USING CORINE DATA TO LOOK AT DEFORESTATION IN ROMANIA: DISTRIBUTION & POSSIBLE CONSEQUENCES

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Abstract. Even though land cover and use changes, climate changes and altered use of energy, known together as the 'global changes' have been studied intensively, their relationships are still under debate, especially with respect of assessing the anthropogenic contribution. The study relies on the hypothesis according to which poverty and lack of environmental awareness could lead to disastrous environmental impacts, with adverse economic consequences. Starting from an assessment of deforestations based on CORINE data and the spatial distribution of floods and landslides, this study used spatial analyses, including kriging-based interpolation, to investigate the spatial pattern of deforestations and its relationships with the spatial distribution of floods, landslides, and natural protected sites. The results show that nearly 7.5 km2 of forests (0.81% of total forested area) were cut down during 1990-2000 and 5.7 (1.06%) during 2000-2006. The percentages of deforested areas per administrative unit ranged between 0 and 83.8 during 1990-2000 and between 0 and 95.9 during 2000-2006. The peaks of distribution coincide with the poorest areas, suggesting an inverse correlation between environmental awareness and poverty. Furthermore, the peaks of floods and landslides appeared to be surrounded by massively deforested areas; while spatial proximity cannot be solely used to ascertain causality, a certain correlation is suggested by the exploratory analyses. Last but not least, peaks of deforestation are situated within protected areas; since the protection status occurred later, these findings raise questions on the effectiveness of protection. Overall, while the limitations of spatial analyses do not allow from proving causality, the results show that deforestations could be the cause of floods and landslides, and certainly amplified their effects, supporting the underlying hypothesis.

Key words: climate change, natural hazards, GIS, poverty, natural protected sites.

1. Introduction

In their 2011 paper, Dale and colleagues introduced the term "global change" to refer all man-generated impact affecting the ecosphere, namely land use changes, climate change and energy use. Looking at the relationship between the first two, some authors looked at how much climate changes can be explained by modifications of land cover and use and how much is due to the emission of greenhouse gases (Kalnay and Cai, 2003; Mahmood *et al.*, 2010). Other authors explored the relationship between climate changes and land use alterations (Feddema *et al.*, 2005; Cheval *et al.*, 2011). Moreover, some authors argued that the evaluation of discernible human influence on global climate consider large-scale land changes that took place in early history and are in fact responsible for current climate changes (Pielke, 2005b). Scientists agree in general on the mechanisms of change; alterations of land cover and use modify the water cycle (Pielke, 2005b), carbon cycle (Dale, 1997; Pielke *et al.*, 2002; Olofsson *et al.*, 2005; Dale *et al.*, 2011) or energy flows (Pielke *et al.*, 2002), resulting ultimately in climate changes. For this reason, wise land management, also named "landscape design" (Dale *et al.*, 2011) could be seen as a means of adjusting to climate changes and reducing their effects (Thomas *et al.*, 2004; Medina and Tarlock, 2010; Dale *et al.*, 2011).

As it can be seen from the discussion above, the question whether climate changes are the result of man activity is still debated. According to Oreskes (2004), scientists attribute climate changes to human activities; in response, Pielke (2005a) argues the opposite, and their debate is going on. Studies carried out in Romania could not find sufficient evidence for a causal relation between predicted climate changes and land cover and use modifications from their spatial distributions (Petrişor, 2012b). While the debate on the exact nature of the phenomenon and causal implications did not lead to consensus, it is clear that different human activities can result into maximizing or minimizing the effects of natural hazards (Ashour, 2012; Cordoneanu *et al.*, 2012).

The analysis of recent flash floods in Romania suggests that deforestations could be a possible cause, and certainly amplified their effects (Barbu *et al.*, 2009; Popescu *et al.*, 2010; Romanescu and Nistor, 2011). In the Atlas of Romania, Rey *et al.* (2000) present the maps of forests in 1930 and 1976. There is no doubt that their total area decreased. Roman (2009) considers that deforestations due to the change of ownership from the state to people who reclaimed their property constitute a true 'drama'. Previous studies of land cover and use changes in Romania place deforestations among the most important ones due to their extent and consequences (Ursu *et al.*, 2007; Lawrence, 2009; Dutcă and Abrudan, 2010; Mortan, 2011; Petrişor, 2012a; Costea, 2013).

Many authors argue that environmental issues, derived from the lack of environmental awareness, are a consequence of poverty or at least directly associated to it (Reichel-Dolmatoff, 1982; Rozelle *et al.*, 1997; Jehan and Umana, 2003), particularly in developing countries, which lack the respect for environment (Leonard and David, 1981; Ianoş *et al.*, 2009) or do not see environmental resources as a means to reducing poverty through sustainable use (Hope *et al.*, 2005). This article relies on the hypothesis according to which poverty associated with the lack of environmental awareness could lead to disastrous impacts on the environment, which at their turn determine adverse consequences with negative economic impact. In more details, forests that were cut off to ensure the short-term subsistence lead to floods and landslides, or at least amplified their effects.

Starting from this hypothesis, the study developed three research questions:
(1) *What is the spatial pattern of deforestations in Romania, and which are the areas mostly affected?* The answer is a map showing the levels of deforestation intensity, pinpointing the most affected areas.
(2) *Is there any spatial relationship between the distribution of deforestation and those of areas at risk for floods and landslides?* The possible answer, obtained through spatial analyses, consists of the possible spatial association of intense deforestation and adverse outcomes.

(3) *Is there any spatial relationship between the distribution of deforestation and the position of natural protected sites?* The question is aimed at the possibility of conserving forests by conferring them a protection status or, if this status already existed, to assess the efficiency of conservation.

2. Data and methods

The study aimed at answering three research questions:

(1) *What is the spatial pattern of deforestations in Romania, and which are the areas mostly affected?* For this reason, the methodology aimed first at mapping the raw data, aggregated at the level of administrative units, and then at interpolating the raw data via simple kriging to find the most affected regions.

(2) *Is there any spatial relationship between the distribution of deforestation and those of areas at risk for floods and landslides?* In this case, the distributions were overlapped to find the spatial relationships.

(3) *Is there any spatial relationship between the distribution of deforestation and the position of natural protected sites?* In this case, there were two issues. One criterion in declaring natural protected areas is their pristine conditions. Declaring natural protected areas in deforested areas would be inefficient. The issue is whether (illegal) deforestations occurred within these protected areas after their decoration. The second question cannot be easily answered, as the last year covered by data is 2006, and most protected areas were declared in 2007, when the legislation was changed. Both issues can be answered overlapping the two spatial distributions.

To achieve the research goals, the study has used several free datasets and images, included in Table 1. The table lists additional details, such as the provider, format and transformations used in each case, as well as the URL where each dataset can be found. Mainly, the datasets referred to land cover and use and their changes and natural protected sites of national importance. Images were part of the National Spatial Plan (Parliament of Romania, 2001). The methodology consisted of the following steps:

1. *Identification of forests*. Forests were defined based on the CORINE classification as items belonging to level 3 classes 311 (broad-leaved forests), 312 (coniferous forests), and 313 (mixed forests).

2. *Identifying deforested areas*. These were defined again based on CORINE classification as any transformation of an area classified as belonging to level 3 classes 311, 312, 313 in any other class at the end of the period. This is different from the method used by Dutcă and Abrudan (2010), who considered that only land cover changes constitute evidence for deforestation, while land use changes indicate the degradation of forests.

3. *Intersection* between deforested areas/areas covered by forests and administrative limits. This method was used to determine the forested area and changes contained within the territorial limits of each administrative unit.

4. *Computation of the surface* of each parcel covered by forests or affected by deforestation using the X-Tools extension.

5. Using the Spatial Analyst extension to *dissolve* the contours of forested and deforested areas within each administrative unit, while *computing their total area*.

6. Computing the percentage of deforestation per administrative using in Excel using the formula:

$$\text{Percentage of deforestation} = \frac{100 \times \text{Deforested area}}{\text{Deforested area} + \text{Area covered by forests in the end of the period}}$$

The percentage was mapped for each administrative unit; the five classes used to build graduated color (choloropleth) maps were determined using quantiles.

7. Using the X-Tools extension to create a dataset reducing each polygonal surface corresponding to an administrative unit to its *geometrical center*, preserving all numerical values
8. *Spatial interpolation via simple kriging* using the centers of administrative units and values of the percentage of deforestation using the Geostatistical Analyst in ArcGIS 9.X. The classes were determined using exactly the same quantile-based limits as for the administrative units.
9. *Overlapping* the kriging maps and maps from the national spatial plan showing the areas at risk for floods and landslides
10. *Overlapping* the kriging maps over the combined limits of all natural protected sites of national interests and limits of the Carpathian Convention.

3. Results and discussion

The study aimed to analyze: (1) the spatial pattern of deforestations, (2) their spatial relationship with areas at risk for floods and landslides, and with (3) the natural protected sites. To answer the first question, results show that nearly 7.5 km² of forests, representing 0.81% of total forested area, were cut down during 1990-2000 and 5.7, representing 1.06%, during 2000-2006. The percentages of deforested areas per administrative unit ranged between 0 and 83.8 during 1990-2000 and between 0 and 95.9 during 2000-2006.

The spatial distribution per administrative unit is shown in Fig. 1. Generalized results of spatial interpolation via simple kriging are shown in Fig. 2. The analysis of distribution reveals similarities between the pattern found during 1990-2000 and the one identified for the next period. In fact, differences were not expected, as the spatial pattern of deforestations coincides with the distribution of forests, with peaks over the mountain area. The kriging-based interpolation pinpoints three areas. One is situated at the limit of North-East and North-West regions of development, coinciding with the poorest area of Romania, supporting the hypothesis according to which environmental awareness and poverty are inversely correlated. The findings are similar to those obtained by Petrişor *et al.*, (unpublished), and Oişte and Breabăn (2011a, b) at different spatial scales. This area is the most important one for both periods.

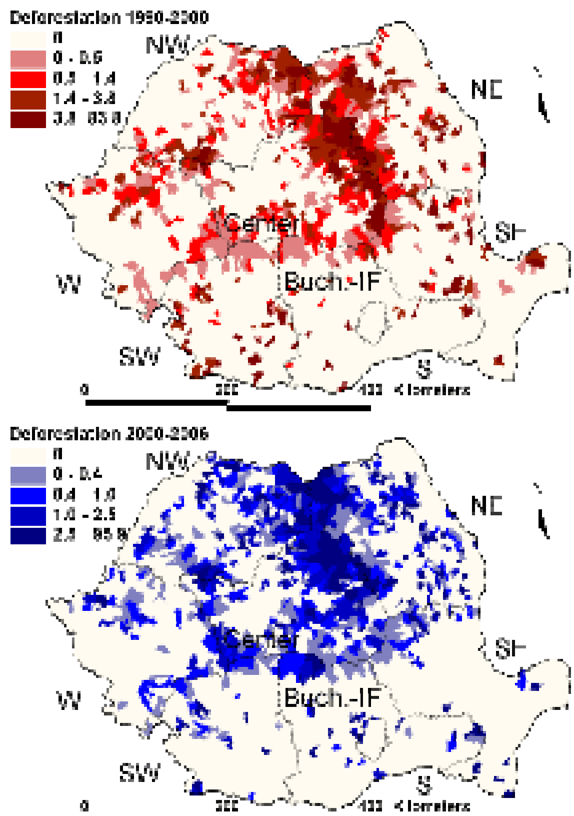

Fig. 1. Distribution of deforested areas by administrative units in Romania during 1990-2000 (top) and 2000-2006 (bottom) based on CORINE data.

A second area, found in both periods, is Dobrudja and may also be related to the development of tourism and infrastructure in the seaside area. A third and last area is found in the South-West region of development, known also for its poverty, supporting the aforementioned hypothesis. However, it is visible mostly during the first period. The third spot can also be correlated with the ongoing desertification of the area (Peptenatu *et al.*, 2013).

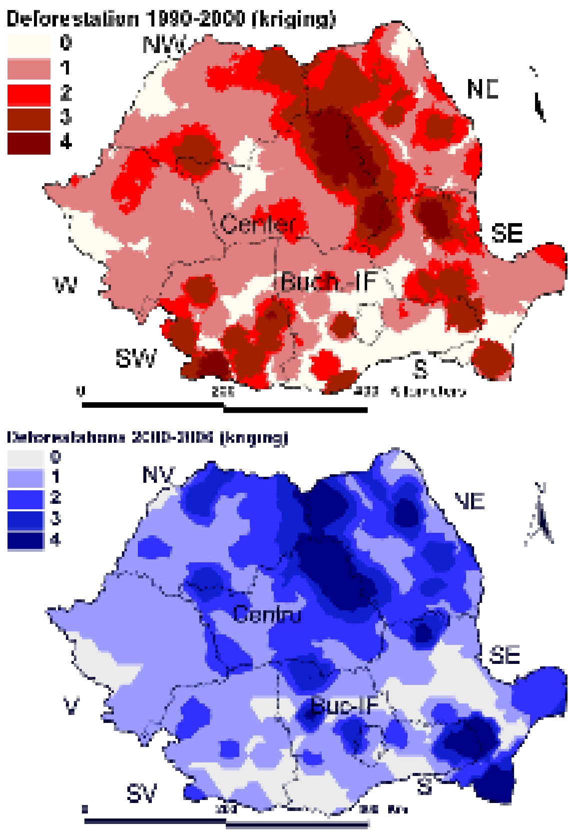

Fig. 2. Kriging-based interpolated distribution of deforested areas regardless of administrative limits in Romania during 1990-2000 (top) and 2000-2006 (bottom) based on CORINE data mapped against the distribution of floods, as published in the law approving the National Spatial Plan. The four levels (0-4) of deforestation correspond to the percentages in Fig. 1.

The second research question looked at the relationship between deforestations and floods or landslides. The latest two distributions were based on the official maps contained in the specialized section of the National Spatial Plan, approved by law. Fig. 3 shows the overlaid distribution of deforestations and floods, and Fig. 4 the overlaid distribution of deforestations and landslides. The relationship is not direct, meaning that the peaks of deforestation do not coincide with the peaks of floods or landslides, but certain proximity can easily be discerned. Areas mostly affected by all types of floods or landslides appear to be surrounded by peaks of deforestation. The same pattern can be seen in all the four maps, suggesting that the peaks of floods or landslides could be related by the spatial proximity of (and containment within) areas affected by floods or landslides; this is particularly visible for the 'hotspots' located around Alba and Bacău (for floods) and Cluj Napoca and Buzău (for landslides).

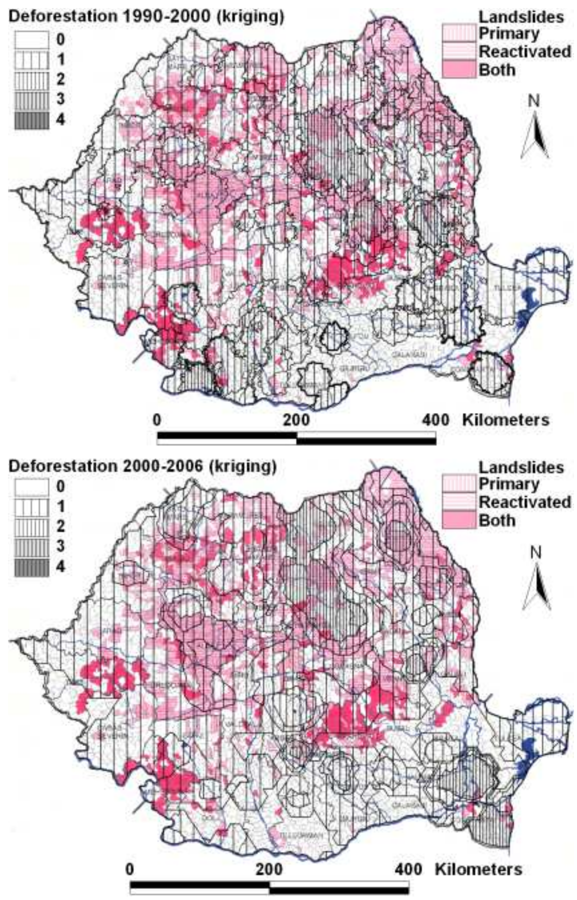

Fig. 3. Kriging-based interpolated distribution of deforested areas regardless of administrative limits in Romania during 1990-2000 (top) and 2000-2006 (bottom) based on CORINE data. The four levels (0-4) correspond to the percentages in Fig. 1.

The third and final research question regarded the spatial relationship between deforestation and conservation through the national system of natural protected sites. The results are displayed in Fig. 5. The image shows all protected areas of national importance, and the limits of applying the Carpathian Convention. This document, even though it does not have the power of laws, attempts to confer the mountain areas a special status, due to their fragility and European importance (Popescu and Petrişor, 2010). The results show that the peaks of deforestation coincide with the limits of the two. As shown in the methodological section, due to the age of data the coincidence is mostly due to the fact that forest cuts occurred prior to the declaration of protected areas. Illegal cuts occurring after this moment cannot be assessed using the available datasets. However, these findings raise questions related to the effectiveness of protection, given that the areas were no longer in a pristine state.

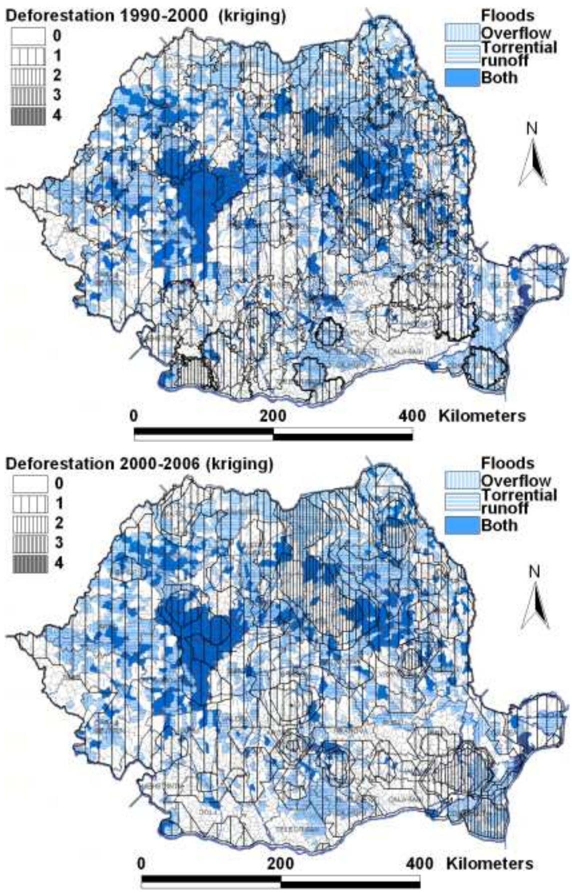

Fig. 4. Kriging-based interpolated distribution of deforested areas regardless of administrative limits in Romania during 1990-2000 (top) and 2000-2006 (bottom) based on CORINE data mapped against the distribution of landslides, as published in the law approving the National Spatial Plan. The four levels (0-4) of deforestation correspond to the percentages in Fig. 1.

The main limitations of this study are:

(1) *Causality*. The main limitation of spatial analysis is that it is an exploratory (and not confirmatory) technique and consequently it cannot ascertain causality when used alone. However, the results can constitute arguments supporting a causal relationship, if they are confirmed by additional ancillary data

(2) *Data*. CORINE data cover a large area and consequently cannot be updated too often. For this reason, they are particularly useful and relevant for analyzing changes covering large areas and occurring at large time intervals (Petrişor, 2011). Moreover, the methodology of producing these data changed, and computations based on them could lead to spurious results.

(3) *Spatial analysis*. The results of interpolation tend to over-generalize, and due to this reason they should not be interpreted as precise geographical limits, lacking any relevance as territorial boundaries (Petrişor, 2012b).

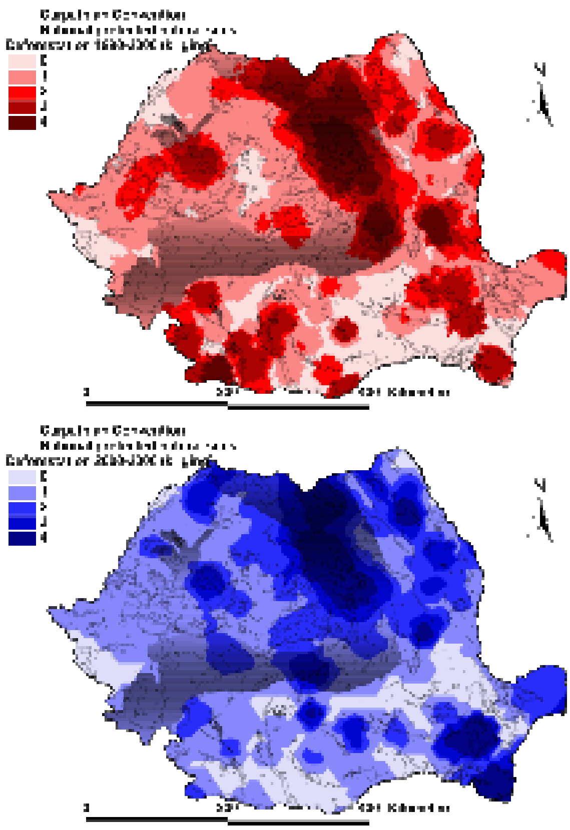

Fig. 5. Kriging-based interpolated distribution of deforested areas regardless of administrative limits in Romania during 1990-2000 (top) and 2000-2006 (bottom) based on CORINE data mapped against the distribution of natural protected sites of national importance and limits of the Carpathian Convention. The four levels (0-4) of deforestation correspond to the percentages in Fig. 1.

4. Conclusions

This study started from the hypothesis according to which poverty and lack of environmental awareness could lead to disastrous environmental impacts, which at their turn determine adverse economic consequences. The coincidence of most intensely deforested areas with the poorest regions confirmed partially the underlying hypothesis. Apart from it, the analysis of the spatial pattern of deforestations showed that the peaks of floods and landslides were surrounded by deforestation peaks, suggesting possible correlations, and also a coincidence between deforestation peaks and natural protected sites, showing the ambiguity of the conservation status.

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