FORUM GEOGRAFIC

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
*Volume **XI**, Issue **1** (**June 2012**), pp. **36-44***
*http://dx.doi.org/**10.5775/fg.2067-4635.2012.023.i***

Land Use Changes in the Bâsca Chiojdului River Basin and the Assessment of their Environmental Impact

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Received on <30-10-2011>, reviewed on <01-03-2012>, accepted on <02-05-2012>

Abstract

The paper aims at analyzing the environmental quality of the Bâsca Chiojdului river basin by calculating a variety of environmental indices: human pressure index through population dynamics, human pressure index through agricultural land use, the naturality index, artificialization index and environmental change index. Choosing a 1 km grid for calculating and comparing these indices at the level of the river basin allows a more concise analysis on the environmental quality. Subsequently, the temporal dynamics of the environmental indices values is highlighted by the 40 years interval used especially in the human factor analysis, and by choosing the year 2005 as reference year. The results, embodied in the values obtained by applying formulas to calculate the environmental indices (human pressure index through agricultural land use - 44.19% agricultural land, the naturality index of the landscape - 50.82%; the artificialization index of the landscape - 2.32%; the environmental change index: Maruszczak version - 33.92; the improved version - 1.09, the completed version - 10.83) present the state of the environment. The proposed measures to stabilize and maintain a good environmental quality in the Bâsca Chiojdului river basin regard mainly the forest ecosystem, because it is the most important factor of maintaining the balance by its protective functionality on the environment.

Keywords: *state of the environment, human pressure, environmental indices, river basin, the Bâsca Chiojdului*

Rezumat. Schimbările modului de utilizare a terenurilor în bazinul hidrografic Bâsca Chiojdului şi evaluarea impactului acestora asupra mediului

Lucrarea îşi propune analizarea calităţii mediului la nivelul bazinului hidrografic Bâsca Chiojdului prin calculul unei varietăţi de indici de mediu: indicele de presiune umană prin dinamica demografică, indicele de presiune umană prin utilizarea terenurilor agricole, indicele de naturalitate, indicele de artificializare şi indicii transformării de mediu (environmentale). Alegerea unui caroiaj de 1 kmp în vederea calculării şi comparării acestor indici la nivel de bazin hidrografic, permite o analiză mult mai concisă asupra calităţii mediului. Ulterior, dinamica temporală a valorilor indicilor de mediu este evidenţiată prin intervalul de 40 de ani ales în analiza a factorului uman, şi prin sectarea anului 2005, ca an de referinţă. Rezultatele, materializate în valorile obţinute în urma aplicării formulelor de calcul ale indicilor de mediu (Indicele de presiune umană prin utilizarea terenurilor agricole - 44,19% suprafeţele agricole; Indicele de naturalitate al peisajului - 50,82%; Indicele de artificializare a peisajului - 2,32%; Indicele transformării de mediu: varianta Maruszczak - 33,92; variantei îmbunătăţită - 1,09; varianta completată - 10,83) redau starea mediului. Măsurile propuse, în vederea stabilizării şi menţinerii calităţii bune a mediului în bazinul hidrografic Bâsca Chiojdului vizează în principal ecosistemul forestier, deoarece prin funcţionalitatea sa protectoare asupra mediului este cel mai important factor de menţinere a echilibrului.

Cuvinte-cheie: *starea mediului, presiune umană, indici de mediu, bazin hidrografic, Bâsca Chiojdului*

Introduction

Human pressure on the environment takes many forms depending on the nature of human activities and the changes in the land use.

To calculate *the human pressure index through the use of agricultural land*, the percentage share that each type of agricultural land has, should be evaluated from the total area of agricultural land in the analyzed space (Dumitraşcu, 2006). *The naturality index* is the ratio of the natural forest area and total area of that space. It is expressed in percentages and its use is absolutely necessary to obtain a correct characterization of the ecological state of the examined river basin (this index actually represents the degree of afforestation).

Given that the value of the naturality index expresses the steady-state of the interrelations at the

level of the landscape, it has been studied in many papers for different geographic regions such as the Sub-Carpathian sector of the Prahova Valley (Armaş et al., 2003), Mostiştei Plain (Apostol, 2004), Oltenia Plain (Dumitraşcu, 2006), The Sub-Carpathians between Buzău and Râmnicu Sărat (Nicholas, 2011), Bălăciţei Piedmont (Ionuş et al., 2011).

Environmental change index can be calculated by various formulas depending on the characteristics of the Bâsca Chiojdului river basin.

The environmental change index was first introduced by Maruszczak in Poland in 1988 and then taken by Malgorzata Pietrzak in 1998, to assess human impact on the Sub-Carpathian landscape from Poland (Armaş et al., 2003). In Romania, it was applied for the Sub-Carpathian sector of the Prahova valley (Armaş et al., 2003), the Iron Gates Natural Park (Manea, 2003), Bărăganului Plain (Panait, 2010) and Bălăciţei Piedmont (Ionuş et al., 2011).

Study area

The Bâsca Chiojdului river basin is part (sub-basin) of the Buzău river basin. It has a total area of 340.29 km², the collector river has a total length of 42 km and an annual average flow of 1.20 m³/s at the Chiojdului hydrometric station, respectively of 2.65 m³/s where it flows into the Buzău river.

It is located within the Curvature Carpathian and Sub-Carpathians territory, and from the administrative point of view, it is equally located within the Buzău and Prahova counties (Zarea and Gheorghe, 2010). Six administrative units (Chiojdului, Cătina, Calvin and Cislău, Starchiojd and Poseşti localities) were analyzed in the study.

The total population of the basin was of 24,684 inhabitants in 1970, then increasing to 25,789 in 1975, when there was registred the maximum number of inhabitants in the whole analyzed period. After 1975, a continuous and constant decrease of population was recorded, leading to 23, 133 inhabitants in 1990; 22,226 in 2000, and 21,064 inhabitants in 2010 (Fig. 1).

The average population density of the basin was of 72.54 inhabitants/km² in 1970. It has increased in the first 5 years, reaching the maximum value of 75.79 inhabitants/km² in 1975, then began to decline, reaching 72.64 inhabitants/km² in 1980; 67.98 inhabitants/km² in 1990; 65.31 inhabitants/km² in 2000, and respectively 61.90% inhabitants/km² in 2010 (Fig. 1).

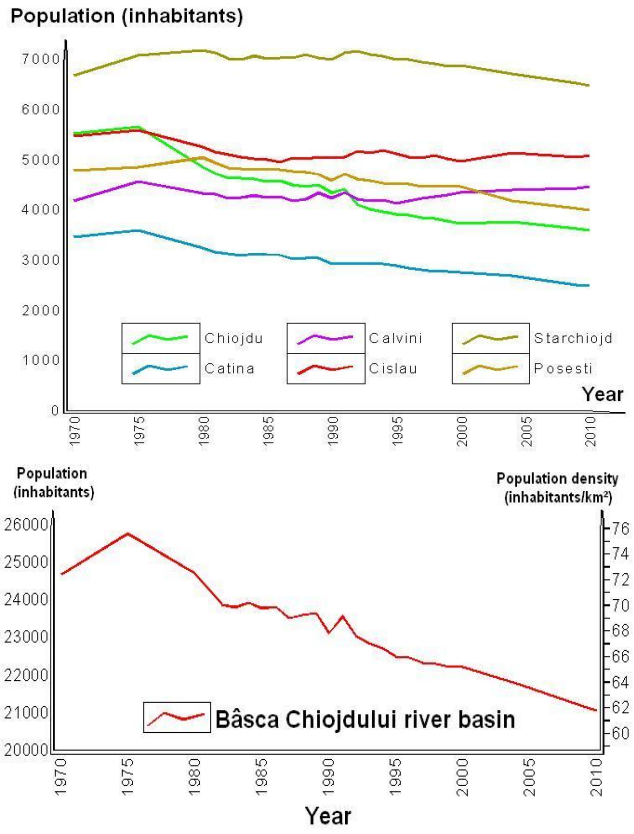

Fig. 1: The demographic dynamics within the Bâsca Chiojdului river basin in 1970-2010: number of inhabitants and the population density; number of inhabitants

In the analyzed period, 1970-2010, a general trend of population decreasing was recorded in the entire basin. The basic explanation is the migration of the population from this area to big cities (Buzâu, Ploieşti and Bucharest), but also to smaller nearby towns (Pătârlagele or Vălenii de Munte). This became obvious since 1975 and continued at lower level after 1990.

A second cause of the general trend of population decline is the reduction of the birth rate, a phenomenon seen after 1990. Also after 1990 the increase of reverse migration was recorded (from towns to these villages), and that is why after 2000 and especially after 2005 we notice a reduction in the rate of inhabitants decrease, recording even a demographic increase in some localities.

The elements that define a particular type of environment differ depending on the degree of human impact on the landscapes. Thus, in the mountain area, the human impact is lower, the defining components of a particular type of environment are the relief, some climate elements or the plant communities. However in the Sub-

Carpathian area, with much higher degree of human intervention, the environmental values are expressed through the land use (Armaş et al., 2003).
The inventoried landscapes in the Bâsca Chiojdului river basin frame in four of the five defined classes using the Corine Land Cover (2006) (Fig. 2):

- artificial surface class
- agricultural areas class
- forests or semi-natural class
- aquatic organisms class

The artificial surfaces class corresponds to the most human influenced landscape types and includes three categories (the built area - urban discontinuous structure, lines of communication - transport units and industrial units). They occupy a total area of 7.91 km², which means 2.32% of the total area of the basin. The impact of these surfaces on the environment is negative, they are directly responsible for the artificial landscape.

The agricultural areas class includes several categories, such as: arable land (irrigated or non-irrigated), orchards of fruit trees and shrubs plantations of berries, vineyards, meadows, pastures and hayfields. This class includes human modified landscapes, but more environmentally friendly than the artificial surfaces (orchards especially).

The agricultural areas occupy a large percentage of the total area of the basin (44.19%), which represent 150.34 km². Under these conditions, their impact on the environment quality is significant in the basin. There are obviously differences between how different types of agricultural land affect the environment (the comparison between a pasture affected by overgrazing and a mature and dense orchard is significant).

The forests and semi-natural class consists of two broad categories (forests and areas with poor vegetation, major river beds or degraded lands). Given the very different impact on the environment, the two categories of land use will be considered separately.

Forests cover a little more than half of the total river basin (172.84 km², which means 50.79% of it). In 2005, forests were far from being uniform, the differences were significant because of tree species and tree age, size and density.

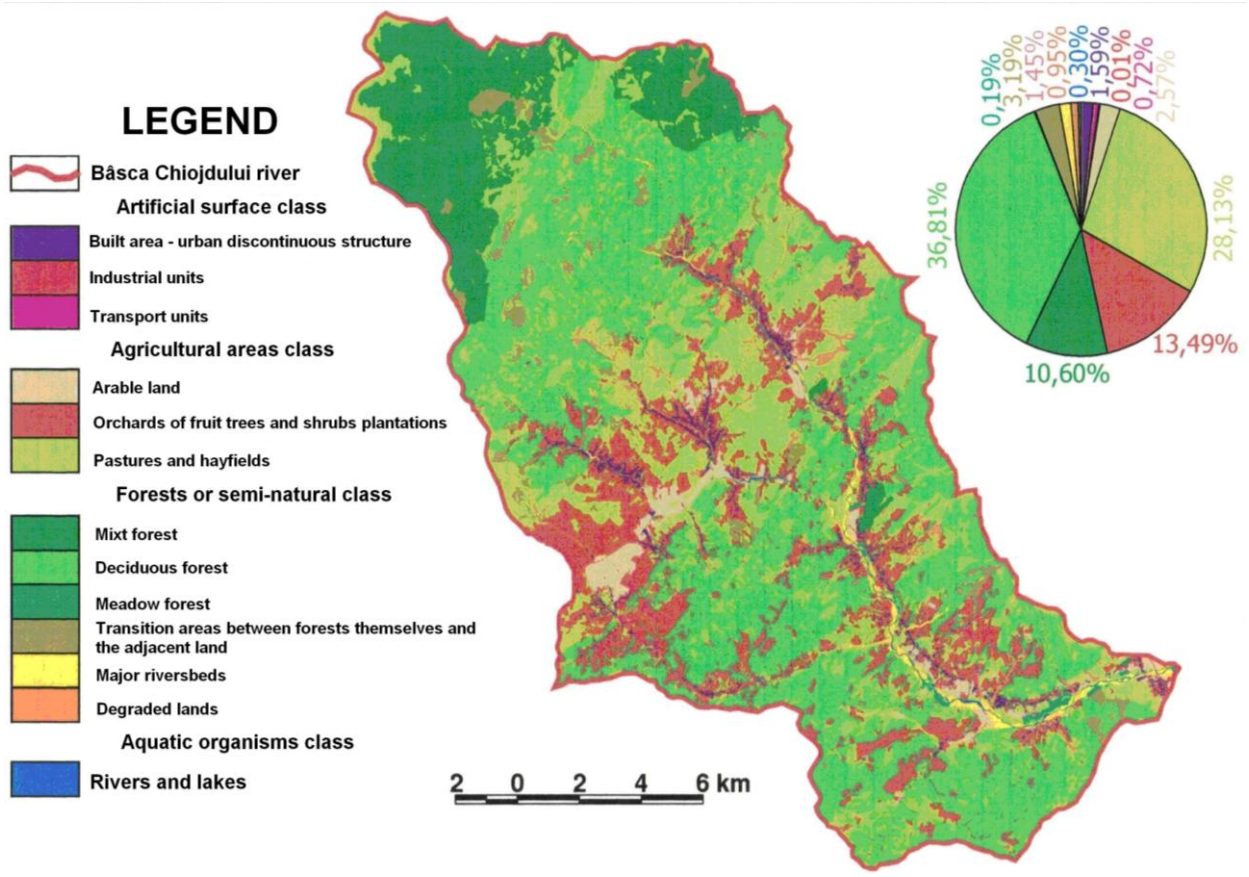

Fig. 2: Spatial dynamics of land use in the Bâsca Chiojdului river basin in 2005

Four main types of forest areas can be identified in the river basin (mixed forest, deciduous forest,

meadow forests and transition areas between forests themselves and the adjacent land - orchards, hayfields and pastures).

Areas with poor vegetation or no vegetation at all are of two types: major rivers beds and degraded lands. Although they are in a certain degree of natural origin, their impact upon environment is largely negative. For this reason, the classification of these types of surfaces within the same class as forests in literature and in Corine Land Cover classification system is forced and irrelevant when the environmental factors are characterized. Although they occupy a relatively small share in the river basin (8.15 km², that is 2.40%), their negative impact on the environment is significant.

The degraded lands largely correspond to the geomorphologic phenomena (of slope or valley). These occupy 3.22 km² (39.60% of all areas with low-vegetation coverage, which means 0.95% of the total basin). An even larger area (1.42% from the entire basin) is covered by rocks with high susceptibility to erosion (Rădoane, 2004).

The class of aquatic organisms is represented in an overwhelming percentage by streams and in a very limited extent by lakes in the Bâsca Chiojdului river basin. The aquatic organisms occupied an area of 1.04 km² in 2005, which means 0.30% of the whole basin.

Data and methods

For the calculation of environmental indices it is necessary in the first stage to use the map with the land use, using Corine Land Cover, adapted to the characteristics and the dimensions of the analyzed basin. Because of the relatively small size of the river basin, the map with the land use was done by digitizing (vectorization) on orthophotomaps made in 2005 and geo-referenced in the national projection-Stereo 70.

Although the values of the environmental indices are calculated at the level of administrative units in the literature, due to the relatively reduced size of the Bâsca Chiojduluii basin, these will be calculated for each area of 1km² of it, based on a grid made in accordance with the Stereo-70 national projection. This working methodology will allow capturing precisely the sectors with the biggest environmental problems, the paper proposing also solutions to improve its quality in the future.

Environmental change index can be calculated by various formulas depending on the characteristics of the Bâsca Chiojdului river basin.

Improved version

Armaş et al. in 2003 (for the Sub-Carpathian sector of the Prahova Valley), Manea, 2003 (for the Iron Gates Natural Park) or Panait in 2010 (for the Bărăgan Plain) have applied a new formula for calculating the environmental change index: Eci = S forest/ S (agricultural + built area). Arable lands and pastures, meadows, hayfields and orchards are included in the "agricultural area" category.

Completed version

In this case, for the Bâsca Chiojdului river basin, there is proposed also the applying of the following formula of the environmental change index (similar formulas are applied also to the natural reservations "Les Hauts of Chartreuse (French Alps)" and "Lăpuşna resonance spruce" (Central Group of Eastern Carpathians) (Băltescu, 2009) or to the Bărăganului Plain (Panait, 2010): Eci = S (forests +acquatic area)/S (built area + areas with poor vegetation).

Both the forest areas and the aquatic ones play a positive role regarding the environmental quality, while the areas with poor vegetation (degraded land or major river beds), respectively the built surfaces, the industrial ones and the lines of communication play a negative role. Being considered "neutral elements" in characterizing the ecological state, the spaces occupied by orchards, pastures and hayfields have not been taken into account in this formula.

Results and discussions

1. The human pressure index through arable land use

The human pressure indices on forest lands and on various types of agricultural lands are relevant for the Bâsca Chiojdului river basin.

Knowing both the evolution of the number of inhabitants and the evolution of forest areas in the last 3-4 decades, we can calculate the temporal dynamics of human pressure index on forest lands in the basin. In figure 3, there may be noted that at the beginning of the interval, a downward trend in the value of this index was recorded, the minimum value was recorded in 1975 (0.637 hectares of forest/capita), followed by a continuous increasing up to 0.708 hectares/capita in 1990, respectively 0.757 ha/capita in 2010.

We should not conclude (wrongly) with an improvement of the overall ecological state in the basin. The continuous increase in the value of this index between 1975-2010 is not due to the expansion

of forest areas (these being reduced with 1.23% during this period), but it is marked by the decline in the number of inhabitants. With regard to human pressure index through arable land use, in 2005 there were 0.76 hectares of agricultural land/capita, of which 0.22 hectares of orchards/capita, 0.45 hectares of pastures and hayfields/capita respectively 0.04 hectares of arable land/capita.

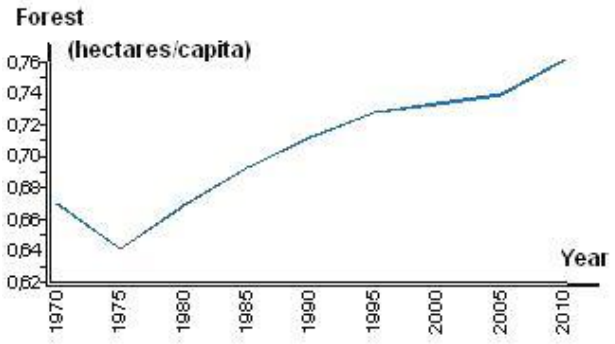

Fig. 3: The evolution of human pressure index on forest lands in the Bâsca Chiojdului river basin

2. The naturality index of the landscape

An analysis of environmental quality for the Bâsca Chiojdului river basin can not be conceived without calculating the naturality index. Speaking in percentages, it can have values between 0 and 100%. Clearly, the higher the value of this index is, the better the state of the analyzed space is from the ecological point of view.

In the Bâsca Chiojdului river basin the formula is applied as follows: Ni = [(172 840 862 m²) / (340 289 950 m²)] x 100 → Ni = 50.79

The mean value of the naturality index at the level of the whole river basin is 50.82%, almost double in comparison to the average at the national level, but insufficient if we refer to physical and geographical conditions of the analyzed area. Regarding the spatial distribution of this index, this records very large variations, ranging from 0% in the middle part of the basin (Starchiojd depression) and almost 100% (99.95%) in the north-west part of the basin, in the mountain area, where the degree of afforestation is very high.

The high values of the index between 80 and 100% are common in the northern part of the basin, in the mountain area, but local in the south part too, especially near the watersheds, where the relief is higher and more fragmented, the forest vegetation occupying large areas. Lower values, but above the basin average (between 50 and 80%), are common in the mountain areas from the northern part of the basin (at lower altitudes, near the main valley, but also at the contact with the Sub-Carpathians), but also in the Carpathian higher area from the southern part of the basin.

As far as the low values of the naturality index are concerned, (20-50%), these are found mainly in the Carpathian area in the centre and south part of the basin, on the slopes that guard the Starchiojd and Chiojdului depressions with or near the main valleys. Such values are found apart in the mountain area also, in the north-western extremity of the basin, at high altitudes, where the forest has been replaced by pastures, or in the lower sectors where deforestation has been made recently.

Very small values (critical) of the naturality index (between 0 and 20%) are found widely in the Chiojdului and Starchiojd depressions and locally in the bottom part of the basin, along the valley of the the Bâsca Chiojdului river. The worst is that in 10 analyzed sectors (1km ² each) the index is "0", the forest area is missing completely, and in other 8, the recorded values are below 1%. All these are found particularly in the Starchiojd depression and less in the Chiojdului depression.

Talking about the temporal dynamics of the naturality index, the massive deforestation carried out mainly in the last two centuries and especially in the middle part of the basin, gradually led to the decrease of this index, as time passed, it became an important indicator to characterize the environmental state of a region. The forest ecosystem, with its protective function on the environment, is the most important factor for maintaining the balance.

3. The environmental change index

The formula for environmental change index, Maruszczak version, for the Bâsca Chiojdului river basin applies as follows: Eci = (172 840 862 m² + 95 299 145 m²) / 7 907 198 m² → Eci = 33.92.

The use of this index is absolutely necessary to study human impact on the environment. While forests and grasslands (alpine and subalpine pastures, Sub- Carpathian grassland or hayfields) reflect the landscape naturalness, the built surfaces (industrial plants, buildings, lines of communication) are a factor of human change on the environment.

In the analysis of figure 4, areas with high values of this index may be identified (over 200), on relatively large areas in the mountain areas from the

northern part of the basin, but locally also in the higher Sub-Carpathian areas from the south and east of the basin. Low values of this index (below 10 and even below 1) are found in depression areas in the middle part of the basin, along the main valleys, especially the Sub-Carpathian valley of Bâsca Chiojdului. This index has several shortcomings. These derive from the fact that the formula equals forest spaces on the one hand and the meadows (Sub-Carpathian pastures, subalpine hayfields and pastures) on the other hand, given that it is a very big difference between ecological functions of the forest and the role played by the pastures and the hayfields.

It should also be kept in mind that the pastures (both those from the sub-Carpathian sector and the subalpine ones from the north part of the basin) are mostly secondary and are used as pastures and hayfields. Although they are oxygenized surfaces, they act as agro-ecosystems (artificial entities of the landscape), their self-regulation ability is little or does not exist at all and it is subordinated to the interests of human society (Armaş et al., 2003).

Applying the formula of the improved version of the environmental change index, at the level of the Bâsca Chiojdului river basin, it results: Eci = 172 840 862 m² / (150 344 917 m² + 7 907 198 m²) → Eci = 1.09

The distribution of this index values in each square kilometre of the basin shows strong contrasts between the mountain area from the northern part (where values above 5 appear frequently and even 100 in 7 cases) and the depressions in the central part of the basin, where the value is 0 in 13 cases and that happens due to the lack of forest in these areas (Fig. 4). High values of the index are recorded locally in the south part of the basin too, even above 100 nearby Salcia Peak. Small sub- unitary values are common not only in the depression area from the median part of the basin, but also along the main valleys, especially in the Sub-Carpathian sector of the Bâsca Chiojdului valley.

Both variants of the environmental change index (both Maruszczak version and the improved version) have some shortcomings in that not all forms of land use found in the analyzed area are taken into account.

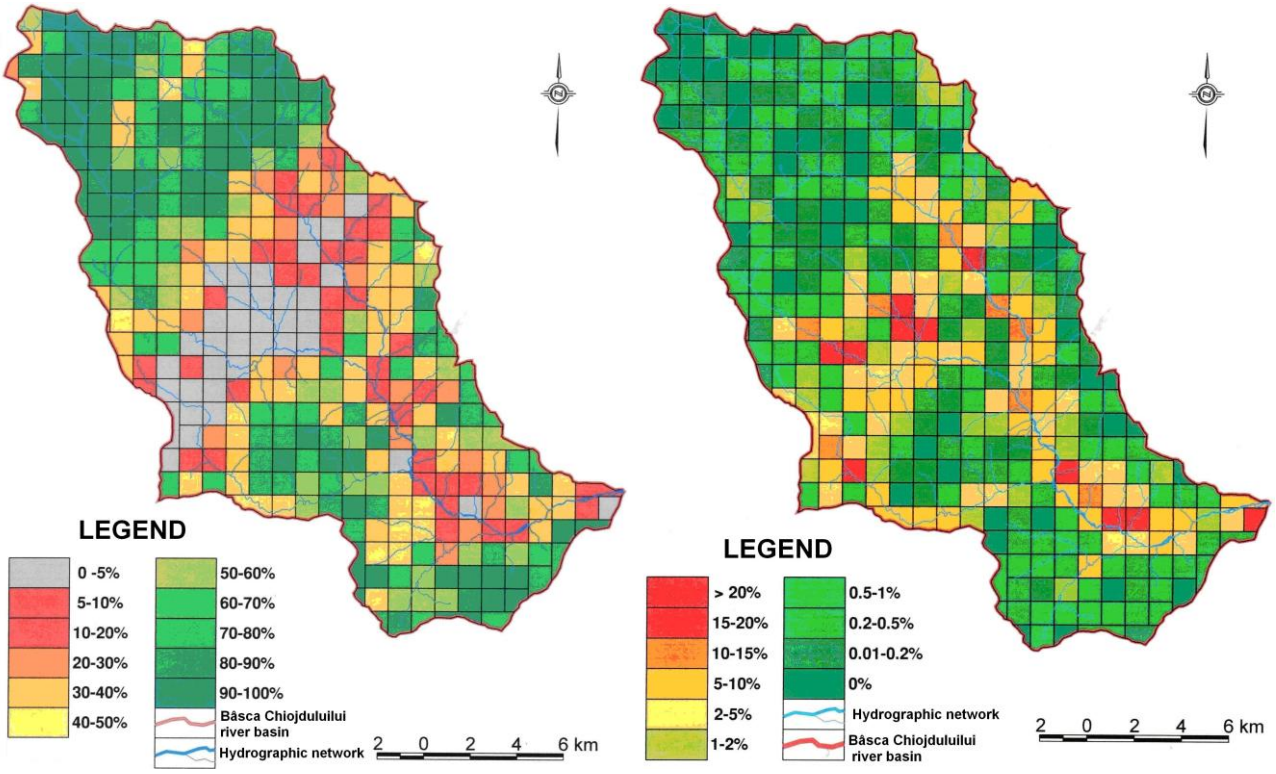

Fig. 4: Spatial dynamics for the values of environmental change index – completed version (left) respectively the arable land use (right) in the Bâsca Chiojdului river basin in 2005

They ignore two subclasses of the land use (aquatic areas, respectively the areas with poor vegetation - major river beds and degraded lands). Although such surfaces occupy small percentages within the Bâsca Chiojdului river basin (0.30% aquatic areas, 2.40% major river beds and degraded

land), they must be taken into account. Thus, aquatic areas (rivers or lakes) play a positive role in the ecosystem, being oxygenized surfaces and having a powerful role of thermal regulator. Major river beds, however, and the degraded lands too (whether of natural or anthropogenic origin) have a negative impact on the environment.

Orchards, pastures and hayfields, given that they have both a positive and a negative role, may be considered "neutral elements" in characterizing the environmental status of a region.

Applying the proposed formula for calculating the index of environmental change, the complete version for the analyzed basin is as follows: Eci = S (172 840 862 m² + 1 042 510 m²) / S (7 907 198 m² + 8 154 463 m²) → Eci = 10.83.

Thus, the average value of environmental change index calculated through the completed method is 10.83. As with the other two versions, big differences result between the minimum values recorded in the depressions in the central part of the basin (less than 0.1 in 14 sectors) and the maximum values recorded especially in the mountain area of the upper part of the basin, and also in the high areas from the lower part of the basin (above 1000 in 51 cases) (Fig. 5).

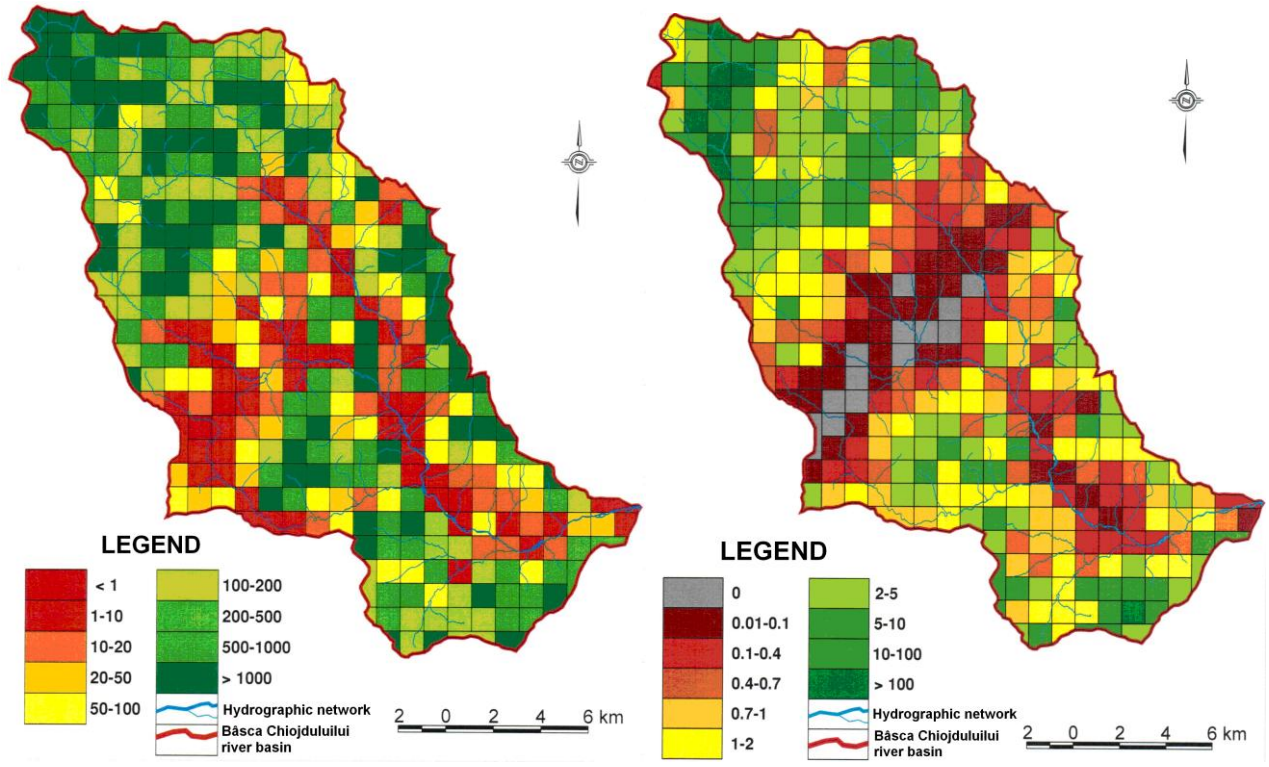

Fig. 5: Spatial dynamics for the values of environmental change index – Maruszczak version (left) and the improved version (right) in the Bâsca Chiojdului river basin in 2005

Conclusions

In terms of environmental quality, the results are similar in the Bâsca Chiojdului river basin regardless the calculated environmental index and the formula used. After analyzing the spatial and temporal dynamics of the environmental indices, the human pressure is increasing by expansion of the built areas and by interventions on the natural ecosystems.

The calculations lead to the conclusion that in the upper part of the basin, corresponding to the mountain area and locally in higher Sub-Carpathians areas, well wooded and with low anthropogenic impact, the environmental pressures are much lower than in the sub-mountain depressions from the median part of the basin (Chiojdului and especially Starchiojd) where the virtual absence of forests and the increased human pressure create a number of disruptions in the ecosystem. Strong environmental pressures also occur along the main valleys, especially on the lower course of Bâsca Chiojdului (Fig. 6). It is advisable, as necessary measures, the extension of the areas occupied by orchards, through planting fruit trees in the areas currently occupied by pastures or

hayfields. A priority should be the sloping lands, where the establishment of orchards would reduce the soil erosion. The climatic conditions should be also taken into account, being highly favourable to fruit trees. For the degraded lands with more accentuated declivity, afforestation works are necessary because orchards could not stop the geomorphologic slope processes.

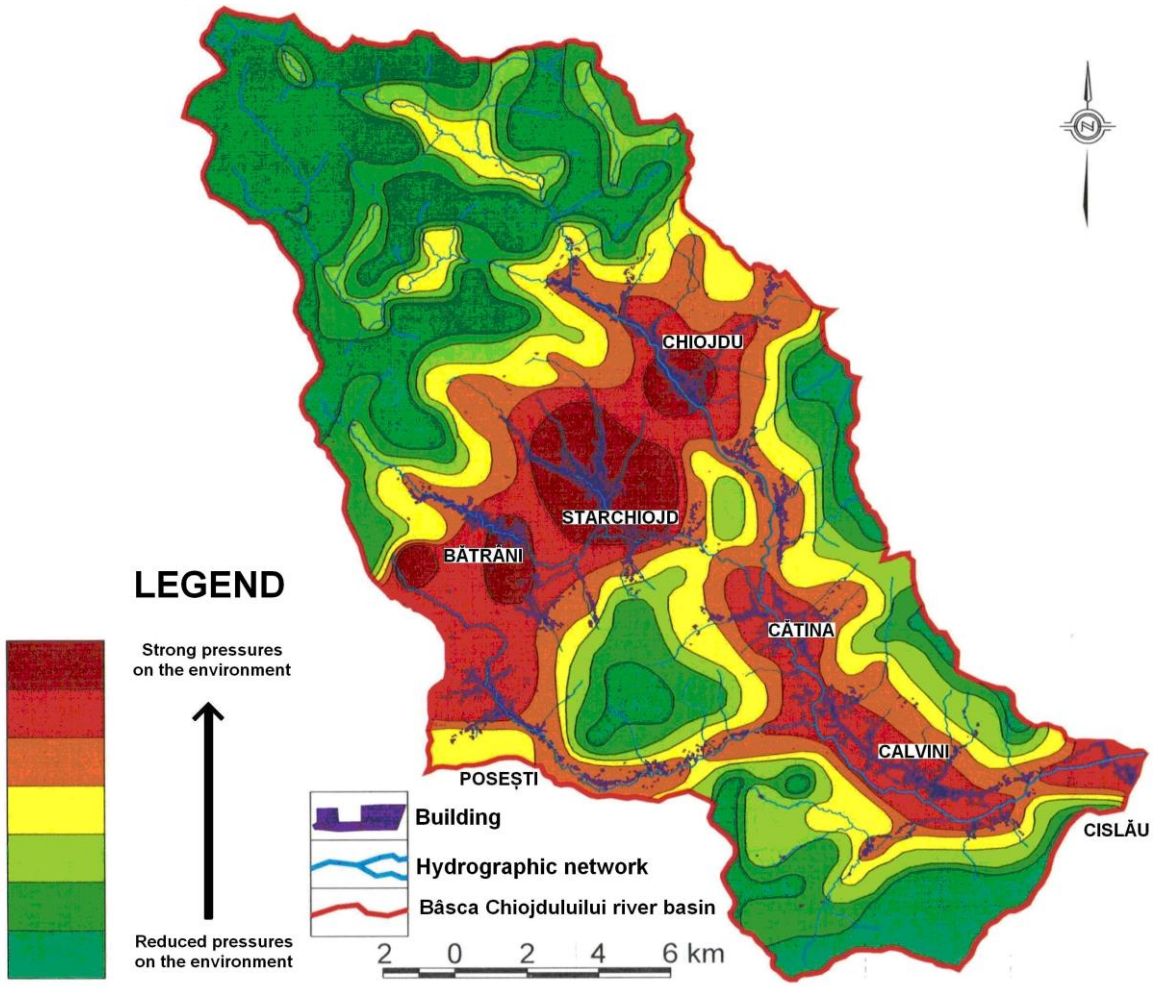

Fig. 6: Spatial dynamics of environmental quality in the Bâsca Chiojdului river basin in 2005

To control and reduce the negative environmental impact, the expansion of the growing stock is done through afforestation works. Expanding the forest areas would certainly have a positive impact on the environment due to the multiple role the forest exercises (air oxygenation, hydrological role, slopes setting etc.).

When the afforestation of the land is impossible for various reasons (ownership issues, financial difficulties, etc.), an effective solution is the establishment of orchards, knowing the fact that a mature and dense grove can achieve 70-80 % of the ecological role of a forest.

Acknowledgements

The research was achieved within the framework of a grant offered by the *Simion Mehedinți Doctoral School* (Faculty of Geography, University of Bucharest), project co-financed through the *Sectoral Operational Programme for Human Resources Development 2007-2013*, POSDRU/6/1.5/S/24/7546 Contract.

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