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Assessing long-term changes in forest cover in the South West Development Region. Romania

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Abstract

The paper is discussing the importance of assessing forest dynamics based on several statistical and cartographic supports considered to be the most representative for the last century. The selected maps are able to point out the forest cover changes for three time frames (1912-1971; 1971-1990; 1990-2006) related to the relevant multi-temporal statistical and cartographic data as well as historical events such as land reforms, political changes related to the transition to the intensive and extensive communist agriculture and the post-communist period strongly related to the decolectivisation and privatisation of agriculture leading to the emergence of new types of property, an excessive land fragmentation and deforestation (illegal logging). The authors are aiming to analyse land use conversion and forest covered areas dynamics in relation to the main socio-political and natural driving forces by means of GIS methods (binary change index and trend index) based on a series of significant cartographic documents and a large and complex geodatabase.

Keywords: *forest cover, land use change, GIS, South West Development Region, Romania*

Rezumat. Evaluarea schimbărilor pe termen lung a suprafeţelor acoperite cu pădure din Regiunea de Dezvoltare Sud-Vest Oltenia. România

Lucrarea urmăreşte importanţa evaluării dinamicii suprafeţelor acoperite de pădure pe baza mai multor date statistice şi cartografice considerate reprezentative pentru ultimii o sută de ani. Hărţile selectate sunt în măsură să evidenţieze schimbările survenite în dinamica suprafeţelor acoperite de pădure pentru trei intervale temporale semnificative (1912-1971; 1971-1990; 1990-2006). Alegerea acestor intervale a fost făcută în corelaţie cu datele statistice şi materiale cartografice multitemporale relevante, precum şi cu evenimentele istorice şi politice cum ar fi reformele funciare, schimbările politice legate de perioadele comunistă şi post-comunistă, de colectivizarea, decolectivizarea şi privatizarea agriculturii care au condus la apariţia unor noi tipuri de proprietate, o fragmentare excesivă a terenurilor şi despăduriri extinse (exploatarea forestieră ilegală), cu precădere în ultimii 20 de ani. Autorii şi-au propus să analizeze modificările utilizării terenurilor şi dinamica suprafeţelor acoperite de pădure în raport cu principalii factori socio-politici şi naturali cu ajutorul metodelor GIS (indicele schimbării binare şi indicele de tendinţă) şi pe baza unor documente cartografice relevante care le-au permis realizarea unei baze de date spaţiale complexe la nivelul Regiunii de Dezvoltare Sud-Vest Oltenia.

Cuvinte-cheie: *suprafaţă împădurită, shimbările utilizării terenurilor, GIS, Regiunea de Dezvoltare Sud-Vest, Romania*

Introduction

It is widely recognized that forest has always been considered a major natural resource having an essential role in maintaining both ecological equilibrium and integrity (Raet et al., 2008; Davedra, 2011), thus providing different ecosystem services for different environmental and societal sectors.

Over the last twenty years, the post-socialist Central and Eastern European countries have witnessed substantial restructuring processes facing the growing challenges of settlements expansion and associated environmental consequences in terms of land use/land cover changes, loss of natural vegetation, habitat fragmentation etc. (Kamal-Chaoui, 2009). Forest cover change involves a wide range of transformations involving deforestation, afforestation, reforestation and natural expansion of forests (Laze et al., 2010) strongly linked to the spatial and temporal variability of different natural, socio-economic and political drivers as well as their actors (Soler and Verburg, 2010).

In Romania, under the socio-economic and political changes brought about by the fall of the socialist regime, significant landscape transformations related to land use changes, mainly in terms of forest cover and forest fragmentation have occurred (Bălteanu and Popovici, 2004 and 2005; Kuemmerle et al., 2009; Popovici et al., 2013). Studies undertaken at national, regional and local level revealed the strong connection between these forest cover transformations and a series of driving forces of change which have evolved in connection with the shifting natural, socio-economic and political environment (Bălteanu et al., 2004; Bălteanu et al., 2005; Kuemmerle et al., 2009;

Dutcă and Abrudan, 2010; Marinescu et al., 2013; Pravalie et al., 2014 etc.).

The present research is dealing with the specific trends in land use changes within the last almost one hundred years which has determined significant changes, especially in favour of agricultural land, forest areas, and residential development.

Study-area

The South-West Development Region is located in the South-Western part of Romania, covering 12.3% (29,010 sq.km) of the national territory and 10.7% of its population (Fig. 1). The area is overlapping the main relief forms from the heights of the Southern Carpathians and Banat Mountains in the north and north-west to the hilly, plain regions and Danube floodplain in the centre and south (Bălteanu et al., 2006) displaying all biogeographical zones and belts of Romania. These environmental features explain the vast surface covered with forests, presently reduced to 29.8% (from up to 35% at the beginning of last century) explaining its spatial dynamics strongly linked with the natural and human-induced land use/land cover changes (deforestation, extreme weather events, urban sprawl etc.).

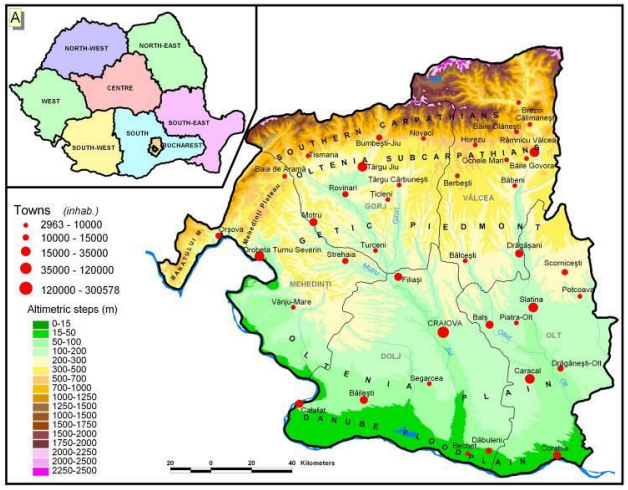

Fig. 1: The South-West Development Region

The South West Development Region mainly develops in the deciduous (nemoral) forest zone and the nemoral belt, which consists of two vegetation sub-belts: the sub-belt of durmast forests and mixed forests of durmast and beech and the sub-belt of forests of beech and beech associated with resinous species reaching altitudes of up to 1,200 m–1,600 m on the south-western slopes of the Southern Carpathians with a southern aspect and rather uniform distribution (Doniţă & Roman, 1976; Bălteanu et al., 2006). Therefore, in terms of forest structure, more than 85% of the study-area is covered by deciduous forests. At altitudes higher than 1,600 m the spruce forest (Picea abies) belt develops, its upper limit reaching the open ridges at approximately 1,700–1,800 m (1,850 m) in natural conditions. In the Southern Carpathians the spruce forest present a rather narrow strip-like distribution around the sub-Alpine belt, narrowing from east to west on the southern slopes of this chain, as compared to the rest of the Romanian Carpathian Chain (Bălteanu et al., 2006).

At NUTS 2 level, due to the qualitative and quantitative proprieties, resinous forests were, to a large extent, subject to forest withdrawal generally due to deforestation processes or degradation.

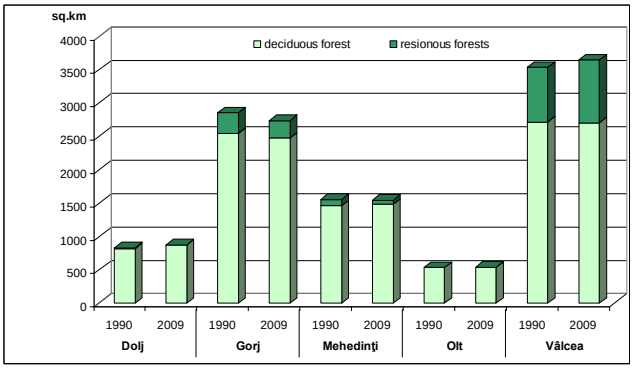

Fig. 2: The share of deciduous and resinous forests in the total forest found in the South West Development Region by County in 1990 and 2009, respectively

Source: National Forest Administration

Except Vâlcea County, which between 1990 and 2009 experienced afforestation processes (over 4%) the rest of the counties were subject to forest withdrawal. In the case of deciduous forests, the situation is more different. Dolj, Mehedinţi and Olt Counties had gain up to 8% forest area, while Gorj and Vâlcea Counties had lost up to -3% of the woodland (Fig. 2).

Methodology and data sources

Assessing forest cover changes based on historical maps in the study-area was undertaken using different data sources: statistical data, topographic maps, aerial photographs and satellite images. A special emphasis was put on spatial data through GIS processing and investigating the most relevant cartographical documents for the analysed period at various spatial scales.

Therefore, in order to retrace and analyse forest cover transformations over the last one hundred years in the South West Development Region, the authors used several historical maps in order to rebuild the forest cover based on different critical drivers of historical, social, political, economic nature: the land reforms, agricultural practices, the

afforestation programs etc.: topographic maps (Austrian Map, 1912 and Russian Map, 1971), scale 1:100,000 and Corine Land Cover - CLC - (EEA, 1990 and 2006), scale 1:100,000 (Table 1, Fig. 3).

The analysis was carried out using GIS-based methods and tools. After data extraction from both topographical maps and CLC database, the authors proceed to the calculation of surfaces for each analyzed element grouped into the following major categories: *forest and semi-natural areas* (forests, scrub and/or herbaceous vegetation associations, open spaces with little or no vegetation), *built-up areas* (urban fabric, industrial, commercial and transport units, mine, dump and construction sites and agricultural, non-agricultural vegetated areas), agricultural areas (arable land, permanent crops, pastures), *water bodies and wetlands*.

Table 1: The main cartographical resources used for the South-West Development Region

Year	Analysed time-frames	Data sources - topographic maps
1912	***T1 – T2*** *(1912 - 1971)*	*Scale 1:200 000, edition 1910-1912 (Austrian Map)*
1971		*Soviet map; Scale 1:100 000; edition 1971*
1990	***T2- T3*** *(1971 - 1990)*	*Corine Land Cover – CLC; Scale 1:100 000 (EEA, 1990)*
2006	***T3- T4*** *(1990 - 2006)*	*Corine Land Cover – CLC; Scale 1:100 000 (EEA, 2006)*

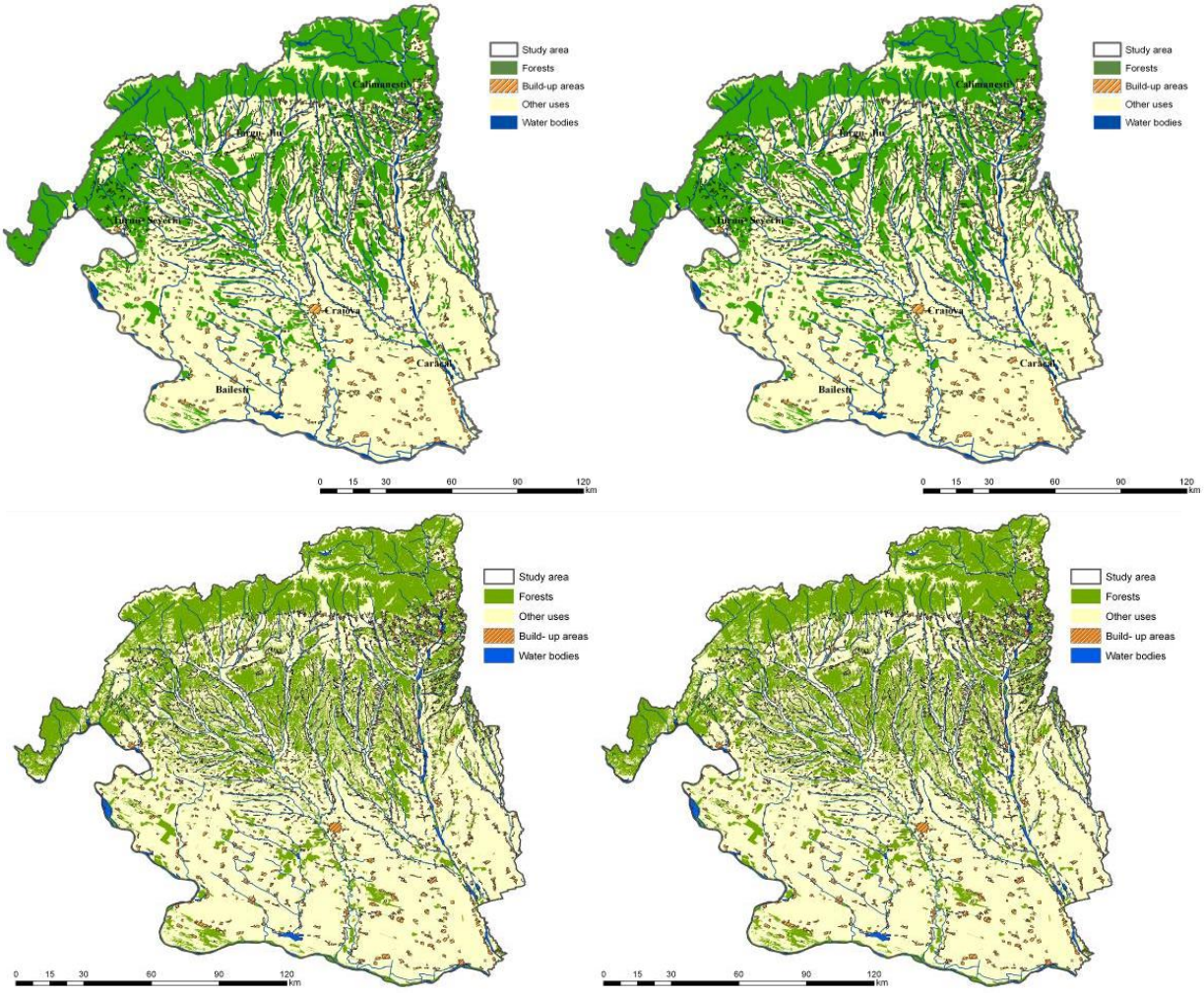

Fig. 3: Land use /land cover maps - 1912 (a), 1971 (b), 1990 (c) and 2006 (d)

Using the direct intersection method the authors were able to compute the changes of each element for the selected intervals: 1912-1971, 1971-1990, and 1990-2006. Based on the changed/unchanged ratio for each analyzed element, the authors computed two relevant landscape metrics: **binary change index (BCI)** and **trend index**. The **binary change index (BCI)** was calculated in order to identify the changes occurred at pixel level following the formula (Van Eetvelde and Kayhko, 2009; Pătru-Stupariu et al, 2009 and 2011; Stupariu et al., 2010; Van Eetvelde et al., 2012):

BCI = NCH – CH / NCH + CH (%)
NCH = unchanged
CH = changed

Moreover, another index used in order to point out the forest cover changes assumed from the mathematical analysis of elements pointing to their evolution trend – **trend index** using the following procedure (Van Eetvelde and Kayhko, 2009; Van Eetvelde et al., 2012):

$$\textbf{TREND} = \frac{\textbf{no. of changes/element}}{\textbf{total no. of changes}}$$

Additionally, the study was completed by statistical data (available at NUTS 5 and NUTS 2 level) supplied by National Institute of Statistics (Romanian Statistics Yearbooks, 1912-1989 and Tempo On-line database 1990-2011 https://statistici.insse.ro/shop/), as well as field surveys in the study area. In order to have a more accurate representation of the current assessment, the authors also took into consideration a wide range of qualitative and quantitative parameters (Raet et al., 2008) related to forest reserves, forest metrics, distribution patterns, health, legal status etc. based on data provided by the National Forest Administration.

Due to the unequal and sometimes incomplete information, the different mapping scales and the particular environmental features of the study-area, some adjustments to the database were undertaken.

Results and discussions

The main driving forces of spatial transformations are related to different *natural* (the main physico-geographical features, climate change-related impacts etc.), *demographic* (population growth, settlements expansion) and *political factors* (political decisions influenced the property status, type of exploitation etc.) which are directly responsible for land use change patterns (Bălteanu and Popovici, 2010; Grigorescu et al., 2012), thus triggering forest cover transformations.

Since the beginning of last century, several evolution periods with intense consequences in terms of land use/land cover changes had affected the Romanian territory. During the **1912-1971 interval**, most of the changes that occurred had affected mainly the forest cover within the study-area. As a consequence, out of the total forest covered area of more than 7,400 ha, over 35% were converted into other categories (mainly agricultural) in relation to two of the most important land reforms: *the 1918-1921 and the 1945 land reforms*. The first was enacted after the Greater Union of Romania in 1918, which brought about the expropriation of huge surfaces of state property which were fragmented and distributed to peasants, thus creating a certain balance between former and new owners and leading to increased social stability. The second land reform, enforced after the Second World War, liquidated the property of great landowners, and prefigured the transition to the socialist regime characterised by the centralised ownership, collectivisation and state farms (Bălteanu et al., 2004; Bălteanu et al., 2006; Popovici et al., 2013).

Significant land use changes occurred during the *communist period (1948-1989)* which had brought in the liquidation of the property of big landowners and the establishment of the centralized state-controlled property (collectivisation) and of large state farms. The socio-economic development recorded radical changes throughout two major transition periods: the 1950–1960/1962 period that marked the passage from the capitalist economy to the highly centralized plan-based communist system and the 1950-1989 interval when Romania, like other Central-European communist countries, choose for an extensive industrialization (Dumitrescu, 2008).

In relation to these socio-political changes, for the analysed period (1912-1971), significant conversions of the forest covered areas into other land use categories took place. According to the **binary change index**, in the study-area the changes were mainly registered in favour of agricultural land (over 32% of the forest covered area was transformed into agricultural). Smaller percents were converted to water bodies (0.57 %) and built-up areas (0.5 %). The rest of about 67% maintained its original use (Fig. 4).

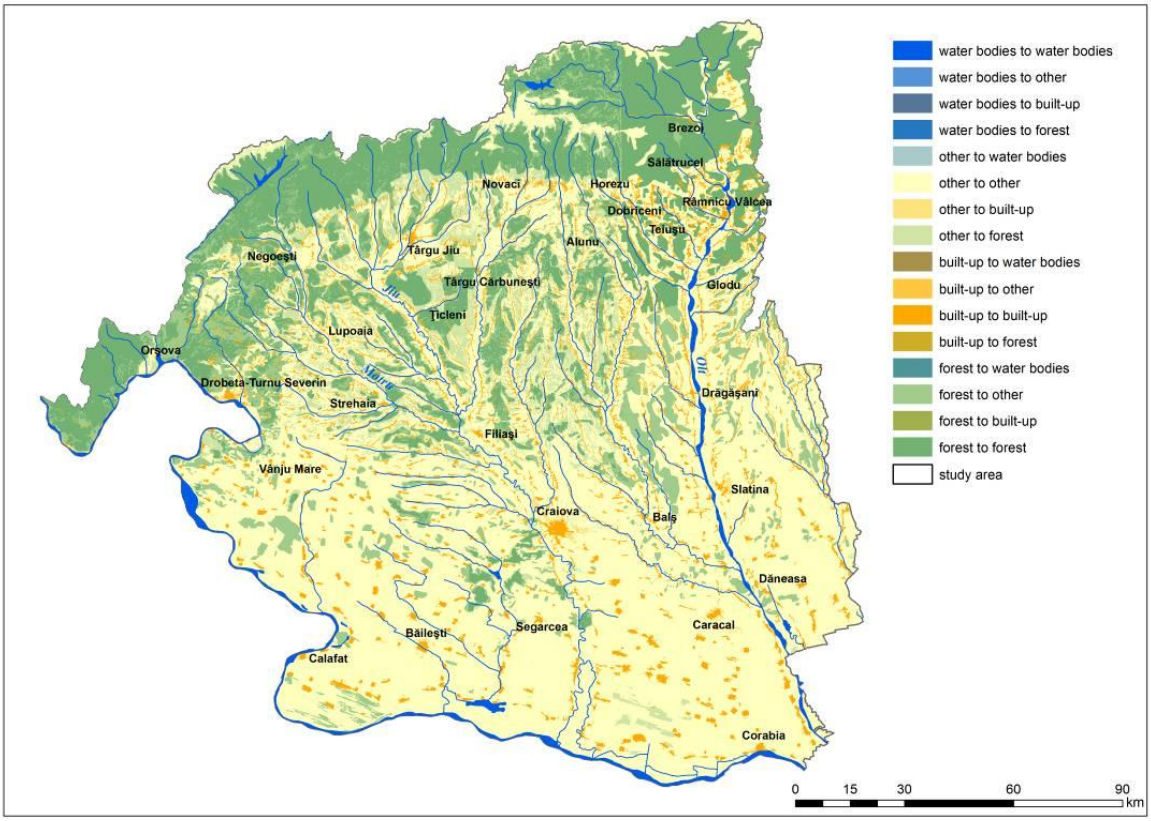

Fig. 4: Land use changes over the 1912-1971 period in the South-West Development Region

The land use changes triggered by the political and socio-economical transformations brought about by the communist period had continued during the next **analysed interval (1971-1990)** in relation to the enhancement of a centralised extensive agriculture, having a significant effect on the forest cover, as well. As a result, over 26% of the water bodies were converted to agricultural areas, especially in the Danube Floodplain area with the aim of extending the agricultural area within the Lower Danube Plain. Moreover, in line with this trend of excessive development of agriculture, woodland areas, too suffered transformations, especially the floodplain forests with different species of *Salix, Populus, Fraxinus angustifolia and Quercus robur*. Almost 20% of the forest covered areas were transformed to agricultural areas, mainly in the plain and plateau/tableland relief units (Fig. 5).

On the other hand, some areas were afforested in order to provide proper infrastructure for agriculture (i.e. forest belts) or for flood control in the Danube floodplain or along the main rivers (i.e. river embankments, protection forests etc.), process which slightly continued after 1990.

Generally, the expansion of the forest area was primarily related to natural regeneration (in the mountainous and the Subcarpathians regions), especially from woodland-shrub to forest categories. Secondly, artificial reforestation (after logging or calamities) took place on smaller areas, directly connected to financial sources. The costs were covered from the state budget and the Land Reclamation Fund destined to such actions (http://mmediu.ro/file/17.11.2010_Programul-National-Impadurire.pdf) and by non-reimbursable European funds dedicated to the tree-planting. Additionally, Measure 3.5 of the SAPARD Programme (Special Accession Program for Agriculture and Rural Development) stipulated the funding of afforestation projects; in 2009, Measure 221 of the National Rural Development Programme had in view the First Afforestation of Agricultural Lands (Popovici et al., 2013). Thus, over the analysed interval, over 14% of the agricultural areas and 15% of the water covered areas were converted to woodland. Overall within the study-area, over the 1989-2009 period, 118.31 sq.m of land (state property) were afforested. Dolj County ranked first as the largest afforested large administrative unit both related to the flood management embankments in the Danube Floodplain and the agricultural betterment works on the sandy dunes from the Southern Oltenia Plain.

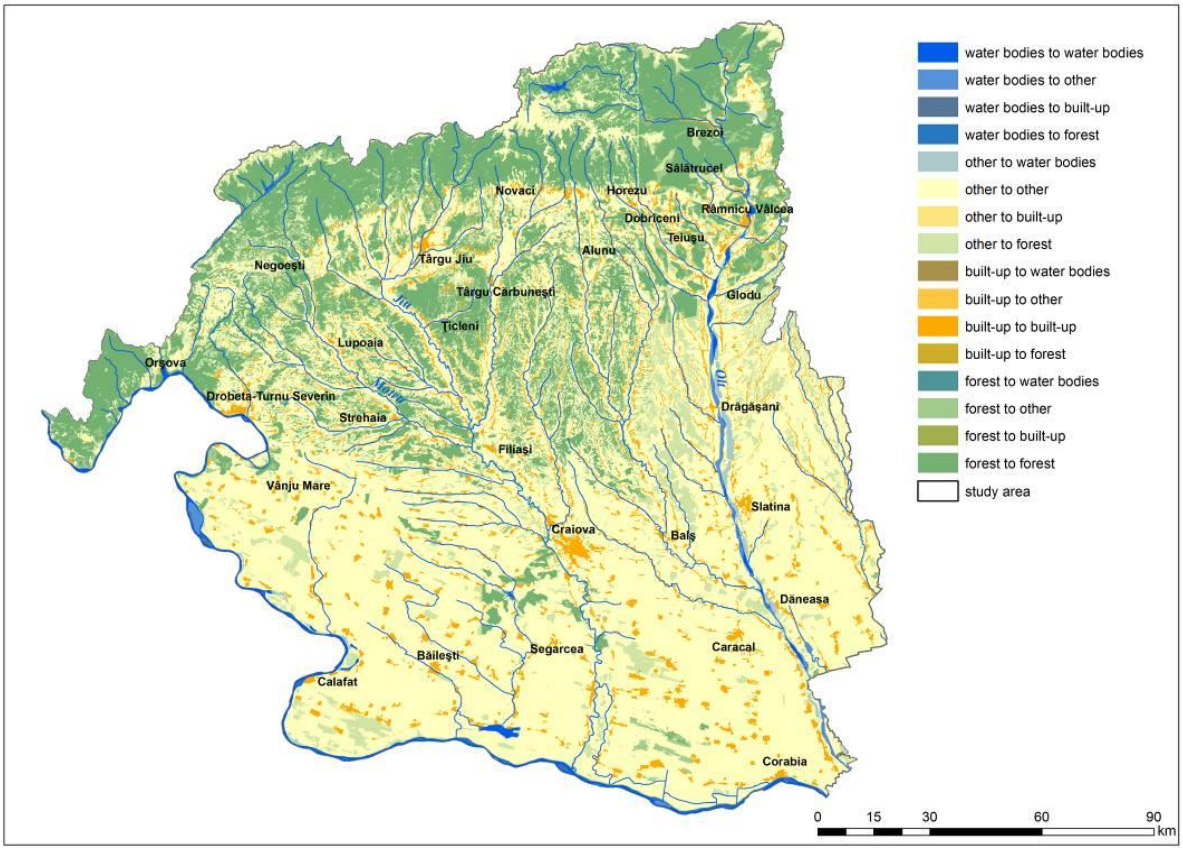

Fig. 5: Land use changes over the 1971-1990 period in the South-West Development Region

The fall of the communist regime (December, 1989) marked the beginning of a new and extremely dynamic period - **the post-communist (1990-to-date)** – which brought about, as major general outline, the transition from a centralised economic system to the market economy. These changes triggered restructuring processes in all fields of activity, leading to a certain dynamics of the land use/land cover categories, including the forest found (Fig. 6).

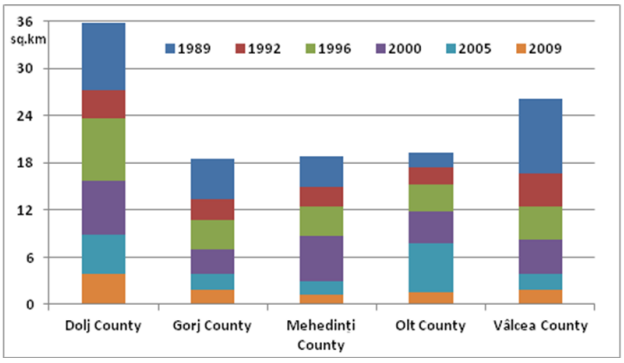

Fig. 6: Afforestation process (sq.km) at NUTS 2 level in the South-West Development Region

Souce: National Forest Administration

The first stage of this period, the so-called *transition period* (1990-2000) set in motion the transition from state property to private ownership through the decollectivisation and privatisation processes, the so-called "land laws" (Geografia României, vol. V, 2005). The related changes determined structural relocations of the different land use categories, thus seriously affecting the forest fund by means of important "land laws" such as *Law No 18/1991 and the additional laws (169/1997, 1/2000)*. These legislative papers had in view to reconstitute the right to ownership of collective farm members, their successors and other categories of persons through privatisation and decollectivisation processes (Bălteanu et al., 2004; Bălteanu et al., 2005).

The second stage – *the post-transition period* (2000-to-date) – involves a new rage of territorial changes and transformations related to Romania's preparation to join the European Union (2007), including complete implementation of the EU environmental and agricultural policies, determining important changes related to land use and, particularly, forest dynamics.

The patterns of change which have characterised the last analysed period had triggered rather difficult to trace statistically land use changes (including forest) due to the increased land fragmentation, agricultural land abandonment, afforestation plans and, not least, the limitations and uncertainties triggered by the CORINE Land Cover database

(minimum mapping area – 25 ha). However, overall, more than 3% of the water bodies were converted to agricultural land, 2% of agricultural areas to woodland and almost 5% of agricultural land and forest covered areas to water bodies. On the other hand, almost 5% of the water bodies, agricultural land and built-up areas were transformed into forest covered areas due to afforestaion actions or natural regeneration (Fig. 7).

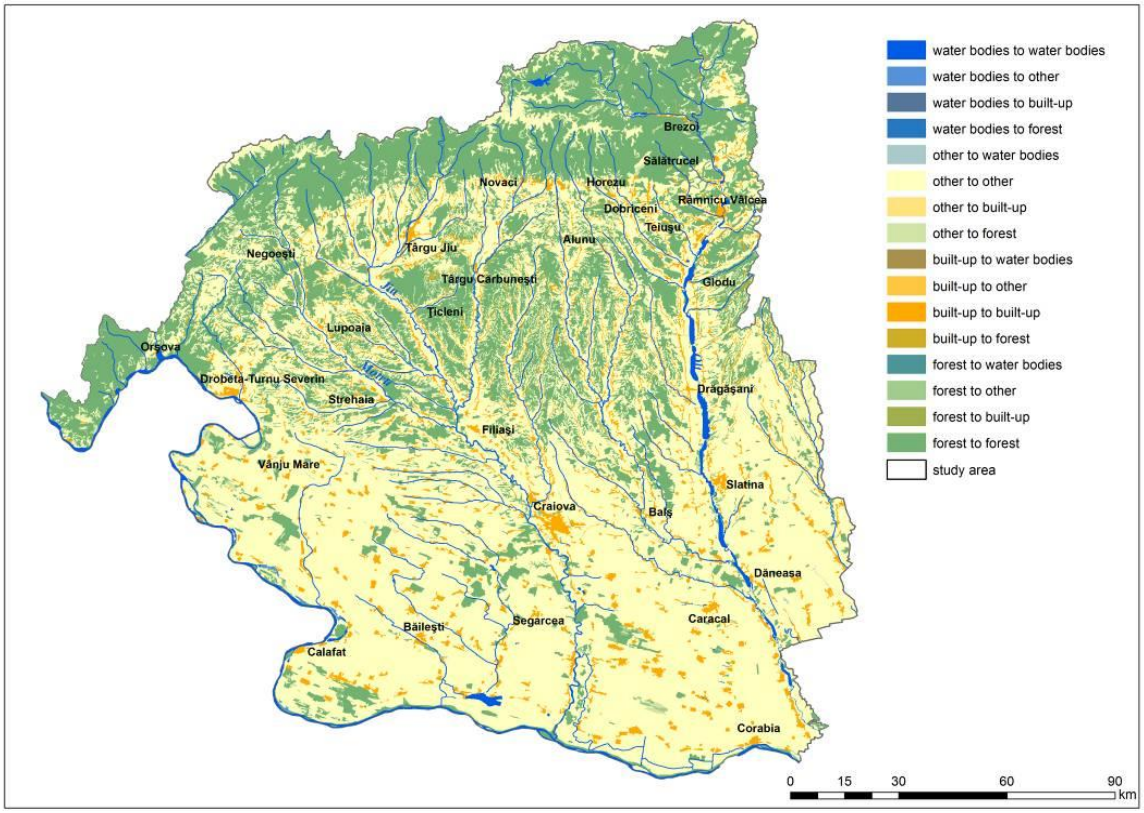

Fig. 7: Land use changes over the 1990-2006 period in the South-West Development Region

After 2000, in relation to Romania's pre-accession to European Union, the arable area tended to increase, while the vine-and-fruit-tree areas continued to drop, especially in the hilly plateau and Subcarpathian areas. It is within this context when mountain forests and protection belts from plain and tableland areas were systematically illegally logged, thus affecting land quality and triggering extreme weather phenomena (Popovici et al., 2013; Dragotă et al., 2011; Bălteanu et al., 2013). Furthermore, the urban sprawl process (mainly sub-urbanization) expands, tending to evolve into large sub-urban areas in the surroundings of large towns, thus leading to significant land use conversions.'

Overall, at NUTS 2 level, the largest forest logging were experienced during the 1992-2000 period following the restitution laws which led to significant forest cover withdrawn, in a certain extent related to illegal logging from the state forest (Fig. 8).

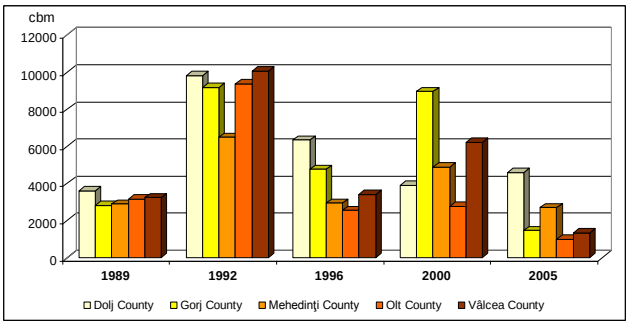

Fig. 8: Illegal logging from the state forest at NUTS 2 level in the South-West Development Region

Source: National Forest Administration

The **trend index**, seen as the number of changes undertaken at pixel level (from one category to another) against the total number of changes, reveal that, generally, the largest amount of transformations took place with respect to water bodies, especially during the 1971-1990 and 1990-2006 intervals, mainly related to flood control management works along the Olt and Jiu Rivers and along the Danube Floodplain. Significant changes

were registered in the built-up areas (with the highest peak in the last analysed interval due to urbanisation and suburbanisation processes) and agricultural areas (over the 1971-1990 and 1990-2006 periods in relation to extensive/intensive agriculture, land abandonment, agricultural land fragmentation etc.) categories (Fig. 9).

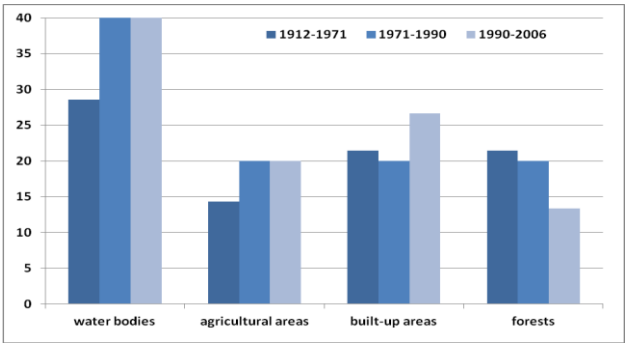

Fig. 9: Trend index for the main land use categories in the South-West Development Region

In line with these changes related to the main land use/land cover categories, the forest covered areas also experienced significant transformations triggered or induced by the above mentioned land conversations. Therefore, as compared to the other changes, forest covered areas register a decreasing trend during the analysed time frames from over 20 index values in the first interval (1912-1971) to less than 15 index values in the last analysed interval (1990-2006) due to the intense and diverse land use transformation related to agriculture and urbanization. The largest share of forest covered related changes were largely linked to agricultural land use, especially during the first and second analysed intervals, and secondly to built-up areas (mainly during the 1912-1971 time frame) and water bodies (particularly during the 1971-1990 period). In the South West Development Region, the areas the most affected by these processes ranged from rather scattered surfaces in the hilly-plateau areas of the Getic Piedmont and Subcarpathians to more compact areas in the mountain regions of the Southern Carpathians.

Conclusion

The analysis undertaken within the current study was focused on the three major intervals with the aim of underling the forest cover transformations in and from three main land use categories: agricultural land, built-up areas and water bodies. The binary change index revealed more significantly the transformations into agricultural land use category mainly during the 1912-1971 interval and constantly decreasing after 1971-up-to date. These conversions were connected to the consequences of land laws (1918-1921 and 1945 land reforms), of different political and economical changes related to extensification and intensification of agriculture. As a result, lower transformations were registered from forest covered to water bodies or built-up area categories (Fig. 10).

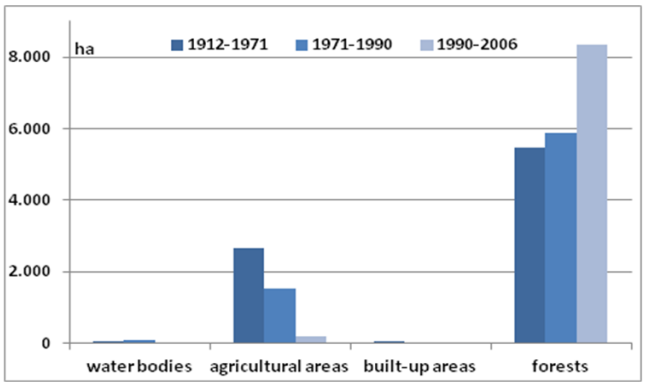

Fig. 10: Forest cover conversion over the 1912-1971, 1971-1990 and 1990-2006 intervals in the South-West Development Region

In line with these conversions, overall, the forest covered area decreased over the 1912-1971 period and steadily increased after 1971, especially after 1990 in relation to extended afforestation actions which took place in the Danube Floodplain, Oltenia Plain, degraded land from the hilly and mountain areas etc. At NUTS 2 level (1990-2009), forest cover dynamics was rather uneven in the study-area mainly related to the physical-geographical conditions which characterise each administrative unit. Dolj County was the most affected by forest withdrawal due to extensive logging of woodland in the plain area, especially with respect to the acacia tree plantations (Fig. 11, Fig. 12).

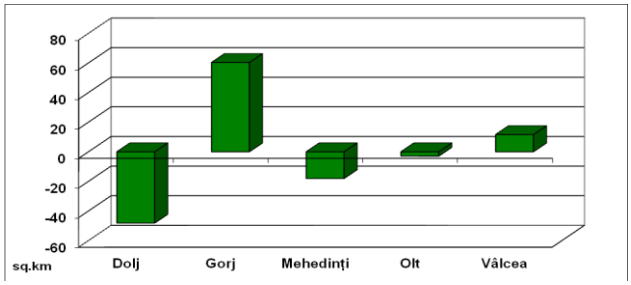

Fig. 11: Forest cover dynamics at NUTS 2 level (1990-2009) in the South-West Development Region

Source: National Forest Administration

Over the last analysed period, the forest fund structure witnessed slight changes, shrinking in the counties situated in the central and southern part (Dolj, Mehedinţi and Olt) and slowly extending in the northern counties (Gorj and Vâlcea) overlapping hilly and mountain areas.

Fig. 12: Accacia forest affected by drought on sandy fields (a) and by sand dunes in Oltenia Plain (b)

The assessment of land use dynamics with an emphasis on forest covered areas is a necessary process in the evaluation of landscape dynamics, ecosystem's balance in terms of structure and functions, land quality etc. The related effects could sum up to several environmental disturbances related to land and soil degradation, intensification of extreme weather events (aridity and drought phenomena, blizzards, hail storms etc.), habitat fragmentation, biodiversity loss, shifting forest limit in the mountain regions etc. Assuming measures to prevent uncontrolled forest cover change especially in the vulnerable regions such as drought prone or flood exposed areas should be coupled with additionally management and conservation measures in order to provide sustainable use of woodland in the study-area.

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