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ASSESSING LAND USE/LAND COVER CHANGE AND ITS IMPACT ON SURFACE RUNOFF IN THE SOUTHERN PART OF THE ȚIBLEȘ AND RODNEI MOUNTAINS

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ABSTRACT. There is an increasing need to assess and quantify the impact of land use/land cover changes, especially on surface runoff, due to rapid population growth. This study aims to investigate the land use/land cover (LULC) changes over time, for an intense rainfall event in Țibleș, Runc and Sălăuța watersheds, and their impacts on surface runoff for various antecedent moisture conditions (AMC). The GIS-based SCS-CN method and the CORINE land cover (CLC) databases for 2000, 2006 and 2012 laid the foundation for this research. Results indicated that even small land cover changes can significantly affect runoff on the short time scale, with quantitatively different effects regarding moisture conditions. The reduction in forest cover due to agricultural intensification and the conversion from pasture to cropland (especially between 2000 and 2006) resulted in higher surface runoff volumes. These changes mostly affected the middle and downstream catchments of the main rivers which means that over the years, the soil water retaining capacity has decreased.

Keywords: Runoff volume, Land use/Land cover changes, Corine Land Cover, Țibleș

1. INTRODUCTION

Global climate change along with human population growth, movement and activities cause noteworthy changes in land surface properties. These changes can have major impacts on the water balance of any drainage system.

Any human activity that alters a natural catchment area, can lead to significant changes on its hydrological behaviour (Booth, 1991). A densely vegetated area as opposed to an artificial one, with higher levels of interception, has a significant resistance effect, thus lengthening the lag time, which is an integrated variable of the rainfall-runoff relationship and all the various watershed impact characteristics (Șarpe and Haidu, 2017). A proper knowledge concerning the surface runoff variability is of great importance for researchers involved in water management activities to reduce the impact of floods, such as runoff prediction (Sahour et al., 2014). Accordingly, monitoring and analyzing the catchment responses to LULC changes, ensures a sustainable management of water resources.

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Numerous investigations of land use change effects on water balance have been conducted around the world, not only in tropical or subtropical (Mahmoud and Alazba, 2015; Yin et al., 2017; Shi et al., 2007; Karamage et al., 2017), but also in temperate regions (Ashagrie et al., 2006, Costache and Fontanine, 2013)

The SCS-CN is an efficient and widely used method for runoff estimation (Strapazan and Petruț, 2017) relying on the CN index which accounts for most of the watershed features such as AMC, land use/cover, soil types and texture (Gyori et al., 2016; Prakash and Sreedevi, 2017), with strong impacts on the mechanism of runoff generation .

In order to investigate the temporal and spatial LULC change patterns and their effects on runoff volume in various hilly and mountainous watersheds, the CLC databases along with the SCS-CN method were applied with regard to a frontal event with substantial amounts of precipitation. These changes were assessed over the entire study period (from 2000 to 2012) to observe their long-term characteristics and by comparing their short-term patterns (for the first 7-year period and the second one).

The sensitivity analysis of runoff to land use changes was carried out considering both total and spatially distributed runoff volumes for each grid cell, catchment and land use category.

Three adjacent watersheds located in the Țibleș and Rodnei Mountains were purposively selected for this study, due to the fact that their flood-prone areas (e.g.,the downstream section of Țibleș from Zagra to Mocod, the section of Telciu between Telciu and Telcișor, Romuli, Dealul Ștefăniței and Coșbuc villages) are among the most important ones in the Someș-Tisa hydrographic area, according to the historical reports from 1991 to 2013 (PPPDEI, 2014).

2. STUDY AREA

Located within the county of Bistrița-Năsăud, the study area encompasses the Țibleș, Runc and Sălăuța watersheds and is composed of mountainous and hilly terrain. All three are right bank tributaries of the Someșul Mare river which meets the Someșul Mic river upstream of Dej city, to form the Someș river.

The Țibleș Mountains are the home of the headwaters of Țibleș and Sălăuța rivers while the Runc river originates from the Năsăud Hills, located in the southern side of the mountains. The Sălăuța river collects its waters not only from the eastern and southeastern sides of the Țibleș Mountains, but also from the western slopes of the Rodna Mountains, draining the Năsăud Hills towards the south. The Țibleș river also drains the Năsăud Hills, but collects its waters from the southern slopes of the Țibleș Mountains. The catchment areas range greatly in size from 49 km^2 (Runc) to 99 km^2 (Țibleș) and 414 km^2 (Sălăuța).

Suplai, Zagra, Runcu Salvei, Romuli, Telciu and Coșbuc are among the main settlements in the area (Fig. 1). The watersheds are monitored on a daily basis by the Bistrița-Năsăud Water Management System and the National Administration ”Romanian Waters”, Someș-Tisa Water Directorate, except for the Runc watershed.

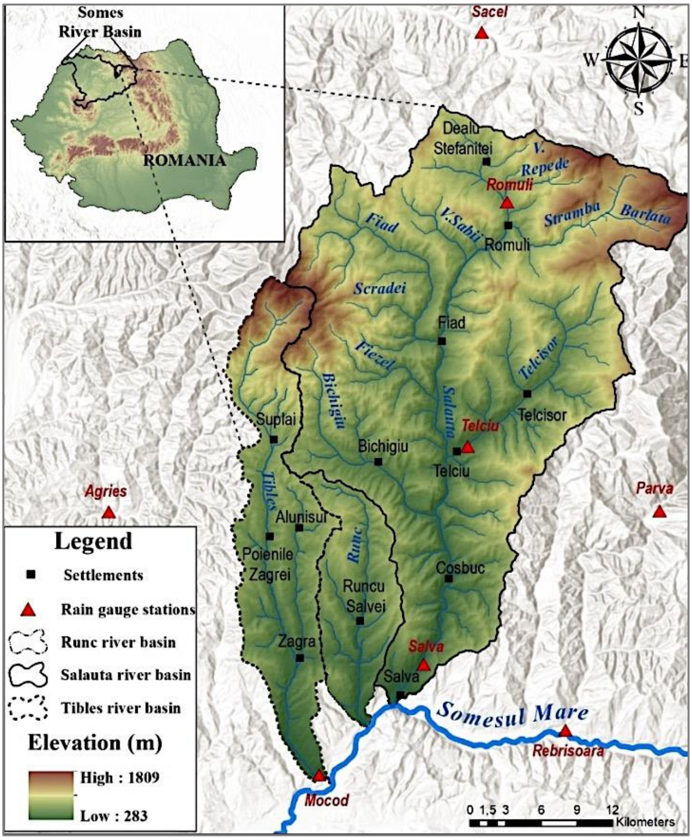


Fig. 1. Location map of the study area

3. DATA AND METHODS

In order to quantify the LULC changes on surface runoff, a frontal rainfall event that occurred on the 5th of September 2015 was chosen. The data was collected from 6 hydrometric stations (Săcel, Romuli, Telciu, Salva, Mocod, Rebrișoara) and 2 rain gauge stations (Parva and Agrieș). located in the proximity of the study area. The event was chosen for two main reasons. First of all, the analysis of the rain-gauge observation data recorded since 2006 until present day, revealed that the above mentioned event was the most relevant for the study. High amounts of rainfall were recorded by all the selected stations (e.g., Parva-37,8 mm, Rebrișoara-45,3 mm , Salva-34 mm). Furthermore, the Mocod station recorded the greatest precipitation amount (50 mm) in the studied period. Secondly, given the large size of the chosen area (562 km^2) and the primary objective of this study, a widespread frontal event with large rainfall amounts and considerable spatial homogeneity was needed.

The digital elevation model for Europe (EU-DEM) with a resolution of 25 m from the GMES RDA project (a realisation of the Copernicus programme, managed by the

European Commission, DG Enterprise and Industry) from the website of the European Environment Agency (EU-DEM Metadata) was used to subtract information on relief. In order to automatically delineate the watersheds a model based on the elevation data and ArcHydro functions was used (Strapazan and Petruț, 2017).

For the information on spatial distribution of LULC and soils, the CLC 2000, 2006 and 2012 raster datasets (available from the European Environment Agency) along with the soil map (provided by the National Research and Development Institute for Soil Science, Agrochemistry and Environment) were used. The CLC 2000 data validation was assessed based on a reinterpretation of IMAGE2000 and Eurostat LUCAS data (Maucha and Büttner, 2006). The CLC 2000 and 2006 layers were revised (V18_5) and an independent validation of CLC 2012 was performed in 2016 (EEA, 2016). The process of estimating the CN was based on the one described in the scientific literature (Haidu et al., 2017, Crăciun et. Al, 2007, Strapazan and Petruț, 2017) (Fig. 2).

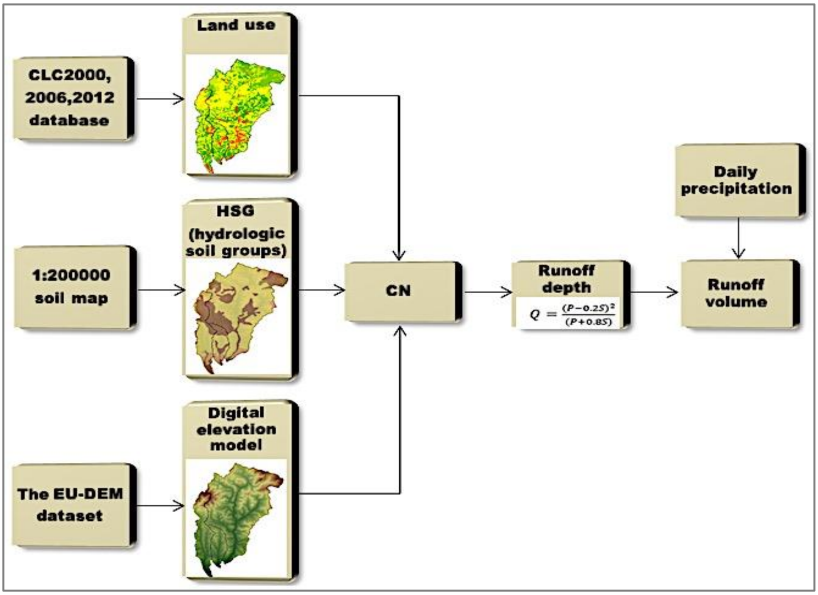


Fig. 2. Flow chart showing the main steps for runoff volume estimation

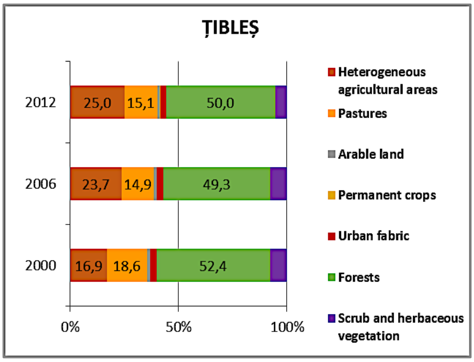
The CN index was adjusted according to different antecedent moisture conditions. In this case, the equation for initial abstractions takes into account the β coefficient that represents the water holding capacity over time for different vegetation types and thus, considering the process dynamics (Crăciun et al., 2009, Crăciun, 2011).

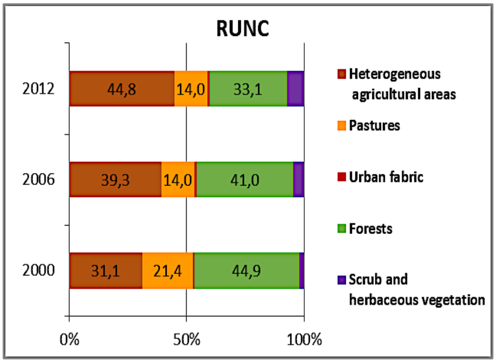
4. RESULTS

The CORINE dataset has 3 hierarchical levels for the land cover type classification, ranging from micro to macro-scale. For a preliminary analysis of the terrain, in order to observe the spatial distribution of land use characteristics, the third and the second levels were used (Fig. 3). According to this evaluation, the Țibleș watershed has the highest land use diversity with large areas occupied by forests, pastures, agricultural heterogenous crops, scrub and herbaceous vegetation and smaller urban, arable (under rainfed farming) and fruit production areas (permanent crops). Except for the permanent crops and arable land (non-irrigated), all three watersheds share the same land use structure. Accordingly, this is a homogenous area of agricultural activities.

As regards the land use structure between 2000 and 2012, the watersheds share the same pattern of land use change. There was a loss in forest cover and pastures due to agricultural expansion. The Runc watershed exhibited the highest changes. In 2000 forests covered about 50% of its total area as opposed to 33% in 2012 and the agricultural areas have increased by over 13,7%. The Runc watershed experienced higher changes in forest cover for the last 7-year period compared to the other ones.

Overall, the highest changes occurred between 2000 and 2006 with the conversion of forest land to agricultural use. Thus, the heterogenous agricultural areas increased by 8,2 %, 6,8% and 4,4% of the total catchment areas of Runc, Țibleș and Sălăuța, respectively.





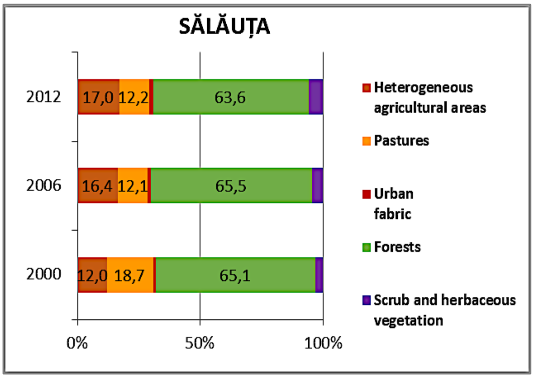


Fig. 3. The dynamics of land use/land cover change in all three river basins (percentage of total area)

Therefore, considering the entire study area, the base year of 2000 and the micro-scale classification of land uses, the complex cultivation, orchard, natural grassland, moor and heathland areas experienced the most notable changes that took place during the first seven years of the studied period. The natural grassland areas had nearly doubled in size, leading to the disappearance of moors and heathlands, and the complex cultivation areas have increased by over 50%. The orchards had the highest increase in area, although in 2000 they occupied just 1 km^2 of the total Țibleș river catchment area (Fig. 4).

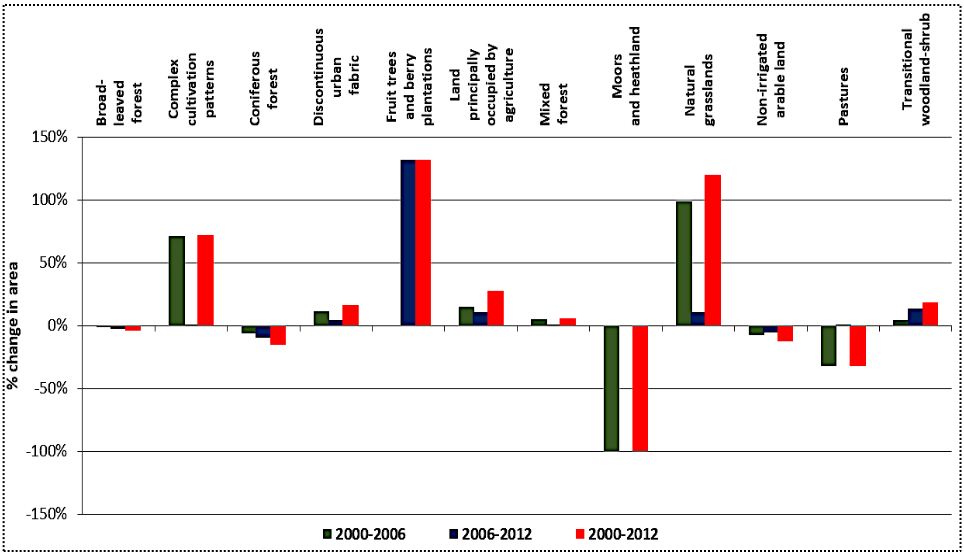


Fig. 4. Graph showing the percentage change in area of different land use/land cover types of the entire study territory

As mentioned above, the SCS-CN method was used for surface runoff simulation, the other key factors being considered constant, in order to accurately evaluate the land use-runoff relationship. The method was implemented in a GIS environment and the spatial statistics and analysis functions were used to compute the values.

Considering the maximum runoff volume per cell (pixel), the results revealed no significant difference between the time periods under the same AMC scenario. The explanation for this phenomena lies in the presence of the built-up areas and the main rivers flowing through them with no or low levels of infiltration. The minor differences are only present in the Sălăuța and Runc river basins reflecting a slight expansion of the urban fabric towards areas with higher precipitation amounts for this event.

The average runoff values (per pixel) tend to increase together with agricultural areas expansion, except for the Sălăuța and Țibleș river basins, in which case this increase is observed only between 2000 and 2006, (given the fact that the major changes occurred during this time period). As a consequence of experiencing high changes regarding the land use, the Runc watershed shows upward trends in runoff volumes during the entire period.

With the exception of the Sălăuța watershed, there was an increase in the minimum runoff values (Table 1).

Based on the spatial distribution of the runoff volumes, regardless of the antecedent moisture conditions, the largest changes can be observed in the middle and downstream catchments of the main rivers where agricultural activities are the most intense and the few forested areas existent here, actually shrunk over time.

Table 1. ***Estimated runoff volumes at cell (pixel) level***

Watersheds	AMC classes	Runoff volume (m^3/cell)								
		2000			2006			2012		
		Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
TIBLES	AMC1	0,0	1,5	13,8	0,0	1,7	13,8	0,0	1,7	13,8
	AMC2	0,0	4,6	18,8	0,0	4,9	18,8	0,1	4,9	18,8
	AMC3	2,1	8,7	23,2	2,1	9,0	23,2	2,6	9,0	23,1
RUNC	AMC1	0,0	1,8	8,5	0,0	1,9	8,5	0,0	2,0	8,6
	AMC2	0,0	5,3	14,7	0,0	5,4	14,7	1,0	5,5	14,9
	AMC3	2,0	9,6	18,9	2,0	9,7	18,9	4,0	9,8	19,1
SALAUTA	AMC1	0,0	0,8	11,2	0,0	0,9	11,2	0,0	0,9	12,0
	AMC2	0,0	3,3	15,5	0,0	3,4	15,5	0,0	3,4	16,6
	AMC3	0,1	6,8	17,9	0,1	6,9	17,9	0,1	6,9	19,0

Furthermore, the spatial distribution of runoff volumes reveals lower values in the headwater areas and higher values in the downstream catchment areas where notable changes affected the plant cover (Fig. 5, Fig. 6, Fig. 7).

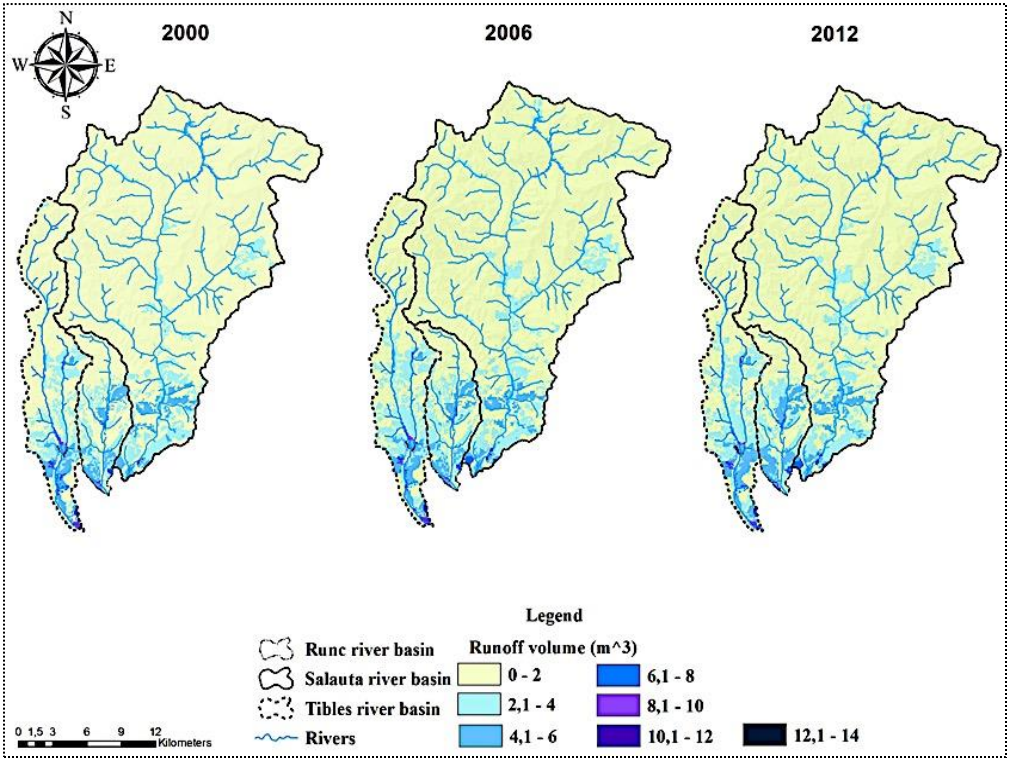


Fig. 5. Spatiotemporal distribution of runoff volumes under dry soil moisture conditions

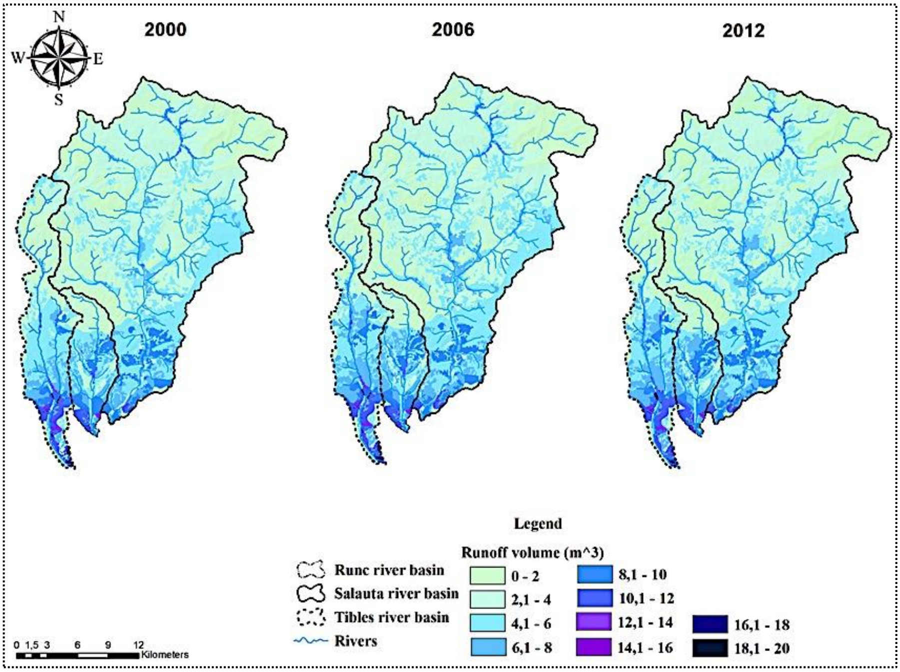


Fig. 6. Spatiotemporal distribution of runoff volumes under normal soil moisture conditions

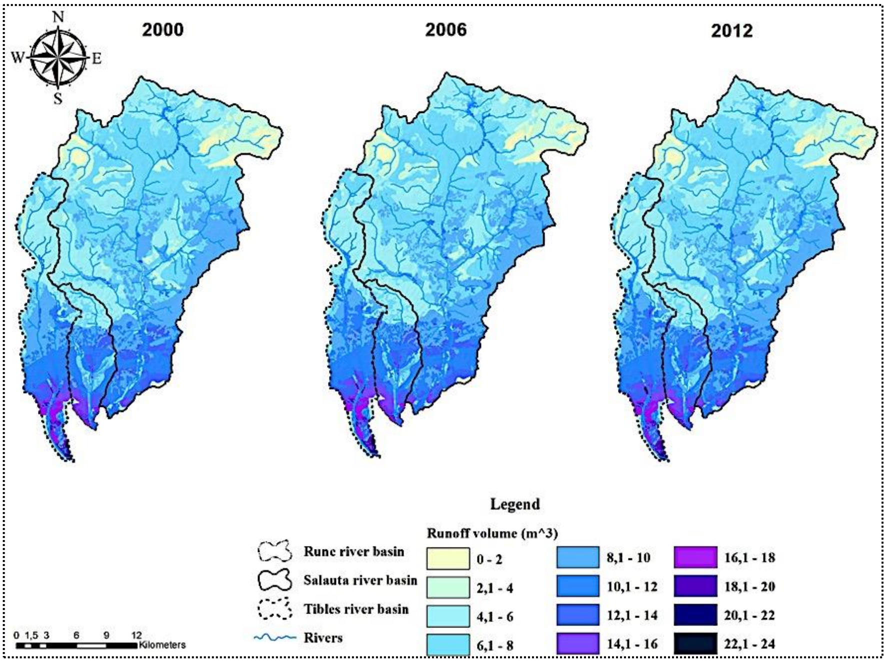


Fig. 7. Spatiotemporal distribution of runoff volumes under wet soil moisture conditions

According to the chosen rainfall event scenario, notable differences in each catchment area's total runoff volume have been observed over time (Table 2).

Table 2. ***The total estimated runoff volume***

Watersheds	AMC classes	Total runoff volume (m^3)		
		2000	**2006**	**2012**
		Sum	Sum	Sum
TIBLES	AMC1	240440	268311	270517
	AMC2	732517	770718	774670
	AMC3	1381816	1416492	1421849
RUNC	AMC1	141369	150738	157419
	AMC2	412915	422658	427118
	AMC3	750266	759371	762513
SALAUTA	AMC1	545683	577335	585489
	AMC2	2172470	2218413	2233001
	AMC3	4510732	4560759	4577983

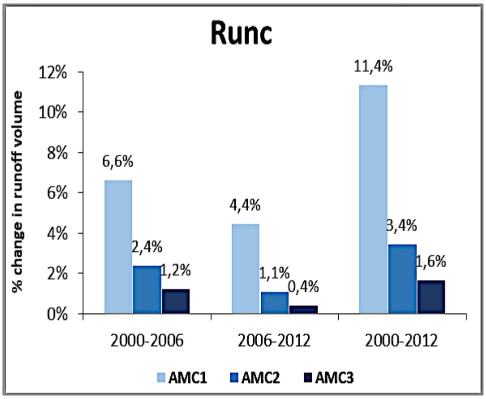
By analyzing these changes as a percentage of the base values (from the begining of each study time period), the same pattern could be observed for all of the catchment areas, with greater changes between 2000 and 2006, strongly linked to the changes in vegetation (Fig. 8).

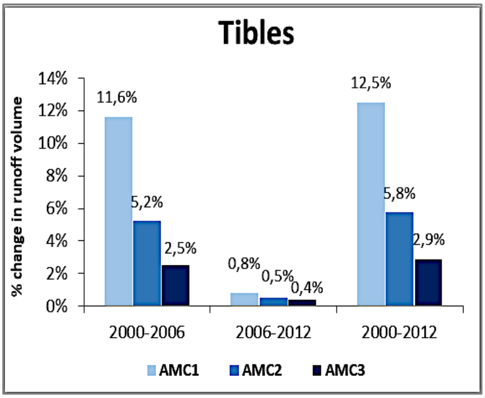
Although the same pattern of land use changes applies to all of the antecedent moisture conditions, according to the dry soil (AMC1) scenario, as opposed to the normal (AMC2) and wet ones (AMC3), higher changes in the total runoff volume between different years were observed. From 2000 to 2006 the total runoff volume at the outlet of the Țibleș catchment area has increased by 11,6%. Within the same time frame the total runoff volumes computed for the Runc and Sălăuța watersheds, increased by 6,6% and 5,8%, respectively.

The minimal percentage changes of runoff volume were observed for AMC3 scenario. The land use change effect on surface runoff volumes is very small under wet soil conditions. When high rainfall events occur, the infiltration rate decreases as the soil becomes oversaturated with water and the infiltration coefficient decreases as the runoff one increases. Under normal AMC, for this rainfall event, the runoff volumes computed for the Țibleș watershed increased by 5,2% in 2006 and by 5,8% in 2012. Considering the totals computed for the Runc watershed, increases of 2,4% and 3,4% are observed in 2006 and 2012, respectively.

With regards to the total study area and the contributions of each land use type to the total runoff volume, the main source of runoff is the vast forested area. Nevertheless, as a wide range of agricultural practices intensify, the forest's influence on the runoff coefficients and velocities decreases (Fig. 9).

If the agricultural runoff volume in the year 2000 represented 25% of the total volume of runoff under normal moisture conditions, with regards to such a rainfall event, by the year 2012, this value would have reached 34,5%. Built-up areas that usually present the highest runoff potential, have in this case a limited influence, as they don't have a wide territorial spread.





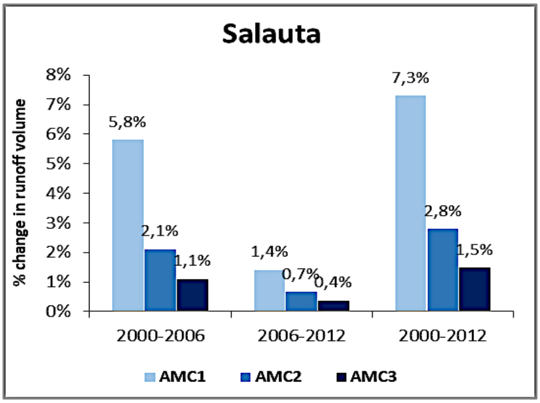


Fig. 8. The relative changes in surface runoff volume under different soil moisture conditions

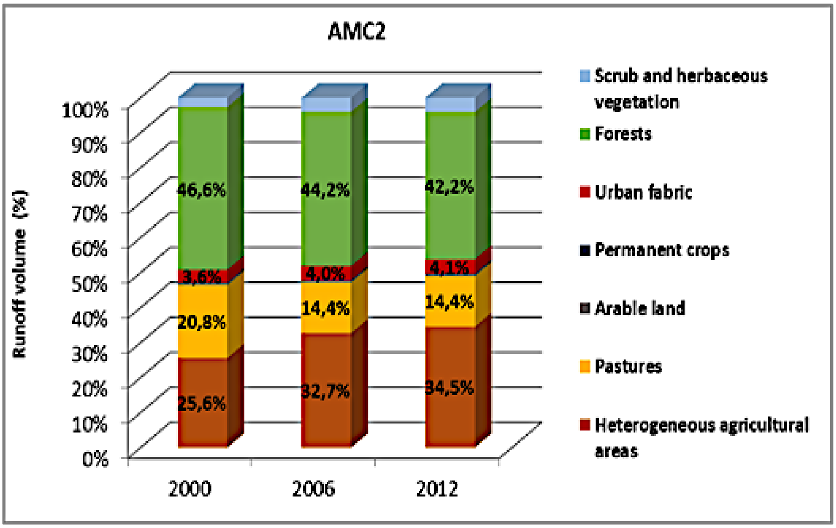


Fig. 9. The contribution of each land use type to the total runoff volume under normal soil moisture conditions

5. CONCLUSIONS

This research was based on the most relevant frontal rainfall event from the past twelve years which was used as a scenario for runoff volume estimation, according to historical land use changes, in order to determine their effects on the water balance The analysis revealed that the whole area can be very sensitive to agricultural exploitation and crop diversity practices with higher runoff potential.

. The Runc watershed was subjected to the biggest changes, with agricultural areas increasing by over 13,7% in 2012 compared to the base year of 2000. The biggest rate of conversion from forested areas and pastures to agricultural areas was observed between 2000 and 2006 with increases of 8,2% 6,8% and 4,4% of the total catchment areas of Runc, Țibleș and Sălăuța, respectively. According to the antecedent moisture scenarios, greater changes were observed for the AMC1 conditions between 2000 and 2006 with runoff volumes increases of 11,6%, 6,6% and 5,8% computed for Țibleș, Runc and Sălăuța, respectively.

However, between 2006 and 2012, the changes were not that significant as opposed to the above mentioned period. If this tendency is to continue, it might lead towards a stagnation of agricultural exploitation and a reduced runoff potential. Regardless, the Runc watershed area seems to be the exception in this case as the agricultural exploitation was only slightly smaller during the second 7-year period, compared to the first one. Considering all these and giving the fact that it is an ungauged river basin, there might be a need to increase awareness of its hydrological processes.

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