SOCIOECONOMIC INDICATORS AND DESERTIFICATION IN THE UPPER COURSE OF THE PARAÍBA RIVER WATERSHED[1]

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Introduction

The inappropriate use of natural resources has led the development model applied to nowadays society to an unsustainable condition. This statement shows the Brazilian watersheds' reality, mainly because they are natural-resource units wherein anthropic actions are often poorly planned (BRASIL, 1997; BOTELHO & SILVA, 2004).

The watersheds and their natural resources in the Brazilian semi-arid region, which demands strong commitment and rationality to promote sustainable development due to the region's climatic conditions, have been degraded and not prioritized because of economic interests. Actions such as intensive grazing, the use of native vegetation as energy source, riparian forest removal, and the traditional agriculture, along with natural features such as sharp slope, torrential rainfall and extreme droughts, among others, lead to soil impoverishment and erosion. Such scenario causes the sedimentation of the rivers and water reservoirs along the watersheds and, consequently, leads to land degradation (desertification).

The concept of desertification concerns land degradation in arid, semi-arid and dry sub-humid areas resulting from several factors such as climate changes and human activities. Land degradation is understood as the reduction or loss of biological or economic productivity, as well as the reduction or loss of the complexity of non-irrigated and irrigated agricultural lands, natural pastures, sown pastures, native forests and woods in these areas. It happens because of the land use systems or due to the combination of processes resulting from human activity and from the land occupation forms (BRASIL, 2004), namely: a) soil erosion caused by wind and/or water; b) the deterioration of soil physical, chemical, biological or economic properties; c) vegetation destruction for prolonged periods.

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The studies conducted so far (Sales, 2002; Conti, 2005; Brasil, 2004; Souza et. al., 2004; Alves et al., 2009; Souza et al., 2010) have diagnosed areas undergoing desertification processes in the Brazilian Northeastern region, mainly in Paraíba State, such as the areas inserted in the upper course of the Paraíba River watershed. Anthropic actions and climate changes have been pointed out as the factors triggering and intensifying this process.

The Paraíba River watershed, mainly its upper course, is very important to Paraíba State, since it encompasses counties located in the Western and Eastern Cariri micro-regions. The exploitation model in place in the region for decades has led to severe degradation of its natural resources, even in areas close to the Paraíba River spring. This watershed has been losing its regional and local development-generating force due to biodiversity impoverishment and to changes in the ecosystems. On the other hand, the rainfall variability and, mainly, the lack of or weak public policies concerning human coexistence with semi-arid features has generated secular social issues in dispersed rural communities adopting the traditional agriculture for survival purposes.

Studies about land degradation processes (Sobrinho, 1978; Rocha, 1997; Araújo, 2002; Sampaio, 2003; Rodrigues, 2006; Matallo Junior, 2008; Nascimento 2014; Khire & Agarwadkar, 2014; Becerril-Piña et al. 2015) have been conducted to consolidate analyses about the problem using socioeconomic indicators rather than only using the biophysical ones. Waquil et al. (2010) and Macêdo & Cândido (2011) have presented a methodology to analyze sustainability indicators that may be successfully used to assess desertification indicators.

According to Sampaio (2003), counties showing the lowest HDI-M are more susceptible to degradation, and it leads to desertification cycles, since the population is forced to use the natural resources on larger scales. The reduction of the illiteracy rate may indicate to what extent a given population can increase its understanding about environmental preservation practices, as well as about a more rational use of natural resources. Population density is a negative indicator, since the population concentration in a given area leads to increased land degradation.

Identifying and mitigating factors contributing to land degradation is the most effective way to reverse the environmental damages observed in the study region, since it enables properly planning the use of natural resources available. The socioeconomic index (Ise), in turn, provides information about the anthropic pressure affecting the environment.

Therefore, the aim of the present study was to assess the socioeconomic indicators related to the land degradation (desertification) in the upper course of the Paraíba River watershed.

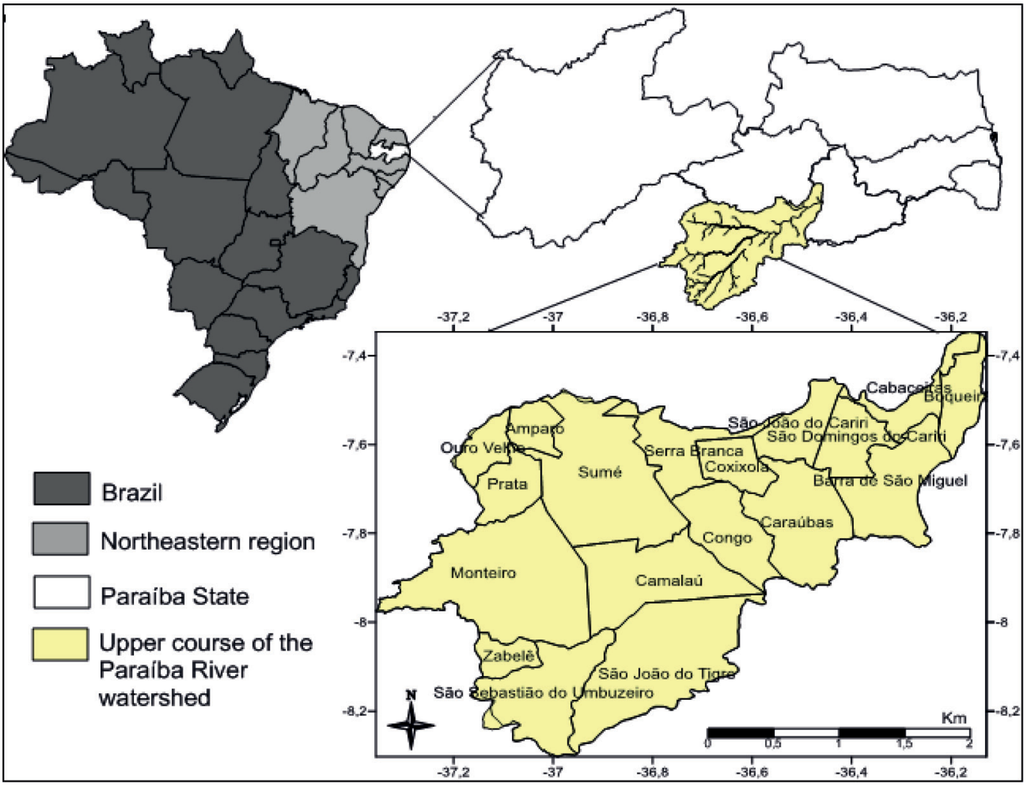
Materials and Methods

Location of the study site

The present study was carried out in the upper course of the Paraíba River watershed (Figure 1), which is located in the Southwestern side of the Borborema Plateau.

The watershed borders the Taperoá River sub-basin, to the North; Pernambuco State, to the South and to the West, and the Paraíba River mid-course region, to the East. It comprises an area of approximately 6,727 km^2, and totally or partially encompasses 18 counties distributed in the microregions of the Western and Eastern Cariri in Paraíba State.

Figure 1: Location of the upper course of the Paraíba River watershed in Paraíba State.



Socioeconomic Indicators

The socioeconomic indicators were selected according to three criteria, namely: the availability of data about the analyzed political unit (county); the characterization of the best land degradation (desertification) process; and recurrence in the specialized literature (Rocha, 1997; Araújo, 2002; Sobrinho, 1983; Rodrigues, 2006 and Sampaio, 2003).

The following assumptions and analysis parameters were used in each indicator:

1 - Demographic density (Dd) – the larger the number of people, the higher the anthropic pressure/land degradation (inhabitant/km^2).

More people cause more degradation if one considers the semiarid soil conditions, the water availability in the region and its supportability. Matallo Junior (2001) has characterized this indicator as follows: very high (> 30 inhabitants/km^2), high (between 15 and 30 inhabitants/km^2) and moderate demographic density (< 15 inhabitants/km^2). However, it is necessary taking into consideration that the population practices are as important as the demographic density. The inadequate exploitation of natural resources in the region over time may characterize the degradation process in moderate demographic density regions.

2 - Municipal human development index (HDI-M) – the lower the HDI-M, the more degraded the areas (order of counties).

The HDI-M is a compound indicator that takes into consideration the three human development pillars, namely: education (measured through indicators such as adult population schooling and young population school flow), longevity (life expectancy at birth), and municipal income per capita. It concerns the main social aspects making the county more or less susceptible to the desertification process (SAMPAIO, 2003). A low HDI-M implies social conditions contributing to desertification increase, since the population is forced to extract more natural resources, as well as may show less environmental awareness. The cause-and-effect relation between HDI-M and desertification is quite complex and may indicate that desertified areas limit the agricultural practice and, consequently, affect income generation.

3 - Land use for agricultural purposes (Luap, in %) – the bigger the cultivated area, the higher the land degradation risk (Luap in the county);

This relation is relevant since the cultivation practices in the region are degrading. The natural vegetation is removed and the soil is left exposed after the end of the cycle of temporary crops; the contour lines are not taken into consideration; the irrigation, whenever performed, leads to soil salinization; among others.

4 - Livestock (Ls) - the more intense this activity, the higher the land degradation (animals/county);

This relation is justified by the unsustainable management practices. The livestock activity is universal in the Brazilian semi-arid region; it is predominantly extensive and shows high stocking rate (animals/area).

5 - Land-ownership structure (Los) – the larger the number of small farms, the worse the land degradation (number of small farms/county);

A large number of small farms showing low productivity, as well as high stocking and plant extraction rates, make the county more vulnerable to land degradation (Sampaio, 2003). Small farms are more limited than the medium and large ones when it comes to the management of areas available for natural pasture recovery, native vegetation preservation; as well as of small areas available for animal breeding, among others. Small farms in the Brazilian semi-arid region derive from agrarian-reform settlement projects, which is another aggravating factor. These areas are already exposed to the desertification process and are gradually losing their resilience due to intensive land use. It does not mean that large farms cannot be affected by degradation; the core matter lies on properly planning the activities, which is much more difficult to be accomplished in small farms.

6 - Plant extractivism (Pe) – the greater the plant extraction, the worse the land degradation (m^3 of wood/county).

The excessive extraction of timber and wood increases land degradation, because it helps enlarging the areas undergoing soil exposure and, consequently, increases these areas' susceptibility to water and wind erosion.

Data used in the current study

Local data gathered through demographic censuses conducted by the Brazilian Institute of Geography and Statistics (IBGE - Instituto Brasileiro de Geografia e Estatística) in 1970, 1980, 1991 and 2000 (IBGE, 2014a) were used to assess the following indicators: demographic density (inhabitants/km^2) and municipal human development index. Information from the agricultural censuses conducted in each county by IBGE in 1970, 1975, 1980, 1985, 1995/1996 and 2006 (IBGE, 2014b) were used to assess the following indicators: Luap, Ls, Pe and Los. The sum of data referring to permanent and temporary crops, planted pastures and planted forests/woods (hectares) was used in the Luap indicator; Ls, the number of bovine, ovine and caprine herds; Pe, timber extraction (m^3); and Los, the number of small farms (less than 20 hectares).

Positive or negative relation between indicators

Since the variables in the current study present different measurement units, the methodological proposal developed by the Inter-American Institute for Cooperation on Agriculture (IICA - Instituto Interamericano de Cooperação para a Agricultura) (Sepúlveda, 2008) was herein used as basis, because it turns the indicators' values into indices - minimum value 0 and maximum value 1. The following relation types were defined for this procedure: positive (HDI-M indicator) and negative (other indicators – 1, 3, 4, 5 and 6).

Thus, the relation was positive when the increased indicator value resulted in improved system or condition. On the other hand, the relation was negative when the increased indicator value resulted in system worsening - in the case of the present study, when it resulted in land degradation reduction or worsening.

Calculating the socioeconomic index

After identifying the positive or negative relation between indicator and land degradation (desertification) process, the socioeconomic index of each indicator (Ise_i) was calculated as follows:

a) when the relation was positive:

$$Ise_i = (X-X_m)/(X_x-X_m) \quad (1)$$

b) when the relation was negative:

$$Ise_i = (X_x-X)/(X_x- X_m) \quad (2)$$

Wherein: X is the value of each indicator; X_m and X_x are the minimum and maximum values, respectively. The minimum and maximum values of each indicator were defined at state level. However, whenever these values were not available, the maximum value of the group of counties under analysis was used, although by always taking into consideration a reference parameter.

The maximum and minimum values of Paraíba State were used for the Dd indicator (Table 1); the HDI-M indicator ranged from 0 to 1, similar to the socioeconomic index. The Brazilian Forestry Code recommendation was used as parameter for the Luap indicator; the Code recommends using at most 80% of the land as rural farm and allocating the remaining 20% for the Legal Reserve. The Ls indicator was analyzed in compliance with the recommended limits for goat/sheep (8 animals/12 hectare) and cattle farming (1 animal/12 hectares) (Souza et al., 2010). Farms smaller than 20 hectares were counted in each county according to each year in the agricultural census series. The Pe indicator was analyzed according to Sampaio et al. (2008), who determine that 1 hectare provides 30 m³ of timber when the entire vegetation is cut leaving stumps right above the ground (Table 1).

Table 1: Reference and mean values of each socioeconomic indicator in the upper course of the Paraíba River watershed.

Indicator/unit	Reference		Mean values of the counties (upper course of the Paraíba River watershed)					
	Xx	Xm	1970	1975	1980	1985	1991	2006
Demographic density – Dd (inhabitants/km²)	1746	5	12	-	13	-	12	13
Municipal human development index (IDH-M)	1	0	0.274	-	0.325	-	0.400	0.621
Soil use – Luap (% of the county area)	80	0	15	14	19	16	10	18
Livestock - Ls Goats / Sheep - animals / 12ha	8 1	0 0	0.2 0.1	0.3 0.1	0.3 0.1	0.3 0.2	0.3 0.1	0.4 0.1
Land-ownership structure – Los (number of small farms)	2928[1]	0	479	703	466	753	347	296
Plant extraction – Pe (m³ of wood/ha)	2.7[1]	0	0.3	0.1	0.2	0.3	0.1	0.1

[1]Maximum value found for one county in the studied area.

The following exceptions for the indicators and reference values should be highlighted: i) low demographic density does not necessarily imply low land degradation, in comparison to the maximum value. However, the way the natural resources are used, the agricultural practices and the cumulative consequences of the exploitation process over time may characterize higher or lower degradation. These arguments also apply to the land use for agricultural purposes in the region; ii) degraded areas showing significant vegetation-cover suppression have no timber extraction potential, considering the herein used maximum value; (iii) the indicators have limitations, although they are very representative and provide information about a given condition.

After the indicators were transformed into indices, the overall socioeconomic index per county (Isec) was calculated as:

$$Ise_c = \sqrt[n]{\prod_{1}^{n} Ise_i} \qquad (3)$$

Wherein: n is the number of analyzed indicators. The socioeconomic index for the entire upper course of the Paraíba River watershed (Ise_w) was:

$$Ise_w = \sqrt[N]{\prod_{1}^{N} Ise_N} \qquad (4)$$

Wherein: N is the number of analyzed counties.

The geometric mean was used as central tendency measure, whereas the coefficient of variation (CV) was used to represent the dispersion and to better characterize the variability of the indices.

Socioeconomic index representation

The following conditions were categorized after the socioeconomic index for each indicator was found: Critical, Substantial, Moderate, Low, Very Low and No degradation. Distinct colors were used to represent the land degradation levels in each county, from the most critical to the ideal condition, as shown in Table 2:

Table 2: Classification and representation of the socioeconomic index of the counties (Ise_c), condition and description according to land degradation.

Index (0-1)*	Condition	Description
0.00-0.19	Critical	It corresponds to an advanced degradation condition characterized by low social indicators (income, longevity and education), high land use for agricultural purposes and inadequate practice rates, large numbers of herds and small farms, and high plant extraction rate. Identification of areas presenting soil exposure, native-vegetation cover suppression, erosion (furrows and gullies), etc.
0.20-0.39	Substantial	Land degradation associated with increase in some indicators, characterizing areas with increasing environmental issues (scarce and sparse vegetation, gullies, etc.) and permanent livestock farming.
0.40-0.59	Moderate	Land degradation associated with increase in few indicators. Vegetation cover reduction, extensive-livestock farming increase and more frequently-exposed soil spots.
0.60-0.79	Low	It corresponds to significant degradation, but the environmental damage can be reversed through recovery strategies. Mean social indicators, low herd concentrations and low land use for agricultural purposes.
0.80-0.99	Very low	Presence of native vegetation cover, slightly better conserved soils, low herd concentrations (goats, sheep and cattle) and reasonable social indicators.
1.00	No degradation	Condition wherein no significant anthropic actions are identified.

*Values adapted from Macêdo & Candido (2011).

The established conditions are related to the indicators used in the current study. Differentiated land degradation (desertification) levels can be found through other methodological proposals.

Results and Discussion

Characterizing the socioeconomic indicators related to land degradation

Table 3 shows the socioeconomic indicators used in the current study, namely: demographic density (Dd), human development index (HDI-M), land use for agricultural purposes (Luap), livestock (Ls), land-ownership structure (Los); and their respective indices. The HDI-M indicator has shown the lowest indices and the highest coefficient of variation throughout the studied period. These results show that, overall, the population in this region has presented low economic and social development, despite its considerable increase in 2006. The indicators "Dd" and "Luap" have presented the highest values; it evidenced that the anthropic pressure, resulting from the number of people living in the region, was minimal; and that the impact of the amount of land used for agricultural purposes was low, if ones takes into consideration the negative relation between these indicators and the land degradation process.

Table 3: Mean annual socioeconomic index (Ise) values per indicator in the upper course of the Paraíba River watershed, from 1970 to 2006.

	Years							
Indicator	**1970**	**1975**	**1980**	**1985**	**1995**	**2006**	**Mean**	**CV***
Dd	0.993	-	0.995	-	0.997	0.997	0.995	0.00
IDH-M	0.274	-	0.325	-	0.399	0.621	0.385	0.40
Luap	0.737	0.743	0.685	0.715	0.784	0.695	0.726	0.05
Ls	0.544	0.485	0.482	0.467	0.549	0.572	0.515	0.08
Los	0.538	0.519	0.457	0.394	0.431	0.520	0.473	0.12
Pe	0.611	0.537	0.527	0.485	0.543	0.293	0.487	0.22

* CV: Coefficient of variation

It was possible seeing that the counties were sparsely inhabited, although Boqueirão and Cabaceiras have shown significant demographic density increase throughout the studied period. However, it is worth emphasizing that, despite the low Dd, the exploitation of natural resources took place over successive decades in this region and that it had cumulative effects, which characterized the current land degradation aspects. The population in the 18 counties that are vulnerable to desertification is close to 128,865 people (IBGE, 2010). The municipal human development index (HDI-M) has also evolved throughout the studied period; this index is able to show improvements in the population's living conditions, since it provides information about income, life expectancy and schooling levels.

The values presented by the IDH-M indicator have shown the socioeconomic evolution in the region; however, they were very low in comparison to the national and state values. Land degradation (desertification) persists in this socioeconomic advance context. Three factors help explaining the relation between the improved social indicators and the existence and/or permanence of land degradation, namely: 1) land degradation causes are cumulative over time; thus, natural environments take longer to recover; 2) there was direct income transfer increase due to actions by the federal government in recent years; thus, the economy increase did not result from the production sectors in the region, and; 3) there was decreased land use for agricultural purposes throughout the period due to rural population decrease.

With respect to the land use for agricultural purposes (Luap), the agricultural censuses conducted by IBGE (2014b) have shown approximate decrease by 51% in permanent crops, mainly in cotton and agave crops. The land use for temporary crops has also decreased by approximately 43% throughout the analyzed years, fact that shows the relative abandonment of the agricultural activity. It is worth highlighting that the period from 1980 to 1985 has shown the highest rates of cultivated area, probably because there was above-average rainfall in 1984 and 1985. The area planted with temporary crops has decreased to 24,389 ha in 2006 - the lowest value in the herein analyzed series.

Costa (2006) has analyzed agricultural data comprising the period from 1970 to 1995 in Paraíba State and found 142.3% decrease in areas planted with permanent crops. According to the author, this process results from the cotton activity decline, which was largely practiced as permanent crop in the 1970s, since arboreal cotton plants were significantly cultivated at that time.

The data have shown approximately 47% decline in natural pastures in the 36 years encompassing the series, except for 1985 and 1995, which showed increase to favorable climatic exceptions (1984/85). On the other hand, the pasture-planted areas have increased by approximately 350%. The public policies focused on land use in the region have addressed the increase in pastures planted for livestock - such as the prickly pear *Opuntia sp*., which is an exotic xerophilous crop indicated for the conditions in the region -; thus, suppressing the natural vegetation cover.

There was significant natural forest increase due to areas that were no longer cultivated with permanent and temporary crops, and that were not used as pasture. On the other hand, the increase in forest-planted areas ranged from 237 ha (in 1970) to 44,585 ha (in 2006) (IBGE, 2014b). The mesquite (*prosopis juliflora* sp) cultivation was strongly introduced during this period. This species is an exotic forest essence that invaded the floodplain areas and the watercourse and reservoir banks. Its allelopathic effect did not allow the typical species native to these ecosystems to occupy the areas formerly used for agriculture and/or livestock (PEREIRA, 2006; DUQUE, 2006).

The cotton production peaks happened in 1970 and 1975; the cotton exceeded the agave production in 1975 and declined in the 1980s due to the emergence of a damaging pest (Anthonomus grandis Boheman); however, the cotton farming was already facing difficulties, such as productivity and price declines. There was approximately 100% cotton production decline in the region between 1970 and 2006, when the production decreased from 3,900 to 3 tons. In addition, the agave production has significantly exceeded that of cotton in 1970, 1980 and 1985. It is worth highlighting that the agave production has decreased approximately 97% from 1970 to 2006, fact that can be attributed to limitations in the international markets, as well as to the increasing agave production in Bahia State.

The extensively-practiced livestock (Ls), which was historically adopted in the study region, has been seen as desertification trigger and intensifier, since the herds (mainly goats) fed on the native vegetation throughout the year. In addition, the trampling of animals, mainly cattle, has compacted the soil, thus hindering water infiltration in it and root development by plants. According to data provided by IBGE (2014b), overall, there was decline in sheep and cattle herds from 1998 on. On the other hand, goat herds have increased throughout most of the period. Reductions in cattle, sheep and goat herds were identified in 1983, 1993, 1998 and 2012 due to droughts in the region, when the rainfall was below the average.

The expansion of the breeding activity from the 1970s on has counted on subsidized credit with low interest rates and long grace period. Banco do Brasil, Banco do Nordeste and Banco da Paraíba (Paraiban) were the main credit and financing policy agents in the state and used funds from foreign banks to be so. Thus, the herds grew throughout the state and Cariri region has assured its specialization in goat and sheep production; the effective animal-number increase was in the order of 50% in most of the counties belonging to the region. The livestock performance has improved due to changes in the animal feeding patterns such as increased planted pasture, prickly pear diffusion, mesquite introduction and the use of industrial feedingstuffs. In addition, the land fencing has led to pasture rotations, to lower subjection to climatic irregularities and to lower workforce coefficient; these factors, which were presented by Moreira & Targino (1997), have also boosted the activity. It is worth emphasizing that the pasture diversification has led to high native vegetation deforestation.

Some inferences are discussed to support the understanding about the herein studied indicators based on their absolute values. It is essential pinpointing that small rural farms resulting from poorly-planned agrarian reform settlement projects (SPs) and often facing a significant desertification state do not allow rural landowners to develop natural resource conservation strategies; thus, it helps worsening the desertification process, according to Pereira (2008). Approximately 4,675 hectares in Monteiro County were expropriated for SP purposes, as well as 3,085 hectares in Camalaú County and 6,749 hectares in Sumé County. In addition to the SPs, another aspect has contributed to the "minifundization" process in the study region, namely: the land-ownership heredity; the land previously belonged to a patriarch and, for inheritance reasons, it was divided into smaller lands, which were used in a more intensive way.

Most settlements took place after 1995, and this is the reason why there was 22% increase in the number of settlements smaller than 10 hectares in the upper course of the Paraíba River watershed in 2006. There was a considerable number of small farms in 1970 and 1980; historically, the land ownership was very concentrated in this region, for low-income families owned these small farms.

According to Duarte (2002), the edaphoclimatic heterogeneity of the Northeastern semi-arid region does not allow estimating the ideal dimension of a farm to enable local families to survive the impacts caused by severe droughts. However, the author has emphasized that the area of farms with poor soils and lacking water points should be bigger than 100 ha; therefore, the size of the settlements identified in the study site was smaller than the recommended, fact that has contributed to the intensified use of these lands. Moreira & Targino (1997) have pointed out that the increased agrarian conflicts and the solution of several of them through the expropriation and purchase of properties by INCRA, mainly from 1993 on, as well as through the settlement of families has helped increasing the number of small farms.

The fiscal module in the counties belonging to the Paraíba River upper course region corresponds to 55 and 60 hectares (LANDAU et al., 2012); the small farms are classified as properties smaller than a fiscal module. Thus, the upper course of the Paraíba River watershed has shown 10,456 small farms in 1970; 14,023, in 1975; 10,008, in 1980; 14,063, in 1985; 7,813, in 1995; and 9,452, in 2006.

According to the number of agricultural settlements in the study region, which was provided through agricultural censuses (IBGE, 2014b) and through the land-registry statistics from INCRA, the large settlements represent a small proportion of the total lands, but they encompass the vast majority of these lands. In 1970, for instance, 2% of the settlements bigger than 500 hectares accounted for 41% of the total lands, whereas 52% of the settlements smaller than 10 hectares accounted for only 5% of the total lands. In addition, it is possible seeing that the land distribution has not changed much throughout the herein analyzed years.

The charcoal production in the upper course of the Paraíba River watershed has significantly decreased in the last two decades; from 5,529 (in 1990) to 252 tons (in 2013). The timber exploitation has reached its peak from 1998 to 2001; the mean charcoal production was 155,688 m^3. This peak has coincided with the disclosure of IBAMA Normative Instruction n. 01/1998, which regulated the sustainable exploitation of native vegetation and of its successor formations in the Northeastern region, and allowed suppressing exotic and native forests, as long as they did not belong to permanent preservation (PPAs) and legal reserve (LR) areas.

According to Cunha & Silva (2012), the subsequent Normative Instruction (n. 08/2004) exempts the planting and breeding of native and exotic species for production and cutting purposes (in altered, underutilized or abandoned agricultural and livestock farming areas, located outside the PPAs and LRs) from presenting project and from being subjected to technical inspection. However, when it comes to the exploitation of planted native species, the same Normative Instruction demands some formal procedures and requirements, such as information supply to IBAMA and to the state environmental agency (data about the farm and the owner, technical report attesting the previous existence of plantation), as well as requesting authorization to transport forest products. In addition, it exempts holders of planted exotic forest species. Still according to the authors, experts from IBAMA and from the Paraíba State Environmental Management Superintendence (SUDEMA - Superintendência de Administração do Meio Ambiente da Paraíba) were interviewed at the time the research was on progress and they have reported that the mesquite plant is a threat to the Caatinga because it is an invasive species. Thus, the cutting off and transportation of mesquite plants would be fully authorized with no need of presenting any management plan documentation, guide or approval.

The timber exploitation, mainly of mesquite trees, is intended to produce firewood for bakery and pottery furnaces, as well as to produce charcoal, stakes and posts for different purposes. According to Travassos & Souza (2014), the timber is commercialized in larger cities such as Campina Grande and João Pessoa, as well as in neighboring states such as Pernambuco. The intense mesquite removal leads to the extinction of an animal food source and, what is even worse, the soil is left exposed to the inclement weather, mainly in ciliary forest areas, which were supposed to be covered by native species.

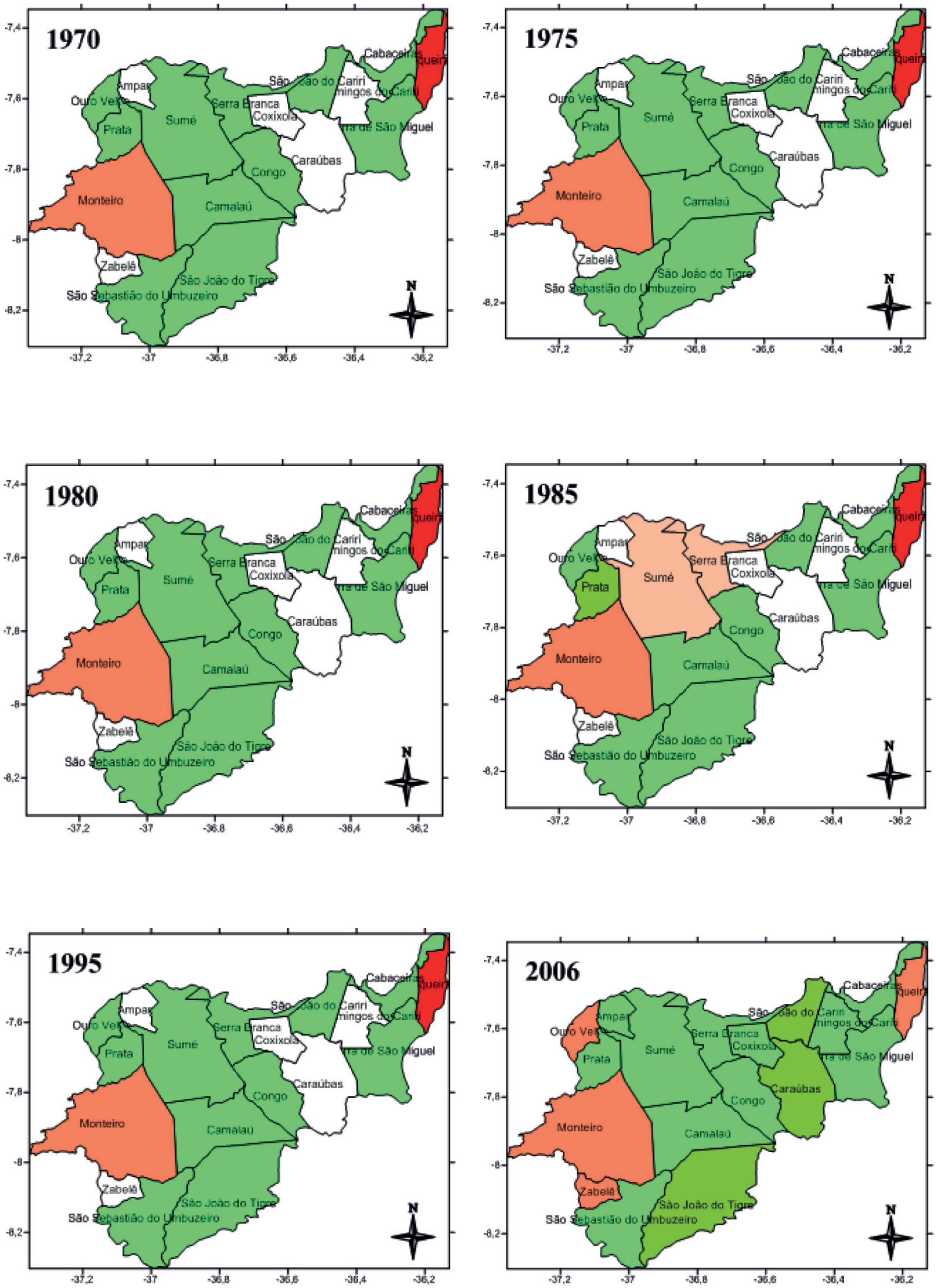
The overall socioeconomic index of each county

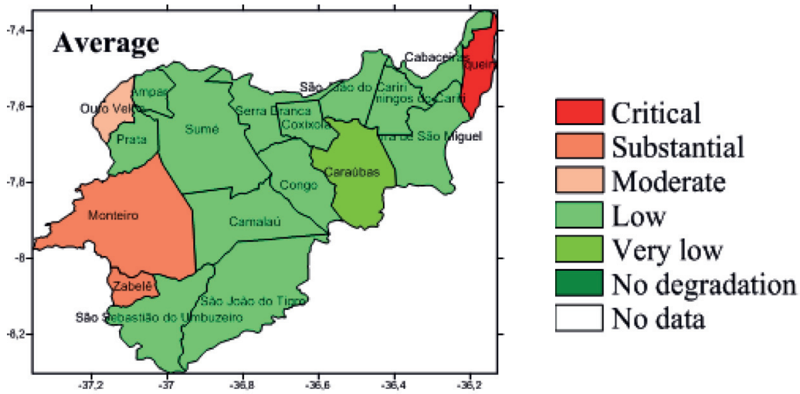
Figure 2 shows the overall socioeconomic index per county (Ise_c) and its relation to land degradation/desertification. It is possible seeing that Boqueirão and Monteiro counties have presented critical and moderate land degradation throughout the studied period. On the other hand, Cabaceiras, Congo, Camalaú, Barra de São Miguel and São Sebastião do Umbuzeiro counties have presented low land degradation, whereas the other counties have presented different land degradation conditions throughout the years. The year showing the lowest Ise_c was 1985, because of the dry period from 1979 to 1984, which caused agricultural and social losses, as well as intensified plant exploitation. The highest values were found in 2006, when there was no record of climatic adversities.

The mean values of 2 out of the 18 studied counties were categorized as substantial degradation, namely: Zabelê (0.360) and Monteiro (0.283). Thirteen (13) counties have shown low land degradation, namely: São Sebastião do Umbuzeiro (0.710), São João do Tigre (0.741), Camalaú (0.726), Congo (0.733), Coxixola (0.719), Barra de São Miguel (0.718), São João do Cariri (0.758), São Domingos do Cariri (0.723), Cabaceiras (0.743), Amparo (0.623), Prata (0.698), Serra Branca (0.674) and Sumé (0.669). Caraúbas has presented very low land degradation level (0.813), Ouro Velho County has presented moderate land degradation (0.588), and only Boqueirão County has presented critical land degradation level (0.137). The mean Ise_c values have shown land degradation throughout the watershed, although predominantly at low level. In addition, the anthropic pressure is higher in the Northwestern portion of the watershed, as well as in Boqueirão and Monteiro counties.

Boqueirão and Monteiro counties have shown the highest herd stocking and plant extraction rates, as well as large numbers of small farms. These factors, in association with each other, lead to the current scenario of more intense degradation. The low-level land degradation in the watershed may be reversed through degraded-area recovery strategies. It is imperative taking political, economic and environmental actions to stop this process and to prevent the region, which is naturally susceptible, from experiencing higher desertification levels.

Figure 2: Spatialization of the overall socioeconomic index per county (Ise_c) in the upper course of the Paraíba River watershed, from 1970 to 2006.





The no-data counties correspond to those that were not politically emancipated before 2006 and whose territories belonged to other counties that belong to the watershed as well.

Temporal evolution of the socioeconomic index in the upper course of the Paraíba River watershed

The evolution of the watershed socioeconomic index (Ise_w) and its correlation with land degradation (desertification) in the upper course of the Paraíba River watershed throughout the studied period were estimated as follows: 1970 (0.574), 1975 (0.566), 1980 (0.576), 1985 (0.525), 1995 (0.602) and 2006 (0.653). This index tends to increase, since its mean value indicates moderate land degradation in the watershed, i.e., the anthropic actions in the region throughout the years have promoted moderate degradation.

There was low land degradation resulting from the anthropic pressure in the years of the analyzed series. The coefficients of variation of the overall socioeconomic index per county (Ise_c) ranged from 0.27 to 0.37 throughout the aforementioned years. The low land degradation may be associated with improvements in the living conditions of the population such as reduced illiteracy rates, direct income transfer increase promoted by the federal government, decreased land use for agricultural purposes and rural population decrease, among others. Although the social indicators have improved in the region and, despite the reduction in land use for agricultural purposes, the previous and latent degradation in the region may get worse if mitigation and recovery measures are not adopted.

It is worth pinpointing that, despite the acknowledged influence of anthropic actions on the desertification process, some natural components (droughts, high aridity index, rainfall variability, etc.) intensify the process and are included in the concept of desertification through the component "climate changes". The vegetation cover in semi-arid regions strongly depends on rainfall; thus, the rainfall variability leaves the soil exposed for longer, fact that increases the soil susceptibility to erosion. In addition, the high aridity index contributes to organic matter oxidation in the soil of the region, which is shallow and often salinized.

Final considerations

The assessment of socioeconomic indicators related to land degradation in the upper course of the Paraíba River watershed allowed concluding that the municipal human development index (HDI-M) has shown the lowest Ise value throughout the studied period, thus evidencing the low economic, educational and social development in the region. Indicators such as demographic density (Dd) and land use for agricultural purposes (Luap) have shown the highest values, thus indicating that the anthropic pressure resulting from the number of people living in the region was minimal and that the land use for agricultural purposes was low. There was increased timber extraction, as well as increased number of small farms. The extension of these economic practices, on an unsustainable basis, jeopardizes the entire area, whose natural conditions (rainfall variability, high aridity index, erodibility potential, droughts, etc.) make it prone to land degradation (desertification). Seventy-two percent (72%) of the herein analyzed counties have presented low land degradation, whereas 11% of them have presented substantial land degradation. Only Boqueirão County has presented critical land degradation. The strongest anthropic pressure was found in the Northwestern region of the watershed.

Overall, the socioeconomic index in the watershed tends to increase, since its mean value indicates moderate land degradation, which may be associated with improvements in the living conditions of the population, reduced illiteracy rates, direct income transfer promoted by the federal government, and with reduced land use for agricultural purposes, among others. However, the desertification process persists even in such context. Thus, it is necessary conducting further temporal and spatial studies to help understanding, as well as to monitor the evolution of this phenomenon in the region.

Finally, it is worth emphasizing that the socioeconomic indicators have allowed deepening the theoretical discussions about desertification. The quantification and aggregation of values, which point out areas with higher anthropic pressure, makes it possible supporting mitigation policies in the region.

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SOCIOECONOMIC INDICATORS AND DESERTIFICATION IN THE UPPER COURSE OF THE PARAÍBA RIVER WATERSHED

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Abstract: The aim of the current study is to assess the relation between socioeconomic indicators and land degradation in the upper course of the Paraíba River watershed. The indicators were selected based on the literature and on the census data available. The positive or negative relation between these indicators and soil degradation was identified. The mean values of the socioeconomic index per county (Ise_c) have shown soil degradation in the entire upper course of the watershed, although predominantly at low levels, whereas the Northwestern area has shown the strongest anthropic pressure. The upper course of the watershed has shown trend to socioeconomic index (Ise_w) increase and its mean value has indicated "moderate" land degradation.

Keywords: agriculture; semiarid; desertification.

Resumo: O objetivo foi avaliar a relação entre os indicadores socioeconômicos e a degradação das terras no alto curso da bacia hidrográfica do Rio Paraíba. Foram selecionados indicadores com base na literatura específica e com disponibilidade de dados censitários, identificando-se a relação positiva ou negativa destes indicadores com o processo de degradação das terras. Os valores médios do indicador socioeconômico municipal (Ise_m) revelam que está havendo degradação das terras em todo o alto curso da bacia hidrográfica, porém predominantemente em níveis baixos, sendo a região noroeste a área com maior pressão antrópica. Há uma tendência de aumento do índice socioeconômico no alto curso da bacia hidrográfica (Ise_b), com valor médio que indica uma situação de degradação "Moderada".

Palavras-chave: agropecuária; semiárido; desertificação.
Resumen: El objetivo fue evaluar la relación entre los indicadores socioeconómicos y la degradación de las tierras del alto curso de la cuenca hidrográfica del Río Paraíba. Se seleccionaron indicadores basados en la literatura y la disponibilidad de los datos del censo, la identificación de la relación positiva o negativa de estos indicadores con la degradación del suelo. El índice socioeconómico se obtuvo con la adición de varios indicadores para cada municipio. Los valores medios de los indicadores socioeconómicos municipales (Ise_m)

muestran que hay una degradación de las tierras alrededor del alto curso de la cuenca, pero predominantemente en niveles bajos, y la zona noroeste con una mayor presión antrópica. Hay una tendencia a aumentar el índice socioeconómico en el alto curso de la cuenca del río (Ise_b), con un valor promedio que indica una situación “moderada” de deterioro de las tierras.

***Palabras Clave*:** agricultura; semiárido; desertificación.