agendas around the world in the next years because of their growing scarcity and decreasing quality that tend to negatively affect quality of life of human populations.

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