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## TRANSITIONAL DYNAMICS BASED TREND ANALYSIS OF LAND COVER AND USE CHANGES IN ROMANIA DURING 1990-2012

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**Key words:** deforestation, agricultural abandonment, urbanization, transition, unplanned development.

**Abstract.** Land cover and use changes, part of the ‘global changes’, are important for the global sustainability and resilience through their negative impacts on ecosystem services and biodiversity, and on the human welfare. In Eastern Europe in general and Romania in special, property restitution was a main driver of change. This study aimed to look at the land cover and use changes in Romania by their transitional dynamic using CORINE data in an attempt to identify the long-term consistent trends. The results show that deforestation and urbanization are more prominent, and the development of agriculture slows down, reflecting the consequences of an unplanned development and low environmental care. The hotspots concentrating land cover and use changes are characteristic to ex-socialist transition countries.

### Introduction

Three types of changes affect the global environment - land cover and use changes, climate changes, and alterations of global energy flows, composing together the ‘global changes’ (Dale, 2011; Faeth and Hanson, 2016).

Land cover and use changes are central to the sustainable development debate (Lambin *et al.*, 2000) through their effects against the natural systems (Elias *et al.*, 2012), but also their contribution to climate change and increase of the frequency of infectious diseases (Foley *et al.*, 2005). As a consequence, they affect the level of ecosystem services (Metzger *et al.*, 2006; Li *et al.*, 2007; Tianhong *et al.*, 2010), global sustainability and food security (Verburg *et al.*, 1999) and can change the

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cultural landscapes (Kuemmerle *et al.*, 2008; Xiao *et al.*, 2006). Nevertheless, transitions in land use are multiple and reversible dynamics (Lambin and Meyfroidt, 2010).

In Romania land cover and use changes were determined by socio-economic and political drivers (Fraser and Stringer, 2009). Several studies were carried out at regional and national scales (Ianoş *et al.*, 2011; Petrişor, 2012a, b, 2015a, b, 2016, 2017c; Petrişor and Petrişor, 2015, 2017; Petrişor *et al.*, 2010, 2014; Popovici *et al.*, 2013), with different aims, focus and methodologies. Their common element is the analysis of land cover and use changes through their associated transitional dynamics. The results pinpointed the main transitional dynamics characteristic to Romania, but also to transition economies, consisting of few antagonistic phenomena: development and abandonment of agriculture, deforestation and forestation, urbanization and other minor causes, such as the construction of dams, draughts and unidentified changes.

This study aims to explore whether the three periods covered by CORINE land cover and use data (1990-2000, 2000-2006, and 2006-2012) show any spatially consistent trends of the transitional dynamics associated to the land cover and use changes in Romania.

### **1. Data and methods**

Land cover and use changes were assessed using several methods, such as the Integrated Spatial Decision Support Systems - which also embed economic models (van Delden and McDonald, 2010), old maps using in conjunction with soil mapping (Stângă and Niacşu, 2016). However, they are hard to monitor without geospatial technology and data (Xiao *et al.*, 2006; Li *et al.*, 2007; Osaci-Costache *et al.*, 2015; Dulamă and Ilovan, 2017).

CORINE land cover and use changes data are freely provided through the European Environment Agency (<http://www.eea.europa.eu/data-and-maps/>) for 1990-2006 and through the Copernicus Land Monitoring Service (<http://land.copernicus.eu/pan-european/corine-land-cover/lcc-2006-2012/view>) for 2006-2012 in a shape file format, usable by ArcView/ArcGIS. The projection is ETRS 1989 Lambert Azimuthal Equal Area L52 M10. In order to use the data and draw the maps, the data needed to be re-projected unto Stereo 1970.

The classification scheme is a mixture of the ones used in the previous studies (Ianoş *et al.*, 2011; Petrişor, 2012a, b, 2015a, b, 2016, 2017c; Petrişor and Petrişor, 2015, 2017; Petrişor *et al.*, 2010, 2014), serving better the purpose of a general overview at the national scale; the following transitional dynamics were defined:

**1. Urbanization:** reflects the transformation of agricultural, natural, wetland or water areas in urban areas or urban changes indicating the urban development within the city limits

2. Forestation: ‘forests’ are CORINE classes 3.1.1 (coniferous forests), 3.1.2 (broadleaved forests), and 3.1.3 (mixed forests); forestation, embedding afforestation and reforestation (Dutcă and Abrudan, 2010), represents the transformation of urban, agricultural, wetland or water areas into forests, including the colonization of abandoned agricultural land into forests (Agnoletti *et al.*, 2011; Blakesley, 2006; Petrișor *et al.*, 2014; Van Uytvanck, 2009), and transformation of other natural categories into forests

3. Deforestation: refers to the transformation of forests into other natural elements

4. Development of agriculture: includes the transformation of urban, natural, wetland or water areas into agricultural ones, and transformations of agricultural areas indicating the development of agriculture

5. Abandonment of agriculture: consists of transformations of agricultural areas indicating the abandonment of agriculture

6. Floods: represents the transformation of urban, agricultural, or natural areas into wetlands or waters

7. Others – other transformations, such as the construction of dams, draughts or unknown transformations, affecting lesser areas

After representing the data, the concentration of changes around several hotspots was noticed. Contours were drawn approximately around each hotspot, and the contours were used to select the administrative units concentrating land cover and use changes over their territory. 20 hotspots were defined by dissolving the contours of adjacent territorial units, and for each of them a geographical analysis, aimed to identify the real region, was carried out. In addition, areas were tabulated within each hotspot for each period and transitional dynamic.

## 2. Results and discussion

The spatial distribution of land cover and use changes produced in Romania during 1990-2012 is showed in Fig. 1.

The image shows that the area affected by changes tends to decrease in time, but also allows, by concentrating the changes occurred over all the three periods, for pinpointing several ‘hotspots’. Although changes occurred in different periods and over large areas, it is relatively easy to see that they cluster around large urban centers or regions, corresponding to the 20 hotspots identified (Fig. 2); for each of them, Table 1 presents the main transitional dynamics characteristic to each period, pinpointing the dominant ones based on their share.

The 20 hotspots are:

- a. The area of Padeș – Gilău – Muntele Mare mountains, known for the metal exploitations (Borcoș and Udubașa, 2012). However, the main transitional dynamic characteristic to this area is represented by deforestation, which is common to the mountain areas (Kuemmerle *et al.*, 2007; Hostert *et al.*, 2008; Müller and Munroe, 2008; Roman, 2009; Knorn *et al.*, 2012; Petrișor, 2012a, 2015b; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Vanonckelen and Van Rompaey, 2015);
- b. The mining area Motru-Rovinari, characterized by the urban sprawl in the first two periods, and also by floods and forestation in the first one. The first trend is paradoxical, as it indicates the growth of a disadvantaged area against the general trend (Braghină *et al.*, 2008a, b, 2009; Cuculici *et al.*, 2011). Forestations are most likely the natural re-colonization or ecological restoration of abandoned mining areas (Ianoș, 2000; Petrișor *et al.*, 2010).
- c. The mining area Petroșani, characterized by deforestation, common to the mountain areas (Kuemmerle *et al.*, 2007; Hostert *et al.*, 2008; Müller and Munroe, 2008; Roman, 2009; Knorn *et al.*, 2012; Petrișor, 2012a, 2015b; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Vanonckelen and Van Rompaey, 2015) and, only during the first period, by forestations resulting most likely from the natural re-colonization or ecological restoration of abandoned mining areas (Ianoș, 2000; Petrișor *et al.*, 2010).
- d. Oriental Carpathians, characterized only by the most massive aforestation (Kuemmerle *et al.*, 2007; Hostert *et al.*, 2008; Müller and Munroe, 2008; Roman, 2009; Knorn *et al.*, 2012; Petrișor, 2012a, 2015b; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Vanonckelen and Van Rompaey, 2015)
- e. The north of Moldova – considered the poorest region of the European Union, but with an increasing population (Camară, 2011), the area was characterized by abandonment of agriculture in the first period, most likely due to the increased emigration and loss of working population (Müller and Munroe, 2008; Müller *et al.*, 2009; Sikor *et al.*, 2009; Prishchepov *et al.*, 2013; Petrișor *et al.*, 2014), and deforestation of the mountain areas (Kuemmerle *et al.*, 2007; Hostert *et al.*, 2008; Müller and Munroe, 2008; Roman, 2009; Knorn *et al.*, 2012; Petrișor, 2012a, 2015b; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Vanonckelen and Van Rompaey, 2015) and urbanization during the second one.
- f. The area of Sibiu, characterized by the abandonment of agriculture in the first period, most likely as a result of the migration of the population (Müller and Munroe, 2008; Müller *et al.*, 2009; Sikor *et al.*, 2009; Prishchepov *et al.*, 2013; Petrișor *et al.*, 2014, particularly of the Saxon descendants to Germany

- (Constantin *et al.*, 2004), deforestation in the second one, and urbanization – probably a consequence of the “Cultural Capital” status of 2007 (Stoica and Chirodea, 2015), deforestation, and forestation – most likely through the colonization of abandoned agricultural land by shrubs (Garcia-Ruiz *et al.*, 1996; Kuemmerle *et al.*, 2006; Václavík and Rogan, 2009) – in the latest one
- g. The area of Reghin – Mureș county, characterized by a massif abandonment of agriculture in the most recent period (Müller and Munroe, 2008; Müller *et al.*, 2009; Sikor *et al.*, 2009; Prishchepov *et al.*, 2013; Petrișor *et al.*, 2014)
  - h. South of Moldova, characterized in the first period by the abandonment of agriculture due to the migration of the work force (Müller and Munroe, 2008; Müller *et al.*, 2009; Sikor *et al.*, 2009; Prishchepov *et al.*, 2013; Petrișor *et al.*, 2014), and in the next two by the deforestation of the mountain areas (Kuemmerle *et al.*, 2007; Hostert *et al.*, 2008; Müller and Munroe, 2008; Roman, 2009; Knorn *et al.*, 2012; Petrișor, 2012a, 2015b; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Vanonckelen and Van Rompaey, 2015; Andronache *et al.*, 2016; Drăghici *et al.*, 2017; Dulamă and Ilovan, 2017; Pintilii *et al.*, 2017)
  - i. Canals of Danube and Hârșova Canals, characterized in the first period by the abandonment of agriculture most likely in relationship to the protection status (Petrișor *et al.*, 2016), but also due to the migration of the work force (Müller and Munroe, 2008; Müller *et al.*, 2009; Sikor *et al.*, 2009; Prishchepov *et al.*, 2013; Petrișor *et al.*, 2014)
  - j. Danube Delta – area of Pardina and Ceatalchioi fisheries, affected by floods in the first and third period, and reforested in the second period, most likely through the colonization of agricultural land abandoned due to the protection status (Petrișor *et al.*, 2016), by shrubs (Garcia-Ruiz *et al.*, 1996; Kuemmerle *et al.*, 2006; Václavík and Rogan, 2009)
  - k. Black Sea seaside – Constanța: tourism determined an increase of the land value with respect for the constructions sector (Grigorescu *et al.*, 2012a, b); people who received their property as a consequence of the property restitution (Davis, 1996; Kuemmerle *et al.*, 2006; Hostert *et al.*, 2008; Müller and Munroe, 2008; Kuemmerle *et al.*, 2008, 2009; Müller *et al.*, 2009; Sikor *et al.*, 2009; Václavík and Rogan, 2009; Bălțeanu and Popovici, 2010; Hostert *et al.*, 2011; Petrișor, 2012a, 2015a; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Prishchepov *et al.*, 2013; Bičík *et al.*, 2015; Vintilă *et al.*, 2017a, b) were not interested in using it for agriculture, but hoped to make easier money selling it to real estate investors (Rusu *et al.*, 2011)
  - l. Rucăr – Bran – Moieciu area, characterized by deforestation in the second period, like most mountain regions (Kuemmerle *et al.*, 2007; Hostert *et al.*, 2008; Müller and Munroe, 2008; Roman, 2009; Knorn *et al.*, 2012; Petrișor, 2012a, 2015b; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Vanonckelen and

- Van Rompaey, 2015). Similar to the Black Sea, tourism increased the land price (Rusu *et al.*, 2011) and agricultural land, most likely restituted, was abandoned (Davis, 1996; Kuemmerle *et al.*, 2006; Hostert *et al.*, 2008; Müller and Munroe, 2008; Kuemmerle *et al.*, 2008, 2009; Müller *et al.*, 2009; Sikor *et al.*, 2009; Václavík and Rogan, 2009; Bălteanu and Popovici, 2010; Hostert *et al.*, 2011; Petrișor, 2012a, 2015a; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Prishchepov *et al.*, 2013; Bičík *et al.*, 2015)
- m. Former mining area Oravița – Anina was affected by the abandonment of agricultural land in the first period, most likely due to the increased emigration and loss of working population (Müller and Munroe, 2008; Müller *et al.*, 2009; Sikor *et al.*, 2009; Prishchepov *et al.*, 2013; Petrișor *et al.*, 2014), characteristic to other former mining centers (Ianoș, 2000; Petrișor *et al.*, 2010), by deforestation and urbanization in the second, and by floods in the most recent. Deforestation could be due to a re-orientation of economic activities after the loss of the primary mining function (Ianoș, 2000)
- n. Brașov area – each period is characterized by a certain dynamic; urbanization occurs in the first period, as a consequence of tourism (Popescu and Corbos, 2010); tourism increases land price and agricultural land, most likely restituted, is abandoned in the second period (Davis, 1996; Kuemmerle *et al.*, 2006; Hostert *et al.*, 2008; Müller and Munroe, 2008; Kuemmerle *et al.*, 2008, 2009; Müller *et al.*, 2009; Sikor *et al.*, 2009; Václavík and Rogan, 2009; Bălteanu and Popovici, 2010; Hostert *et al.*, 2011; Petrișor, 2012a, 2015a; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Prishchepov *et al.*, 2013; Bičík *et al.*, 2015); in the third period, abandoned agricultural land is colonized by shrubs (Garcia-Ruiz *et al.*, 1996; Kuemmerle *et al.*, 2006; Václavík and Rogan, 2009)
- o. Southern Oltenia – Dăbuleni, characterized by the development of agriculture in the most recent period and deforestations in the first one; as a matter of fact, the history of the processes differ; the area, prone to aridity (Dragotă *et al.*, 2011) was forested before 1990 to help the development of agriculture (Dumitrașcu *et al.*, 2014) deforestations occurred after the property restitution (Kuemmerle *et al.*, 2007; Hostert *et al.*, 2008; Müller and Munroe, 2008; Roman, 2009; Knorn *et al.*, 2012; Petrișor, 2012a, 2015b; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Vanonckelen and Van Rompaey, 2015); recognizing that the deforestation, combined with the natural aridity, can have strong negative consequences, efforts, made through policies, were able to re-launch the agricultural activity (Simulescu and Zamfir, 2015)
- p. Bucharest – Ilfov region is a typical example of sub-urban development in the metropolitan areas (Pauchard *et al.*, 2006; Václavík and Rogan, 2009; Grigorescu *et al.*, 2012a, b; Petrișor, 2012b, 2017a, b; Kupková *et al.*, 2013; Ianoș *et al.*, 2016), and is characterized by urbanization, and, to a little extent,

by deforestation; the later is still related to urbanization, and relates to the restitution of forests (Kuemmerle *et al.*, 2007; Hostert *et al.*, 2008; Müller and Munroe, 2008; Roman, 2009; Knorn *et al.*, 2012; Petrișor, 2012a, 2015b; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Vanonckelen and Van Rompaey, 2015) in conjunction with the increase of land price by the real estate developing (Rusu *et al.*, 2011); forests were cut off to make room for large-scale residential estates

- q.* Iași area is affected by deforestation, development of agriculture and forestation in the first period. This dynamic relates to the fact that the area around Iași is the only developing one in the poorest region of Romania (Camară, 2011); the dynamic is explained by forest and agricultural land restitution (Davis, 1996; Kuemmerle *et al.*, 2006; Hostert *et al.*, 2008; Müller and Munroe, 2008; Kuemmerle *et al.*, 2007, 2008, 2009; Müller *et al.*, 2009; Sikor *et al.*, 2009; Václavík and Rogan, 2009; Bălțeanu and Popovici, 2010; Hostert *et al.*, 2011; Knorn *et al.*, 2012; Petrișor, 2012a, 2015a, b; Prishchepov *et al.*, 2013; Kupková *et al.*, 2013; Petrișor *et al.*, 2014; Bičík *et al.*, 2015; Vanonckelen and Van Rompaey, 2015); forests are cut to obtain more agricultural land, which is abandoned and colonized by shrubs (Garcia-Ruiz *et al.*, 1996; Kuemmerle *et al.*, 2006; Václavík and Rogan, 2009). In the second period, the trend continues, but agricultural land is abandoned as population moves to Iași, and urbanization occurs in the metropolitan area (Iurea and Braghină; Petrișor, 2017a, b), a characteristic of Eastern-European urbanization (Pauchard *et al.*, 2006; Václavík and Rogan, 2009; Grigorescu *et al.*, 2012a, b; Petrișor, 2012b; Kupková *et al.*, 2013)
- r.* Maramureș – Someș plain and hills: the area is characterized by the development of agriculture in the first and last period, and by deforestations, characteristic also to the sub-Carpathians, occurred after the property restitution (Kuemmerle *et al.*, 2007; Hostert *et al.*, 2008; Müller and Munroe, 2008; Roman, 2009; Knorn *et al.*, 2012; Petrișor, 2012a, 2015b; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Vanonckelen and Van Rompaey, 2015) in the intermediary one
- s.* Maramureș – Lăpuș area is also characterized by deforestations occurred after the property restitution (Kuemmerle *et al.*, 2007; Hostert *et al.*, 2008; Müller and Munroe, 2008; Roman, 2009; Knorn *et al.*, 2012; Petrișor, 2012a, 2015b; Petrișor *et al.*, 2014; Kupková *et al.*, 2013; Vanonckelen and Van Rompaey, 2015) in the first two periods
- t.* Arad area is characterized by the sub-urbanization of metropolitan areas (Pauchard *et al.*, 2006; Václavík and Rogan, 2009; Grigorescu *et al.*, 2012a, b; Petrișor, 2012b, 2017a, b; Kupková *et al.*, 2013) in the first two periods, but also to deforestations related to it in the second period

**Table 1.** Main transitional dynamics within the hotspots characterized by intense land cover and use changes during 1990-2012, based on CORINE data. The table displays the share of each transitional dynamic from the total per period. Shaded values are the largest.

Hotspot	Period (1)	Transitional dynamic (2)						
		1	2	3	4	5	6	7
1	3	0	0	12	88	0	0	0
	2	0	0	0	100	0	0	0
	1	0	0	15	85	0	0	0
2	3	0	0	0	0	100	0	0
	2	0	0	0	0	100	0	0
	1	14	0	29	0	29	29	0
3	3	0	0	0	100	0	0	0
	2	0	0	0	100	0	0	0
	1	0	0	50	50	0	0	0
4	3	0	0	8	92	0	0	0
	2	0	0	2	98	0	0	0
	1	5	4	29	62	0	0	0
5	3	0	0	0	0	0	0	0
	2	12	12	0	38	38	0	0
	1	45	18	28	10	0	0	0
6	3	0	0	33	33	33	0	0
	2	0	0	0	100	0	0	0
	1	39	30	17	13	0	0	0
7	3	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	1	78	0	22	0	0	0	0
8	3	20	0	0	40	20	0	20
	2	20	20	0	40	20	0	0
	1	52	8	24	8	2	2	6
9	3	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	1	90	0	0	10	0	0	0
10	3	0	0	0	11	0	89	0
	2	0	0	100	0	0	0	0
	1	0	0	0	0	0	100	0
11	3	0	0	0	0	0	0	0
	2	0	0	0	0	100	0	0
	1	88	12	0	0	0	0	0
12	3	0	0	0	0	0	0	0
	2	0	0	0	100	0	0	0
	1	0	0	100	0	0	0	0
13	3	0	0	0	0	0	100	0
	2	0	0	0	50	50	0	0
	1	0	0	100	0	0	0	0

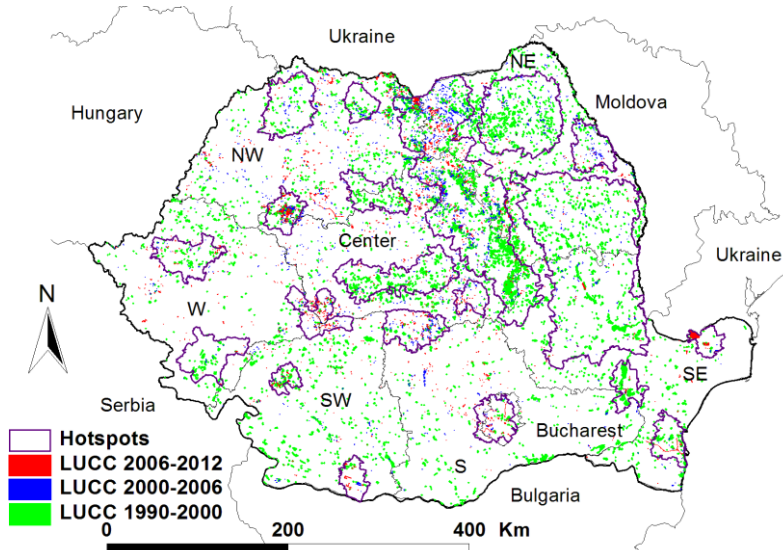


Hotspot	Period (1)	Transitional dynamic (2)						
		1	2	3	4	5	6	7
14	3	0	0	0	0	100	0	0
	2	100	0	0	0	0	0	0
	1	0	100	0	0	0	0	0
15	3	0	75	0	25	0	0	0
	2	0	0	0	0	0	0	0
	1	0	0	0	100	0	0	0
16	3	0	14	0	0	86	0	0
	2	0	0	0	50	50	0	0
	1	0	0	0	0	100	0	0
17	3	0	0	0	0	0	0	0
	2	50	0	0	0	50	0	0
	1	0	33	33	33	0	0	0
18	3	0	100	0	0	0	0	0
	2	0	0	0	100	0	0	0
	1	38	46	8	8	0	0	0
19	3	0	0	0	0	0	0	0
	2	0	0	0	100	0	0	0
	1	0	0	0	100	0	0	0
20	3	0	0	0	0	0	0	0
	2	0	0	0	50	50	0	0
	1	33	0	17	50	0	0	0

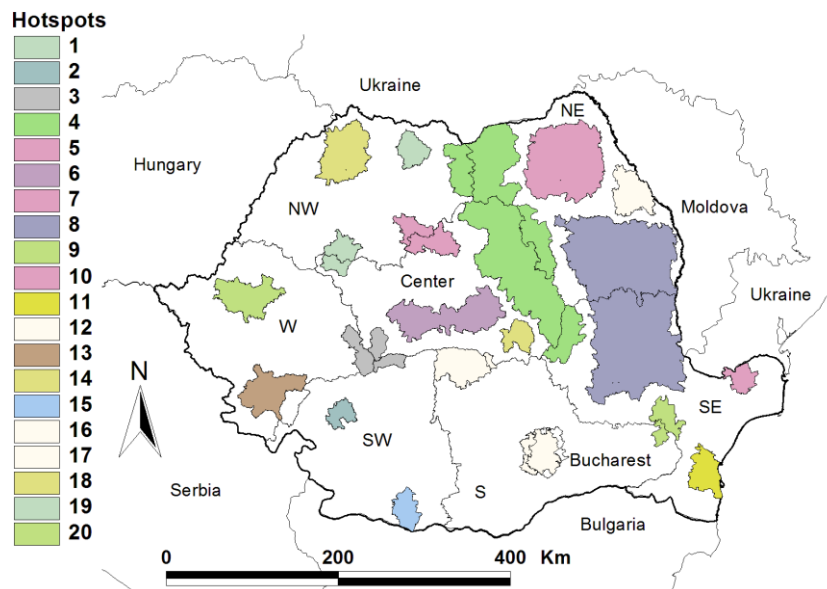
(1) 3 – 2006-2012, 2 – 2000-2006, 1 – 1990-2000; (2) 1 – Abandonment of agriculture, 2 – Development of agriculture, 3 – Forestation, 4 – Deforestation, 5 – Urbanization, 6 – Floods, 7 – Others

Possible limitations are inherent to the use of CORINE data, including misclassification, and different classification schemes and resolutions from one period to another (Jansen, 2007; Pelorosso *et al.*, 2011; Verburg *et al.*, 2011; Petrișor *et al.*, 2010, 2014).

Summing up the findings, the results show the consequences of an unplanned development (Mierzejewska, 2017) and low environmental care (Panagopoulos *et al.*, 2016; Ianoș *et al.*, 2017). Deforestation and urbanization tend to become more prominent (see the increasing trend), and the development of agriculture slows down (see the decreasing trend). The only ‘good news’ is that the abandonment of agriculture shows a decreasing trend, but since it was associated to the restitution of property (Petrișor, 2015a), a process that is completed, the results are not surprising. Similarly, the decreasing total affected area from one period to another (Petrișor and Petrișor, 2017) may be explained by the different length of the three periods.



**Fig. 1.** Spatial distribution of land cover and use changes in Romania during 1990-2000 (green), 2000-2006 (blue), and 2006-2012 (red), based on CORINE data. The areas are enlarged by dilating their borders for a better visualization. The image shows that changes seem to concentrate in several hot-spots (purple contours).



**Fig. 2.** Spatial distribution of the 20 hot-spots concentrating land cover and use changes in Romania during 1990-2012, based on CORINE data.

### Conclusions

The study aimed to identify the consistent trends of the transitional dynamics associated to the land cover and use changes in Romania in the three periods covered by CORINE land cover and use data (1990-2000, 2000-2006, and 2006-2012). The only consistent trends seem to be a decrease in the total area affected (although this association may be due to the different time span) and a decreasing trend for the development of agriculture. The increasing deforestation and urbanization and decreasing development of agriculture may be seen as consequences of an unplanned development associated with low environmental care. The hot-spots concentrating land cover and use changes are characteristic to ex-socialist transition countries, reflecting dynamics such as the sub-urbanization of metropolitan areas, deforestation and cropland abandonment after the fragmentation determined by property restitution, colonization of abandoned cropland by shrubs, associated with or amplified by the local particularities.

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