SPATIAL AND TEMPORAL DYNAMICS OF URBAN SPRAWL IN THE ROMANIAN PLAIN OVER THE LAST CENTURY

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Key-words: urban sprawl, built-up areas expansion, spatial analysis, Romanian Plain.

Abstract. The current study is a spatial and temporal assessment of urban sprawl dynamics, considered as a key parameter for quantifying urban sprawl. The assessment was carried out in a large geographical unit, i.e. Romanian Plain, located in the southern and south-eastern part of Romania and characterised by favourable natural and socio-economic conditions for urban growth and sprawl over time. The authors carried out an historical evolution of the built-up areas in order to explain urban growth over the past century using different cartographic materials (Austrian maps, 1912 and topographical maps, 1970) and Landsat satellite images (1990, 2002 and 2016). In order to identify and understand the spatial differentiations, the spatial and temporal statistical analysis was performed for four time frames: 1912–1970, 1970–1990, 1990–2002 and 2002–2016. The results were quantified using two indicators able express the magnitude of the built-up areas expansion at each LAU2 level: the Built-up Areas Expansion and the Annual Expansion Rate. Furthermore, in order to detect the geographical expansion trend of the built-up areas, the data on the annual expansion rate were interpolated using the global polynomial function. The spatial analyses revealed significant spatial differences in the urban sprawl process during the analysed intervals in relation to the main triggering factors.

1. INTRODUCTION

Urban sprawl is a global phenomenon regularly driven by population growth, increase of economy and infrastructure initiatives and large scale migration (Sudhira *et al*., 2004). Urban sprawl is currently one of the most important land use/cover changes which is affecting Europe with impacts on the environmental (e.g. surface sealing, transport emissions, ecosystem fragmentation), social (e.g. segregation, lifestyle changes), and economic (e.g. distributed production, land prices) functions (EEA, 2006; Patacchini and Zenou, 2009). In Europe, in particular, urban sprawl has developed over the past decades, notably contributing to how cities have expanded, thus leading to an increase in the housing, transport and infrastructure demand (EEA, 2006). In 2014, almost three quarters (72.5 %) of European Union (EU) 28 inhabitants lived in cities, towns and suburbs, however with significant differences in terms of size and spatial distribution of urban development. Population projections indicate that this pattern is expected to continue during the next 35 years (Eurostat, 2016).

The traditional urban development model of van den Berg *et al*. (1982) distinguishes four main stages: urbanization, suburbanization, desurbanization, and reurbanization, the first two generally characterising the urbanisation processes which took place in Europe during the last century. The urbanisation refers to different processes of change in the rural countryside induced by the urban centres, with different spatial patterns and forming different spheres of influence around the main cities (Antrop, 2000). The 20th century has been generally characterised by record population and economic growth, urban development increasing gradually through the concentration of population inside towns and cities mainly under urban-industrial growth. To the end of the 20th century, urban growth has pushed cities further and further out (Glaeser and Kahn, 2004). Thus, the compact urban areas which have characterised the largest part of the 20th century have increasingly been replaced by diffusive, leapfrogged, linear or clustered growth (Allen and Lu, 2003; Cheng and Masser, 2003;

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Wilson *et al*., 2003; Berling-Woff and Wu, 2004) with new functions (e.g. commercial, housing, logistic) outside the city outskirts. New suburbs and metropolitan areas emerged characterized by decentralized homes and jobs (Glaeser and Kahn, 2004). In many cities, people have tended to move out of the inner cities to suburban and peri-urban areas (hybrid areas of fragmented urban and rural characteristics) on the outskirts of existing metropolitan areas (Eurostat, 2016). It normally takes place in radial direction around the city centre or in linear direction along the highways. Usually sprawl takes place on the urban fringe, at the edge of an urban area or along the highways (Sudhira *et al*., 2004).

In Central and South-East European countries, urban growth, under the form of suburbanisation, has become the foremost urban development process bringing in population deconcentration and major spatial transformations related to land use/land cover patterns (Bičík and Jeleček, 2009). Suburbanisation has been described as a general model of development by linear tendencies along the main transportation axes, as well as low-density residential areas in the outskirts of towns in several post-communist metropolitan areas e.g. Budapest (Kok, Kovacs, 1999; Soós and Ignits, 2003), Prague (Sýkora, 2006; Ourednicek, 2007; Sýkora and Ourednicek, 2007; Bičík and Jeleček, 2009; Špačková and Ouředníček, 2012), Warsaw (Degórska, 2004; Lisowski, 2004; Degórska, 2012) or Sofia (Hirt, 2007; Hirt and Stanilov, 2007; Stanilov and Hirt, 2014).

In Romania, urban development, manifested through urbanisation and suburbanisation processes, has significantly affected the landscape over the last almost one hundred years. The scientific investigations on the urban development phenomenon throughout the last century underlined a strong relationships between the spatial dynamics and patterns of the built-up areas and the foremost explanatory driving factors (e.g. political, economic, demographic, natural) (Popovici *et al*., 2013; Grigorescu et a., 2015; Kucsicsa and Grigorescu, 2018). The scientific literature on urbanisation processes mostly explained the role of industry in the territorial planning and urban development (Șandru *et al*., 1984; Popescu, 1994; Ianoș, 2001; Săgeată and Dumitrescu, 2004) but also, reversibly, the role of deindustrialization and urban shrinkage after the fall of communism (Popescu, 2014). However, many studies have focused on the characteristics and typologies of suburbanisation and urban sprawl at national scale (Nicolae, 2002; Suditu *et al*., 2010; Suditu, 2012; Iojă *et al*., 2011; Ianoş *et al*., 2012; Petrișor, 2012; Grădinaru *et al*., 2015; Dumitrache *et al*., 2016; Iațu and Eva, 2016), but also at the level of different metropolitan areas (e.g. Bucharest, Constanța, Iași, Suceava, Brașov, Cluj-Napoca) or other urban areas (Sinaia). The largely addressed issues include: residential development and real-estate market (Conway *et al*., 1995; Niculiţă *et al*., 2011; Zilişteanu, 2011; Grigorescu *et al*., 2012a; Pocol and Jitea, 2013), spatial transformations and conflicts triggered by land cover/land use changes (Bălteanu and Grigorescu, 2006; Simion, 2010; Pătroescu *et al*., 2011; Iojă *et al*., 2011; Iojă *et al*., 2014; Grigorescu *et al*., 2012b, 2015), counter-urbanisation process and rural-urban fringe patterns (Ianoş *et al*., 2010; Guran-Nica and Sofer, 2011; Guran-Nica and Sofer 2012), suburbanization and metropolization processes (Erdeli and Simion, 2006; Dumitrache *et al*., 2016; Guran-Nica *el al*., 2016); the relationships between urban sprawl and transportation (Iațu *et al*., 2011), environmental issues (Cocheci, 2014) or different socio-demographic processes (Sârbu, 2012; Istrate, 2015; Cocheci and Mitrea, 2016).

In spatial analyses, urban growth is regularly quantified by considering the impervious or the built-up as the key parameter of assessing urban sprawl (Sudhira *et al*., 2004; Rahman *et al*., 2011; Shahraki *et al*., 2011). Urban sprawl can be assessed using different methodologies and tools, such as: logistic regression models (Cheng and Masser 2003; Allen and Lu 2003; Abebe 2013; Duwal 2013; Corodescu and Cîmpianu 2014; Shu *et al*. 2014; Kucsicsa and Grigorescu, 2017), remote sensing (Sudhira *et al*., 2004; Şandric *et al*. 2007; Feng, 2009; Bhatta, 2010; Rahman *et al*., 2011; Huzui *et al*. 2013; Tayyebi *et al*., 2013; Mihai *et al*. 2015); a combination of methods (Torrens, 2006, 2008) urban sprawl indices (Oueslati *et al*., 2015), bibliometric analysis (Chen *et al*., 2014) etc.

The population in the Romanian Plain is in continuous dynamics especially in the urban and suburban areas. This general trend which stimulates the urban sprawl process is putting significant pressures on land resources at the expense of agricultural or abandoned land use categories through built-up areas dynamics. As a result, the current study is aimed at assessing the spatial distribution of built-up areas expansion over a large period of time in order to identify and understand the spatial disparities of urban sprawl in relation to the social, economic and political features of the selected intervals.

2. STUDY-AREA

The Romanian Plain, together with the Danube Floodplain, also known as the Lower Danube Plain, is the largest plain area in Romania located in the southern and south-eastern part of the country. It stretches west to east over 500 km along the Danube River (which delimits it to the south, east and west on a distance of 840 km) and the Getic Piedmont, the Curvature Subcarpathians and the Moldavian Plateau in the north. The total area of the this vast plain is of 52,600 km^2, which is 21% of the territory of Romania, the second largest relief unit after the Carpathians (28%) (Posea and Iordan, 2005; Bălteanu, 2016)

This relief unit stands out as country's main agricultural region mainly due to its specific natural conditions. E.g. the relatively low altitudes of 10–200 m (locally 300 m), low declivity, the existence of large areas covered with high fertility soils (e.g. chernisols, brown and reddish-brown argilluvic), relative homogeneity of morpho-hydrographic and climate features, high percentage of arable land (80–90% of total agricultural surface) (Posea and Iordan, 2005). To these, the political and socio-economic factors the area had faced over time, had led to significant spatial transformations which have significantly changed the landscape aspect and pattern.

The Romanian Plain (including the Danube Floodplain) comprises about 650 localities which are totally overlapping its territory and more than 100 LAU 2 which are located at the border with the neighbouring relief units (Getic Piedmont, Curvature Getic, Moldavian and Dobrogea Plateau). In order to analyse urban sprawl dynamics, out of the border localities, the authors took into the consideration only the LAU 2 with more that 50% built-up area included within the Romanian plain limits. Thus, for the current study, 762 LAU2 (67 cities and nearly 695 communes) were analysed (Fig. 1).

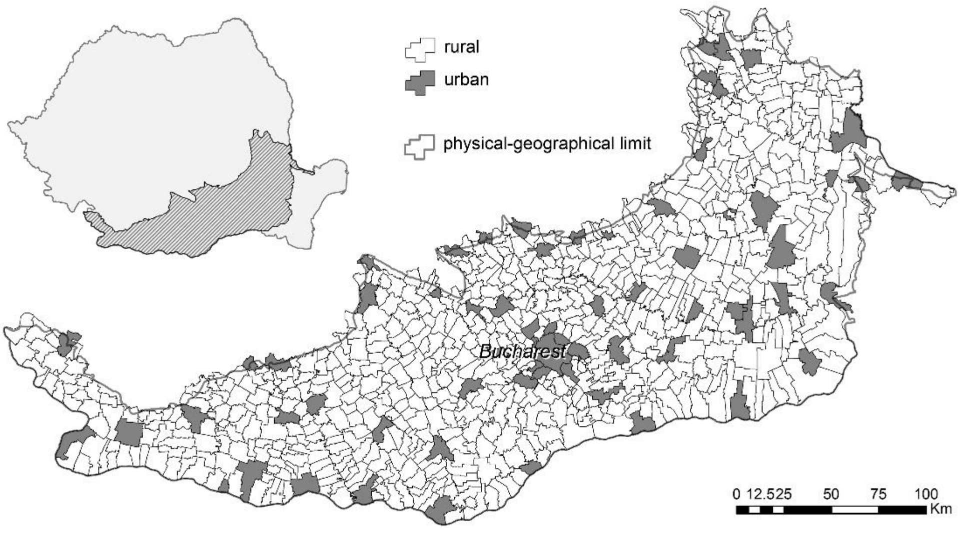

Fig. 1 – The local administrative units (LAU2 level) included in the Romanian Plain.

Spatially, Frecăţei, Borcea, Măraşu, Stăncuţa, Făcăeni, Borduşani and the towns of Galaţi and Bucharest are the largest LAU 2 (>20,000 ha), while Copăceni, Dobroeşti, Bărbuleşti, Cosoba, Goleşti and Chitila are the smallest (<1,500 ha).

According to the most recent classification of the urbanization process in Europe (carried out at LAU 2 level), the classification of the urbanisation level includes three major categories: densely-populated areas; intermediate areas (moderately populated areas) and thinly-populated areas. This classification was defined using a criterion of geographical contiguity in combination with a minimum share of population based on grid square cells of 1 km^2 living in different types of clusters defined by the according to their size and density (DEGURBA, 2011).

In the Romanian Plain the largest part of the densely-populated and intermediate areas overlap the main towns (including growth and development poles) and their suburban areas, while the thinly-populated areas are covering the urban void between the urbanised/suburbanised areas, as well as the peripheral areas, thus pointing to a visible spatial dispersion of urban growth phenomena from a demographic point of view (Fig. 2, Tab. 1).

Table 1

The characteristics of the urbanization level

Urbanisation degree	**Urban/rural structures**	**Characteristics**	
Densely-populated areas	Cities/large urban areas	At least 50% lives in high-density clusters	***high-density clusters*** = contiguous grid cells of 1 km^2 with a density of at least 1,500 inh./ km^2 and a minimum population of 50,000 inh. (alternative names: urban centre or city centre)
Intermediate areas	Towns and suburbs/small urban areas	Less than 50% of the population lives in rural grid cells and	
		Less than 50% lives in high-density clusters	***rural grid cells*** = 1km^2 grid cells outside urban clusters;
Thinly-populated area	Rural areas	More than 50% of the population lives in rural grid cells	***urban clusters*** = clusters of contiguous grid cells of 1 km^2 with a density of at least 300 inh./ km^2 and a minimum population of 5,000 inh.

Source: DEGURBA, 2011

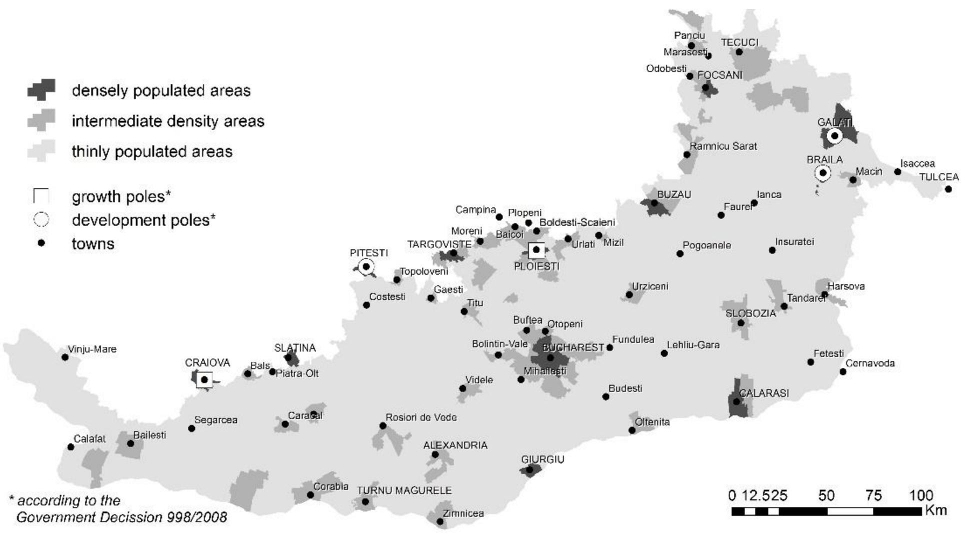

Fig. 2 – The urbanization degree in the Romanian Plain (processed after DEGURBA, 2011).

Rural-urban relations in the Romanian Plain have changed significantly in the last century in favour of the urban structures (Urucu and Bordânc, 2005b), in terms of demographic size (cities concentrate over 50% of population) and by the increasingly high and complex pressure exerted on the agricultural rural space which represents the largest land use category of this relief unit (over 80%). Regularly, the large cities developed as growing poles, generating emergent peri-urban and metropolitan areas (e.g. Bucharest, Galați, Craiova), while the small and medium-sized towns have a reduced influence on the surrounding rural areas.

3. METHODS AND DATA

The current assessment provides an historical overview on the built-up areas dynamics in the Romanian Plain, one of the areas largely affected by major spatial transformations over the last almost one hundred years (1912–2016) in relation to the socio-economic and political context.

The historical assessment of the territorial analysis was carried out using multi-temporal geospatial such as: cartographic materials from 1912 (Austrian maps scale 1: 100 000) and 1970 (topographical maps scale 1: 100 000) and Landsat satellite images (Table 2). In order to highlight the local differences, the authors used the boundaries from LAU2 database (2013). For further spatial differentiations, the spatial and temporal statistical analysis was performed for four time frames: 1912–1970, 1970–1990, 1990–2002 and 2002–2016. The first two intervals (1912–1970 and 1970–1990) overlap the largest part of the 20th century which involved significant political and socio-economic changes principally related to the main land reforms (1921, 1945) and the consequences of the communist policies on agriculture, town planning and industry. The last two analysed intervals (1990–2002 and 2002–2016) refer to the post-communist period characterised by the transition to the market economy followed by pre- and post-accession to the European Union. The resulted spatial transformations included major land use/cover changes related to the intensification (the intense use of land through investments in production means and labour force) and extensification (the conversion of additional land for the cultivation of commodities) of agriculture, deforestation and urban growth (mainly suburbanization) (Popovici *et al*., 2013; Grigorescu *et al*., 2015).

Table 2

Cartographic sources and satellite images used. Built-up area resulted after vectorisation

Maps					
Source		*Year*		*Scale*	*Area (ha)*
Austro-Hungarian map		1912		1:100 000	190,547
Topographic map		1970		1:100 000	304,171
Satellite images					
source	*year*	*data*	*Path/row*	*resolution*	*Area (ha)*
LANDSAT 4-5 TM	1990	July 07 August 21	182/029 183/029	30 m	357,943
LANDSAT 7 ETM	2002	August 23 September 15	182/029 183/029	30 m	373,448
LANDSAT 8 OLI_TIRS	2016	July 07 April 09	182/029 183/029	30 m	400,237

The statistical analysis of the spatial and temporal dynamics of urban sprawl in the Romanian Plain was carried out based on the processing, integration and querying of the geospatial data using the Geographical Information Systems (GIS) – ArcMap software 10.4. The initial geospatial data resulted from the extraction of built-up areas from the maps/satellite images in the selected years: 1912, 1970, 1990, 2002 and 2016 resulted from the raster data vectorisation. The delineation of built-up areas also included areas with farms, parks/green spaces inside towns, spaces under construction etc. As a result, the authors computed two spatial indicators at LAU2 level: *Built-up Areas Expansion, Annual Expansion Rate*. The first indicator (*Built-up Areas **E**xpansion*, ha) measures the difference between the built-up area computed for the last *(Y)* and first year *(X)* for the period under review, at LAU2 level: $\boldsymbol{E} = (Y\text{-}X)$, while the second indicator (*Annual Expansion **R**ate*, ha) was calculated based on the ratio between the built-up area expansion *(E)* over a certain analysed period and the number of years *(ny)* of each period under review: $\boldsymbol{R} = E/ny$ (Grigorescu *et al*., 2015). Both indicators were computed for each LAU2, as well as for the entire Romanian Plain in order to spot the areas subject to historical built-up areas dynamics under urbanization/suburbanization processes over the analysed period. Furthermore, in order to detect the geographical expansion trend of the built-up areas, the data on the annual expansion rate were interpolated using the global polynomial function.

4. RESULTS AND DISCUSSIONS

Over the last century, Romania experienced significant structural and functional transformations which have triggered land use/cover changes, thus imprinting specific territorial development at different spatial scales. Generally, the twentieth-century is characterized by widespread and diversified environmental changes mainly triggered by a continuous population growth which required the expansion of agricultural areas for extensive and intensive farming, followed by the intensification of the urbanization and forced industrialization processes. Together with the demographic growth and the upsurge of the urbanization process, the modernization and diversification of the communication means also occurred, the main roadways starting to spread by modernising some of the old routes or by opening new ones.

Until 1990, both the demographic increase and the landscape transformations were strongly influenced by the consequences of the two World Wars and the two agrarian reforms of 1921 and 1945. The first agrarian reform was endorsed after the Greater Union of Romania (1918), leading to the expropriation of large surfaces of state property which were fragmented and distributed to peasants. The second land reform, enacted after World War II, had in view the abolition of the great landowners property, preparing the transition to the socialist regime characterised by the centralised ownership, collectivisation and state farms (Bălteanu *et al*., 2006; Popovici *et al*., 2013). In the context of agricultural land expansion, after 1963 land betterment works continue to expand and intensify through the construction of dams and drainage systems in wetland areas (e.g. Danube Floodplain) and large irrigation systems in drought-prone areas (e.g. Oltenia Plain, Mostiștea Plain). Apart from the transformations which took place in agriculture, the second half of the 20^{th} century was also characterised by rapid urbanization and forced industrialization which played a decisive role in the country's urban development, the industrial town becoming the representative urban settlement type (Dumitrescu, 2008; Grigorescu *et al*., 2015). Consequently, the post-war industrialisation and urbanisation policies were followed by the gradual transition from the traditional rural-agrarian society to the urban-industrial society of the 1990s (Mitrică, 2014). After 1945, the regional polarization, aimed at diminishing regional imbalances, was carried out mainly through the establishment of new industrial plants in the new county seats or small and medium-size towns, including the towns located along the Danube Floodplain e.g. the metallurgical sector (e.g. Galați, Buzău, Zimnicea, Călărași), the chemical sector (e.g. Turnu Măgurele), machine building (Alexandria), textiles and food industry (e.g. Focșani, Tecuci), machine tool industries (e.g. Târgoviște). As a result, the economy of some towns boomed and their population tripled or quadrupled between 1966 and 1990 (Popescu, 2014). The development of the industrial platforms had contributed to the spatial transformations through industrial diffusion, i.e. the extension of the old industrial nuclei or the establishment of new industrial units in the rural areas located on the outskirts of towns (Popescu, 1994), thus acting as means of spatial expansion and as centres of towns' planning and development (Urucu and Bordânc, 2005b). As a result, the urbanization process has developed rapidly, over 10 new cities being built in the vicinity of the existing industrial centres or on bare land following the implantation of the new industrial sites. However, in most cases, the new industrial sites were located in small towns with agricultural or commercial functions (fairs) or even in rural settlements, leading to an explosive growth as a result of migratory flows (Săgeată and Dumitrescu, 2004). In line with that, the continuous increase in the number of inhabitants, especially after 1966, favoured largely by some facilities for commuting in industry and other non-agricultural activities in the surrounding of the main towns (e.g. Bucharest, Craiova, Slatina, Galați, Oltenița, Călărași) (Urucu and Bordânc, 2005b), triggered significant spatial transformations, mainly related to built-up areas expansion. From the second half of the 20th century, especially after 1960-1965, the Romanian Plain could be also defined as a space (or production) supplier for other activities than housing and agriculture, i.e. industry, construction (build-up), transport, storage (warehouses), recreational areas, tourism, experimental fields for cultural and research institutions, etc. (Urucu and Bordânc, 2005a). The magnitude of these changes has increased significantly within the last decades, especially after 1990, with notable spatial and functional differentiations.

The period that followed the year 1990 brought in major spatial and structural changes triggered by the fundamental political and socio-economic transformations which took place after the fall of the communist regime (1989). The resulted spatial changes embodied different forms in relation to the particularities of the two periods wherein of the post-communist periods: transition (1990–2003) and post-transition (2003-to date). The first period marked a major changeover in the economy in terms of replacing the old centralised system with the free market system, decollectivisation and privatisation of agriculture. The immediate consequences of these changes included the excessive land fragmentation, the conversion of big farms into small, peasant-type family farms, the degradation of the productive quality of agricultural terrains (Popovici *et al*., 2013), and land abandoned (mainly arable lands and permanent crops land use categories) which, in turn, led to the conversion to other urban sprawl-related categories (e.g. residential, commercial, warehouses) (Grigorescu *et al*., 2015). During the post-transition period, the main spatial transformations were related to Romania's pre- and post-accession to the European Union and the implementation of the Common Agricultural Policy (CAP) when the most important land-use changes were related to the conversion of agricultural, forest or pastures to residential, commercial and industrial/logistic under suburbanisation processes (Kucsicsa and Grigorescu, 2018). Thus, the major land transformations involved built-up areas dynamics which emerged mainly along the main transport axes (e.g. along the main motorways: Bucharest – Ploiești, Bucharest - Giurgiu, Bucharest – Urziceni, or along the highways: Bucharest-Pitești, Bucharest – Constanța) and, generally at city outskirts, taking the form of a leapfrog suburban sprawl (Sýkora, 2007) and linear built-up area expansion or "ribbon sprawl" which generally triggered new functional areas such as commercial, logistic or residential (Torrens, 2008; Kucsicsa and Grigorescu, 2018). Moreover, the conversion of non-urban areas within the remaining open spaces within the already existing built-up areas occurs under the form of "infill" development describing an outward direction of the urban development in the nearby urban fringe, sometimes called urban fringe development (Camagni *et al*. 2002; Abebe 2013; Duwal 2013).

Built-up areas dynamics. After 1900, in the Romanian Plain a continuous expansion of the built-up areas has been registered, a process related to the demographic evolution (e.g. positive birth rate, the transformation of rural settlements in towns and the migratory movements mainly after the Second World War or related to rural-urban migration) (Deică *et al*., 1983), with significant differences both spatially and temporally (Fig. 3). Thus, the resulted spatial data revealed that in 1912 the built-up area covered over 190,000 ha (3.8% of the entire study area) with larger surfaces registered mainly in Bucharest (~6,000 ha), and in some emerging industrial towns: Ploiești (~1,300 ha), Giurgiu (~1,200 ha), Galați (~1,100 ha) and rural settlements with predominantly agricultural functions: Costești (~1,000 ha), Suseni (~1,200 ha), Tătărăștii de Jos (~1,000 ha), Nicorești (~800 ha), Poiana Mare (~700 ha) etc. Compared to 1912, in 1970 the built-up area grew by almost 60% (+ 113,600 ha) in most of localities, with an average annual growth rate of 3.8 ha, predominantly in Bucharest (+7,500 ha), Brăila (+1,160 ha), Ploiești (+1,150 ha), (Galați (+940 ha), but also in Corabia, Fetești, Băileşti, Dăbuleni, as well as in Dor Mărunt, Bârla, Brazi, Radomireşti, Dragalina, Snagov etc. An important fact shown by the spatial analysis is that during this period new villages emerged, especially in the western half of the Romanian Plain, e.g. Nicolae Bălcescu (in Vânju Mare Town), Bistreţu (in Devesel Commune), Cozia (in Pristol Commune), Gemeni (in Dârvari Commune), Pisculeţ (in Piscu Vechi Commune), Vârtopu and Tudor Vladimirescu (in Corabia Town) or the nuclei of new settlements such as: Ştefan cel Mare, Urzica, Bucinişu, Traian (Olt County) or Gruia (Mehedinţi County). These new localities developed through the strengthening of their agro-industrial function or compensating the local polarisation role of the urban settlements which were insufficiently covering the area. At the end of this period (1968), a large number of rural localities were declared towns in the Romanian Plain, most of them having an important role as local centres in agricultural areas (e.g. Segarcea, Topoloveni, Vânju Mare), in the food industry (e.g. Ţăndărei) or as railway centres (Făurei) (Deică *et al*., 1983).

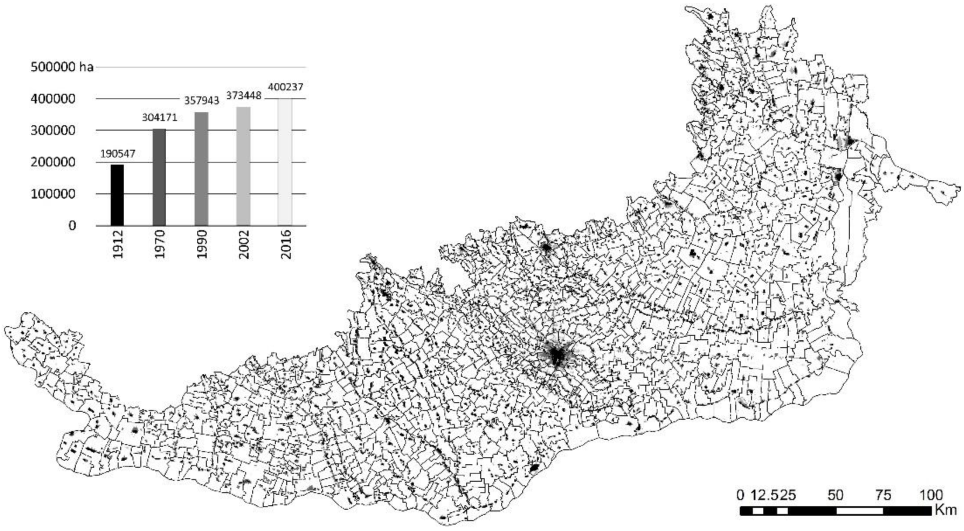

Fig. 3 – The spatio-temporal dynamics of built-up areas in the Romanian Plain (1912–2016).

Between 1970 and 1990, the annual expansion rate is reduced to 3.0 ha, due to the general slowdown of urbanisation in the 1980's (Benedek, 2006). However, significant increases were registered in the cities of Bucharest (+3,850 ha), Galați (+1,900 ha), Buzău (+8,020 ha), Ploiești (+650 ha) and Brăila (+550 ha). At the same time, the built-up areas records significant increase in some new industrial towns along the Danube Floodplain (e.g. Turnu Măgurele, Zimnicea, Giurgiu, Oltenița, Călăraşi) or in some localities near Bucharest (e.g. Popeşti-Leordeni, Otopeni, Pantelimon). The increase of the urban density after 1968, contributed to more complex relations between cities and the surrounding rural areas. As a result, urbanization has been accompanied by an intensification of the city's influence on the suburban areas, incorporating new suburban localities into their administrative territory (Deică *et al*., 1983; Șandru *et al*., 1983). The main scope of this process was to improve urbanisation indicators and provide a faster territorial diffusion of urbanisation (Benedek, 2006).

Within the 1990–2002 interval, the built-up areas expansion is further reduced to an annual expansion rate of 1.5 ha. However, following the post-communist period, the urban sprawl-related processes, i.e. suburbanization, in the environs of the main cities has been characterised by the spreading of population in the urban-rural interface, triggering built-up areas expansion, mainly at the expense of agricultural and forested lands (Grigorescu *et al*., 2015). Thus, significant increases were registered in Bucharest (+630 ha) and in some localities in its metropolitan area: Voluntari (+530 ha), Pantelimon (+220 ha), Otopeni (+180 ha), Snagov (+160 ha), Chiajna (+140 ha), Bragadiru and Popeşti-Leordeni (+130 ha each). Also, significant increases have been recorded in the cities of Galaţi (+190 ha), Ploieşti and Pitești (+150 ha each), Giurgiu, Buzău and Amara (+130 ha each), Olteniţa (+120 ha) etc.

After 2002, large cities with developing services (e.g. Bucharest), as well as towns with high value-added manufacturing industries (e.g. Piteşti) continued to grow (Benedek, 2006), so as the small towns and rural settlements located under the influence area of large cities or the medium-sized towns with mixed functions. Thus, during the 2002–2016 period, the built-up areas dynamics grown to an annual expansion rate of 1.8 ha, with significant increases registered in Bucharest (+1,310 ha) and its neighbouring localities (e.g. Bragadiru, Pantelimon, Chiajna, Corbeanca, Popeşti-Leordeni, Domneşti, Otopeni, Măgurele, Voluntari with 300–600 ha each), followed by Galați (+ 170 ha) and Vânători (+ 200 ha) in its metropolitan area, Focșani (+ 150 ha), Pitești (+ 110 ha), Buzău and Slobozia (+ 90 ha each) etc.

Overall, after 1912, the most significant increase of the built-up areas were recorded in Bucharest (+13,310 ha), Galați (+3,210 ha), Ploieşti (+1,950 ha), Brăila (+1,800 ha), Voluntari (+ 1,640 ha), Buzău (+1,530 ha), Călăraşi (+1,360 ha) and Piteşti (+1,310 ha). At the opposite side, the lowest increases were registered in the localities Păunești (+20 ha), Râca (+23 ha), Malu (+40 ha), Robeasca (+42 ha), Colelia (+44 ha), Gălbinaşi (+62 ha), Bueşti (+ 64 ha), Drăgăneşti de Vede (+65 ha) and in some localities situated at contact of the plain with the hilly or the plateau relief units (Fig. 4).

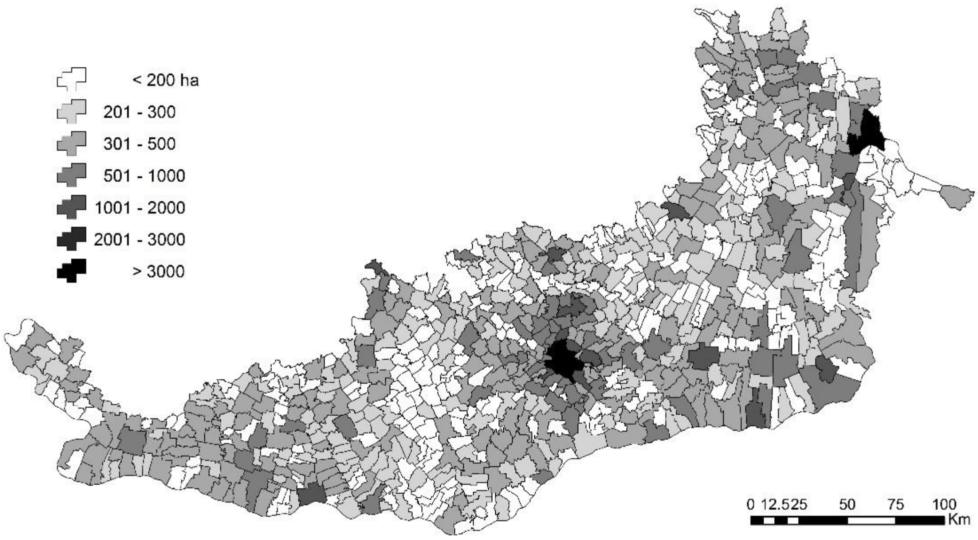

Fig. 4 – Built-up areas expansion in the Romanian Plain after 1912 (LAU2 level).

Within the relief sub-units of the Romanian Plain, the largest built-up areas growth took place in the localities of the Vlăsia Plain (e.g. Bucharest, Voluntari, Otopeni, Pantelimon, Corbeanca, Buftea, Baloteşti), the Prahova Piedmontan Plain (e.g. Ploieşti, Târgovişte, Brazi) and in the Danube Floodplain (especially Galaţi, Brăila, Feteşti, Călăraşi, Turnu Măgurele and Corabia). Significant increases have also been recorded in the localities of Mostiştea Plain (e.g. Dor Mărunt, Dragalina, Perişoru), Romanați Plain (e.g. Dăbuleni, Amărăştii de Jos, Caracal, Celaru, Daneţi), Galaţi Plain (e.g. Matca, Cudalbi, Pechea, Vânători), and along the Olt (e.g. Rusăneşti, Izbiceni, Tia Mare, Băbiciu), Argeş (e.g. Piteşti, Ştefăneşti, Găeşti, Bradu, Bolintin Vale, Cornetu, 1 Decembrie, Colibaşi), Ialomiţa (e.g. Ţăndărei, Slobozia, Urziceni), Bârlad (e.g. Tecuci, Drăgăneşti, Barcea, Umbrăreşti) and Buzău (Buzău) rivers.

The spatial trend of the built-up areas expansion. In order to detect the expansion trend of the built-up areas, the data on the annual expansion rate were interpolated using the global polynomial function. Thus, according to the data on the annual expansion rate during the entire analyzed period (1912–2016), there is a more evident expansion trend in the Municipality of Bucharest and the neighbouring localities with average values of 4-10 ha/year. A significant trend is also noted close to the municipalities of Galaţi, Călăraşi, Oltenița, Tecuci, Piteşti, Târgoviște, Calafat and Fetești (Fig. 4).

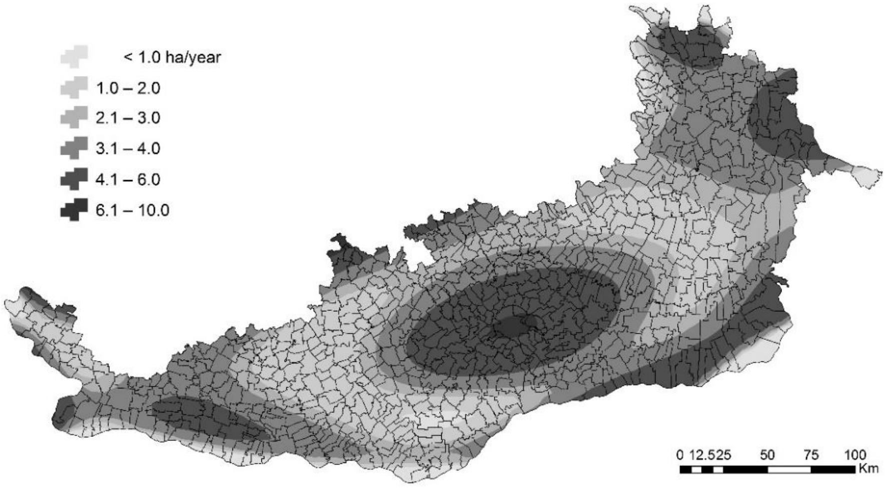

Fig. 5 – The built-up areas expansion trend (1912–2016).

The temporal analysis of the data reveals significant spatial differences in the built-up areas expansion trend between 1912 and 2016 (Fig. 6).

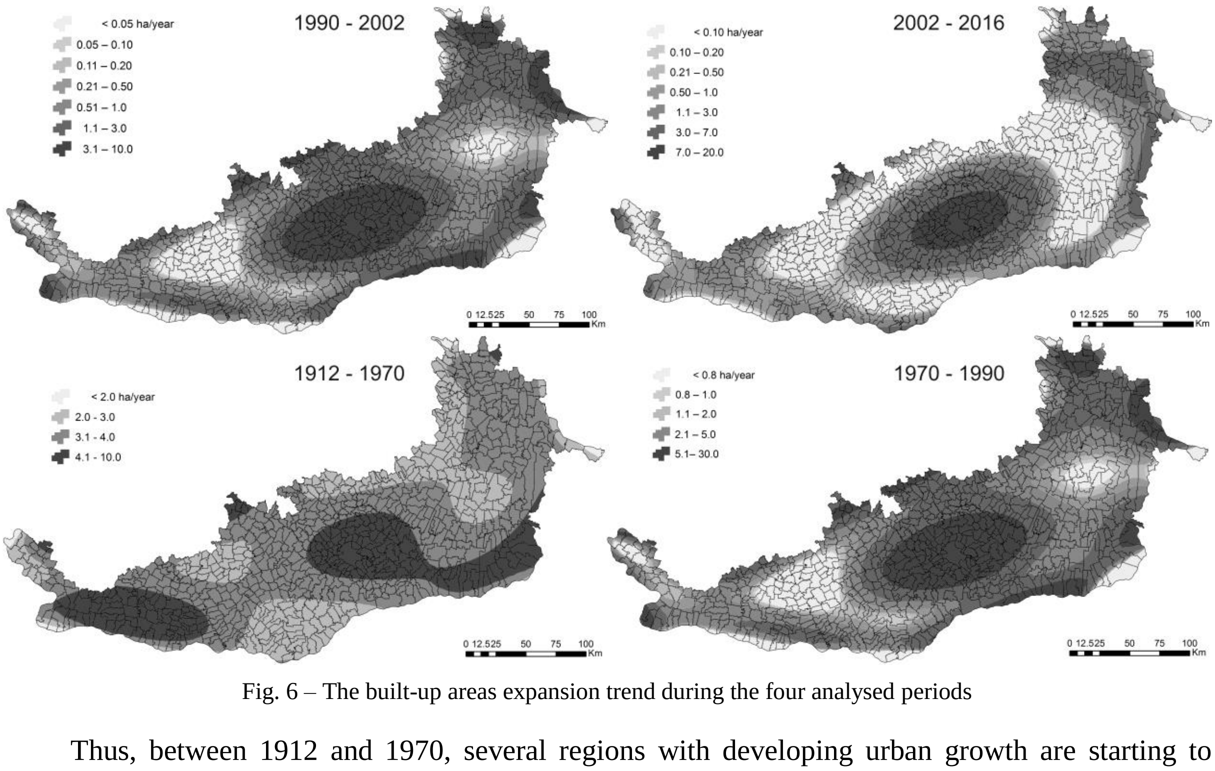

Fig. 6 – The built-up areas expansion trend during the four analysed periods

Thus, between 1912 and 1970, several regions with developing urban growth are starting to emerge in the central, south-eastern and western parts of the Romanian Plain. This trend predicts significant spreading in the settlements located in the Vlăsia Plain, in the south-eastern part of Bărăgan

Plain and Oltenia Plain. Between 1970 and 1990, the trend of growth emerged in the central part of the Romanian Plain, especially in the southern half of the Vlăsia Plain, but also in the Mostiştea, Burnas and Prahova Piedmontan Plains. At the same time, another important nucleus is formed in the north-eastern part of the Romanian Plain, around the towns of Galați and Tecuci.

After 1990 the built-up areas expansion becomes more evident especially in Bucharest and its surrounding localities, with a significant increase after 2002 when the annual expansion rate reaches maximum values. During this period, the nuclei around the cities of Galaţi and Tecuci become better outlined.

Within the last almost thirty years, the continuous built-up areas expansion trend was mainly triggered by the shifting of most of agricultural related functions to residential, commercial or logistics in some of the settlements located in the urban-rural interface (Grigorescu *et al*., 2015). Overall, the built-up areas dynamics analysis over the last century in the Romanian Plain highlighted significant spatial and temporal differences in the urban sprawl phenomenon (urbanization and suburbanization) as a result of urban and rural development, but also in relation to the changing the urban-rural relations through time.

5. CONCLUSIONS

The current study is an analysis of the urban sprawl phenomenon in the Romanian Plain over the last one hundred years using an analytical method for cross-examining, comparing and evaluating built-up areas dynamics, the main parameter used for the spatial quantification of urban processes. The main scope was to identify urban transformations and their spatial differences and understand them in relation to the key socio-economic and political changes of the analysed period.

Since the beginning of the 20th century the Romanian Plain was subject to a continuous expansion of the built-up areas, with significant differences both spatially and temporally. In order to pinpoint the spatial differences, a detailed analysis for four time frames (1912–1970, 1970–1990, 1990–2002 and 2002–2016) was performed. Thus, between 1912 and 1970, the total built-up area grew with almost 60%, from over 190,000 ha in 1912 to more than 300,000 ha in 1970 with an average annual expansion rate of 3.8 ha/LAU2. During this interval, extensive urban growth was registered in Bucharest followed by some emerging towns (e.g. Ploieşti, Giurgiu, Galaţi, Brăila) and rural settlements with predominantly agricultural functions (e.g. Suseni, Tătărăşti de Jos, Nicoreşti, Poiana Mare).

Between 1970 and 1990, a slight decrease of the built-up area of nearly 54,000 ha was registered, thus triggering a relatively shrinkage of the average annual expansion rate (3.0 ha/LAU2). This could be largely explained by the spatial transformations caused by the land management works which were carried out especially in the Danube Floodplain, sometimes at the expense of different built-up areas categories. Moreover, this built-up areas drawback was also explained by the restrictive regulations of the communist period regarding urban development. Nevertheless, individually, notable increases were registered in Bucharest, Galați, Buzău, Ploiești, Brăila or in other new industrial towns along the Danube River (e.g. Turnu Măgurele, Zimnicea, Giurgiu, Oltenița, Călăraşi) or small settlements near Bucharest (e.g. Popeşti-Leordeni, Otopeni, Pantelimon).

After the fall of communism, the unleashing urban polices explained the increase in the built-up during the 1990-2002 interval (15,500 ha). However, the reduced average annual expansion rate (1.5 ha/LAU2) justifies a higher growth in the localities where urbanization and suburbanization processes were more dynamic. During the last interval (2002–2016), under an overall increase of 26,800 ha and an average annual expansion rate of 1.8 ha, the built-up areas growth was largely registered in Bucharest and some localities from its metropolitan area (e.g. Bragadiru, Pantelimon, Chiajna, Corbeanca, Popeşti-Leordeni, Domneşti, Otopeni, Măgurele, Voluntari), mainly triggered by suburbanisation.

The spatial trend of built-up areas dynamics highlights the general evolution of the urban sprawl phenomenon from the first delineation of areas with urban growth occurrence until 1970, to the more compact growth nuclei which emerged and developed between 1970 and 1990. After 1990 the built-up areas expansion becomes more obvious in some towns (e.g. Bucharest, Galați, Brăila, Pitești) and the surrounding localities, with a significant increase after 2002 when the annual expansion rate reaches the maximum values.

The results of such study provide detailed spatial information on the urban sprawl phenomenon that might become useful for future planning interventions, as well as identifying planning strategies and projects that will enable urban and regional adaptive development. On the other hand, the already built database on the spatio-temporal build-up areas expansion represents essential information for predicting future urban spatial growth in relation to its explanatory driving factors.

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Image courtesy for the LANDSAT satellite images of U.S. Geological Survey available at: www.usgs.gov.

REFERENCES

Abebe, G. A. (2013), *Quantifying urban growth pattern in developing countries using remote sensing and spatial metrics: A case study in Kampala, Uganda*. Ph.D. Thesis, ITC Enschede, The Netherlands. Retrieved from https://www.itc.nl/library/papers_2013/msc/upm/abebe.pdf, 108 p.

Allen, J., Lu, K. (2003) *Modeling and prediction of future urban growth in the Charleston region of South Carolina: a GIS-based integrated approach. Conservation Ecology*, 8(2) https://www.ecologyandsociety.org/vol8/iss2/art2/inline.html

Antrop, M. (2000), *Changing patterns in the urbanized countryside of Western Europe,* Landscape ecology, 15(3), pp. 257–270.

Bălteanu (2016), *Unitățile de relief*, în România. Natură și Societate, (coord. Bălteanu D., Dumitrașcu M., Geacu S., Mitrică B., Sima M.),Editura Academiei Române, pp. 82–101.

Bălteanu D., Grigorescu Ines (2006), *The impact of Changing land Use upon the Environment in the Metropolitan Area of Bucharest.* Preliminary Considerations, Romanian Review of Regional Studies – Journal of the Centre for Regional Geography, II, Cluj-Napoca, pp. 35–44.

Benedek, J. (2006), *Urban policy and urbanisation in the transition Romania*, Romanian Review of Regional Studies, 2(1), pp. 51–64.

Berling-Wolff, S., Wu, J. (2004), *Modeling urban landscape dynamics: a case study in Phoenix, USA,* Urban ecosystems, *7*(3), pp. 215–240.

Bhatta B. (2010) *Urban Growth and Sprawl,* In: Analysis of Urban Growth and Sprawl from Remote Sensing Data, Advances in Geographic Information Science. Springer, Berlin, Heidelberg, pp. 1–16.

Bičík, I., Jeleček, L. (2009), *Land use and landscape changes in Czechia during the period of transition 1990–2007,* Geografie – Sbornik ČGS, 114, 4, pp. 263–281.

Camagni, R., Gibelli, M. C., Rigamonti, P. (2002), *Urban mobility and urban form: the social and environmental costs of different patterns of urban expansion,* Ecological economics, 40(2), pp. 199–216.

Cheng, J., Masser, I. (2003), *Urban growth pattern modeling: a case study of Wuhan city, PR China*, Landscape and Urban Planning, 62(4), pp. 199–217.

Cocheci, M. (2014), *Environmental impact assessment of urban sprawl in the Brașov Metropolitan Area,* Urbanism. Arhitectura. Constructii, *5*(2), pp. 21–37.

Cocheci, V., Mitrea, A. (2016), *Youthification in the Metropolitan Area of Cluj*, Urbanism. Arhitectură. Construcții, 9 (2), pp. 121–130.

Conway, F., Katsura H., Budisteanu, Ileana, Pascal, Ileana (1995), *The Transition to a market-based housing sector in Romania. Final Report. Report prepared for International City County Management Association. Local Government and Housing Privatization*, USAID Contract No. EUR-0034-C-00-2034-00, The Urban Institute, Washington, D.C.

Corodescu, Ema, Cîmpianu, C. (2014), *Assessing the Spatial Differences among Some Urban Expansion Driving Forces in Constanta Metropolitan Area (Romania),* Analele Științifice ale Universității "Al. I. Cuza", Iași, vol. LX, no. 2, s. II – c, Geography series, 77–95.

Deică, P., Cândea, Melinda, Erdeli, G., *Dinamica și căile de creșetre a orașelor*, în vol. Geografia României. Geografia Umană și Economică, II, Editura Academiei Republicii Socialiste România, pp. 137–149.

Degórska, Bożena (2004), *Spatial conflicts between the shaping of open spaces and the socio-economic development in the metropolitan area of Warsaw*, In: New Aspects of Regional Transformation and the Urban-Rural Relationship (Ed. András Donát Kovacs), Centre for Regional Studies of the Hungarian Academy of Sciences, Pecs, Hungary. http://discussionpapers.rkk.hu/index.php/DP/article/viewFile/2221/4137

Degórska, Bożena (2012), *Spatial growth of urbanised land within the Warsaw Metropolitan Area in the first decade of the 21st century,* Geographia Polonica, 85(3), pp. 77–95.

DEGURBA (2011), *The New Degree of Urbanization – Local Administrative Units* http://ec.europa.eu/eurostat/ramon/miscellaneous/index.cfm?TargetUrl=DSP_DEGURBA.

Dumitrache, Liliana, Zamfir, Daniela, Nae, Mirela, Simion, G., Stoica, Valentina (2016), *The Urban Nexus: Contradictions and Dilemmas of (Post) Communist (Sub) Urbanization in Romania*, Human Geographies, 10(1), pp. 39–58.

Dumitrescu, Bianca (2008), *Oraşele monoindustriale din România, între industrializare forţată şi declin economic*, Edit. Universitară, Bucureşti, 301 p.

Duwal, S. (2013), *Modeling urban growth in Kathmandu Valley*, Ph.D. Thesis, University of Twente, Enschede, The Netherlands, 89 p, Retrieved from https://www.itc.nl/library/papers_2013/msc/upm/duwal.pdf.

Erdeli, G., Simion, G. (2006), *Local Decentralization and extended suburbanization: A geographical approach of the metropolisation process in Romania*, Buletinul Societăţii de Geografie din România, XII (XXCII), Bucureşti, pp. 107–120.

Eurostat (2016), *Urban Europe — statistics on cities, towns and suburbs — patterns of urban and city developments*, doi: 10.2785/91120; Cat. No: KS-01-16-691-EN-N http://ec.europa.eu/eurostat/statistics-explained/index.php/Urban_Europe_%E2%80%94_statistics_on_cities,_towns_and_suburbs.

Feng, L. (2009), *Applying remote sensing and GIS on monitoring and measuring urban sprawl. A case study of China*, Revista Internacional Sostenibilidad, Tecnología y Humanismo, (4), pp. 47–56.

Grădinaru, Simona, Iojă, C.I., Onose, Andreea, Gavrilidis, A.A., Pătru-Stupariu, Ileana, Kienast, F., Hersperger, Anna (2015), *Land abandonment as a precursor of built-up development at the sprawling periphery of former socialist cities*, Ecol. Indic., 57, pp. 305–313.

Glaeser, E. L., Kahn, M. E. (2004), *Sprawl and urban growth*, Handbook of regional and urban economics, *4*, pp. 2481–2527.

Grigorescu, Ines, Mitrică, Bianca, Mocanu, Irena, Ticana, Nicoleta (2012a), *Urban sprawl and residential development in the Romanian Metropolitan Areas*, Romanian Journal of Geography, 56 (1), pp. 43–59.

Grigorescu, Ines, Mitrică, Bianca, Kucsicsa, G, Popovici, Ana, Dumitraşcu, Monica, Cuculici, Roxana (2012b), *Post-communist land use changes related to urban sprawl in the Romanian Metropolitan Areas*, Journal of Studies and Research in Human Geography, 6(1), pp. 35–46.

Grigorescu, Ines, Kucsicsa, Gh., Mitrică, Bianca (2015), *Assessing Spatio-Temporal Dynamics of Urban Sprawl in the Bucharest Metropolitan Area over the last century*, In: Land use/Cover Changes in Selected Regions in the World, vol. X, Issued by IGU-LUCC, Charles University in Prague, Faculty of Science, Prague, pp. 19–27.

Guran-Nica, Liliana, Sofer, M., Ştefan, Narcizia (2011), *New rural-urban relationships in Romania. Issues at the rural-urban fringe of Bucharest*, Studia Universitatis Babeş-Bolyai, Geographia, 1, Cluj-Napoca, pp. 127–140.

Guran-Nica, Liliana, Sofer, M. (2012), *Migration dynamics in Romania and the Counter-Urbanisation Process: A Case Study of Bucharest's Rural-Urban Fringe*, in vol. Translocal Ruralism: Mobility and Connectivity in European Rural Space, 103, pp. 87–102.

Guran-Nica, Liliana, Sofer, M., Bistriceanu-Pantelimon, Corina (2016), *From Urbanization to Metropolization; A Case Study of Romania*, Procedia of Economics and Business Administration, vol. 3, no. 1, pp. 106–113. ftp://ftp.repec.org/opt/ReDIF/RePEc/icb/wpaper/ICESBA2016_12GURAN_p106-113.pdf.

Hirt, Sonia (2007), *Suburbanizing Sofia: Characteristics of post-socialist peri-urban change*, Urban Geography, 28(8), pp. 755–780.

Hirt Sonia, Stanilov K. (2007), *The perils of post-socialist transformation: Residential development in Sofia,* In: The Post-Socialist City (Edit. Stanilov K.), The GeoJournal Library, vol. 92. 215–244, Springer, Dordrecht.

Huzui Elena, A., Abdelkader, A., Patru-Stupariu, Ileana (2013), *Analysing urban dynamics using multi-temporal satellite images in the case of a mountain area, Sinaia (Romania)*, International Journal of Digital Earth, 6(6), pp. 563–579.

Ianoş, I. (2001), *Economic transition and urban industrial employment in post-communist Romania*, in vol. Post-Communist Romania, Palgrave Macmillan UK, pp. 191–206.

Ianoş, I., Cercleux, Andreea-Loreta, Pintilii, R.D. (2010), *Remarks on identity building of rural and urban communities in the Bucharest Metropolitan Area*, Analele Universităţii din Oradea – Seria Geografie Tom XX, no. 2/2010 (December), pp. 173–183.

Ianoş, I., Peptenatu, D., Drăghici, Cr., Pintilii, R. D. (2012), *Management elements of the emergent metropolitan areas in a transition country. Romania, as case-study*, Journal of Urban and Regional Analysis, IV(2), pp. 149–172.

Iojă, C. I., Niţă, M. R., Vânău, G. O., Onose, D. A., Gavrilidis, A. A. (2014), *Using multi-criteria analysis for the identification of spatial land-use conflicts in the Bucharest Metropolitan Area*, Ecological Indicators, 42, pp. 112–121.

Iaţu, C., Munteanu, A., Boghinciuc, M., Cernescu, R., Ibănescu, B. (2011), *The effects of transportation system on the urban sprawl process for the city of Iași, Romania,* Urban Transport XVII: Urban Transport and the Environment in the 21st Century, vol. 116, pp. 291–302.

Iaţu, C., Eva, M. (2016), *Spatial profile of the evolution of urban sprawl pressure on the surroundings of Romanian cities (2000–2013),* Carpathian Journal of Earth and Environmental Sciences, *11*(1), pp. 79–88.

Iojă, C., Onose, D., Nită, M., Vanău, G., Pătroescu, Maria, Gavrilidis, A., Saghin, I., Zarea, R. (2011), *The conversion of agricultural lands into built surfaces in Romania,* Recent Researches in Urban Sustainability and Green Development, USCUDAR Proceedings, pp. 115–120.

Istrate, M. I. (2015), *Urban sprawl and demographic dynamics in Suceava Metropolitan Area*, Journal of Community Positive Practices, 15(2), pp. 43–55.

Kok, H., Kovacs, Z. (1999), *The process of suburbanization in the agglomeration of Budapest*, Netherlands Journal of Housing and the Built Environment, 14(2), pp. 119–141.

Kucsicsa, Gh., Grigorescu, Ines (2018), *Urban growth related to distance explanatory factors in Bucharest Metropolitan Area. Spatial and temporal assessment using logistic regression*, Journal of Urban Planning and Development, ASCE Library, vol. 144, ISSUE 1.

Lisowski, A. (2004), *Social aspects of the suburbanisation stage in the agglomeration of Warsaw*, Dela, (21), 531–541.

Mihai, B., Nistor, C., Simion, G. (2015), *Post-socialist urban growth of Bucharest, Romania-a change detection analysis on LANDSAT imagery (1984–2010)*, Acta Geographica Slovenica, 55(2), pp. 225–234.

Mitrică, Bianca (2014), *Changes in the dynamics and demographic structures of the Romanian urban population. An overview of the post-communist period*, Revue Roumaine de Géographie, *58*(2), pp. 201–212.

Nicolae, I. (2002), *Suburbanismul, ca fenomen geografic în România,* Edit. Meronia, București 397 p.

Niculiţă, L., Iojă, C., Tudor, A., Pavelescu, G., Iojă, Annemarie (2011), *Evaluation of environmental impact caused by new residential areas in the Bucharest Metropolitan Area*, pp. 130–135, ISBN: 978-1-61804-037-4.

Niculiţă, L., Iojă, C., Tudor, A., Pavelescu, G., Iojă, Annemarie (2011), *Evaluation of environmental impact caused by new residential areas in the Bucharest Metropolitan Area*, Proceedings of USCUDAR, 35, pp. 130–135.

Oueslati, W., Alvanides, S., Garrod, G. (2015), *Determinants of urban sprawl in European cities,* Urban Studies, *52*(9), pp. 1594–1614.

Ouředníček, M. (2007), *Differential suburban development in the Prague urban region*, Geografiska Annaler: Series B, Human Geography, 89(2), pp. 111–126.

Patacchini, E., Zenou, Y. (2009), *Urban sprawl in Europe*, Brookings-Wharton Papers on Urban Affairs, (1), pp. 125–149.

Pătroescu, Maria, Vânău, G., Niţă, M., Iojă, C., Iojă, Annemarie (2011), *Land Use Change in the Bucharest Metropolitan Area and its Impacts on the Quality of the Environment in Residential Developments*, Forum Geografic, X(1), doi:10.5775/fg.2067–4635.2011.036.i, pp. 177–186.

Petrişor A.I. (2012), *Land cover and land use analysis of urban growth in Romania*, Human Geographies – Journal of Studies and Research in Human Geography, 6(1), doi: 10.5719/hgeo.2012.61.47, pp. 47–51.

Pocol, C. B., Jitea, I. M. (2013), *The residential function of the countryside and the development of the peri-urban area of Cluj Napoca City*, Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Horticulture, 70(2), pp. 368–373.

Popescu, Claudia (1994), *Rolul industriei în organizarea spațiului geografic*, Analele Universității din Oradea – Geografie., tom IV, pp. 184–191.

Popescu, Claudia (2014), *Deindustrialization and urban shrinkage in Romania. What lessons for the spatial policy?,* Transylvanian Review of Administrative Sciences, 10(42), pp. 181–202.

Popovici, E. Ana, Bălteanu, D., Kucsicsa, G. (2013), *Assessment of changes in land-use and land-cover pattern in Romania using Corine Land Cover Database*. Carpathian Journal of Earth and Environmental Sciences, 8(4), pp. 195–208.

Posea, Gr., Iordan, I. (2005), *Câmpia Română. Caracterizare generală* în vol. *Geografia României,* Câmpia Română, Dunărea, Podişul Dobrogei, Litoralul Românesc al Mării Negre și Platforma Continentală, V, pp. 27–31, Edit. Academiei Române, București.

Rahman, A., Aggarwal, S. P., Netzband, M., & Fazal, S. (2011), *Monitoring urban sprawl using remote sensing and GIS techniques of a fast growing urban centre, India,* IEEE Journal of selected topics in applied earth observations and remote sensing, 4(1), pp. 56–64.

Săgeată, R., Dumitrescu (Mitrică), Bianca (2004), *Impactul industrializării supradimensionate asupra spaţiului urban. Studii de caz: Galaţi, Târgovişte, Oţelu Roşu*, Geographica Timisiensis, vol. 13, nr. 1, pp. 103–114.

Sârbu C. (2012), *Urban Expansion – Urban Shrinking Considerations on Brașov Agglomeration Urban Dynamics*, Human Geographies – Journal of Studies and Research in Human Geography, 6(1), pp. 53–58

Shahraki, S. Z., Sauri, D., Serra, P., Modugno, S., Seifolddini, F., Pourahmad, A. (2011), *Urban sprawl pattern and land-use change detection in Yazd, Iran,* Habitat International, 35(4), pp. 521–528.

Shu, B., Zhang, H., Li, Y., Qu, Y., Chen, L. (2014), *Spatiotemporal variation analysis of driving forces of urban land spatial expansion using logistic regression: A case study of port towns in Taicang City, China, Habitat International*, 43, pp. 181–190.

Simion, G. (2010), *The spatial changes of land use in the Bucharest Metropolitan Area 1970s – 2000s,* Human Geographies, vol. 4, issue 2, doi:10.5719/hgeo.2010.42/115, pp. 115–123.

Soós, G., Ignits, G. (2003), *Suburbanization and its consequences in the Budapest metropolitan area,* 3rd EuroConference "The European City in Transition, The City and the Region", Bauhaus-Universität Weimar, Germany, Supported by the European Commission https://core.ac.uk/download/pdf/11871881.pdf.

Špačková, P., & Ouředníček, M. (2012). *Spinning the web: new social contacts of Prague's suburbanites*. Cities, *29*(5), 341–349.

Stanilov, K., & Hirt, S. (2014), *Sprawling Sofia. Postsocialist Suburban Growth in the Bulgarian Capital* in vol. Confronting Suburbanization: Urban Decentralization in Postsocialist Central and Eastern Europe, (eds K. Stanilov and L. Sýkora), John Wiley & Sons, Ltd, Chichester, UK. doi: 10.1002/9781118295861.ch6, pp. 163–191.

Sudhira, H. S., Ramachandra, T. V., Jagadish, K. S. (2004), *Urban sprawl: metrics, dynamics and modelling using GIS*, International Journal of Applied Earth Observation and Geoinformation, *5*(1), pp. 29–39.

Suditu, B. (2009), *Urban sprawl and residential mobilities in the Bucharest area – reconfiguration of a new residential geography*, Human Geographies, vol. 3, issue 2, pp. 79–93.

Suditu, B. (2012), *Urban sprawl – the legal context and the territorial practices in Romania*, Human Geographies – Journal of Studies and Research in Human Geography, Volume 6, Issue 1, pp. 73–77.

Suditu, B., Ginavar, Anca, Muică, Ana, Iordăchescu, Crenguţa, Vârdol, Amalia, Ghinea B. (2010), *Urban sprawl characteristics and typologies in Romania*, Journal of Studies and Research in Human Geography, vol. 4, issue 2, pp. 79–87.

Sykora. L., Ourednicek M. (2007), *Sprawling post-communist metropolis: commercial and residential suburbanisation in Prague and Brno, the Czech Republic,* in vol. Employment Deconcentration in European Metropolitan Areas, Springer Netherlands, DOI: 10.1007/978-1-4020-5762-5_8, 91, pp. 209–233.

Sykora, L. (2006), *Urban development, policy and planning in the Czech Republic and Prague,* in vol. Spatial Planning and Urban Development in the New EU Member States: From Adjustment to Reinvention, (Eds. Altrock U., Güntner S., Huning S., Peters D.) Routledge, Aldershot and Burlington: Ashgate, pp. 113–140.

Şandric, I., Mihai, B., Savulescu, I., Suditu, B., Chitu, Z. (2007), *Change detection analysis for urban development in Bucharest-Romania, using high resolution satellite imagery,* in: 2007 Urban Remote Sensing Joint Event IEEE, pp. 1–8.

Șandru I., Cucu V., Deică P. (1984), *Esența, formele și factorii urbanizării*, în vol. Geografia României. Geografia Umană și Economică,II, Editura Academiei Republicii Socialiste România, pp. 170–172.

Tayyebi, A., Perry, P.C., Tayyebi, A.H. (2013), *Predicting the expansion of an urban boundary using spatial logistic regression and hybrid raster–vector routines with remote sensing and GIS,* International Journal of Geographical Information Science, 28(4), pp. 639–659.

Torrens, P. M. (2006), *Simulating sprawl,* Annals of the Association of American Geographers, 96(2), pp. 248–275.

Torrens, P. M. (2008), *A toolkit for measuring sprawl*. Applied Spatial Analysis and Policy, 1(1), pp. 5–36.

Urucu, Veselina, Bordânc F. (2005a), *Agricultura* în vol. *Geografia României,* Câmpia Română, Dunărea, Podişul Dobrogei, Litoralul Românesc al Mării Negre şi Platforma Continentală, V, Edit. Academiei Române, București, pp. 99–121.

Urucu, Veselina, Bordânc Floarea (2005b), *Industria* în vol. Geografia României, Câmpia Română, Dunărea, Podişul Dobrogei, Litoralul Românesc al Mării Negre şi Platforma Continentală, V, Edit. Academiei Române, București, pp. 122–127.

Van den Berg, L., Drewett, R., Klaasen, L. H., Rossi, A., Vijverberg, C. H. (1982), Urban Europe: A study of growth and decline, Pergamon Press, 184 p.

Wilson, E. H., Hurd, J. D., Civco, D. L., Prisloe, M. P., & Arnold, C. (2003). *Development of a geospatial model to quantify, describe and map urban growth*. Remote sensing of environment, *86*(3), 275–285.

Zeng, C., Liu, Y., Liu, Y., & Qiu, L. (2014) *Urban sprawl and related problems: Bibliometric analysis and refined analysis from 1991 to 2011,* Chinese geographical science, 24(2), pp. 245–257.

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SPATIAL MODELLING OF URBAN INFRASTRUCTURE: A STUDY FROM A DEVELOPING COUNTRY (INDIA)

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Key-words: disparity, utility services, Cronbach's Alpla, Principal Component Analysis.

Abstract. Regional disparity is a challenging issue for urban planners, policy makers, academicians, bureaucrats and technocrats in the developing countries. In India, a wide-range of socio-economic disparities are commonly evident even in Class – I cities. Such an undesirable phenomenon reflects on the spatial variation of the quality of life, level of living, as well as well-being and welfare of the inhabitants. Moreover, it is against the constitutional law of equity and social justice. The present study is based on the empirical observation focused on ward wise variation of availability and accessibility to the socio-economic utility services and infrastructure accessibility in Rajarhat – Gopalpur Municipality of West Bengal. On the basis of 'Cronbach's Alpha' and 'Principal Component Analysis', the entire set of data has been arranged by five factors of which the first three (cumulative percentage of variance is 89.84) have been considered to examine the dimension of socio-economic disparities and the level of development in the city. From Cronbach's Alpha Analysis of thirty-four variables, eleven were eliminated, while transport facilities (i.e. Auto stand, Bus terminus, Bus stop, Post Office), health facilities (i.e. Hospital, Nursing Homes, PHC, etc.) and education services (Schools and Colleges) were taken into consideration for further study. The factor score determines the first three components with 89.84 % of variance. In the first component the highlight falls on the economic factors, while the second and the third components depict education and transport factors, respectively.

1. INTRODUCTION

The development of the socio-economic infrastructure and urban facility-utility facilities indicate the quality of life of the people of a particular area (Clark, 1997; Densam, 1994). The availability of all socio-economic infrastructures in itself is not meant for development until and unless it is adequately available, corresponding to population-size and extent of area. Such an adequacy should ensure people's accessibility to the socio-economic infrastructure (Guo *et al.*, 2001). But, unfair political practices, physiographic characteristics and the socio-cultural dogma have resulted in the unequal and irrational distribution of infrastructure in the region, leading to regional disparities (Batty, 1997; Brown *et al.*, 2004; Harris and Batty, 1993). Regional disparity emerges when any state fails to a certain extent to ensure development distribution assets equitably to all the corners of the region. An unchecked and uncontrolled process of growth, leading to regional disparities, may result in economic, social and cultural problems (Augustijn-Beckers, 2011; Hungaragi 2008). The coexistence of developed and underdeveloped regions in a country, or state, produces misallocation and underutilization of resources with untapped potential of some areas. Such disparities are not conducive to regional development (Almedia *et al*., 2008; Kumar 2009), a phenomenon characteristic of a developing economy. The poor countries of the world are characterized by great and growing regional disparities, while rich countries generally present small and diminishing development gaps (Williamson 1965; Itzhak *et al.* 2002).

Inequalities at the level of development have been an integral feature of the history of India's economic development. The magnitude of regional disparity widened during the British colonial period, when, the colonists' own business interest, led to the development of a few port-areas alone, other parts of India being left in a very backward state. After independence in 1947, considerable emphasis

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was placed on eliminating this disparity. In the Third Five-Year-Plan (1961–1966), a separate chapter was devoted to balancing regional development (Chapter IX). Policies for the development of backward areas, at central and state levels, identification of backward areas and indicators of development for different sectors etc., were initiated and all efforts were based on the Pandey Committee, Chakraborty Committee and National Council for Development of Backward Areas (NCDBA) recommendation in the Third Five-Year-Plan (Kumar, 2009). Despite the efforts made, India was still experiencing wide inter-and intra-regional socio-economic and cultural development disparities at both macro-and-micro level (Pradhan and Kaberi, 2015).

Several studies on the magnitude of regional inequality covered a broad area and so they did in India as well. Different scholars, like Mathur (1983) and Dadibhavi (1998), tried to address regional disparities in socio-economic development by measuring the per-capita income. Rao (1985) analysed the extent of inter-state development disparities measured on the basis of the per-capita state domestic product. A group of scholars, e.g. Rao (1984), Rao and Babu (1996), Soen *et al.* (1997), Mallikarjun (2000), Hassan (2007) and Paul (2012) attempted to focus on the leading factors of different regional socio-economic development disparities by adopting the Principal Component Analysis and the Composite Index techniques. Sao (2007), Paul and Dasgupta (2008), Rahaman and Salauddin (2009) and Julfikar and Deepika (2010) tried to find out the nature and determinants of disparities of urban utility-facility services in the intra-ward variation of urban centres.

A review of studies on the issue of regional disparities reveals that most of them are based on a broad area and not on the smallest unit like the ward in a municipality. Hence, the work is an attempt to examine the spatial distribution of facility-utility services and inter-ward disparities of socio-economic development in Gopalpur Municipality.

2. STUDY AREA

The Rajarhat Gopalpur Municipality, established in the year 1994, is one of the newly-built Urban Local Body of the state of West Bengal. It is situated in the southern part of district 24 Parganas North. The Geographical location is 22°37'12" latitude and 88°25'48" longitude. The municipal area is bounded by the following:

- In the north – Dum Dum Municipality, Netaji Subhas International Airport.
- In the east – Panchayat area, New Township.
- In the south – Bidhan Nagar Municipality, South Dum Dum Municipality,
- In the west – Dum Dum Cantonment Canal (Fig. 1).

The current Rajarhat Gopalpur Municipality includes 35 wards, covers a 28 sq km-area and has 402,844 inhabitants (census report of 2011, Govt. of India). The historically famous Najrul Sarani (previously known as V.I.P. Road) crosses the Urban Local Body. The Municipality is situated 11 km from Kolkata by road. It is accessible by the Eastern Railways from Sealdah. Nearest Railway Station is Dum Dum Junction and Dum Dum Cantonment. Dum Dum Metro Railway Station is also at a distance of 5 km from the Municipality. The nearest port is Kolkata at Kidderpore, at a distance of 25 km. However, Haldia port is also connected by the National Highways situated at a distance of 130 km. The city is only 5 km away from Dum Dum International Airport, which is known as Netaji Subhas Chandra Airport. The Municipality is well-connected by a road and flyover network, which takes only 10 minutes to reach the Airport (Draft Development Plan Main Handbook for 2007–12).

The main objectives of this study are as follows:

- To analyse the spatial distribution of socio-economic facilities for the people at micro level;
- To identify the leading factors of socio-economic disparities and
- To examine the magnitude of inter-ward disparities in the socio-economic development of Rajarhat-Gopalpur Municipality.

3. MATERIALS AND METHODS

The study is based on the primary data collected by an intensive field survey (2016) in all the wards of Rajarhat-Gopalpur Municipality. The primary information is supplemented with secondary data whenever needed. To estimate the quantitative weight of a variable (i.e. number of primary schools per 1,000 population) the total population of each ward as per Census of India, 2011 was projected to 2016, when the field investigation was carried out.

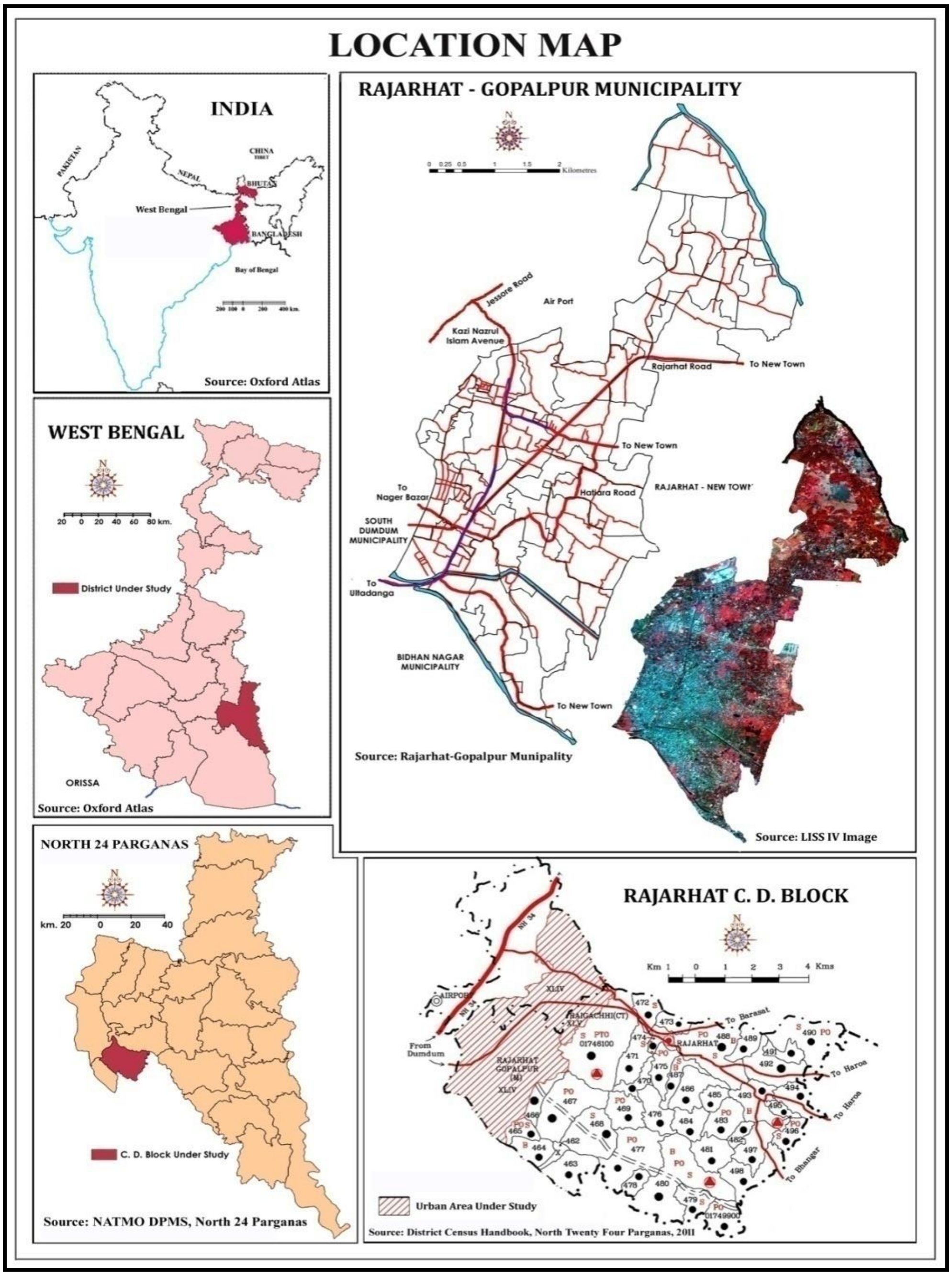

Fig. 1 – Location of the study-area.

Sample Design and Data Collection

In order to access the unequal resource distribution leading to development variation among the core area, the intermediate area and the peripheral part of the Municipality, samples were selected from each part of the wards. All the thirty-five wards were selected for the purpose of sampling. Information on the number of selected socio-economic and facility-utility services were collected not in part, but as a whole, i.e. the total number of the facilities concerned being obtained by field investigation. The field survey was conducted during November–December, 2016 and collected data were analysed.

Use of Statistical Techniques

For the purpose of the present study, both qualitative and quantitative methods were used. However, to infer the facts, the quantitative analysis relied on both simple and standard statistical techniques:

- The availability of infrastructure facility per unit of population was estimated in terms of the actual number of this facility per 1,000 projected population in 2016.
- The population for 2016 was projected using the simple arithmetic progression techniques.
- The accessibility of each facility in terms of the nature of distribution per unit area was measured by Mathur's method of Mean Spacing, which reads:

$$\mathbf{D = 1.0746 \sqrt{(A/N)}}$$

where, **D** stands for the theoretical distance between facilities in a hexagonal pattern of area, **A** denotes the area of the ward and **N** represents the number of facility in that ward.

- In order to prove the internal reliability of the model used, the author checked it by ***Cronbach's Alpha Test of Reliability***. Applying this test specifies whether the items pertaining to each dimension are internally consistent and whether they can be used to measure the same construct or dimension of service quality.
- Development levels were estimated after constructing a composite index based on selected physical indicators.

Certain weights were assigned to each indicator based on their value judgment to arrive at a meaningful and comparable composite index of development. For this purpose, ***Factor Analysis*** was used to derive factor loading, or coefficient of each variable.

The factor loading of each variable was multiplied by the corresponding standardized value to obtain factor score.

Finally, the factor score of each variable was added in order to estimate the index of development of each unit of the Municipality ward study.

The statistical model used can be expressed as:

$$\mathbf{P_1 = \Sigma\, a_{j1}\, X\, Z_j \text{ or } P_1 = a_{11}.\, Z_1 + a_{21}.Z_2\, a_{11}.+ \dots\dots\dots\, a_{n1}.\, Z_n}$$

where, $\mathbf{P_1}$ denotes the composite index of development of a unit study, as first factor is the factor loading of $\mathbf{j^{th}}$ variable and **1** indicates the factor number, i.e. first factor – vector of factor loadings. $\mathbf{Z_j}$ denotes the standardized value of $\mathbf{j^{th}}$ variable, which is expressed as:

$$\mathbf{Z_j = \frac{X_j - X_m}{\delta_j}}$$

where, $\mathbf{X_j}$ denotes the original value of $\mathbf{j^{th}}$ variable, $\mathbf{X_m}$ stands for the mean of $\mathbf{j^{th}}$ variable and $\mathbf{\delta_j}$ for the standard deviation of $\mathbf{j^{th}}$ variable.

4. RESULTS AND DISCUSSION

4.1. Availability of and Accessibility to Urban Facilities in Rajarhat-Gopalpur Municipality

The problem of the unequal distribution of facilities across the region is a common phenomenon in India. Such a problem leads to regional disparities in socio-economic development. The present study is an attempt to highlight the unequal distribution of socio-economic facilities by analysing availability per unit of population and per unit of area extension **(mean spacing)** of the different wards of the study area.

Communication Facility

Auto Stand, Bus Terminus, Bus Stop, Post Office and Telephone Exchange are important facilities of the urbanites. Basically, these communication facilities enable people to achieve different amenities located in the Municipality. Maximum number of Auto Stands is found in ward no. 11 (0.36 / '000 Population), Bus Terminus in ward no. 7 (0.14 / '000 Population), Bus Stops in ward no. 19 (0.28 / '000 Population), Post Offices in ward no. 13 (0.16 / '000 Population) and Telephone Exchanges in ward no. 25 (0.12 / '000 Population). The Post Office also determines the level of people's life. It is available only in 9 wards, with one in each ward (25.71%) out of all the wards. In ward no. 23 (0.54 km.), Bus Stop facility is better accessible as people can avail it within a shorter distance.

Health Facility

Providing availability and accessibility to health services can ensure better health conditions for the inhabitants. It is another important indicator of human development. Among the four selected health facilities, i.e. Hospital **(X_6)**, Nursing Home **(X_7),** Integrated Child Development Services **(X_8)** and Primary Health Centre **(X_9)**, the availability of ICDS per unit of population is much more consistent (C.V. = 75.00). Out of the 35 wards, nine (25.71 %) have a Hospital facility, twenty one (60.00%) have a Nursing Home facility. Wards no. 25 and 17 have been identified as having better availability to the first two health facilities (**X_6** and **X_7**). However, the mean spacing analysis reveals better accessibility to health facility in wards no. 25 (0.66 km.) for **X_6** and no. 22 (0.41 km.) for **X_7**. It is evident from the analysis that the health facility is more accessible and more numerous in the core-area of Rajarhat-Gopalpur Municipality.

Education Facility

The Education facility is one of the most significant determinants of social well-being and welfare, as well as human development. Among all the educational facilities, the highest coefficient of variability (591.61) had the Library in Rajarhat-Gopalpur Municipality. However, among the education facilities, the lowest coefficient of variation, i.e. C.V. = 64.01 was computed in the distribution of Primary School. Highest availability of Primary School **(X_{11})** i.e. 0.49, followed by High School **(X_{12})**, i.e. 0.39 per 1,000 inhabitants were found in wards no. 4 and 12, respectively. However, the respective analysis of the area, revealing a similar figure was depicted in the distribution of Primary School. Highest and lowest mean spacing of Primary School, 1.69 km and 0.34 km were recorded in wards no. 2 and 16, respectively. Primary Schools in ward no. 16 are much more closely spaced, ensuring better accessibility for the inhabitants than in the other wards, while a reverse situation is found in ward no. 2. High Schools are located at great distance (1.69 km) from one another in ward no. 2, the lowest distance (0.51) being recorded in ward no. 27. Further more, the highest availability of the College facility per 1,000 inhabitants was found in ward no. 12 (0.13), while thirty-one wards had no such facility at all. It comes out from the above assessment that better availability of and accessibility to education facilities were recorded in ward no. 4 (peripheral location) followed by ward no. 12 (peripheral location).

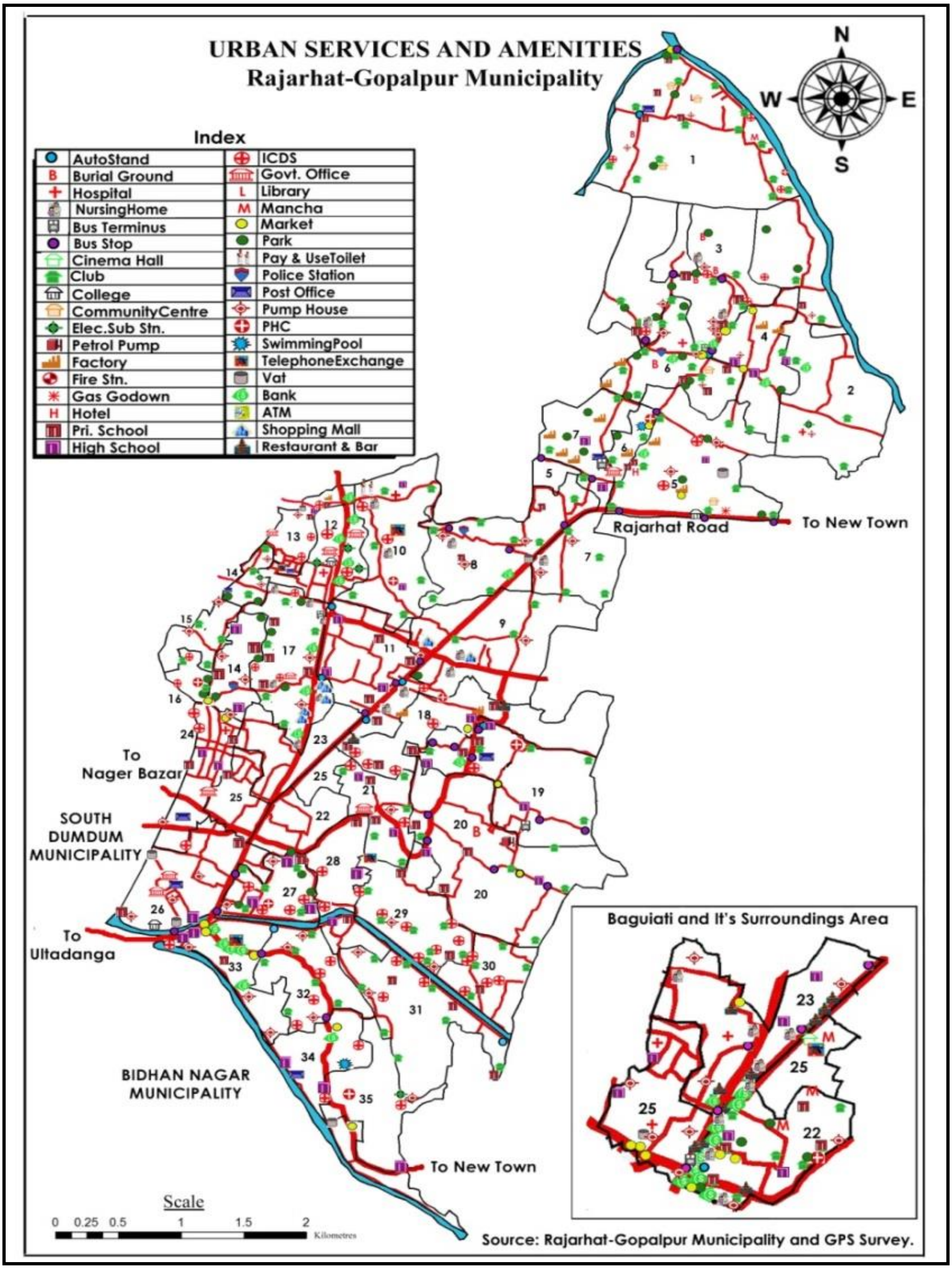

Fig. 2 – Distribution of different urban infrastructures and amenities
in Rajarhat-Gopalpur Municipality.

Economic Facility

This is an important indicator of economic development. The analysis reveals a disparity in the availability of and accessibility to Banking facility for people in Rajarhat-Gopalpur Municipality. Among the wards, the Banking facility **(X_{17})** is available in 17 wards (48.57 %). In case of availability per 1,000 of population, ward no. 22 (0.90) is in a better position, followed by ward no. 12 (0.65), while in the case of accessibility, the same positions are found in ward no. 22 (0.27 km) and no.12 (0.41 km) since banks are located centrally. In case of availability of ATM counters **(X_{18})**, the central position of Rajarhat-Gopalpur Municipality was found to have the highest concentration of facilities. It is evident from the above analysis that the central portion of the Municipality has a better financial facility than the other wards.

Another financial indicator of socio-economic development is Markets **(X_{16})**. Besides being the place of selling and purchasing goods, it is also the meeting-place of people who exchange social, cultural and political ideas leading to the socio-cultural transformation of society. It reveals a high degree of variability (C.V. =108.72) in availability among the other wards. Among wards, it is ward no. 25 that recorded a better position to market availability (0.48 per 1,000 population). However, accessibility to the market is by far better in ward no.25, where markets are located at an average spacing as low as 0.46 km, against 1.79 km mean spacing in ward no. 1.

Administrative Facility

The Electric Sub-Station, Govt. Office, Police Station and Pump House are also important facilities of the urbanites. The highest Electric Sub-Station is found in ward no. 12 (0.39 / '000 Population), Govt. Office in ward no. 12 (0.26 / '000 Population), Police Station in ward no. 6 (0.16 / '000 Population) and Pump House in ward no. 14 (0.58 / '000 Population). The Police Station oversees the security of people's life. It is available only in 3 wards, with one station in each ward (8.57%) out of all wards. The Police Station facility **(X_{23})** in ward no. 14 (0.94 km.) has better accessibility, as people can reach it within a short distance.

Other Facilities

The Cinema Hall, Community Centre, Petrol Pump, Gas Godown, Pay & Use Toilet, Vat, Mancha, Burial Ground, Park and Swimming Pool, etc. are very important facilities for urban people. Parks (C.V. =64.49) followed by Vats (C.V. =176.26) have the lowest variability among the other facilities. Also in case of accessibility, ward no. 22 (0.57 km) and no. 16 (0.34 km) have the least mean spacing in Pay & Use Toilets and Manchas **(X_{29} and X_{31})** and Parks **(X_{33})**, respectively.

4.2. Reliability Statistics

In order to prove the internal reliability of the model used, the authors have gone through Cronbach's Alpha Test of Reliability. Applying this test specifies whether the items pertaining to each dimension are internally consistent and whether they can be used to measure the same construct or dimension of service quality. According to Nunnaly (1978), Cronbach's Alpha should be 0.700 or above. But in some of the studies, 0.600 is also considered acceptable (Gerrard *et al.* 2006, Kenova and Jonasson 2006). The table below indicates some of Cronbach's Alpha accuracy values (-.072 for **X_{13}**, .096 for **X_{25}**, .164 for **X_{26}**, .307 for **X_{27}**, .399 for **X_{28}**, .582 for **X_{29}**, .356 for **X_{30}**, .527 for **X_{31}**, .131 for **X_{32}**, .358 for **X_{33}** and .278 for **X_{34}**) less than 0.600. Therefore, these items were eliminated from the factor analysis. However, if Cronbach's Alpha value of all items were acceptable, it means that the present data would be suitable for factor analysis.

Table 1

Reliability Statistics Using Cronbach's Alpha.

	Description of Variables (Per ' 000 Population)	Cronbach's Alpha		Description of Variables (Per ' 000 Population)	Cronbach's Alpha
X_1	***Auto Stand***	.627	X_{18}	***ATM***	.801
X_2	***Bus Terminus***	.627	X_{19}	***Shopping Mall***	.751
X_3	***Bus Stop***	.684	X_{20}	***Restaurant & Bar***	.627
X_4	***Post Office***	.654	X_{21}	***Electric Sub-Station***	.682
X_5	***Telephone Exchange***	.698	X_{22}	***Govt. Office***	.642
X_6	***Hospital***	.613	X_{23}	***Police Station***	.639
X_7	***Nursing Home***	.780	X_{24}	***Pump House***	.623
X_8	***ICDS***	-.774	X_{25}	***Cinema Hall***	.096
X_9	***PHC***	-.654	X_{26}	***Community Centre***	.164
X_{10}	***College***	.738	X_{27}	***Petrol Pump***	.307
X_{11}	***Primary School***	.623	X_{28}	***Gas Go down***	.399
X_{12}	***High School***	.662	X_{29}	***Pay & Use Toilet***	.582
X_{13}	***Library***	-.072	X_{30}	***Vat***	.356
X_{14}	***Factory***	.662	X_{31}	***Mancha***	.527
X_{15}	***Hotel***	.653	X_{32}	***Burial Ground***	.131
X_{16}	***Market***	.812	X_{33}	***Park***	.358
X_{17}	***Bank***	.691	X_{34}	***Swimming Pool***	.278

Source: computed by the authors.

4.3. Socio-economic Development Levels

An unequal and irrational distribution of facilities in urban centres without considering the size of the population and extent of the area causes regional socio-economic development of disparities. This is characteristic of a developing economy. Development is a multi-facet phenomenon which a society, or a region, achieves. As a spatial phenomenon, the development of a region can be explained in two ways: firstly, as the state of change in the distribution of parameters between given time points, and secondly, as the state of their existing distribution. The state of development imbalance inspires regional planners to formulate a diagnostic plan in order to achieve a balanced regional development.

The analysis of the development index of each ward estimated each variable with a factor coefficient above 0.50 as factor score composite. Using the Principal Component Analysis, the factor coefficients were arranged by five factors (i.e. Factor I, Factor II, Factor III, Factor IV and Factor V) in which the first factor reveals a 54.65 per cent variance, while the second, third, fourth and fifth factors indicate 22.87, 12.32, 6.07 and 3.02 per cent, respectively. Therefore, all the five factors cumulated show a 98.93 per cent variance. Among them, the first three were taken into consideration for estimating development, as the combination of these three factors indicates an 89.84 per cent variance. A value of the factor coefficient higher than 0.5 was considered for determining the development index. Since variables $\mathbf{X_7}$**,** $\mathbf{X_{15}}$**,** $\mathbf{X_{16}}$**,** $\mathbf{X_{17}}$**,** $\mathbf{X_{18}}$ and $\mathbf{X_{20}}$, showing a factor coefficient above 0.50 in Factor I, they were multiplied by the standardized value of the respective variable to derive their factor score and finally to estimate the composite index of development. Likewise, variables $\mathbf{X_4}$, $\mathbf{X_{11}}$ and $\mathbf{X_{12}}$ with their factor coefficient over 0.50 were identified in Factor II. Again, for Factor III, $\mathbf{X_1}$ **and** $\mathbf{X_3}$ are considered as they have a coefficient value above 0.50. But no single variable shows a factor coefficient above 0.50 in Factor IV though variables $\mathbf{X_9}$ and $\mathbf{X_{18}}$ factor coefficient in Factor IV is over 0.50, which reveals only a 6.07 per cent variance, have not been included in the estimation of the development index. Subsequently, out of the 23 variables, 14 variables were observed as significantly responsible and 12 variables were taken to examine the spatial variation of socio-economic development in Rajarhat-Gopalpur Municipality.

Table 2

Factor Loading of Variables, Rajarhat-Gopalpur Municipality, 2016.

Variables and Definitions (Per ' 000 Population)		Component		
		Factor - I	**Factor - II**	**Factor - III**
X_1	***Auto Stand***	0.328	0.746	**0.81**
X_2	***Bus Terminus***	0.479	-0.146	0.413
X_3	***Bus Stop***	0.382	0.036	**0.61**
X_4	***Post Office***	-0.049	**0.646**	-0.101
X_5	***Telephone Exchange***	0.131	-0.045	0.042
X_6	***Hospital***	0.294	0.322	0.059
X_7	***Nursing Home***	**0.754**	0.346	0.258
X_8	***ICDS***	-0.013	0.05	0.046
X_9	***PHC***	0	0.037	0.031
X_{10}	***College***	0.088	0.002	0.36
X_{11}	***Primary School***	0.376	**0.672**	-0.025
X_{12}	***High School***	0.493	**0.703**	0.164
X_{14}	***Factory***	-0.002	0.237	-0.002
X_{15}	***Hotel***	**0.84**	-0.12	0.069
X_{16}	***Market***	**0.696**	0.399	0.271
X_{17}	***Bank***	**0.795**	0.045	0.28
X_{18}	***ATM***	**0.859**	0.097	0.184
X_{19}	***Shopping Mall***	0.46	0.058	0.105
X_{20}	***Restaurant & Bar***	**0.587**	0.032	0.416
X_{21}	***Electric Sub-Station***	0.347	0.001	0.268
X_{22}	***Govt. Office***	0.248	0.399	0.155
X_{23}	***Police Station***	-0.149	0.728	-0.061
X_{24}	***Pump House***	0.034	0.789	0.019
% of Variance		**54.65**	**22.87**	**12.32**
Cumulative % of Variance		**54.65**	**77.52**	**89.84**

Source: computed by the authors.
Note. Extraction Method – Principal Component Analysis, Rotation Method

Levels of Development – Factor I (Health and Economic Facility)

On the basis of the composite development index of Factor I, all the wards were arranged by three levels in order to study the inter-ward development disparities in socio-economic amenities. Out of the 35 wards, seven wards (20%) with a development index above 1.00 fall into the high development level. These wards are located almost in the core-area of the Municipality. Due to the old built-up area, these wards have essential amenities like, education, health, communication, drinking water, marketing and easy transport facilities.

Eleven wards (i.e. ward no. 24, 6, 4, 33, 26, 3, 10, 8, 21, 19 and 5) with a development index ranging between 0.31 and 1.00 come under the medium development level. Further more, it emerges that with a development index under 0.31, seventeen wards (49%) fall under the low development level in the Municipality. All these wards are located in the buffer area and the peripheral part of Rajarhat-Gopalpur Municipality. People living in these wards have access difficulties to health and economic facilities. As a result, people's quality of life and living level in these areas are gradually deteriorating.

Table 3

Levels of Development – Factor I (Health and Economic), Rajarhat-Gopalpur Municipality.

Level of Development	**Indices**	**Number of Wards**	**Identity of Wards**
High	Above 1.00	07 (20 %)	Ward no. 22, 12, 25, 17, 23, 34 and 11
Medium	0.31-1.00	11 (31 %)	Ward no. 24, 6, 4, 33, 26, 3, 10, 8, 21, 19 and 5
Low	Below 0.31	17 (49 %)	Ward no. 13, 27, 18, 35, 7, 9, 32, 14, 20, 2, 1, 29, 15, 16, 28, 30 and 31

Source: computed by the authors.

Levels of Development – Factor II (Communication and Education Facility)

Variables $\mathbf{X_4}$, $\mathbf{X_{11}}$ and $\mathbf{X_{12}}$ in Factor II altogether explain the levels of development of communication (Post Office) and education (primary school and high school) in the Municipality. Only nine wards (9 %) i.e. ward no. 14, 4, 11, 25, 24, 12, 13, 6 and 22 with a development index above 0.40, fall into the high development level category. The nine wards in this category are scattered within the Municipality.

Table 4

Levels of Development – Factor II (Communication and Education), Rajarhat-Gopalpur Municipality.

Level of Development	**Indices**	**Number of Wards**	**Identity of Wards**
High	Above 0.40	09 (26 %)	Ward no. 14, 4, 11, 25, 24, 12, 13, 6 and 22
Medium	0.21–0.40	10 (28 %)	Ward no. 7, 17, 34, 16, 1, 27, 19, 3, 5 and 21
Low	Below 0.21	16 (46 %)	Ward no. 35, 10, 26, 20, 23, 28, 18, 33, 30, 8, 2, 31, 29, 32, 9 and 15

Source: computed by the authors.

Ten wards (i.e. ward no. 7, 17, 34, 16, 1, 27, 19, 3, 5 and 21), with a development index ranging between 0.21 and 0.40, registered a medium level of communication and education development in the municipality. Further, sixteen wards (i.e. ward no, 35, 10, 26, 20, 23, 28, 18, 33, 30, 8, 2, 31, 29, 32, 9 and 15) were found to have a development index below 0.21, being considered under the low level of the communication and education infrastructure facility in the municipality. These wards are scattered within the municipality.

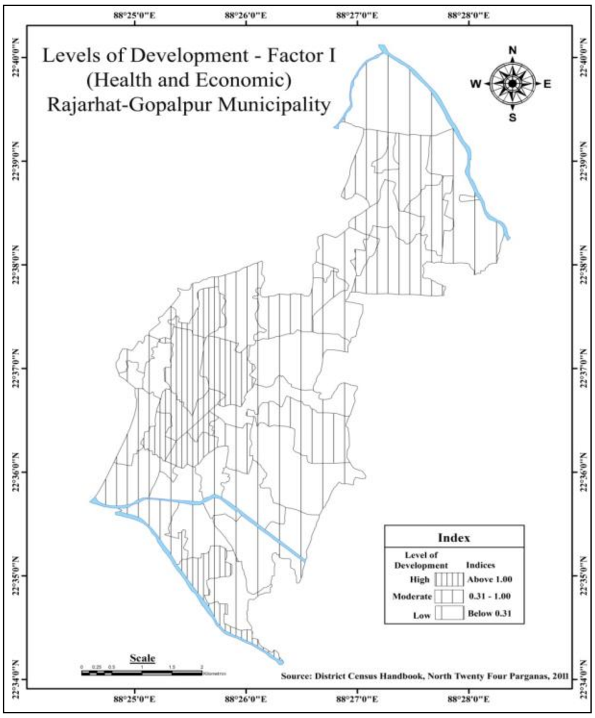

Fig. 3 – Development level – Factor I.

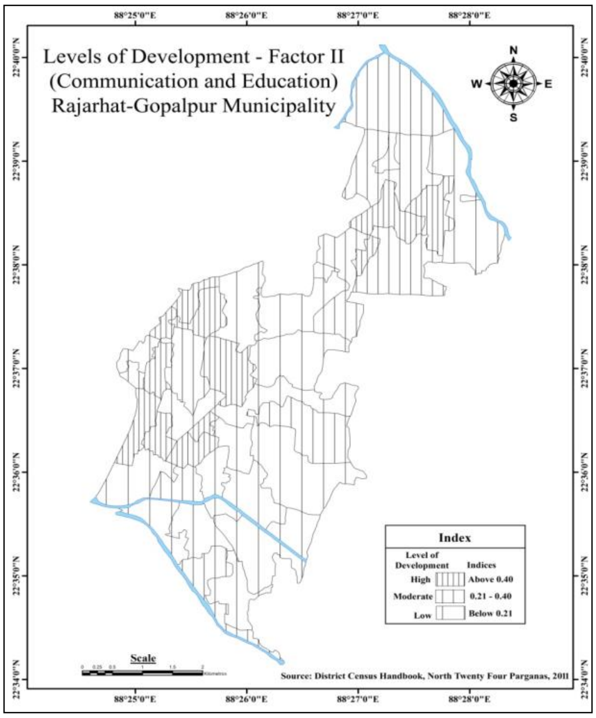

Fig. 4 – Development level – Factor II.

Development Levels – Factor III (Communication Facility)

On the basis of Factor III, variables $\mathbf{X_1}$ and $\mathbf{X_3}$ were marked as important factor for the socio-economic development of Rajarhat-Gopalpur Municipality. Six wards with a development index above 0.20 fall into a high degree of development. These are ward no. 11, 12, 25, 34, 23 and 19. Due to the location of the Rajarhat-Gopalpur Municipality C.B.D., this area provides some good market, high transport and auto stand and bus stop facilities.

Table 5

Levels of Development – Factor III (Communication), Rajarhat-Gopalpur Municipality.

Level of Development	Indices	Number of Wards	Identity of Wards
High	Above 0.20	06 (17 %)	Ward no. 11, 12, 25, 34, 23 and 19
Medium	0.11–0.20	11 (31 %)	Ward no. 22, 17, 3, 1, 8, 21, 26, 32, 10, 9 and 20
Low	Below 0.11	18 (52 %)	Ward no. 33, 6, 14, 7, 5, 18, 27, 28, 31, 2, 4, 13, 15, 16, 24, 29, 30 and 35

Source: computed by the authors.

Eleven wards (i.e. ward no. 22, 17, 3, 1, 8, 21, 26, 32, 10, 9 and 20), with a development index between 0.11 and 0.20, fall under the medium development level. Again a majority (52 %) of the wards have a low development index level, that is, under 0.11. These wards are scattered within the Municipality. It was found that market, auto stand and bus stop facilities fail (see Figs. 5 and 6).

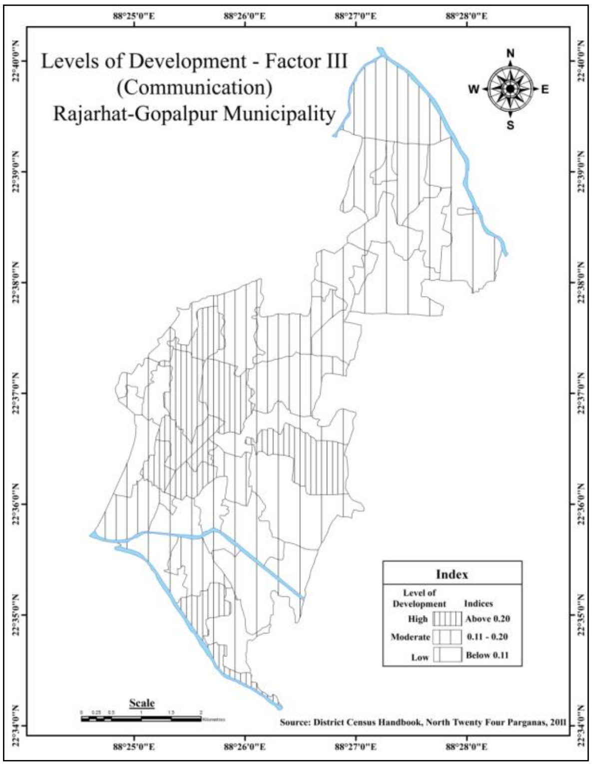

Fig. 5 – Level of Development – Factor III.

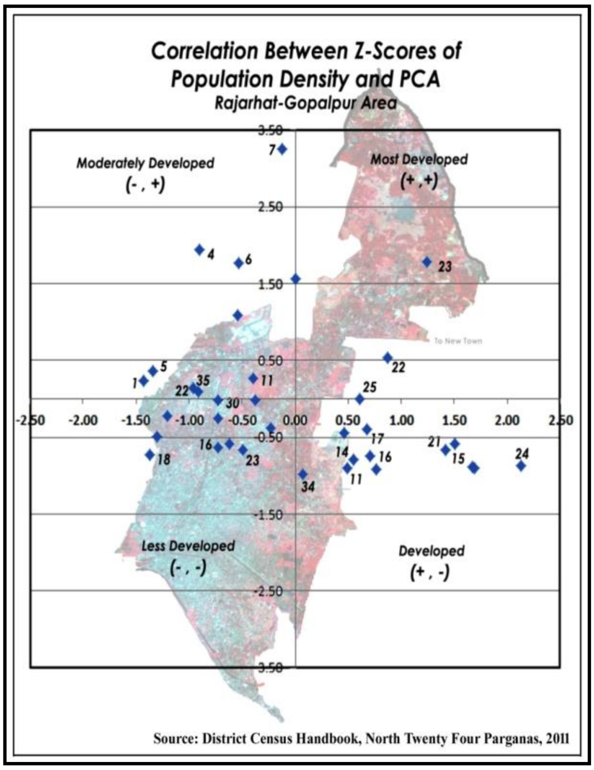

Fig. 6 – Clusters of Wards under Rajarhat Gopalpur Municipality based on Population Density and PCA.

4.4. Correlation between Z-Scores of Population Density and PCA

A z-score is defined as the deviate score (the observed score minus the mean) divided by the standard deviation.

$$z = \frac{\left(X - \overline{X}\right)}{s}$$

The correlation

- Provides means to assess the magnitude and direction of relationship between two variables.
- Although it does not prove causality, it is a first step toward investigating how one variable causes another.
- If one variable correlates with another, then it might be causally related.
- No correlation is evidence against a causal relationship.

If the **X** and **Y** variables are first standardised (to Z-scores) before the regression, the regression weight for **X** will be equal to the correlation between **X** and **Y**. This illustrates another interpretation of the correlation coefficient: it is the numbers of standard deviations that two cases are predicted to differ on **Y** if they differ by one standard deviation on **X**. So, for example, if applicant **A** scored one standard deviation higher than applicant **B** on the logical reasoning test, we would predict that applicant **A** would be about 0.736 standard deviations above applicant **B** on the creativity test (because the correlation is about 0.736).

Here, the Z-Scores values fall in 4 categories: Most Developed **(+, +)**, Developed **(+, -)**, Less Developed **(- , -)** and Moderately Developed **(- , +)**. Thus, three wards (i.e. ward no. 22, 23 and 25) fall into Most Developed, eleven wards (i.e. ward no. 33, 34, 12, 14, 17, 2, 3, 31, 21, 15 and 24) fall into Developed, eleven wards (i.e. ward no. 30, 13, 19, 18, 27, 10, 9, 29, 8, 16 and 32) into Less Developed and ten wards (i.e. ward no. 35, 11, 5, 1, 20, 28, 26, 4, 6 and 7) into the Moderately Developed category.

5. CONCLUSIONS

The foregoing analysis, based on field surveys, infers the inter-ward disparities in socio-economic development consequent upon the irrational, as well as unequal distribution of amenities and facilities. The study has revealed that the peripheral part of the city is lagging behind in socio-economic amenities, hence a low level of development. During the last decade (i.e. 2001–2011), the growth of population in this urban area was enormous and the nature of development of civic amenities was not keeping pace with the population growth. The gap in services provision was constantly widening during that period. The low level of development in the wards was due, mainly, to the allocation of facilities which did not correspond to the size of the population, the poor condition of the roads and finally carelessness of the city government to allocate resources. Another important finding of empirical observation is that the government banking facility is very little available to the people of Rajarhat-Gopalpur Municipality. To deal with this problem of inter-ward disparities in the socio-economic development of Class – I Indian cities like Rajarhat-Gopalpur, a diagnostic plan should be elaborated to provide and locate resources according to population size. Subsequently, balanced development should be achieved and social justice for the people would be ensured; consequently human well-being and welfare should be the desired result of relentless and selfless efforts made by the people, the government and the NGOs.

Presently, this urban area has merged with Bidhan Nagar Municipality and formed a new Corporation named Rajarhat-Bidhanagar Corporation, so that the local citizens could get all the urban facilities, amenities properly, according to the SMART CITY PROJECT declared by the Govt. of India in 2016.

REFERENCES

Almeida, C. M., Gleriani, J. M., Castejon, E. F., Soaresb., S. (2008), *Using neural networks and cellular automata for modelling intra-urban land-use dynamics*, International Journal of Geographical Information Science, **22**, pp. 943–963.

Augustijn-Beckers, E., Bas Retsios, J.F. (2011), *Simulating informal settlement growth in Dar es Salaam, Tanzania: an agent-based housing model*, Computers, Environment and Urban Systems, **35**, pp. 93–103.

Batty, M. (1997), *Cellular automata and urban form, a primer*, Journal of the American Planning Association, **63**, pp. 264–274.

Brown, D. G., Page, S. E., Riolo, R. Rand, W. (2004), *Agent-based and analytical modeling to evaluate the effectiveness of greenbelts*, Environmental Modelling & Software, **19**, pp. 1097–1109.

Clarke, K. C., Hoppen, S., Gaydos L. (1997), *A self-modifying cellular automaton model of historical urbanization in the San Francisco Bay area*, Environment and Planning B: Planning and Design, **24**, pp. 247–261.

Dadibhavi, R.V. (1998), *Disparities in Development of North Karnataka*, Indian Journal of Regional Science, **30** (*2*), pp. 84–97.

Dalal, S. (2007), *Infrastructural Facilities and Population Growth in Medium Towns in the States of Gujarat and Haryana, India*, Regional Symbiosis, **15**, pp. 103–120.

Densham, P.J. (1994), *Integrating GIS and spatial modelling: visual interactive modelling and location selection*, Geographical Systems, **1**, pp. 203–219.

Guo, H.C., Liu, L., Huang, G.H., Fuller, G.A., Zou, R., Yin, Y.Y. (2001), *A system dynamics approach for regional environmental planning and management: a study for the Lake Erhai Basin*, Journal of Environmental Management, **61**, pp. 93–111.

Hangaragi, S.S. (2008), *The Dimension of Inter-Taluka Disparities in the Levels of Development of Old Bijapur District of Karnataka State*, Indian Journal of Regional Science, **40** (*2*), pp. pp. 41–53.

Hassan, M., I. (2007), *Regional Inequality in Orissa: Some Emerging Issues*, Indian Journal of Regional Science, **39** (*1*), pp. 40–49.

Harris, B., Batty, M. (1993). *Locational models, geographic information, and planning support systems*, Journal of Planning Education and Research, **12**, pp. 184–198.

Pradhan, J., Kaberi, S. (2015), *Site suitability analysis using remote sensing and GIS for proper selection of solid waste disposal ground within Rajarhat Gopalpur municipal area, Kolkata, West Bengal*, International Journal of Geomatics and Geosciences, Vol. **5** (*4*), pp. 640–654.

Itzhak, B, Itzhak, O., Erez, H. (2002), *Entity-based modeling of urban residential dynamics: the case of Yaffo, Tel Aviv*, Environment and Planning B: Planning and Design, volume **29**, pp. 491–512.

Julfikar, M., A., Deepika, V. (2010), *Factors of Inter-ward Socio-Economic Disparities in Aligarh City, Uttar Pradesh*, Indian Journal of Regional Science, **42**(*2*), pp. 40–53.

Kumar, S. (2009), *Inter Regional and Inter District Disparities in Agricultural Development: A Study of Uttar Pradesh*, Indian Journal of Regional Science, **41** (*1*), pp. 22–36.

Landis, J.D. (1995), *Imagining land use futures: applying the California urban futures model*, Journal of the American Planning Association, **61**, pp. 438–57.

Mallikarjun, M. (2000), *Inter-Regional Disparities in Economic Development – A Study of Andhra Pradesh*, Indian Journal of Regional Science, **32** (*2*), pp. 1–10.

Masser, I., Campbell, H. (1991), *Conditions for the effective utilisation of computers in urban planning in developing countries*, Computers, Environment and Urban Systems, **15**, pp. 55–67.

Mathur, A. (1983), *Regional development and Income Disparities in India – A Sectoral Analysis*, Economic Development and Cultural Change, **31** (*2*), pp. 475–505.

Mondal, S.M., Garg, R.D. (2007), *Urban Utility Facility Mapping and Assessment of Ward-Wise Infrastructure Development of Rishikesh – A Geoinformatics Approach*, Indian Journal of Regional Science, **39** (*1*), pp. 111–123.

Nishanth, T., Prakash, M.N., Vijith, H, (2010), *Suitable site determination for urban solid waste disposal using GIS and Remote sensing techniques in Kottayam Municipality, India*, International journal of geomatics and geosciences, **1**(*2*), pp. 197.

Paul, S. (2012), *Factors and Dimensions of Inter-Ward Disparities in Urban Facility-Utility Services in Burdwan City, India*, Archives of Applied Science Research, **4** (*3*), pp. 1376–1388.

Paul, S., Dasgupta, A. (2008), *Urban Facility-Utility Mapping of Krishnagar Municipality – An Appraisal of Ward-wise Infrastructure Development*, Indian Journal of Landscape Systems and Ecological Studies, **31** (*2*), pp. 91–98.

Rao, Hemlata (1984), *Regional Disparities and Development in India*, Ashish Publishing House, New Delhi.

Rao, Hemlata (1985), *Inter-State Disparities in Development in India*, in Mishra, G. P. (ed.), Regional Structure of Development and Growth in India, New Delhi, **1**, pp. 68–101.

Saini, Vipin (2008), *Growth of Towns in Different Size Classes: Study of a Less Developed Region*, Indian Journal of Regional Science, **40** (*1*), pp. 93–97.

Singh, Yogeshwar, Dr. M.S., Chauhan, Dr. S.K., Katiyar (2012), *SWM of Kolar Municipality Using Remote Sensing and GIS Techniques*, International Journal of Advance Technology & Engineering Research, **2** (*1*), pp. 30–33.

Shiffer, M.J. (1995), *Interactive multimedia planning support: moving from standalone systems to the World Wide Web*, Environment and Planning B: Planning and Design, **22**, pp. 649–664.

Veldhuisen, K., Timmermans, H., Kapoen, L. (2000), *Ramblas: A regional planning model based on the microsimulation of daily travel patterns*, Environment & Planning A, **32**, pp. 427–443.

Williamson, J., G. (1965), *Regional Inequalities and the Process of National Development: A Description of Patterns*, Economic Development and Cultural Change, **12** (*4*), pp. 121–129.

Wray, C., Van Olst, R. (2012), *Enabling g-government in the Gauteng City-Region*, The African Journal of Information and Communication, **12**, pp. 65–83.

Yeh, A. (1990), *A land information system in the programming and monitoring of new town development*, Environment and Planning B: Planning and Design, **17**, pp. 375–84.

Yeh, A., Li, X. (1996), *Urban growth management in the Pearl River Delta: an integrated remote sensing and GIS approach*, ITC Journal, **5**. pp. 77–85.

Annual Administrative Report of Rajarhat-Gopalpur Municipality (2008–2009), Bureau of Urban Affairs, Govt. of West Bengal, India.

Rajarhat-Gopalpur Municipality (2012), Draft Development Plan Main book for 2007–12, Overview of the Municipality, CMU, KUSP, pp. 24.

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DEMOGRAPHIC CHANGES IN THE RURAL AREA OF THE SOUTHERN CARPATHIANS (1992–2011)

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Key-words: demographic structures, rural area, Southern Carpathian Mts.

Abstract. The Southern Carpathians cover 21% of the Carpathian area in Romania and encompass 19% of all rural settlements. The population of this geographical space numbers some 640,000 people. The human habitat consists of numerous urban and rural communities grouped administratively into 11 counties and four development regions. It is the medium-sized communes that have the highest concentration of population. The varied range of landforms in the Southern Carpathians (depressions, valley corridors, and mountain slopes) have always offered favourable condition for the development of human settlements. The expansion of the household, its organisation and functional typology are influenced by the geographical position. The demographic transition has changed the age-group structure, the young-population group decreasing through migration in search for better-paid jobs (as did also other age-groups), ageing of the population, etc.

1. INTRODUCTION

As part and parcel of the Carpathian-Danubian-Pontic space, the Southern Carpathians have permanently been inhabited, the population developing a true Carpathian circulation. Archaeological finds stand proof to the presence of man from times immemorial, the caves that dot the area constituting secure natural shelters for habitation. However, the mountain zone has both positive and negative habitation assets. But, while the Alps and the Prealpine areas are inhabited in proportion of 60 and 50 per cent, respectively, settlement in the Romanian Carpathians has almost a compact character (Nancu, 1989). The geographical landscape of depressions has evolved in close correlation with and under the specific geographical influence of the great mountainous unit it falls into (Cândea, 1997).

The present study looks at the changes occurred in the demographic structure of the Southern Carpathian rural area in terms of evolution, making a comparative approach at micro-scale level (viz., local administrative units – LAU2). One finds ever more socio-economic and political factors involved in the evolution of the settlement network, local interests focussing on making the best of the natural and economic resources.

2. METHODOLOGY

Our study resorts to statistical information – LAU2 data-base (NUTS V), to the Tempo Online data-series published by the National Institute of Statistics, as well as to the 1992 and 2011 population and housing census results. The calculation of relevant indices, e.g. population by age-groups; population ageing; demographic dependence; workforce renewal; population sex structure; ethnic and confessional structure, outlining the changes experienced by the demographic structures.

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The main analysed indicators, referring to dynamics of population change, had in view the following aspects:

a. Population structure by large age-groups (0-14, 15-64, 65 and over), the population being divided in three categories: young, adult and elderly.
b. Population ageing index represents the ratio between those aged 65 and over, on the one hand, and young people (0-14 year olds), on the other.
c. The demographic-dependence ratio was calculated by the formula:

$$Rd = [(P0\text{-}14 + P>65\text{-year olds}) / P15\text{-}64\text{-year olds}]* 100$$

where:
Rd = demographic dependence ratio
P = population.

d. The labour renewal index was calculated by referring the population aged 15-29 and 30-44-years old.
e. The sex structure expressed the numerical proportion of men / women per total population.
f. Nationality and confession are important elements for a population-structure analysis, the data obtained revealing the proportion of a certain ethnicity or confession / total population.

3. STUDY-AREA

The Southern Carpathians are flanked by the Timiş-Cerna Corridor in the West and the Prahova Valley in the East. They are approximately 50-70 km long from North to South and 250 kms from East to West. Geographically speaking, the Southern Carpathian eastern boundary is marked by the Dâmboviţa Valley. With over 2,500 m altitude, massive build-up, and imposing rocky crests, justifies the name of Transylvanian Alps they are referred to in the older geographical literature (Emm. de Martonne, 1907); the main mountain groups are Bucegi-Leaota, Făgăraş-Iezer, Parâng-Cindrel, Retezat-Godeanu, and the Haţeg-Orăştie Depression (Badea *et. al.*, 2001; Badea, 2014).

The Southern Carpathians cover 14,040 km^2, basically 21% of the mountainous area, and 5.9% of Romania's surface-area. Average altitude: 1,136 m, most frequently with heights of 1,100-1,500 m (4%), and 700-1,000 m (19%) (*Geografia României*, **I**, 1983; *Geografia României*, **III**, 1987). Although they are the tallest mountains of the Romanian Carpathian Arch (with 16 out of the 21 peaks of over 2,000 m alt.), yet the valleys crossing, or bounding them (the Prahova, Olt, Jiu, and Cerna), their platforms and Intra-Carpathian depressions make this branch the best humanised one (Bugă, Vişan, 1997). The presence of some depressionary corridors or passes benefitting by traffic axes, was also a reason for settlement-building at higher or lower altitudes (the corridors of Rucăr-Bran, Timiş-Cerna-Bistra, the Merişor sector etc.) (Cândea, 1994-1995). Seemingly depressions closed within the compact Southern Carpathian mass, they are nevertheless inter-connected by passes and passages (Cândea, 1996).

The human habitat contains numerous rural and urban communities, grouped administratively on the territory of 11 counties (Alba, Argeş, Braşov, Caraş-Severin, Dâmboviţa, Gorj, Hunedoara, Mehedinţi, Prahova, Sibiu, Vâlcea) and four development regions (South, South-West, Centre and West) (Fig. 1).

The extended geographical space of this mountain range englobes 94 communes and 25 towns, with a population of some 640,000 inhabitants in 2011, i.e. 3.1% of Romania's total population; population density: over 50 inhab./km^2 in the depressions. A part of the area covered by 40 LAU2, overlaps administratively the Southern Carpathians, however, settlements are located in neighbouring relief units (Fig. 2).

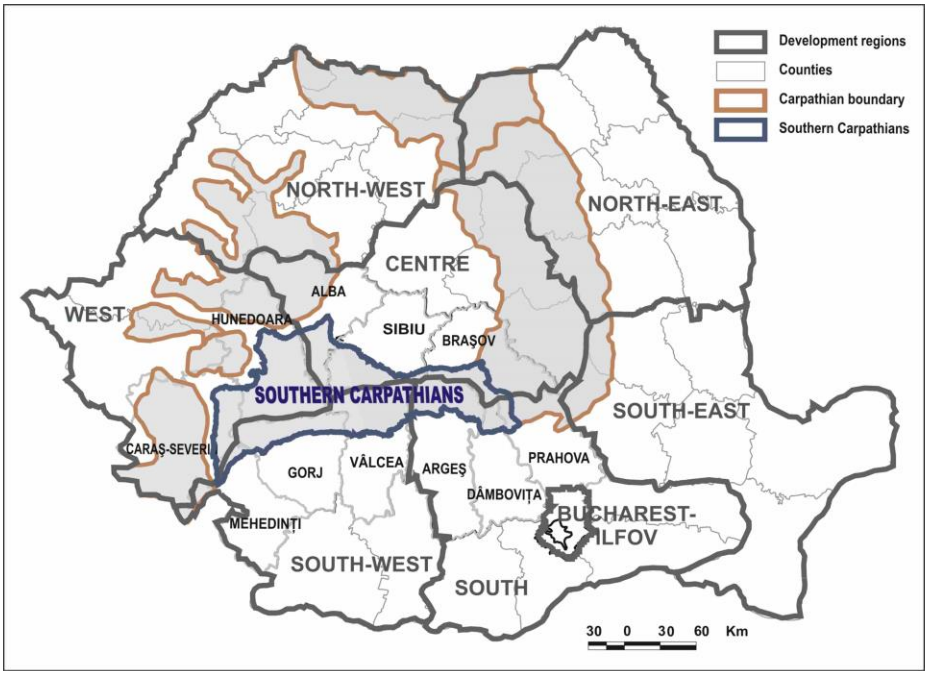

Fig. 1 – The Southern Carpathians administrative-territorial structure.

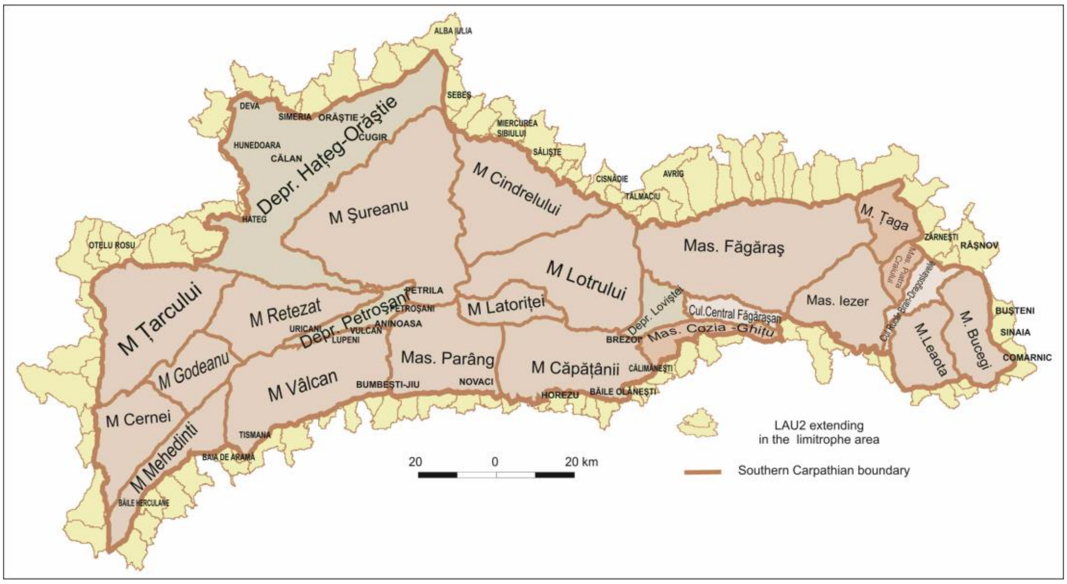

Fig. 2 – LAU2 extending in the limitrophe area.

A percentage of 60.6 urban and 39.4 rural population live here. The large intra-montane depressions (Petroşani, Haţeg and Loviştea), as well as the limitrophe valley corridors (Rucăr-Bran) concentrate nearly two-thirds of these settlements.

Highest concentrations of population have the middle-sized communes (55 of them hosting each between 2,000 and 5,000 people, 57.9%); small communes (34, with under 2,000 inhab. each, i.e. 35.8% in all); large and very large communes (5 of them with over 5,000 inhab. each, i.e. 6.3% of the whole rural population) (Fig. 3).

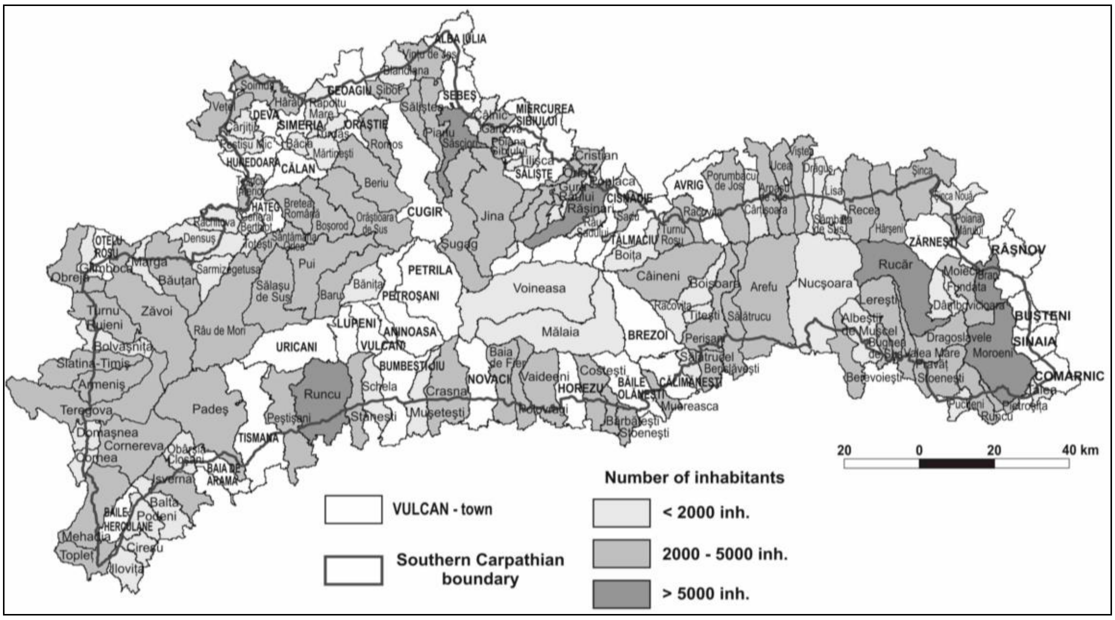

Fig. 3 – The demographic size of the Southern Carpathian communes.

The varied natural background has largely influenced the area's population, humanisation featuring a number of particularities shaped by the interaction among demographic, social and economic factors.

4. DEMOGRAPHIC STRUCTURE

4.1. Age-group structure of the population

The Southern Carpathians display a wide physical and economic-geographical diversity and complexity. Demographic transition in Romania lags a few decades behind the West-European countries, a situation derived from the pro-birth policies imposed by the communist regime, the result being major structural changes in the population: modification of age-groups, a depleted young population ratio, migration of people in search for better-paid jobs, population ageing, etc.

In analysing a territory it is important to look at the age, sex, nationality and religious structure of its population, which is largely influenced by political and socio-economic changes.

The time-variation of demographic processes induces changes in the age and sex structure, in that the share of some groups of people increases, while the share of others decreases correspondingly. It has been convened that a population is young provided the old age-group percentage is below 7%; between 7% and 12% the ageing process is underway; above 12% we have a demographically old population.

In 1992, the under 15-year-olds represented 20.4%, a value that fell to 16.1% in 2011. On the other hand, the over 65-year-olds and over would increase from 14.9% to 19.4%, the young population dropping by 4.5% between the two censuses. According to 1992 data, the youth topped 20% of the population (a value deemed to be optimal for a balanced structure) in over 50% of the administrative units, lower percentages (under 12% of the total population) being registered in the communes of Cârjiţi, Mărtineşti and Sălaşu de Sus. In 2011, there were by 4.3% fewer young people than at the 1992 census, more than 20% youth below 15 years of age being registered only in eleven communes: Valea Mare Pravăţ, Orlat, Gura Râului, Poiana Sibiului, Şinca, Săsciori, Câineni, Câlnic, Racoviţa and Jina.

The evolution of population by representative age-groups in-between the two censuses shows a steady decline, from 57,694 to 39,508 among in the 0-14-year-olds, that is by more than 18,000 fewer individuals compared to an increase from 42,004 to 47,516 in the over 65-year-olds. This situation raises doubts as to the workforce renewal capacity.

The proportion of labour-supplying mature people (15-64 olds) had slightly dropped from 64.7% in 1992 to 64.5% in 2011. In 1992, highest values in the 15-64-age group exceeded 69% of the total population in Băniţa, Zăvoi, Dâmbovicioara, Mălaia, Teliucu Inferior and Voineasa communes, with lowest values in Jina, Şinca, Perişani and Săsciori. In 2011, maximum values registered Băniţa, Boiţa, Moroeni andVoineasa.

In 1992, the elderly group held the highest share (over 21%) in the communes of Şibot, Fundata, Podeni, Cârjiţi and Mărtineşti, lowest values (<10%) being recorded at Voineasa, Jina, Orlat, Mălaia and Şugag. In 2011, this group continued to increase in all the communes, highest values (over 30%) scoring five communes: Titeşti, Boişoara, Cârjiţi, Fundata and Podeni, and lowest ones for the 65 and over age-group being found in the communes of Jina, Orlat, Moroeni, Poplaca and Câlnic.

The age-group structure of the population accounts for the labour potential and for the specific share of the active population, it also underlies socio-economic planning (necessary consumption goods, jobs, education, health services, etc.). There is a close inter-dependence between the age-group distribution of population and the indicators of population dynamics (fertility, birth-rate, death-rate, migrations). A decrease of the natural balance and of female fertility entrained an ageing process, of the rural population, in particular.

Age-group evolutions indicate a steady numerical decrease of young people, with the elderly age-group on the increase, hence a diminished labour-renewal capacity and a greater burden on the pension and social security fonds.

4.1.1. The population ageing index

The index value for this category was 0.2 in 1992. More than half the administrative units (66) registered sub-unity values, with a minimum score at Jina (Sibiu County) and Voineasa (Vâlcea County), maximum values (over 1.5) recording the Hunedoara County communes: Sarmizegetusa, Şoimuş, Pestişu Mic, Sălaşu de Sus, Mărtineşti and Cârjiţi (Fig. 4).

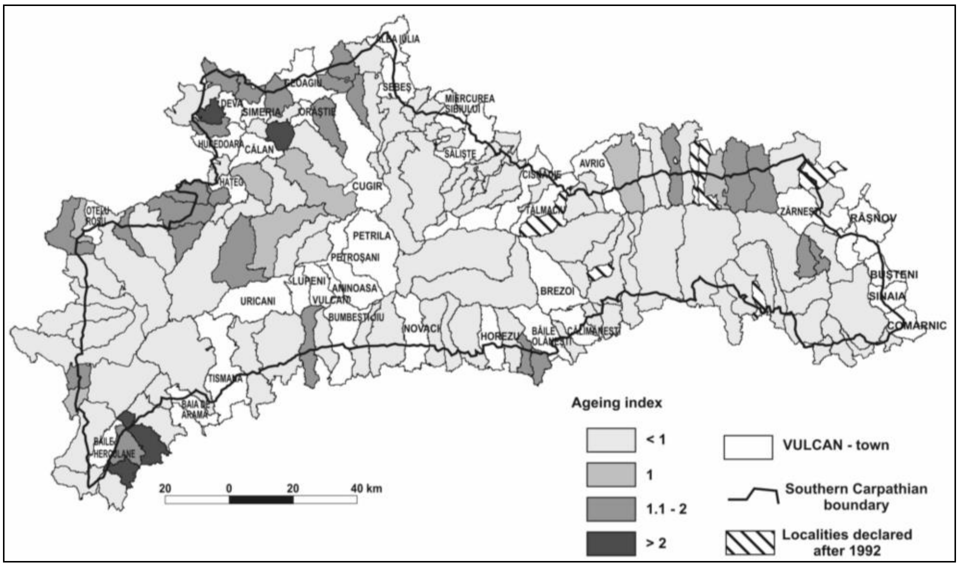

Fig. 4 – The Ageing Index (1992).

In 2011, this index registered an eight-time increase up to 1.6, the average Southern Carpathian value. That year it was only 21 rural settlements that had a low, sub-unity, record with a minimum in Jina (0.4), Câlnic, Orlat and Săsciori, each staying at 0.6; the best score was attained by the communes of Peştişu Mic (3.1), Cârjiţi (3.8) and Fundata (3.9) (Fig. 5).

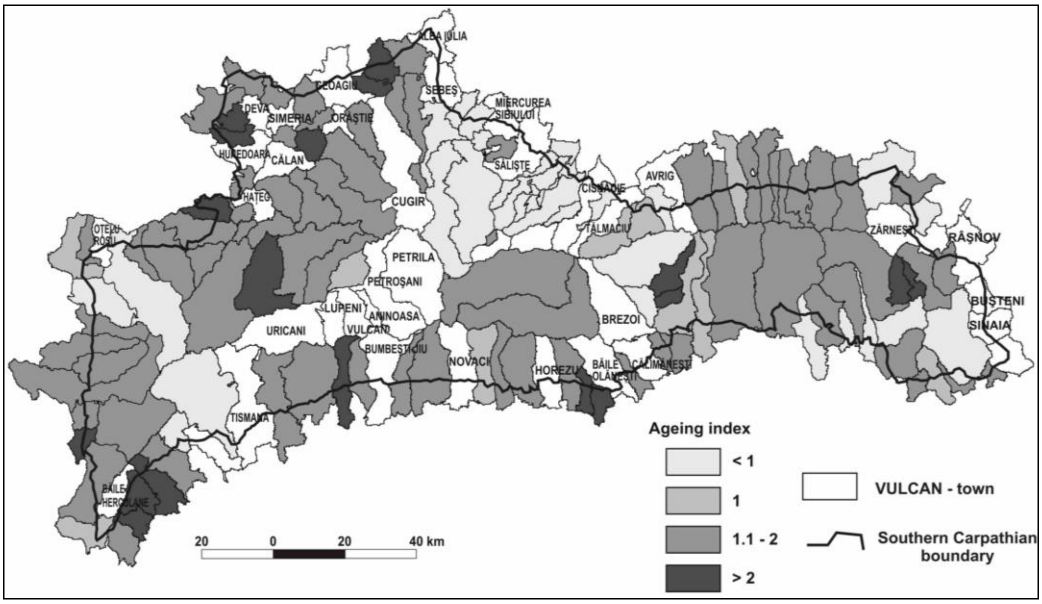

Fig. 5 – The Ageing Index (2011).

The number of elderly tops that of youth, an indication that the ageing index value is higher than in 1992; this situation suggests that the population ageing process is on the increase. An obvious correlation between this process at settlement level and the other demographic phenomena (higher average population age, lower fertile population age and labour-fit population age) all of which do influence the future of a population. Demographic ageing in the region is also closely related to the existence of small villages deprived of favourable natural and human development conditions.

4.1.2. The demographic dependence ratio

The changes recorded in the population age and sex structure did affect the socio-economic activities by altering the age-dependent ratio, which kept growing steadily due to the numerical increase of elderly people, hence the pressure put on the adult working population. The effects of ageing on the economic and social life, as well as on the prospects of demographic evolution are expressed in the dependency ratio.

Economically speaking, the relation between the extreme age-groups (0-14 and 65 and over) on the one hand, and the labour potential population (15-64) on the other, yields the demographic dependence ratio, which is an edifying theoretical expression of the pressure put by the upkept population on the potentially active one.

In 1992, this ratio was of 54.6% in the Southern Carpathians. However, territorial differences between depleted birth-rates and population ageing do exist among the area's administrative units, 42 settlements having an above-average score in the Southern Carpathians, with highest ratio values in the communes of Şinca (69.8%) and Jina (70.7%) (Fig. 6). One can explain the lower or higher demographic dependence ratio values by analysing a settlement's birth-rate, death-rate, life expectancy, development level, etc.

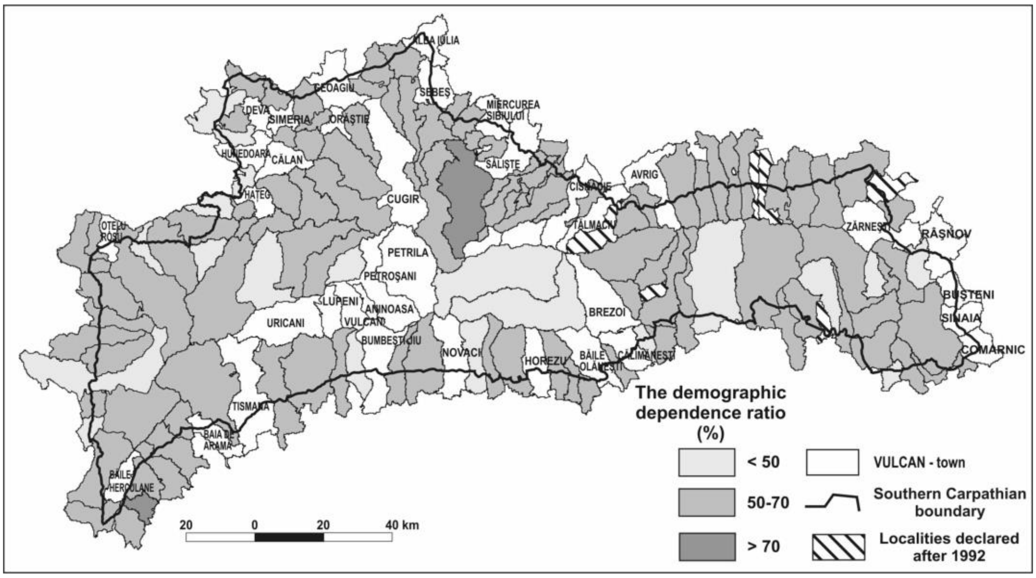

Fig. 6 – Demographic dependency ratio - 1992.

At the 2011 census, the average dependency ratio was 55.0. Approximately half the number of communes had a below average dependency score, with lowest values at Voineasa (39.0), Moroeni (41.7), Boiţa (43.4) and Băniţa (44.0) (Fig. 7). The value of this indicator highlights the advanced deterioration of the age-group structure in the development of this region population caused by village depopulation.

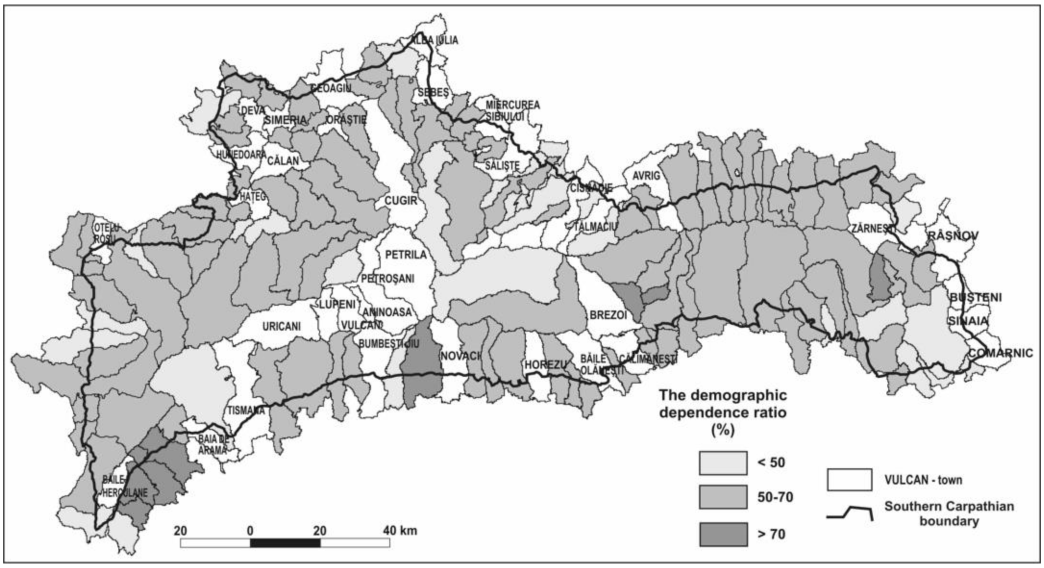

Fig. 7 – Demographic dependency ratio - 2011.

The working-age population is well-represented, but age-groups are dominated by people close to retirement age. There are ever fewer youth (depleted birth-rates by the year), thus ever fewer young occupants in the labour-market and increasingly more elderly. In view of it, measures are required to stimulate population increase, the more so, as the expected economic upsurge relies largely on the quality of the stock of human resources.

4.1.3. The labour renewal ratio

This index is characteristic of a settlement's demographic and economic vitality. Calculations refer to the years 1992 and 2011. According to this indicator, labour renewal values were of 1.3 in 1992. Most administrative units had an above-unity score, except for Sarmizegetusa commune (0.9); six communes Bretea Română, Băuţar, Mehadia, Zăvoi, Bolvaşniţa and General Berthelot were not above unity score, maximum values (over 1.6) recording Boişoara, Racoviţa and Dâmbovicioara, which indicates a higher Southern Carpathian population aged 15-29 than the 30-44 olds (63,091 pers. to 48,955) (Fig. 8).

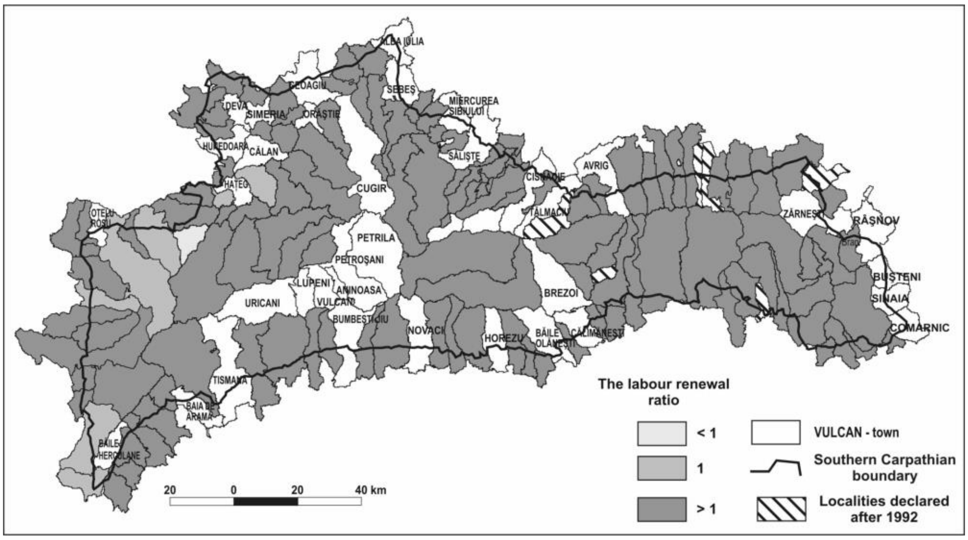

Fig. 8 – The Labour Renewal Index in 1992.

In 2011, this index value was by far lower (only 0.8) than in 1992, which is suggestive of a significant decrease (by more than 20,000 people) in the 15-29-year-old group (Fig. 9). Census data showed subunity values in most communes, only four (Racoviţa, Săsciori, Gârbova and Jina) having an above-unity score.

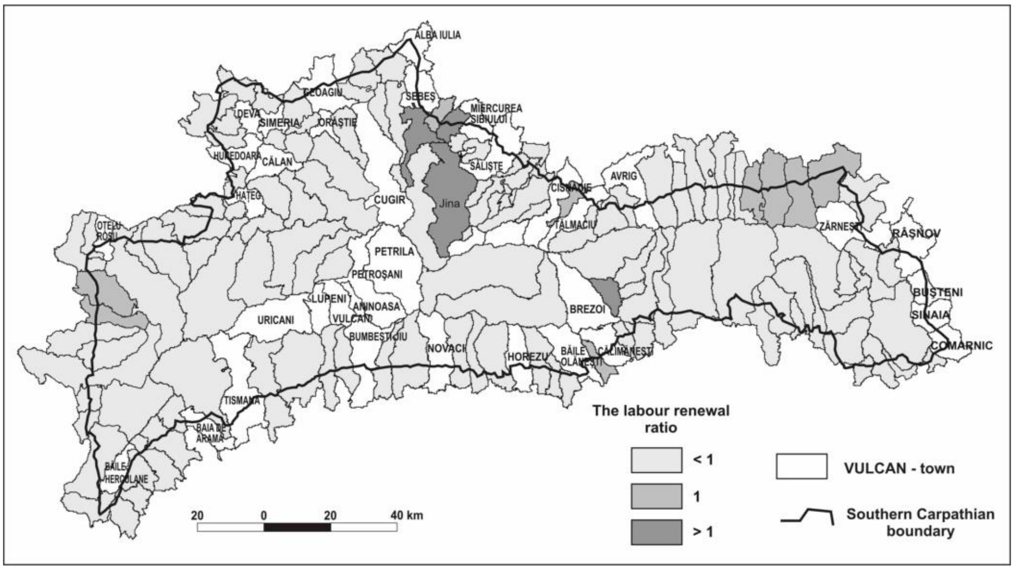

Fig. 9 – The Labour Renewal Index in 2011.

The youth-to-elderly ratio should be viewed not only in terms of quantity but especially of legislation to ensure the workforce for the present and the future, in particular. Therefore, measures are required to stimulate the numerical growth of population. Some demographic indicators have outlined specific types of evolutions.

4.2. The population sex structure

This represents an important element for a geo-demographic analysis of population. Normal evolution conditions between the two sexes (males and females) stay at a 1-3% difference in favour of female, hence a process of feminisation of the population. In the wake of a demographic decline, the age-structure suffered some changes.

Towards the end of the 20^{th} and the beginning of the 21^{st} cc., the female population prevailed (50.3% - 1992, 50.4% - 2011). Between 1992 and 2011 decreases in the number of females were lower than among males, which did maintain the numerical gap between the two sexes. The ratio between the two being relatively balanced, the female population exceeding the male one by 1,505 and 1,937 individuals in 1992 and 2011, respectively.

The statistical data of the last two censuses afford several conclusions: a decrease in the proportion of young population (0-14-year-old) and an increase in the elderly one (65-year-old and over), with the female population prevailing especially in the latter category, women living longer than men. Small oscillations were found in the adult population (15-64-year-olds).

The age-and-sex structure of the population reflects the impact of natural population dynamics and of the migratory balance. The age and sex distribution indicates certain tendencies in the time-evolution of demographic phenomena and in the internal and external migratory flows. The population sex-structure is of particular importance for its notable demographic, economic and social consequences.

4.3. The ethnic structure

"The Romanians' ethnical and territorial unity has been acknowledged from times immemorial. The expression of this unity is found in the look, language and customs of the inhabitants" (Cucu, 1992). Nationality is a major element in analysing the structures of a population.

At the October 20, 2011 census, ethnicity and religion were registered based on the responders' free declaration. Information on people who did not wish to declare it, or information on people collected indirectly from administrative sources are not available. Therefore, the structures further presented are calculated in terms of the total number of persons who did declare their ethnicity and religion and not of the total number of stable population. Information on ethnicity was available for 237,309 persons (out of a 245,179 total).

The ethnical structure reveals the majority proportion of the Romanian ethnic block along the time. According to data analysis, Romanians represented 96.0% of the population (227,955 pers.) in 2011, compared to 97.6% (277,065 pers.) in 1992. Next in line come the Rroma – 3.5% (8,227 pers.), with a two-fold increase versus the first census (1.4% – 3,935 pers.); the Magyars – 0.3% (814 to 1,897 in 1992); other ethnicities: 197 pers. to 319 in 1992.

By and large, the nationality structure in 2011 is not different from that in 1992. Beside the majority Romanians with close percent values in the two census years, the three more important national minorities in terms of number and proportion are the Rroma (Gypsies), on the increase, the Magyars and the Germans, on the decrease versus 1992.

The 1992 Romanian population held the majority (over 82%) in all the Southern Carpathian communes, 14 of these settlements having only Romanian inhabitants; lowest percentages of Romanian ethnics were at Bolvaşniţa (Caraş-Severin County), Valea Mare Pravăţ (Argeş County), Mărtineşti (Hunedoara County) and Gârbova (Alba County). In the studied area, next in line stand the

Rroma (1.4 of population total), but no Rroma inhabitant existed in 38 communes; the Magyars (over 5%) live in four communes: Harău, Băcia, Mărtineşti and Bolvaşniţa.

In 2011, the Romanians represented over 68% in all the settlements, and 100% in 11 of them. Looking at these data, it appears that next in line after the Romanians, come the Rroma, with over 20% of the population in settlements like Turdaş, Dragoslavele, Valea Mare Pravăţ, Câlnic and Bughea de Sus, an increase due to a high natural balance, migration from other settlements, awareness of belonging to this ethnicity and declaring it.

4.4. Confessional structure

According to the space-time analysis, the Orthodox religion is in the majority, having constantly held this position through time. Favourable conditions of habitation have made other ethnics settle here. Co-habitation with the local population has led to changes in elements of culture and civilisation.

The religious structure, resulting from one's free response, come close to 2002 census data, despite referring to a numerically decreased population. By and large, the confessional structure in 2011 does reflect the ethnical structure, the vast majority of Romanians identifying themselves with the *Orthodox Christian* creed (93.0%, i.e. 221,916 pers.); other confessions: Pentecostals (2.5%) – 5,889 pers. and Baptists (1.6%) – 3,933 pers.; other religions in the Southern Carpathians: Roman-Catholic – 0.7%; Evangelist – 0.6%; Adventist of the Seventh Day – 0.5%, etc. a fairly high proportion (0.3%) of no religion answers, atheists, or no appurtenance to a religious belief.

The territorial distribution of the population by religious belief shows the *Orthodox* to be dominant in all the Southern Carpathian communes, and in proportion of 100% in four of them (Câineni, Talea, Muereasca and Titeşti).

The neo-Protestant cults are present mostly in the multi-confessional counties. The *Pentecostal* Cult (2.5%) has most believers in the communes of Beriu, Densuş, Râu de Mori, Obreja and Turnu Ruieni.

The *Baptist* cult has a higher percentage – 1.6% of the entire population, with significant values – over 11 of the total population, in five communes (Turnu Ruieni, Băuţar, Răchitova, Râu de Mori and Bolvaşniţa). The Evangelist cult (0.6%) registers notable values, totalling over 5% at Rucăr, Gârbova, Stoeneşti and Dragoslavele.

5. CONCLUSIONS

The Southern Carpathian population is steadily decreasing, simultaneously with advanced ageing and depleted birth-rate. All small villages show a depopulation trend. Changes in the age-structure of the population reveal enhanced demographic ageing – reduced number of young people (under 15-age old) and an increase of the elderly category (65 and over). Improving the current situation and the proportion of population by age-groups requires legislative measures.

There are several factors liable to alter the structure of a population. The intensity of this alternation in a geographical space depends on living standard, natural conditions and the main demographic characteristics.

Certain groups of populations and the changes having affected them in time and space are related to characteristic territorial, demographic, socio-cultural and economic features. The socio-economic development of a territory is accompanied by several modifications and studying them represents a prerequisite for sustainable development.

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REFERENCES

Badea, L., Niculescu, Gh., Roată, S., Buza, M., Sandu, Maria (2001), *Unităţile de relief ale României.* **I**. *Carpaţii Meridionali şi Munţii Banatului*, Edit. Ars Docendi, Bucureşti.
Badea, L. (2014), *Dicţionarul unităţilor de relief ale României*, Edit. Universitaria, Craiova.
Bugă, D., Vişan, Gh. (1997), *Evoluţia populaţiei şi dezvoltarea aşezărilor omeneşti din Carpaţii Meridionali în secolul XX*, Buletin Geografic, anul **I**, nr. *1*, Bucureşti.
Cândea Melinda (1994–1995), *Rolul Carpaţilor Meridionali în formarea şi diversificarea reţelei de aşezări omeneşti din spaţiul geografic românesc*, Terra, an **XXVI-XXVII**, Bucureşti, pp. 70–76.
Cândea, Melinda (1996), *Carpaţii Meridionali în sistemul montan românesc. Studiu de geografie umană*, Edit. Universităţii din Bucureşti, Bucureşti, 155 p.
Cândea, Melinda (1997), *Evoluţia peisajului geografic sub influenţa factorului uman în depresiunile intracarpatice din Carpaţii Meridionali,* Edit. Universităţii din Bucureşti, Bucureşti, pp. 99–101.
Cucu, V. (1992), *Consideraţii geografice privind unitatea etnică a României*, Terra, 1–2.
Giurcăneanu, C. (1988), *Populaţia şi aşezările din Carpaţii Româneşti*, Edit. Ştiinţifică şi Enciclopedică, Bucureşti.
Martonne, Emm. de (1907), *Recherches sur l'évolution morphologique des Alpes de Transylvanie (Carpates Méridionales)*, Revue de Géographie annuelle, t. **I**, Paris.
Nancu, Daniela (1989), *Habitatul rural în spaţiul montan european*, Terra, an **XXI (XLI)**, Bucureşti, pp. 70–72.
*** (1983), *Geografia României*, vol. **I**, *Geografie Fizică*, Edit. Academiei R.S. România, Bucureşti.
*** (1987), *Geografia României,* vol. **III**, *Carpaţii Româneşti şi Depresiunea Transilvaniei*, Edit. Academiei R.S. România, Bucureşti.
*** *Recensământul populaţiei şi locuinţelor din 1992*, CNS, Bucureşti.
*** *Recensământul populaţiei şi locuinţelor din 2002*, INS, Bucureşti.
*** *Recensământul populaţiei şi locuinţelor din 2011*, INS, Bucureşti.

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ATTRACTIVITÉ COMMERCIALE ET NOUVELLE CENTRALITÉ DANS LE BAS-SAHARA ALGÉRIEN: CAS DE LA VILLE DE BISKRA

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Key-words: centrality, commerce, structure, concentration, Biskra, Algeria.

Commercial attractiveness and new centrality in the Algerian Lower Sahara: Biskra City case-study. New dynamics affect the contemporary city triggering a real redistribution of the urban functions and redefining of the notion of territory. Indeed, the phenomenon of urban relaxation stimulated the emergence of new points of attractiveness at the periphery, so breaking with the model of the traditional town. These new centrality points generate effects related to the space gravity leading to the concentration of economic activities, among them is the commercial one, which plays a fundamental role in the structuring and dynamics of space. In fact, this was a determining factor in "shaping" the contemporary centrality of the city of Biskra. The spatial distribution of fixed shops (retailing) in the city responds to the concentration factor which is interesting to study in order to identify more central places than others. Thus, our work I lies essentially at the crossroads of two approaches: qualitative and quantitative, with emphasis on the commercial activity. The main objective of our research is to assess commercial centrality in the city of Biskra and its impact on the structure and space organization. It is also interesting to envisage an urban strategy able to support and anticipate urban developments at the best in Biskra.

1. INTRODUCTION

L'extension urbaine et la diversification des fonctions que connaissent les villes à l'ère contemporaine ont fait apparaître, au niveau de la trame urbaine, de nouveaux points dotés d'un pouvoir d'attractivité, rompant ainsi avec le modèle et la logique de la ville traditionnelle. Par conséquent, ces nouveaux points, dits de centralité, génèrent des effets liés à la gravité spatiale qui tire sur la concentration des activités économiques dont la fonction commerciale. Cette dernière joue un rôle fondamental dans la structuration de l'espace et ses transformations et représente le secteur le plus dynamique de l'économie urbaine (Diop A, 2008).

En effet, les commerces détiennent une importance capitale par rapport à la dynamique et animation urbaine. Ils font de la ville un espace économique, un espace de vie et de sociabilité (Lebrun N, 2002). Ils représentent également des facteurs de croissance économique parce qu'ils ont le pouvoir de constituer un pôle d'attraction incontournable pour les nombreux usagers de la ville. Ainsi, une place centrale est avant tout un groupement d'établissements et services de commerce de détail localisés dans un endroit qui fournit un point de réunion accessible aux consommateurs (Raham D, 2001). La centralité quant à elle est l'essence même de ce point de réunion (Berry B.J.L, 1971). La production de la centralité est donc basée sur les offres économiques ou commerciales des lieux ou localités, qui peuvent créer des mouvements de population ou des concentrations de multiples activités.

Nous nous sommes penchés, dans cette étude, sur la compréhension du phénomène de l'attractivité commerciale et de ses impacts spatiaux sur la ville de Biskra en Algérie.

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Ainsi, un quartier commerçant exerce son pouvoir sur le voisinage immédiat et souvent même au delà. Quand à la rue commerçante, elle représente un véritable spectacle gratuit, grâce à la multiplicité des boutiques qui la composent. Tout cela crée une ambiance urbaine qui attire le flâneur, l'oisif aussi bien que le véritable acheteur. Nous constatons que dans une ville, les rues commerçantes sont beaucoup plus fréquentées que les autres, quand aux centres commerciaux, ils jouent le rôle de véritables pôles d'attraction (Beaujeu-Garnier J& Delobez A, 1977).

Le commerce est donc une fonction clef pour assurer le développement d'une ville, définir la géographie du commerce (particulièrement de détail) permet de dégager des points de réunion et d'attraction, plus accessibles aux consommateurs (Raham D, 2001). Ce sont des centralités éventuelles qui peuvent déterminer l'organisation d'un espace et sa dynamique.

Cette ville du bas Sahara représente un nœud important à la porte du désert algérien, ses nombreux atouts et sa position stratégique lui confèrent un rôle de carrefour d'échange entre le Nord et le Sud du pays. Biskra représente aujourd'hui un centre industriel mais surtout un centre commercial du fait de la dominance du secteur tertiaire, occupant plus de 63% de la population active (Kouzmine Y. 2007) (Fig. 1).

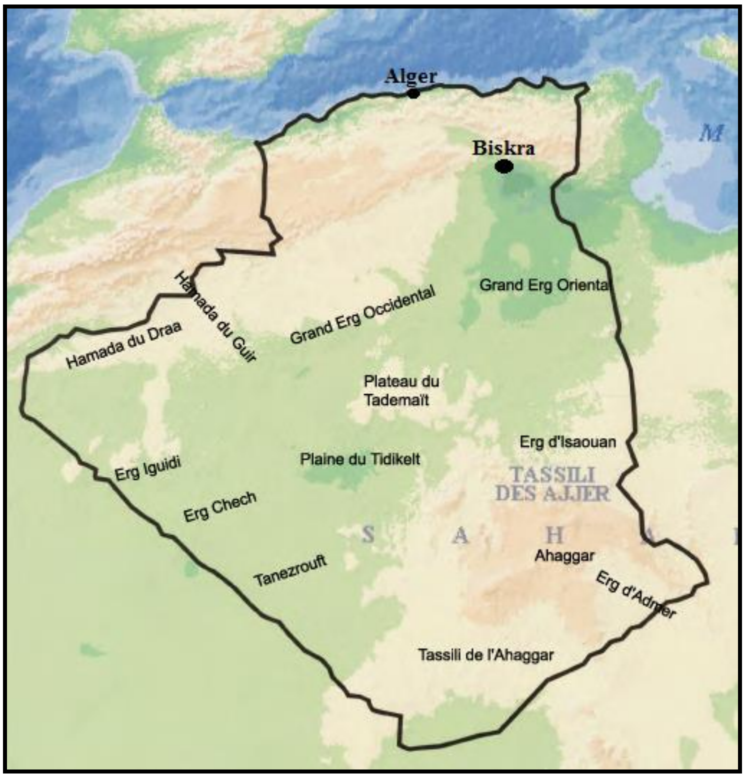

Fig. 1 – La situation géographique de la ville de Biskra.
Source: Atlas Encarta 1998 et M.BEGILLE-G, PAVAUX.

Cette situation reflète l'importance de l'activité commerciale et sa grande expansion dans la ville. La répartition spatiale des commerces fixes dans la ville de Biskra semble répondre à des logiques de concentration, qu'il serait intéressant d'analyser et surtout d'interpréter. En effet, il semblerait qu'un nouveau modèle de centralité se met progressivement en place à Biskra.

L'objectif principal de ce travail est de s'interroger sur cette situation et surtout de mesurer l'importance de ce nouveau "schéma": Quel nouveau fonctionnement, quelle nouvelle structure urbaine pour la ville et quelles nouvelles relations entre la centralité existante et nouvelle ?

2. MÉTHODOLOGIE D'APPROCHE ET SOURCES DES DONNÉES

2.1. Méthodologie d'approche

Pour mieux saisir et cerner l'ensemble de cette situation, nous avons développé deux approches: qualitative et quantitative.

L'objectif de la première approche "qualitative" est de définir la structure commerciale et tenter de mettre en évidence une spatialisation de celle-ci à Biskra. Nous avons donc procédé à la classification des commerces et leur rayonnement, en nous intéressant au nombre d'établissements existants et les différents types de commerce.

La seconde approche "quantitative", permet d'établir une analyse de l'espace commercial à travers des indicateurs quantifiables, l'objectif étant d'utiliser des indices et calculs statistiques afin d'évaluer la centralité commerciale, parvenir à mettre en relief sa prépondérance spatiale et d'élaborer une hiérarchie des lieux. Notre lecture de synthèse s'est appuyée sur un outil technique qu'est l'analyse en composantes principales (ACP) et les résultats matriciels. Cet outil a été retenu parce qu'il permet de synthétiser de vastes ensembles de données, de classifier les oppositions et d'ébaucher une hiérarchisation des facteurs de localisation différentielle. L'ACP aide à la simplification de grands tableaux de données en y décrivant les observations par un nombre restreint de nouvelles variables synthétiques. Si les observations sont des lieux et les variables expriment l'importance des différents types de commerce en ces lieux, les nouvelles variables synthétiques représentent les principaux axes de différenciation des paysages commerciaux. Ces axes ont le mérite d'être documentés au travers des corrélations qu'ils ont avec le profil de localisation des variables, c'est-à-dire les types de commerce. Notre Analyse en Composantes Principales (ACP) pour la ville de Biskra a été conçue par l'analyse d'une matrice dont les observations sont les lieux (les 10 secteurs de la ville) et les variables traduisent la présence des différents types de commerce. L'enquête sur terrain a permis de dénombrer 69 types d'activités commerciales (variables).

2.2. Sources des données statistiques et enquêtes

Données statistiques et enquêtes

Les principales sources de données sur lesquelles nous nous sommes appuyés sont les recensements généraux de la population et de l'habitat (RGPH) effectués sur la population algérienne de 1966, 1977, 1987, 1998 et 2008. Nous avons également procédé à l'examen de tous les documents ayant trait aux questions d'aménagement et d'urbanisme, en l'occurrence, le plan d'aménagement de Wilaya (PAW), le plan directeur d'aménagement et d'urbanisme, PDAU (1995) – (2008) et le schéma national d'aménagement du territoire (SNAT 2030).

En plus des statistiques officielles, nous avons effectué une série d'enquêtes et relevés sur terrain, entre autres:

– Dénombrement systématique de tous les types de commerce en 2008, durant une période de plus de 6 mois de travail.

– Relevé des locaux de commerce et de services en 2008.

– Entretiens ouverts avec la population locale

– Nous avons également procédé à une enquête auprès des commerçants de la ville de Biskra, avec plus de 381 enquêtes, soit 10% du nombre total des établissements commerciaux (appareil commercial Biskri).

Données bibliographiques

Le présent travail a nécessité l'utilisation d'une bibliographie riche et variée afin de cerner la problématique traitée. En effet, la compréhension des concepts clés de ce travail (centralité, commerce, concentration...etc.) a été élaboré au carrefour de nombreux travaux entre autre: Ascher, F. 2003; Belamine, M.A. 1995; Bondue, J.P. 2000; Gaschet, F. & Pouyanne, G. 2011; Oueslati Hammami, I. 2010.

3. RÉSULTATS ET DISCUSSION

3.1. Dynamique urbaine et transformations de la centralité à Biskra

Biskra, au début de son développement au 17éme siècle, bénéficiait d'une centralité géographique parfaite et concordante comme le montre la Figure n° 2. Il s'agissait du modèle traditionnel de la centralité (centre/périphérie) sur lequel reposait l'organisation de la plupart des villes islamiques à savoir: la mosquée et le marché. Ce modèle a perduré jusqu'à l'arrivée des français au 19éme siècle (Cote M, 1991). Cette époque fut marquée par la construction en 1850 du Fort Saint Germain, qui représentait le premier noyau de la ville coloniale. Ce dernier fut érigé afin de contrôler les sources d'eau et se détacher physiquement de la ville autochtone. Créant ainsi un territoire réservé uniquement aux européens, une nouvelle forme de centralité est venue se greffer au système préexistant. Les structures de la centralité se transférèrent vers la ville nouvelle (coloniale) et l'ensemble de l'agglomération connut un véritable développement urbain, économique et social. De ce fait, le vieux Biskra a été marginalisé, séparé et isolé par rapport au tissu nouvellement érigé.

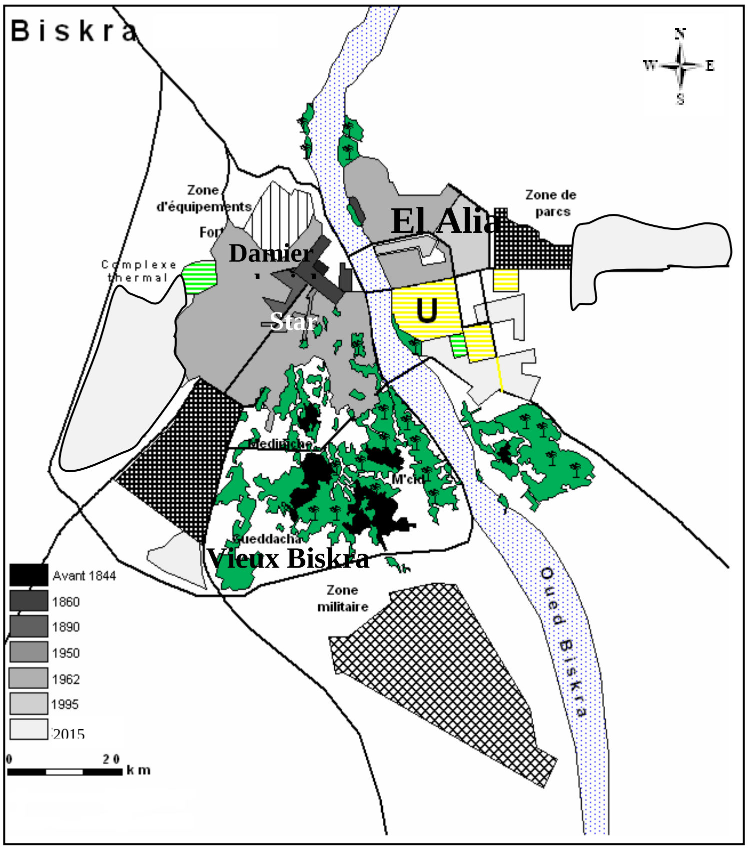

Fig. 2 – Evolution spatiale de l'agglomération de Biskra.
Source: plan de la ville de Biskra; image satellitaire ASTER 2005+ réactualisation auteurs.

Depuis l'indépendance en 1962, l'évolution de la ville de Biskra a connu trois grandes phases d'urbanisation distinctes.

La première (de 1962 à 1977) s'est caractérisée par la lenteur des transformations, la ville a vécu un développement spontané sans véritable organisation urbaine. Elle a également connu un prolongement d'urbanisation de la cité "Star Mlouk" qui abritait la population autochtone en période coloniale, sous forme de logements individuels et quelques équipements: marchés, hôtels, hammams, etc. Cette dernière a réussi a captiver une attractivité et créer une centralité (surtout commerciale) parallèle à celle du damier colonial. Mais c'est grâce à sa promotion au rang de chef lieu de Wilaya (CLW) au début des années 70, que la ville de Biskra a été marquée par une urbanisation très rapide, basée sur une consommation massive et sans précédant des terres de la palmeraie.

Ce deuxième stade d'urbanisation de 1977 à 1998, s'est caractérisé par un développement soutenu et continu, sur un axe horizontal, se dirigeant vers l'Est et l'Ouest avec le lancement d'un nouveau mode de construction d'habitat collectif établi par l'état algérien à la fin des années 70. La centralité quant à elle, s'étendait dans un prolongement formé par le damier colonial et le quartier star Mlouk.

Durant le dernier stade, de 1998 jusqu'à nos jours, la ville de Biskra s'est caractérisée essentiellement par son extension vers l'Est et l'Ouest, donnant lieu à une conurbation avec les centres péri-urbains de Chetma et d'El Hdjeb.

Ainsi, la ville de Biskra a connu une forte croissance démographique à travers les différentes périodes allant de1954 à 2008 (année du dernier RGPH). En effet, sa population à presque quadruplée (passant ainsi d'une petite ville de quelques milliers d'habitants en 1845 à la ville moyenne de plus de 200 000 habitants qu'elle est devenue aujourd'hui), elle occupe actuellement le rang de neuvième ville à l'échelle nationale en terme de population (RGPH 2008). Cette explosion démographique est le résultat logique de l'imbrication de trois mécanismes: la croissance naturelle, la migration et la promotion de la ville au rang de (CLW) à partir de 1974.

Aujourd'hui, elle semble s'inscrire puissamment dans une nouvelle forme de territorialité marquante des processus d'urbanisation contemporaine, avec des différences évidentes liées à son contexte local ou encore à ses spécificités régionales. En effet, la ville connait des recompositions actives de ses centralités urbaines et ce, à fur et à mesure qu'elles s'étendent et se transforment. Les mutations des centralités relèvent de logiques bien particulières; certaines centralités sont anciennes, leur rayonnement va parfois de plus en plus loin (en dehors de la ville) d'autres sont récentes et souvent liées à l'extension spatiale du bâti, qui coïncide avec une modification des attentes sociales, ou alors des nouveaux usages et pratiques. Une réalité est pourtant sûre, l'effigie de la ville n'est plus celle qui prédominait avant: avec un centre originel en possession de toutes les fonctions et activités. Bien au contraire, celle-ci est en mutations rapides puisque sa périphérie symbolisée par de nouvelles constructions à vocation résidentielle d'abord est en voie d'attirer de nombreuses activités (notamment commerciales) de type anormal, dont l'acquisition provoque de longs déplacements au sein de la population. De plus, Biskra de par sa position géographique et stratégique (porte du désert) se caractérise par son héritage commercial riche et fort, d'autres facteurs ont participé à l'évolution de l'appareil commercial et ainsi à développer une centralité dynamique à Biskra.

Notre travail tente d'apposer une lecture synthétique à la croisée des deux approches précédemment citées, de mettre en évidence les lieux les plus centraux par rapport à d'autres dans la ville et d'évaluer le rôle dominant que joue aujourd'hui le commerce dans la dynamique urbaine et l'organisation globale des structures de Biskra.

3.2. Commerces et attractivité à Biskra: l'approche qualitative

Dans cette approche, nous avons d'abord procédé à la répartition spatiale et la concentration des commerces à travers toute la ville, ensuite à leur classification selon leur rayonnement. Nous avons donc recensé les établissements commerciaux par classe, en plus de leur répartition spatiale.

La répartition spatiale des commerces et leur concentration dans la ville de Biskra

Biskra compte plus de 3813 établissements de plusieurs types (selon une enquête de terrain effectuée en 2008). La Figure n° 3, représente la répartition spatiale des établissements commerciaux à Biskra, elle démontre l'existence de certaines logiques de concentration. Deux facteurs primordiaux ont guidé l'évolution de l'appareil commercial de la ville. D'une part, un héritage historique et culturel riche et fort, qui a donné lieu à une concentration commerciale au niveau des anciens tissus urbains et d'autre part, une position géographique stratégique, qui a participé à la consolidation de la fonction commerciale et à l'expansion des commerces au niveau de la périphérie. Ceci nous a permis de dégager, dans un premier temps, des « secteurs » ou des « lieux » plus centraux que d'autres (Fig. 3).

Par ailleurs, la forte concentration du commerce dans la ville de Biskra est enregistrée au niveau de deux unités urbaines principales à savoir: Le secteur N°5 (s'y ajoute des petites parties des secteurs N°1, 2, 6 et 4) et le secteur N°8, autrement dit, au niveau des zones à fortes densité de peuplement:

- La première unité de concentration dégagée représente le cœur même de la ville, il s'agit du damier colonial (centre ville) et du quartier Star Mlouk.
- La deuxième unité correspond à la nouvelle extension de la ville du côté Est, c'est-à-dire El Alia Nord.

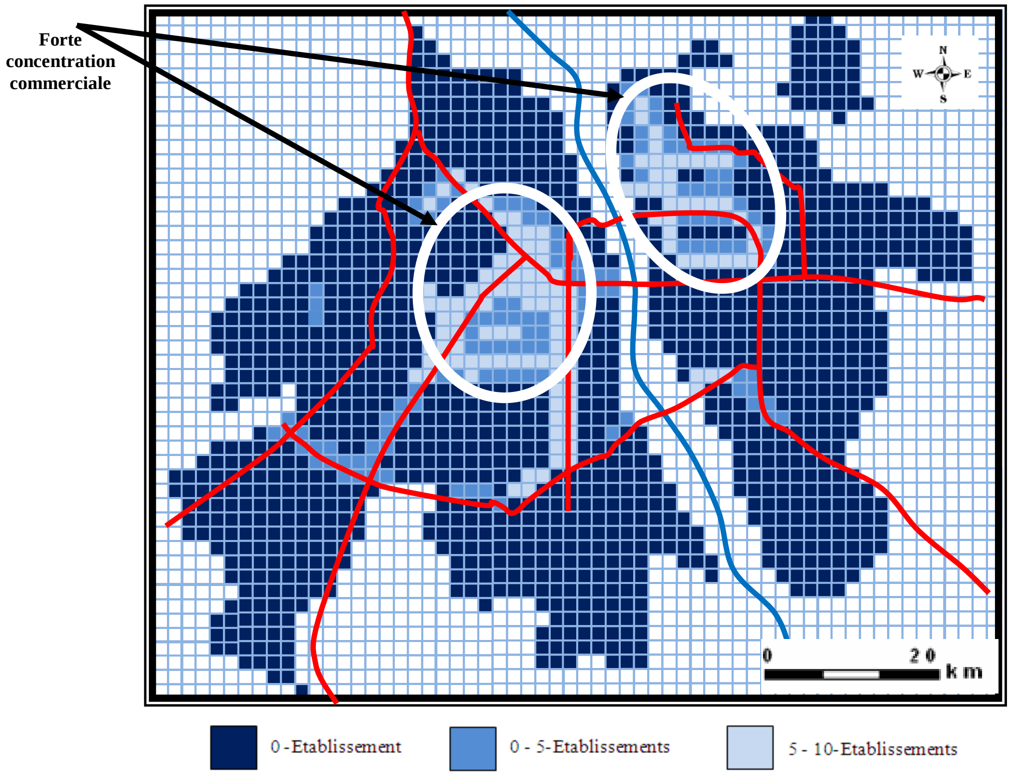

Fig. 3 – La ville de Biskra: Concentration commerciale.
(Source : Enquête sur terrain en 2008).

Classification des types de commerce selon le rayonnement des lieux d'implantation dans la ville

Nous avons procédé, au niveau de ce point, au classement des différents types de commerce selon le rayonnement des secteurs ou noyaux dans lesquels ils sont implantés (Wayens B. 2006). Notre objectif serait de faire ressortir les secteurs ayant un fort rayonnement par rapport aux secteurs de faible rayonnement, en nous basant sur la relation entre les différents types de commerce existants à Biskra et leur implantation à travers les secteurs urbains.

Pour ce faire, nous avons d'abord effectué un classement général des types de commerces fondé essentiellement sur des résultats obtenus (Lekehal A., 1996) et selon 5 principales catégories de rayonnement, comme l'illustre le tableau 1. Cette attribution de différentes valeurs aux commerces existants à Biskra, nous a été inspirée par les différentes méthodes de classification existantes.

Tableau 1

Classement des types de commerces selon le niveau de rayonnement et le nombre des localités desservies

	I (0–2000hab)	**II (2000–3500 hab)**	**III (3500–8000 hab)**	**IV (8000–35000 hab)**	**V (+ 35000 hab)**
Alimentation	– Alimentation générale	– Boulangerie – Boucherie – Pâtisserie – Fruits et légumes – Produits laitiers – Vente semoule – Grossiste alimentation générale			
Equipement de la personne			– Cosmétique – Articles scolaires	– Mercerie	– Habillement – Chaussures – Vente tissu
Equipement de la maison			– Produits domestiques	– Tapisserie – Electroménager – Ameublement – Fleuriste/décors maison	– Mobilier de bureau
Equipement de la profession	– Quincaillerie	– Droguerie&peinture – Librairie	– Vente cassette & cassette vidéo	– Produits de la pâtisserie – Vente matériel électronique/informatique/ appareil téléphonique/matériel frigorifique – Pièces détachées/ – peinture automobile	– Vente matériels plomberie & chauffage – Vente matériaux de construction – Vente véhicule
Artisanat	– Coiffeur – Tailleur, teinturier – Cordonnier	– Tôlier – Electricien – Vulcanisateur – Soudeur – Réparateur TV – Réparateur appareil électroménager – Réparateur motocycle – Lavage et graissage – Tourneur – Mécanicien	– Menuiserie – Vitrier	– Réparateur montre	– Bijouterie
Services	– Pharmacie – Cybercafé/ bureau d'informatique – Cafés – Taxi phone	– Pizzeria – Restaurant – Douche – Hammam – Photographe	– Dégraissage – Dentiste – Clet minute	– Auto-école – Bureau d'étude d'architecture – Agence immobilière – Opticien – Assurances – Imprimerie	– Comptables – Location de voiture – Expertise et contrôle de voiture

Source: D'après les résultats de la Figure n° 3 & traitement personnel 2010.

Les différentes catégories commerciales, associées au plus faible rayonnement (groupe I moins de 2000 hab), correspondent à des commerces de première nécessité, elles sont donc plutôt de rareté faible. Le deuxième groupe comprend la plupart des commerces et services de base, essentiellement issus de l'alimentation spécialisée, des services et de l'artisanat. Quand au groupe III (3500–8000 hab), il traduit un rayonnement plus étendu que les deux premiers et comprend les commerces de l'équipement de la personne, de l'artisanat et des services. Le groupe IV (8000–35000 hab) qui se caractérise par un fort rayonnement, correspondant à des besoins plus spécifiques ou exceptionnels dont l'acquisition nécessiterait de longs déplacements au sein de la population. Enfin, le groupe V (+35000 hab), regroupe des commerces ayant un large éventail d'attraction, tels que: habillement, chaussures, bijouterie, vente de véhicules, etc. De ce fait, un secteur urbain regroupant un taux élevé des commerces du niveau V, sera logiquement doté d'une très forte attractivité au niveau de la ville, cela n'empêche qu'il peut également comprendre des commerces de niveau I et ainsi de suite.

Rayonnement des secteurs de la ville de Biskra

Sur la base de la classification en 5 groupes présentée précédemment (Tab. 1), nous pouvons attribuer une côte de 1 (très faible rayonnement) jusqu'à 5 (très fort rayonnement) à tous les types de commerce. Cette côte informe sur le niveau de rayonnement des secteurs, là où s'installe de manière préférentielle le type de commerce considéré.

Pour les secteurs urbains de Biskra et à partir de l'inventaire des commerces existants, nous avons pu produire une idée sur le rayonnement probable, en se référant à la grille de lecture préalablement proposée (rayonnement des types de commerce). Nous avons pu distinguer la part de commerce ayant un très faible rayonnement (ceux dont l'activité relève du groupe I) de ceux possédant un rayonnement important (c'est à dire appartenant aux groupes IV, V).

Par conséquent, les secteurs N° 05, 01, 04 et 08 se caractérisent par un fort rayonnement, qui traduit la concentration et la diversité des commerces des groupes V et IV. Par contre, les secteurs N° 02, 09, 03, 07 et 10 se définissent, plutôt, par un faible rayonnement (Fig. 4).

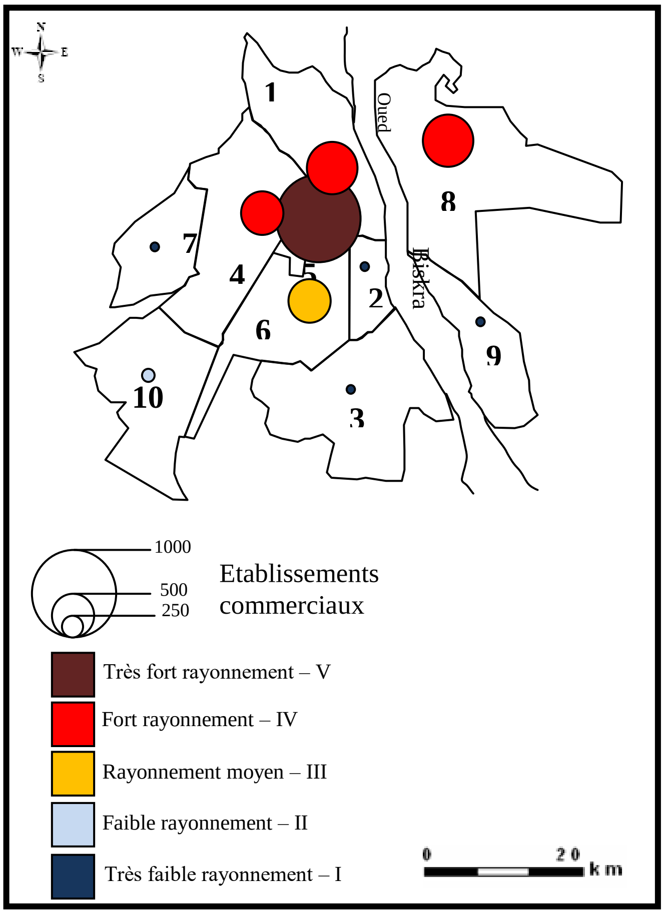

Fig. 4 – Le rayonnement des secteurs de la ville de Biskra (2010).
(Source: Conception personnelle 2010).

La lecture de la Fig. n° 4 nous permet d'établir une certaine concordance avec les résultats dégagés à partir de l'analyse de la concentration des commerces. En effet, les secteurs dotés d'un rayonnement important correspondent aux deux unités précédemment ressorties. Nous parvenons a déduire à partir de cette première approche que la ville de Biskra se structure désormais autour de deux points de concentration commerciale.

3.3. Commerces et attractivité a Biskra: l'approche quantitative

Cette seconde approche vient compléter la précédente en abordant la structure commerciale de Biskra à travers des indices et calculs statistiques afin de délimiter réellement la centralité, faire ressortir les polarisations existantes par secteur et selon leur spécialité et d'élaborer ainsi une hiérarchie des lieux centraux de la ville. A ce stade nous avons pu effectuer une lecture de synthèse qui s'est appuyée sur un outil technique: l'analyse en composantes principales (ACP) et les résultats matriciels.

Les polarisations des secteurs selon leur spécialité

Pour parvenir à déterminer la fonction commerciale principale des secteurs urbains selon leur spécialité, nous avons étudié la structure d'activité de chacun d'eux en se référant à une méthode mathématique. Nous avons donc procédé à la comparaison de la structure d'activité à deux structures différentes: la structure moyenne de la ville de Biskra – et la moyenne des structures de chaque secteur. Les écarts observés par rapport à ces deux structures nous ont permis de dégager deux types de secteurs, les uns spécialisés, les autres plutôt multifonctionnels (tableau 2).

Tableau 2

Typologie commerciale des secteurs en 2008.

Secteurs	Etablissement des commerces purs	Etablissement des commerces de l'Artisanat	Etablissement des commerces de services	Total	Part commerces purs	Part commerces de l'Artisanat	Part commerces de services
Secteur 1	415	81	166	662	62.68	12.23	25.07
Secteur 2	53	26	27	106	50	24.52	25.47
Secteur 3	47	22	22	91	51.64	24.17	24.17
Secteur 4	271	69	145	485	55.87	14.22	29.89
Secteur 5	815	167	142	1124	72.50	14.85	12.63
Secteur 6	254	96	87	437	58.12	21.96	19.90
Secteur 7	10	10	14	34	29.41	29.41	41.17
Secteur 8	347	113	201	661	52.49	17.09	30.40
Secteur 9	22	11	17	50	44	22	34
Secteur 10	62	43	58	163	38.03	26.38	35.58
Total	2296	638	879	3813	60.22	16.73	23.05

Secteurs	Ecart / moyenne des secteurs			Typologie
	commerces purs	Artisanat	Services	
Secteur 1	+2.46	-4.5	+2.02	
Secteur 2	-10.22	+7.79	+2.42	
Secteur 3	-8.58	+7.44	+1.12	
Secteur 4	-4.35	-2.51	+6.84	
Secteur 5	+12.28	-1.88	-10.42	
Secteur 6	-2.1	+5.23	-3.15	
Secteur 7	-30.81	+12.68	+18.12	
Secteur 8	-7.73	+0.36	+7.35	
Secteur 9	-16.22	+5.27	+10.95	
Secteur 10	-22.19	+9.65	+12.53	
Total	60.22	16.73	23.05	

Pôle de commerce pur
Pôle de Service
Pôle de l'Artisanat
Pôle multifonctionnel

Source: Enquête sur terrain en 2008.

Les pôles multifonctionnels

Ils sont représentés par les secteurs N° 01, 02, 03, 07, 08, 09, 10. Cet ensemble détient 46,34% de l'appareil commercial de la ville de Biskra qui se réparti de façon inégale entre le commerce pur (54.10%), le commerce de l'artisanat (17.31%) et le commerce de service (28.58%).

Le secteur N°01 (Damier colonial et Hart El Oued) peut être considéré comme un pôle particulièrement dynamique, il détient deux atouts majeurs qui ont été à l'origine du développement de l'activité commerciale: tout d'abord son ancien statut de centre ville (ville coloniale, fort turque / facteur historique et culturel), ceci a encouragé plusieurs activités à s'y implanter. Ensuite, il concentre un poids démographique important; de plus, ce secteur est bien équipé, surtout en matière de service tels que: hôtellerie, banques et établissements administratifs. Sa spécialisation est diversifiée et se base essentiellement sur le commerce pur et le commerce de service.

En deuxième position, on retrouve le secteur N°08 (El Alia Nord), il détient plusieurs caractéristiques, nous citerons: un nombre d'établissements commerciaux de 661, un nombre important de la population (plus de 40.000 habitants), ainsi que l'implantation de plusieurs équipements importants de la ville (université, lycées, salle de sport, etc.). Tout ceci a favorisé le développement d'un commerce plus ou moins équilibré, caractérisé par la suprématie du commerce de service et de l'artisanat.

Pour les autres secteurs (secteur N°02, 03, 07 et 09) qui font également partie de ce groupe, leur structure commerciale est moins dense et peu diversifiée. Elle se caractérise par la prédominance du commerce pur, mais avec une spécialisation multifonctionnelle entre le commerce de service et d'artisanat.

Les pôles spécialisés

Ils sont au nombre de trois, parmi lesquels, nous distinguons un pôle de commerce pur (Secteur N°05), un pôle de service (Secteur N°04) et un centre de commerce de l'artisanat (Secteur N°06). Au sein de cet ensemble hétérogène, le pôle de commerce pur est le mieux représenté avec 1124 établissements commerciaux, suivi par le pôle de commerce de service avec 485 établissements, tandis que le pôle de commerce de l'artisanat occupe la dernière place avec 437 établissements. Dans ce qui suit, nous nous sommes focalisé sur le pôle de commerce pur, car il détient une importance particulière dans la structuration et fonctionnement de l'espace Biskri par rapport aux deux autres pôles.

Le pôle de commerce Pur (Un rayonnement non négligeable)

Le secteur N°05 est essentiellement caractérisé par sa fonction dominante de pôle commercial pur. Il monopolise plus de 35% des commerces purs de la ville de Biskra. Dans ce domaine, nous noterons que le secteur N°05 qui est représenté par le quartier Star Mlouk (Est et Ouest), est bien équipé et relativement diversifié, il se spécialise particulièrement dans la catégorie de l'équipement de la personne (habillement avec 312 établissements, et chaussures avec 50 établissements).

Cette activité s'accorde bien avec sa position centrale, car le quartier Star Mlouk est au cœur de la ville, dans le prolongement du damier colonial. Mais elle s'accorde aussi avec les autres quartiers et secteurs de voisinage qui connaissent un mouvement démographique et se caractérisent par un bon niveau d'équipement administratif. En plus des activités commerciales liées à l'équipement de la personne, il a développé d'autres activités, nous citerons essentiellement l'équipement de la maison (tapisserie – 25 établissements, ameublement – 30 établissements, électroménager – 26 établissements – et décors de maison – 32 établissements), ainsi que l'équipement de la profession (quincaillerie et vente matériel électronique, informatique, etc.).

Tout ceci a permis au secteur N°05 d'exercer une forte attraction sur la clientèle de la ville ainsi que sur toute la région des Zibans et du Bas Sahara.

Les niveaux de la hiérarchie

La détermination de la hiérarchie des villes ou des centres se fait selon les étapes suivantes: L'utilisation des activités commerciales selon le type et la rareté des établissements; L'organisation des lieux selon les valeurs de l'indice de Davies (Davies R.L., 1972) pour comprendre l'importance de la centralité commerciale dans les différents secteurs de la ville de Biskra; Enfin, l'organisation des activités commerciales par ordre de fréquence pour obtenir les différents niveaux de la hiérarchisation.

Le tableau n° 3 illustre les résultats obtenus grâce à l'analyse de la matrice dont la lecture nous a permis de dégager six niveaux de hiérarchisation à Biskra:

Tableau 3

Matrice des activités commerciales (Source : Enquête sur terrain en 2008).

Secteurs	1	5	8	6	4	10	2	3	9	7		Rareté d'établissement
Alimentation générale	■	■	■	■	■	■	■	■	■	■	10	0,0036
Pièces détachées/	■	■	■	■	■	■	■	■	■	■	10	0,0061
Cafés	■	■	■	■	■	■	■	■	■	■	10	0,0082
Pizzeria	■	■	■	■	■	■	■	■	■	■	10	0,0108
Taxi phone	■	■	■	■	■	■	■	■	■	■	10	0,0048
Articles scolaires	■	■	■	■	■	■	■	■	■		9	0,0141
Quincaillerie	■	■	■	■	■	■	■	■	■		9	0,0063
Mécanicien	■	■	■	■	■	■	■		■	■	9	0,0159
Boulangerie	■	■	■	■	■	■	■	■			8	0,0263
Vente semoule	■	■	■	■	■	■	■	■			8	0,0345
Menuiserie	■	■	■	■	■	■	■	■			8	0,0222
Coiffeur	■	■	■	■	■	■	■	■			8	0,0099
Pharmacie	■	■	■	■	■	■	■	■			8	0,0154
Bijouterie	■	■	■	■	■	■	■	■			8	0,0083
Vente cassette & cassette vidéo	■	■	■	■	■	■	■	■			8	0,0167
Librairie	■	■	■	■	■	■	■	■			8	0,0154
Soudeur	■	■	■	■	■	■	■		■		8	0,0313
Réparateur appareil électroménager	■	■	■	■	■	■	■		■		8	0,0294
Cybercafé/bureau d'informatique	■	■	■	■	■	■	■		■		8	0,0132
Restaurant	■	■	■	■	■	■	■		■		8	0,0111
Vente matériel électronique/informatique/appareil téléphonique/matériel frigorifique	■	■	■	■	■	■	■		■		8	0,0085
Vulcanisateur	■		■	■	■	■	■	■	■		8	0,0182
Patisserie	■	■	■	■	■	■	■				7	0,0182
Fruits et légumes	■	■	■	■	■	■	■				7	0,0303
Photographe	■	■	■	■	■	■	■				7	0,0667
Cosmétique	■	■	■	■	■	■	■				7	0,0069
Agence immobilière	■	■	■	■	■	■	■				7	0,0169
Réparateur motocycle	■	■	■	■	■	■		■			7	0,0256
Boucherie	■	■	■	■	■	■		■			7	0,0175
Tailleur, teinturier	■	■	■	■	■	■		■			7	0,0294
Vente matériaux de construction	■	■	■	■	■	■		■			7	0,0114
Chaussures	■	■	■	■	■		■	■			7	0,0128
Ameublement	■	■	■	■	■		■	■			7	0,0112
Douche	■	■	■	■	■	■					6	0,0435
Clet minute	■	■	■	■	■	■					6	0,0556
Fleuriste/décors maison	■	■	■	■	■		■				6	0,0213
Habillement	■	■	■	■	■		■				6	0,0024
Cordonnier	■	■	■	■		■	■				6	0,0345
Vitrier	■		■	■	■	■			■		6	0,0625
Produits laitiers	■	■	■	■	■						5	0,1250
Electroménager	■	■	■	■	■						5	0,0122
Opticien	■	■	■	■	■						5	0,0667
Produits de la pâtisserie	■	■	■	■	■						5	0,0500
Grossiste alimentation générale	■	■	■	■					■		5	0,0256
Hammam	■	■	■		■	■					5	0,1111
Dégraissage	■	■	■		■	■					5	0,1111
Réparateur TV	■	■	■			■	■				5	0,0556
Auto-école	■		■	■	■	■					5	0,0625
Lavage et graissage	■		■	■	■	■					5	0,0714
Bureau d'étude d'architecture	■		■		■	■	■				5	0,0500
Dentiste		■	■	■	■	■					5	0,0909
Électricien			■	■		■	■			■	5	0,0909
Tôlier				■	■	■	■			■	5	0,0625
Vente tissu	■	■	■				■				4	0,0313
Mobilier de bureau	■		■	■	■						4	0,0833
Comptables	■			■	■	■					4	0,2000
Expertise et contrôle de voiture	■			■			■			■	4	0,1667
Imprimerie		■		■	■		■				4	0,1250
Tapisserie	■	■	■								3	0,0213
Produits domestiques	■		■		■						3	0,1429
Vente véhicule	■				■				■		3	0,1429
Mercerie		■	■	■							3	0,0303
Location de voiture			■	■	■						3	0,1667
Peinture automobile				■	■		■				3	0,2500
Assurances	■		■								2	0,2500
Vente matériels plomberie & chauffage	■			■							2	0,2500
Tourneur	■			■							2	0,1667
Droguerie&peinture				■		■					2	0,5000
Réparateur montre	■										1	0,2500
Indice de Davies	14.4812	13.9661	11.9053	9.7169	9.3543	4.4974	2.1069	1.2477	1.0720	0,6523		
Niveaux	B3			B2		B1	A3	A2		A1		

A partir du tableau 4, nous distinguons des taux de rareté et indice de Davies relativement faibles pour les deux premiers niveaux. Les secteurs représentés dans ces niveaux se localisent à la périphérie de la ville. En ce qui concerne le troisième et quatrième niveau, nous constatons une augmentation assez sensible de ces taux.

Au cinquième niveau, la concentration commerciale représentée par l'indice de Davies a une valeur élevée en comparaison avec les autres secteurs urbains. Nous constatons qu'à ce niveau, un important changement s'est opéré; que ce soit par rapport au nombre d'habitants qui est plus élevé, ou au regard du nombre d'établissements, ou en encore, de la qualité qui demeure de rang supérieur. En effet, il existe des fonctions qui polarisent les habitants et requièrent ainsi un certain nombre de clientèle c'est-à-dire un seuil d'apparition (à titre d'exemple: Clefs minute, fleuristes/décors maison, vitreries, etc. Mais aussi les activités commerciales de couvertures, telles que: dégraissages, hammams). Cette concentration se fait dans les secteurs urbains localisés dans une zone péricentrale de la ville de Biskra et représentent une polarité indispensable au service de la ville.

Tableau 4

Les niveaux de la hiérarchisation des activités commerciales (d'après les résultats matriciels).

Niveaux	**Activités commerciale**	**Rareté d'établissement 1/total des établissements**	**Indice de Davies**	**Fréquences**
Niveau 01 « A1 » (secteur 07)	– Alimentation – Equipement de la profession – Services	[0,0036–0,0108]	0,6523	10
Niveau 02 « A2 » (secteurs 03,09)	– Alimentation – Equipement de la profession – Artisanat	[0,0063–0,0345]	[1,0720–1,2477]	[8–9]
Niveau 03 « A3 » (secteur 02)	– Alimentation – Service	[0,0069–0,0667]	2,1069	7
Niveau 04 « B1 » (secteur 10)	– Artisanat – Alimentation – Equipement de la profession	[0,0114–0,0294]	4,4974	7
Niveau 05 « B2 » (secteurs 04,06)	– Alimentation – Services – Artisanat – Equipement de la profession	[0,0024–0,1111]	[9,7169–9,3543]	[5–7]
Niveau 06 « B3 » (secteurs 08, 05,01)	– Alimentation – Equipement de la personne – Equipement de la maison – Equipement de la profession – Artisanat – Services	[0,0213 et 0,5]	[11,9053–14,4812]	[5–7]

Source: Enquête sur terrain en 2008.

Le dernier niveau (sixième) comprend vingt activités commerciales, avec une fréquence d'apparition entre 5 et 7. Nous avons enregistré un nombre important d'établissements commerciaux, ce qui renseigne sur l'importance commerciale des secteurs urbains N°1, N°5 et N°8 correspondant successivement au damier colonial, au quartier Star Mlouk et à El Alia Nord. Nous avons relevé également, que la majorité des activités, dont il est question, se trouvent dans des secteurs urbains à forte concentration démographique et d'une rareté élevée (entre 0,0213 et 0,5). De plus, la moitié des établissements commerciaux existants possèdent une rareté supérieure à 0,05, tels que: Expertise et contrôle de voitures, imprimeries, concessionnaires de véhicules, produits domestiques, etc.

L'ensemble de ces commerces existe seulement aux secteurs N° 1 et N° 5. Ainsi, la plus importante valeur de l'indice de Davies a été enregistrée au niveau de ces secteurs. Nous pouvons conclure que le secteur N °1 (le damier colonial /et centre ville) reste le plus important lieu commercial de la ville de Biskra.

L'analyse en composantes principales (ACP)

L'Analyse en Composantes Principales (ACP) a été retenue pour notre étude parce qu'elle permet de synthétiser de vastes ensembles de données, en identifiant un petit nombre de facteurs qui décrivent la plupart des oppositions observées dans l'ensemble des variables d'origine. Elle permet donc la simplification de grands tableaux de données en décrivant les observations par un nombre restreint de nouvelles variables synthétiques. Cette technique permet d'ébaucher une hiérarchisation des facteurs de localisation différentielle.

Notre Analyse en Composantes Principales (ACP) a été conçue par l'analyse d'une matrice dont les observations sont les lieux (les 10 secteurs de la ville) et les variables traduisent la présence des différents types de commerces. L'enquête sur terrain, a permis de dénombrer 69 types d'activités commerciales (variables).

Etape I: Identification des variables

L'opération d'identification des variables représente la première étape de l'analyse. Elle est très importante car elle permet de simplifier la lecture et la représentation graphique de l'ACP. Dans un souci de clarté et afin d'obtenir une meilleure interprétation des résultats nous avons procédé à l'identification des variables (différents types de commerces) en utilisant les lettres par ordre alphabétique de A à BQ (tableau 5).

Tableau 5

Identification des variables.

Variables	**Signification**
A	Alimentation générale
B	Boulangerie
C	Boucherie
D	Pâtisserie
E	Fruits et légumes
F	Vente semoule
G	Produits laitiers
H	Grossiste alimentation générale
I	Habillement
J	Chaussures
. . BQ (69 variables)	. . . Expertise et contrôle de voiture

(Source: Traitement personnel en 2008).

Etape II: Représentations graphiques et interprétation (Le Diagramme des composantes et le diagramme de dispersion).

Les corrélations entre les variables préalablement identifiées sont établies grâce à la matrice des corrélations (tableau 6). Cette dernière est obtenue par l'usage d'un logiciel statistique spécifique.

Les graphiques sont une représentation schématique de la matrice des corrélations entre les variables et les axes principaux, d'une part et la matrice des coordonnées des lieux sur les axes principaux, d'autre part.

Le diagramme des composantes (Fig. 5) est la représentation graphique de la matrice des composantes, c'est-à-dire la matrice de corrélation entre les types d'activités commerciales. La position des différentes variables sur l'hyperplan permet de constituer des groupes homogènes ayant relativement les plus forts coefficients de corrélation et qui peuvent comporter les mêmes paramètres d'explication. Par ailleurs, la même opération sur le graphique relatif aux lieux (diagramme de dispersion) permet de dégager des groupes partiellement homogènes (Fig. 6).

Tableau 6

Matrice des corrélations des variables.

Variables	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**……………BQ**
A	1,00											
B	0,72	1,00										
C	0,92	0,82	1,00									
D	0,89	0,65	0,78	1,00								
E	0,90	0,56	0,78	0,91	1,00							
F	0,75	0,93	0,78	0,72	0,58	1,00						
G	0,66	0,30	0,45	0,68	0,82	0,23	1,00					
H	0,46	0,27	0,44	0,53	0,73	0,28	0,45	1,00				
I	0,77	0,27	0,70	0,61	0,63	0,28	0,53	0,12	1,00			
J	0,79	0,31	0,73	0,62	0,65	0,32	0,52	0,15	1,00	1,00		
K	0,74	0,26	0,67	0,56	0,57	0,26	0,47	0,05	1,00	0,99	1,00	
. . . . BQ												

Source: Enquête sur terrain et analyse statistique en 2008.

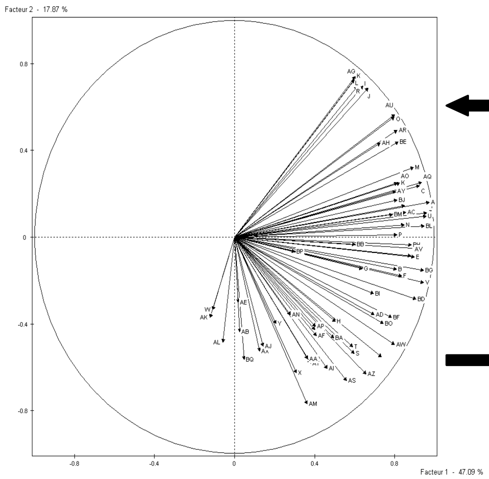

Fig. 5 – Diagramme des composantes (Cercle des corrélations).

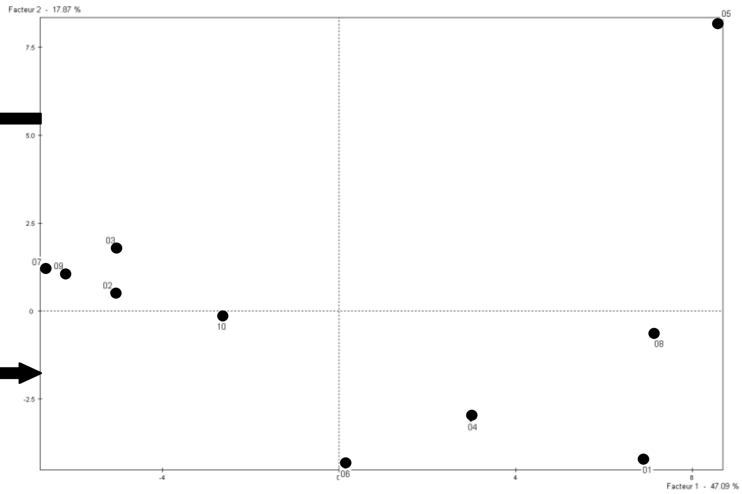

Fig. 6 – Diagramme de dispersion (Représentation des secteurs de la ville de Biskra).

Source: Enquête sur terrain et analyse statistique en 2008.

L'analyse factorielle permet de créer deux nouvelles variables. En effet, en plus des observations qui sont les lieux (10 secteurs) et les variables qui expriment l'importance des différents types de commerces en ces lieux, les nouvelles variables synthétiques représentent les principaux axes de différenciation des paysages commerciaux. Ces axes ont le mérite d'être documentés au travers des corrélations qu'ils ont avec le profil de localisation des variables c'est-à-dire des types de commerces. Bien que fondée sur l'analyse de la composition de l'offre des lieux, cette méthode met clairement l'accent dans ses résultats sur le profil de localisation des types de commerces, ce qui rencontre la volonté de caractériser les distributions spatiales plutôt que de documenter les lieux. Une fois les deux diagrammes obtenus, il s'agit de faire ressortir les corrélations entre les lieux (les 10 secteurs) et les variables (les 69 types d'activités commerciales).

Enfin, la superposition des deux plans (Fig. 7) permet de dégager des groupes d'individus pouvant avoir relativement les mêmes caractéristiques et constituer des groupes homogènes.

La typologie commerciale obtenue par l'utilisation de l'analyse factorielle fait apparaître quatre groupes de circonscriptions (tableau 7).

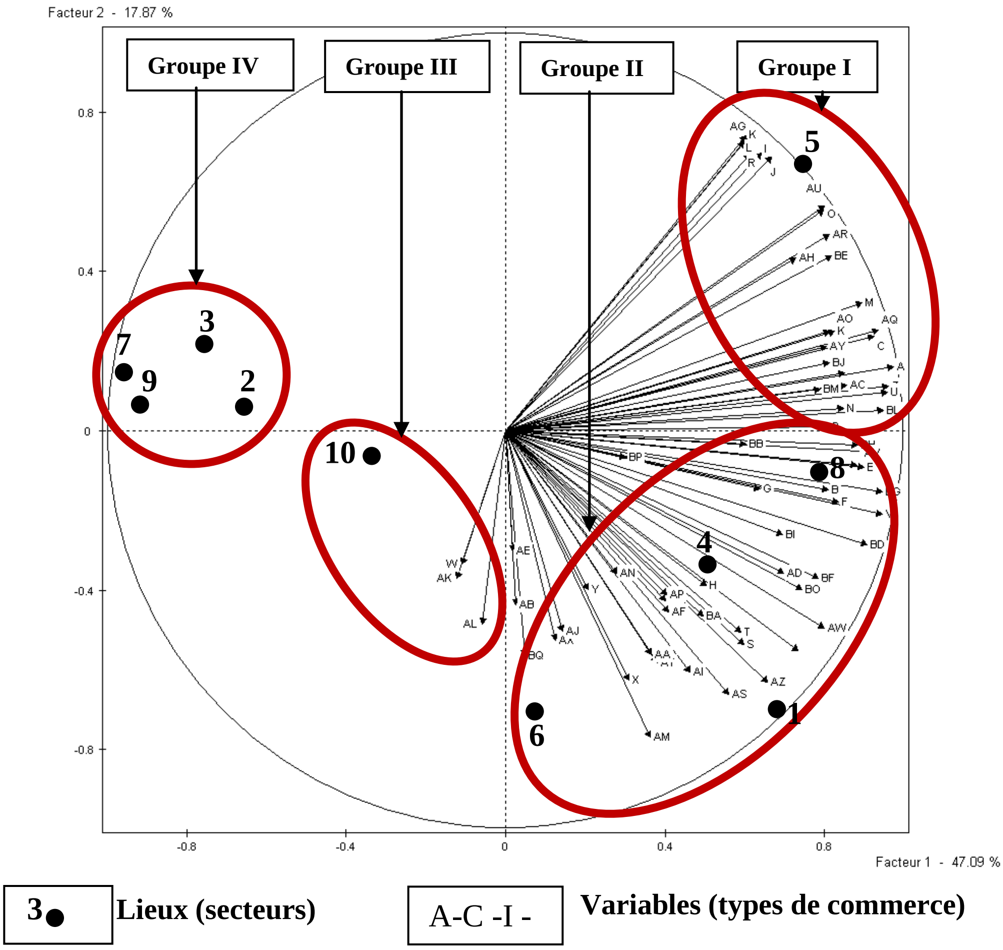

Fig. 7 – Les grands groupes de la typologie commerciale.
Source: Traitement personnel par superposition des 2 diagrammes précédents.

Tableau 7

Les correspondances.

Groupes	Variables	Lieux (secteurs)
I	A-C-I-J-K-L-M-N-O-P-R-U-AC-AG-AH-AO-AQ-AR-AU-AY-BE-BJ-BK-BL-BM	5
II	B-D-E-F-G-H-Q-S-T-V-X-Y-Z-AA-AB-AD-AE-AF-AI-AJ-AM-AN-AP-AS-AT-AV-AW-AX-AZ-BA-BB-BC-BD-BF-BG-BH-BI-BN-BO-BP-BQ	8–4–1–6
III	W-AK-AL	10
IV		2–3–9–7

Source: Enquête sur terrain et analyse mathématique en 2008.

- **Le groupe I.**

Ce groupe est représenté par le secteur N° 5 qui se singularise par 25 variables, soit un taux de 36,23%. Il se caractérise par une dominance du commerce de l'équipement de la personne, de l'équipement de la maison et de l'artisanat de production. Le nombre d'établissements en ce secteur est égal à 1124 soit un taux de 29,47%, ce qui traduit la forte densité et diversité commerciales. Nous parvenons à conclure que le secteur N° 5 est le centre géométrique et le cœur de la ville de Biskra (Fig. 6).

- **Le groupe II.**

Cet ensemble de secteurs se singularise par 41 variables, soit un taux de 59,42%. Il se caractérise par une forte diversité et densité commerciales. Il comprend les secteurs N° 1, 4, 6 et 8 (Fig. 6), avec une dominance du commerce de service, de l'artisanat de service, de l'équipement de la profession et de l'alimentation. La densité et la diversité des établissements commerciaux dans ce groupe sont relativement importantes, car leur nombre est égal à 2245 soit un taux de 58,87%.

- **Le groupe III.**

Ce groupe est représenté uniquement par le secteur N° 10. Il est défini par un ensemble de 03 variables: drogueries, électriciens et tôliers, le nombre des établissements dans ce groupe est égal à 163 soit un taux de 4,27%. Ce dernier se traduit par une densité moyenne et l'absence de la diversité commerciale.

- **Le groupe IV.**

C'est un groupe qui se compose des secteurs N° 2, 3, 7 et 9 et se singularise par de très faibles densité et diversité commerciales, le nombre des établissements est égal à 281 soit un taux de 7,36%.

La méthode de l'ACP a permis de mettre en relief les nuances essentielles qui existent entre les différents secteurs qui constituent la ville de Biskra. Il s'avère donc, que le secteur N° 5 reste le plus dense du point de vue nombre d'établissements commerciaux malgré que les secteurs N°8, 4, 1 et 6 se caractérisent également par une forte densité commerciale (Fig. 6).

4. CONCLUSIONS

A la fin de notre travail de recherche, nous avons pu constater que, d'une manière générale, le profil de la structure commerciale de la ville de Biskra présente différentes caractéristiques et particularités.

D'abord, sur le plan qualitatif, la ville de Biskra enregistre la présence de plusieurs catégories commerciales; lesquelles répondent à différents facteurs de localisation et de concentration, ils obéissent à des logiques particulières d'agencement. Ainsi, l'appareil commercial a été façonné principalement par l'aspect historique et culturel, par un glissement de centralité qui s'est opéré entre le vieux Biskra (noyau initial formé par les 7 villages autochtones) et le damier colonial avec son prolongement immédiat, le quartier Star Mlouk. La structure et l'attractivité commerciale de la ville, illustrent une certaine évolution historique, le vieux Biskra a été dans la phase pré-coloniale le "souk de la ville". La colonisation a complètement changé le pôle d'attraction du Sud au Nord, par la création du marché couvert, ce dernier monopolisait toutes les activités commerciales (Bakhouche Z, 2002). Par la suite de nouveaux éléments ont caractérisé la ville contemporaine (croissance, extension, nouveaux besoins...) poussant la structuration d'un autre lieux d'attractivité commerciale, qui s'est matérialisé par une centralité périphérique émergente.

Sur un plan quantitatif, nous avons remarqué l'importance numérique des établissements commerciaux, ainsi la ville jouit d'un nombre conséquent de commerces qui font d'elle une zone commerciale incontournable dans toute la région. L'analyse de La structure commerciale de Biskra, par le biais de l'approche quantitative, a confirmé l'existence d'une forte centralité commerciale dans trois secteurs principaux: le secteur N° 1 (damier colonial), le secteur N° 5 (le quartier Star Mlouk, il est la première extension du damier colonial) et enfin le secteur N° 8 (quartier d'El Alia Nord) qui représente une nouvelle centralité dans la ville.

La superposition des données issues des approches établis et des éléments analysés ont démontré l'existence d'une forte attractivité au niveau de deux points de concentration commerciales. Cette structuration de l'espace Biskri, a été porteuse d'une nouvelle logique urbaine et productrice d'une fréquentation soutenue au niveau de ces deux pôles. Elle a conduit à la naissance d'une sorte de complémentarité entre le centre ancien et la centralité émergente

Nous sommes parvenus à conclure qu'une véritable redistribution des fonctions urbaines s'est opérée à Biskra, la ville connait une redéfinition de son "territoire" urbain qui se structure désormais autour de deux pôles majeurs, deux centralités, l'une principale centrale, géographique; et l'autre périphérique, émergente et secondaire.

Ainsi, de nouvelles relations se mettent en place, le centre ne détient plus à lui seul les fonctions majeures et attractives de la ville et n'est plus opposé à la périphérie, de nouveaux lieux sont apparus au niveau de la zone périphérique d'El Alia, ils devront désormais compléter et valoriser le rôle du centre principal, dans une logique de poly-centralité, On devra:

- Redynamiser le centre ancien qui connait de multiples difficultés liées à la dégradation et congestion (en rapport avec la centralisation d'importantes fonctions à son niveau);
- Maîtriser le nouveau pôle qui a émergé en périphérie et essayer de préserver l'ensemble de la ville à travers une vision stratégique cohérente à même d'impulser un développement local complémentaire et équilibré.

BIBLIOGRAPHIE

Ascher, F. (2003), *En finir avec la notion de centralité ? in Centralités dans la ville en mutation*, CERTU, coll: Aménagement et urbanisme, **39**, Paris, pp. 22–30.

Baggio, S., Renaud, O. (2015), *Détecter la centralité des éléments d'une représentation sociale: un indice alternatif de mesure*, Edit. Presses universitaires de Liège, **1**, *105*, pp. 33–52.

Bakhouche, Z. (2002), *Structures commerciales et dynamique urbaine: cas de Biskra*, Thèse de Doctorat, Université de Provence, Marseille, 428 p.

Beaujeu-Garnier, J.& Delobez, A. (1977), *Géographie du commerce*, Masson, Paris, 283 p.

Belamine, M.A. (1995), *Les activités tertiaires dans la ville nouvelle de Fès, aspects spatiaux et socio-économiques*, Thèse de Doctorat, Université de Tours, 517 p.

Berry, B.J.L. (1971), *Géographie des marchés et du commerce de détail*, Edit. Armand Colin, Paris, 255 p.

Bondue, J.P. (2000), *Le commerce dans la géographie humaine*, in Annales de Géographie, Edit. Armand Colin, **109**, *611*, pp. 94–102.

Bourdeau-Lepage, L., Huriot, J., Perreur, J. (2009), *A la recherche de la centralité perdue*, Edit. Armand Colin, Revue d'Économie Régionale & Urbaine, **3**, pp. 549–572.

Cercle, Mont Cameroun (2009), *De la centralité du principe politique: Manifeste*, Edit. Karthala, Paris, 24 p.

Certu, (2003), *Centralités dans la ville en mutation: Quelles perspectives d'action pour les pouvoirs publics*, Certu, coll: Aménagement et urbanisme, **39**, Lyon, 214 p.

Cote, M. (1991), *Biskra, encyclopédie berbère*, Edit. Peeters Publishers, **10**, Aix-Marseille, pp. 01–06.

Davies, R.L. (1972), *The retail pattern of the central area in Coventry*, in Institute of British Geographers, Occasional publication of the urban study group, **1**,pp. 1–32.

Diop, A. (2008), *Quelles centralités pour la ville de Dakar, Sénégal ?*, in Rives nord-méditerranéennes, Centralités en mouvement, pp. 75–92.

Dris, N. (1999), *Espaces publics et centralité à Alger, entre logique urbanistique et mémoire urbaine*, Thèse de Doctorat, Université Paris **X**, 451 p.

Fleury, A. (2003), *De la rue-faubourg à la rue « branchée »: Oberkampf ou l'émergence d'une centralité des loisirs à paris*, Edit, L'Espace géographique/, **3**,*32*, pp. 239–252.

Fray, J.L. (2007), *Villes et bourgs de Lorraine: réseaux urbains et centralité au Moyen Âge*, Presses Universitaires Blaise-Pascal, France, 551 p.

Gaschet, F., Pouyanne, G. (2011), *Nouvelles centralités et valeurs immobilières: vers un découplage des centralités résidentielles et économiques ?*, Edit. Armand Colin, Revue d'Économie Régionale & Urbaine /, **3**, pp. 499–525.

Gasnier, A. (1949), *Centre ville, urbanité et jeunes: de la conception a l'aménagement à son usage spatial*, Thèse de Doctorat, Université Le Mans, 371 p.

Gasnier, A. (1991), *Centralité urbaine et recompositions spatiales: l'exemple du Mans*, in Revue Géographique de l'ouest et des pays de l'Atlantique nord, In*:* Norois /, **151**, *1*, Poitiers, pp. 269–278.

Gaschet, F., Lacour, C. (2002), *Métropolisation, centre et centralité*, Edit. Armand Colin, Revue d'Économie Régionale & Urbaine /, **1**, pp. 49–72.

Jari, D. (1999), *Dynamique et croissance urbaine de la ville de Khénifra*, Thèse de Doctorat, Université de Poitiers, 463 p.

Kouzmine, Y. (2007), *Dynamiques et mutations territoriales du sahara Algérien: vers de nouvelles approches fondées sur l'observation*, Thèse de Doctorat, Université de Franche-Comté, 424 p.

Lebrun, N. (2002), *Centralités urbaines et concentrations de commerces*, Thèse de Doctorat, Institut de Géographie, Université de Reims-Champagne Ardenne, 479 p.

Lekehal, A. (1996), *Bases économiques et rôle spatiale des petites villes dans l'Est algérien: essai de typologie*, Thèse de Doctorat, Université Mentouri-Constantine, 372 p.

Lemarchand, N. (2009), *Géographie du commerce et de la consommation: les territoires du commerce distractif*, Partie 1, Habilitation à Diriger des Recherches. Université Paris-Sorbonne, 220 p.

Marchal, H., Stébé, J.M. (2015), *La multiplication des centralités à l'heure de la périurbanisation*, Edit. Presses Universitaires de France/, 1,65, pp. 239–252.

Marchand, D. (2005), *Le centre-ville est-il le noyau central de la représentation sociale de la ville ?*, Edit. Presses Universitaires de Liège, Les Cahiers Internationaux de Psychologie Sociale /, **2**, *66*, pp. 55–64.

Merenne Schoumaker, B. (2001), *Evolution des accessibilités et des mobilités et dynamiques des localisations commerciales*, In: *Travaux de l'Institut Géographique de Reims*/, **27**, *107*, Reims, pp. 7–23.

Nouralichahi, D. (1994), *Le centre et la centralité: le cas de la ville de Téhéran*, Thèse de Doctorat, Université Paris XII, 333 p.

Oueslati Hammami, I. (2010), *Les centralités du grand Tunis acteurs, représentations et pratiques urbaines*, Thèse de Doctorat, Université Toulouse-le Mirail, 640 p.

Raham, D. (2001), *Les structures spatiales de l'Est algérien Les maillages territoriaux, urbains et routiers*, Thèse de Doctorat, Université Mentouri, Constantine, 276 p.

Riquet, P. (1976), *Secteur tertiaire et métiers tertiaire, approche statistiques des activités de services en Allemagne Fédérale*, in Annales de géographie/, **467**, pp.1–33.

Wayens, B. (2006), *Structure et dynamique du commerce de détail bruxellois*, Thèse de Doctorat, Université Libre de Bruxelles, 242 p.

Zadi, E. H. (2003), *Alger, une centralité éclatée: crise du centre et nouvelles tendances urbaines*, Thèse de Doctorat, Université Montpellier III, 512 p.

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HEAT STRESS-CROP YIELDS INTERACTIONS UNDER SUMMER WARMING TRENDS: INSIGHTS FOR THE SOUTHERN CROPPING LOWLANDS OF ROMANIA

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Key-words: heat stress, crop yield, summer warming, southern cropping regions of Romania.

Abstract. Extreme heat is an emerging threat to the agricultural sector, which severely affected the crop yields in many regions of Romania during the last two decades. Here we investigate a 53-year climatology of daily maximum air temperatures to extract the regional characteristics of summer heat stress in the southern cropping lowlands of Romania (Oltenia and Muntenia regions) and to estimate the yield sensitivity of three major crops (winter wheat, grain maize and sunflower) to the changing heat stress under the ongoing warming. In our approach we aim to test the hypothesis of a cause-effect relationship between seasonal heat stress and the annual crop production at county level (NUTS3), considering the existing adaptation potential through irrigations, especially during the heat stress representative years of 2000, 2007 and 2012. Our results reveal that, in both cropping regions, there is a significant and spatial robust increase in the frequency and duration of heat stress, especially since the mid-1980s, confirming the findings of previous studies on climate variability and climate extremes. The changes in summer heat stress determined different and spatially variable crop yield sensitivities. The main findings of the regression analyses on heat stress-crop yield relationships are: *summer heat stress* allowed explaining 17 to 55% of the annual variability of yields at county level; during the hot and droughty summers of 2000, 2007 and 2012, the detrimental effect of heat stress on crop yields was particularly evident and worsened by the lack of efficient water compensations through irrigations (generally below 5% in Oltenia and 7% in Muntenia); heat stress was found to be an important predictor of crop yield failures, especially for maize crops; for the summer harvesting crops (winter wheat) and good high temperature and drought resistance (sunflower), the detrimental effects of heat stress appear less evident; recurrent heat stress days (HSD, HSDD) and heat stress spells (HSSfr) have had a greater influence on final crops than the persistent individual heat stress spells (HSSdurmax). Both agricultural regions are heat stress sensitive, but the cropping areas which underwent substantial crop production losses due to extreme high temperatures are located in the southernmost floodplain areas (e.g. in the Dolj, Olt, Gorj, Giurgiu, Călăraşi counties), where heat stress is particularly intense and frequent. Rehabilitation of irrigation emerges as an important adaptation measure in agriculture to reduce the current vulnerabilities and future impacts of heat stress on national food security.

1. INTRODUCTION

Climate and agriculture are intrinsically linked and variability in yield, crop biodiversity and water use provides key evidence on the effects of a changing climate. Climate change is impacting the agricultural sector in multiple ways, both directly (e.g. alterations in crop agroecosystems, low productivity levels, changes in the length of the growing season, timing of crop growth stages and harvest dates) and indirectly (e.g. weed competition, expansion of pests and diseases, food-market instability), exacerbating some important challenges faced by this sector (e.g. water scarcity, soil degradation). In the Fifth Assessment of IPCC (AR5, 2014), heat stress is included among crop-focussed threats to global food security.

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The observed effects of recent climate trends and extreme events on agricultural crop production are robust and widespread, with more negative than positive impacts, especially on wheat and maize yields (e.g., Peltonen-Sainio *et al*., 2010; Lobell *et al*., 2011; Olensen *et al*. 2011; Porter *et al*., 2014). Heat waves, drought and excess precipitation were found particularly detrimental to wheat yields (e.g., Zampieri *et al*., 2017; Semenov and Shewry, 2011), while hot weather and severe drought, especially during the sensitive stages of crop development are a significant threat to maize yields in many regions worldwide, including Romania (e.g., Deryng *et al*., 2014; Sandu *et al*., 2010; Croitoru *et al*., 2012). To our knowledge, compared to cereals, only few studies explored the effects of heat stress on sunflower crops (e.g., Harris *et al*., 1978; Rondanini *et al*., 2003, 2006; Moriondo *et al*., 2011; De la Haba *et al*., 2014).

Over the past decades, the frequency and severity of extreme events increased in many regions of Romania (e.g. Croitoru and Piticar, 2012; Vlăduţ and Onţel, 2013; Dumitrescu *et al*., 2015; Busuioc *et al*., 2015; Piticar *et al*., 2017), where farming experienced a wide range of effects: e.g. very low agricultural outputs in the very dry years; important crop losses during flooding; hailstorms-related damages; development of invasive plants; shortening of the vegetation period of certain crops; degradation of the land productive capacity. Currently, agriculture is recognized as one of the most climate-sensitive economic sector. The *National Climate Change Strategy 2013–2020* (2013) highlighted the urgent need for action-oriented measures to support climate change adaptation in this sector, especially in the light of the great economic losses caused by the hot weather episodes and severe droughts of the 2001–2012 period (2000–2003, 2007 and 2012).

The results of prior studies suggest an increased crop sensitivity to various weather and climate-related aspects, especially to drought, heat stress and air freeze (e.g. Fabian and Gomoiu, 1981; Ţerbea *et al*., 1995; Balotă *et al*., 1997; Petcu *et al*., 2001; Prăvălie *et al*., 2017). Increasing temperatures and heat stress were found to play a major limiting role on crop growth and final yields (e.g. Sandu *et al*., 2010; Sandu and Mateescu, 2014; *Cod de bune practici agricole în contextul schimbărilor climatice actuale şi previzibile*, 2014), mainly by being involved in the rate of plant metabolic processes, photosynthesis rates and timing of growth stages. The study of Lazăr and Lazăr (2010) on the effects of temperature increase on winter wheat yields and development in south-eastern Romania showed that an increase in the average daily temperature of 1°C is tolerable for the winter wheat phenology, while a 2°C increase is detrimental and poses a great risk to the stability of high-yield cultivars. Croitoru *et al*. (2012) also evidenced the changes in winter wheat phenology of in the south-eastern region of Romania in response to the long-term seasonal warming: a decreasing length of the anthesis period (up to 3 days/decade) and maturity period (about 1 day/decade), yet not statistically significant. Despite the growing interest in understanding climate change impacts on agriculture, there is still a need for further investigation of the complex and diverse climate-crop interactions, to better cope with the uncertainties related to the occurrence of heat stress under field conditions and the corresponding plant response to stress in changing climatic and socio-economic contexts.

This study investigates the effects of heat stress on the yield anomalies of three major crops in the southern agricultural lowlands of Romania (winter wheat, grain maize and sunflower). The rationale behind our work was to test the hypothesis of a cause-effect relationship between seasonal heat stress and annual production at county level (NUTS3), having in view the regional social and political constraints of the post-communist period, reflected in the poor functioning of the existing irrigation infrastructure.

2. STUDY REGION

The study focuses on the southern agricultural lowlands of Romania, including the territory of the most important and highly productive cropping regions of this country (Oltenia and Muntenia). The study region largely overlaps the Romanian Plain region (Fig. 1).

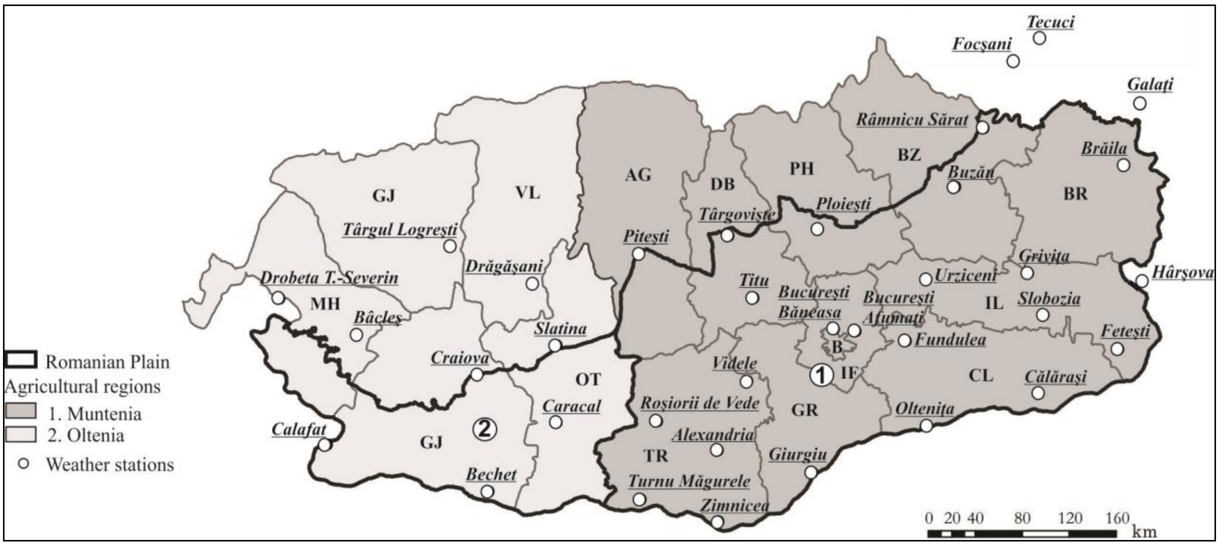


Fig. 1 – Location of the study region

Agricultural land use is prevalent among the main land use types of the region and accounts for 61% in Oltenia and 71% in Muntenia. The agricultural productivity of the two cropping regions is generally high relative to the total national yields: sunflower 40%, winter wheat 37% and maize 17%. At regional scale, winter wheat, maize, sunflower and rapeseed are the dominant crops, representing 79.4% (Muntenia) to 82.2% (Oltenia) of the total cultivated areas. In ”normal” precipitation years, the high soil fertility of arable land and the high technical equipment level of the farms (especially of the large ones), could ensure the conditions for achieving high agricultural yields: e.g., 6,000–10,000 kg/ha for maize; 4,000–6,000 kg /ha for wheat; 2,500 kg /ha for sunflower.

Muntenia and Oltenia agricultural regions exhibit fairly comparable average agro-climatic conditions, attributed to *Dfa climate type*[1] in the Köppen-Geiger climate classification system. According to the national agro-climatic zonation (Neacşa and Berbecel, 1979), the average climate of the two regions is a warm (10–11°C) and moderately dry one (below 500–550 mm/year), with rich radiative resources (sunshine duration over 2,100–2,200 hours/year). During the warm half of the year (April–October), these regions are highly exposed to hot weather episodes, intense evapotranspiration and persistent water deficit, especially in the western-, southern- and easternmost areas (Păltineanu *et al*., 2007; Sandu *et al*., 2010; Bojariu *et al*., 2015). Over the last two decades, Muntenia and Oltenia experienced considerable impact from various hydro-meteorological extremes, such as severe droughts (2000, 2003, 2007 and 2012), persistent heat waves (e.g. 2007, 2012) and extensive flooding in 2005, which had adverse effects on crop yields (*Cod de bune practici agricole în contextul schimbărilor climatice actuale şi previzibile*, 2014).

Despite the prevailing warm and dry summer climate, the two agricultural regions have a low adaptive capacity through irrigations, due to the small effectively irrigated areas per total area provided with irrigation (Fig. 2). The social and political constraints of the post-communist period are well reflected in the poor functioning of the existing irrigation infrastructure, which is currently unable to fully compensate for the impacts of climate change and associated weather extremes. According to the last updates of the National Institute of Statistics (2013), the total area equipped for irrigations in Muntenia and Oltenia agricultural regions is about 2,109.3 ha, distributed as follows: 71.5% in Muntenia (mainly in Balta Brăilei) and only 28.5% in Oltenia. A substantial decline of the effectively

[1] The *Dfa climate type* is defined as warm (temperate) continental, humid in all seasons with hot summers and cold winter (Kottek *et al*., 2006).

irrigated area has been recorded over the last few decades in both agricultural regions (Fig. 3). Most of this trend is due to the advanced state of the physical degradation of the irrigation infrastructure, through age and low reliability (great energy consumption, great water losses in the system). At county level, the decline is very obvious especially in Oltenia region. Generally, between 2000 and 2013, the largest irrigated areas were in 2007 in the counties of Brăila (29.5% of the total agricultural area managed for irrigation), Călărași (13.3%) and Ialomița (12.6%), where the large farms (over 2,000 ha) are mostly located.

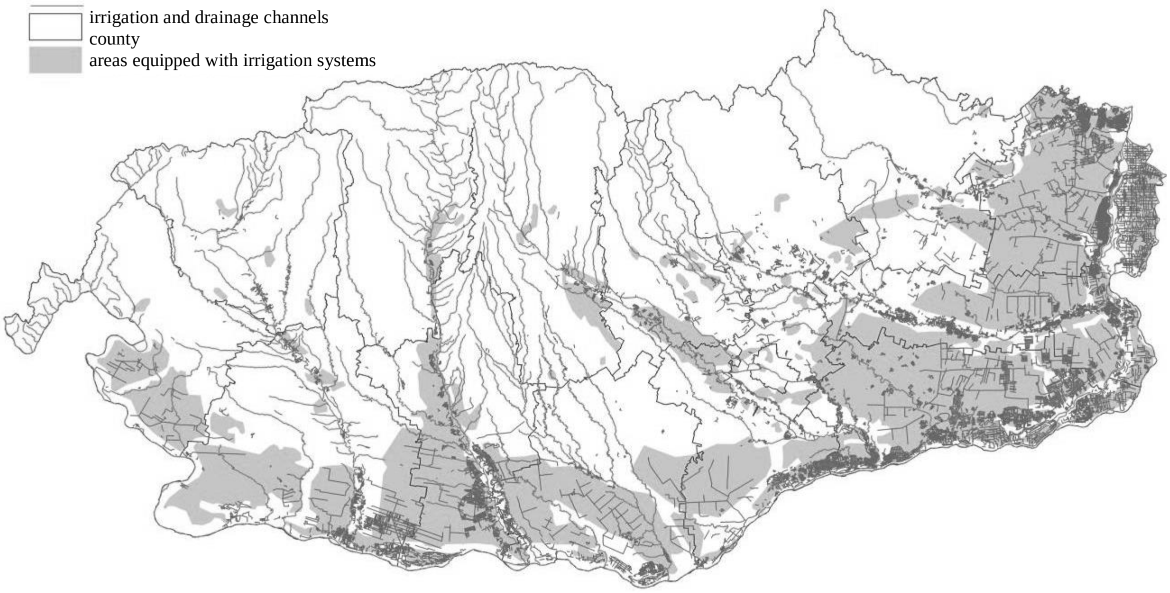


Fig. 2 – Distribution of the agricultural areas equipped for irrigation (1997–2013) in southern Romania.

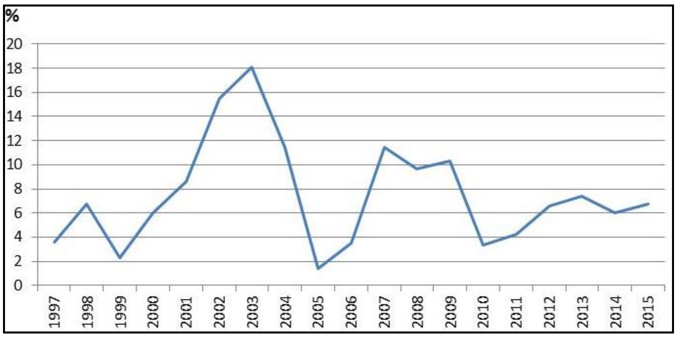


Fig. 3 – Dynamics of the effectively irrigated area in southern Romania between 1997 and 2015. Values are expressed as % of the total area equipped for irrigation.

3. DATA AND METHODS

3.1. Data

The detection of heat stress is based on the ROCADA dataset (Dumitrescu and Bîrsan, 2015), an observational climatic dataset for Romania, which integrates measurements from all weather stations with full data records and missing data up to 30% in the monitoring network of the National Meteorological

Administration. This dataset is homogenized and gridded using MASHv3.03 (Multiple Analysis of Series for Homogenization) and MISHv1.03 algorithms (Meteorological Interpolation based on the Surface Homogenized Data Basis), both developed by the Hungarian Meteorological Service. In this study we investigate the agro-climatic heat stress using the daily maximum temperature T_{max} on a 0.1°×0.1° longitude-latitude grid between 1961 and 2013. The input meteorological data have been extracted from the corresponding ROCADA grid points for 37 representative weather station locations from the two agricultural regions of southern Romania and their surroundings, which lie in their lowland areas (with elevations below 400–300 m), where selected crops are cultivated. The grid point selection (Figure 1) comprises 21 locations for Muntenia, 9 for Oltenia and, for spatialization reasons, another 5 located close to the study region boundary (Galaţi, Tecuci, Focşani, Hârşova, Drobeta Turnu-Serverin). We present our results for each selected grid point, but also as county or regional averages, based on the grid point selection for the two agricultural regions.

This study uses annual crop yield data (kg/ha/year) for three major crops in Romania: winter wheat (*Triticum aestivum L.*), grain maize (*Zea mays L.*) and sunflower (*Helianthus annuus*). Yield data cover the 1990 to 2013 period and have been obtained at NUTS3 level (county) from the National Institute of Statistics. Irrigation data cover the 1997–2013 period and are available also at NUTS3 level (county).

3.2. Methods

Our investigations focus on the extended summer season (May to September), having in view the following considerations: irrigations are usually applied in this interval of high-water demand crops (e.g. grain maize); grain maize is sensitive to heat stress during its vegetative-reproductive stages (May–September), especially when associated to drought in July–August; winter wheat is highly sensitive to heat stress three months prior to harvesting (May–July, roughly corresponding to the anthesis and grain filling stages); high summer temperature could damage sunflower crops during specific sensitive development stages (e.g. seed filling) and oil quality.

In this study, *hot summers* are evidenced from local average seasonal temperature anomalies exceeding at least two standard deviations.

Agro-climatic heat stress. Crop plant response is variable among species, being dependent on the development stages of the species. There are defined ranges and critical thresholds ("cardinal values") of maximum daily temperatures which affect negatively crop development and the final yields. Exposure to high maximum temperatures above 30–35°C of wheat (e.g. Balotă *et al*., 1997; Porter and Gawith, 1999; Porter *et al*., 2014), 35–38°C of maize (e.g. Hatfield and Prueger, 2015; Meluţ *et al*., 2014) and above 31°C of sunflower (e.g. Chimenti *et al*., 2001) were reported as unfavourable during the sensitive development stages. In our approach, we considered the daily maximum temperature threshold of 32°C (Tx_{32}), which is a critical biological temperature for crops during the period of maximum water demand according to Sandu *et al*. (2010). Beyond this threshold, heat becomes extreme and adversely impacts the key physiological processes involved in crop growth and development, especially when coinciding with drought episodes.

In this study four metrics (indices) are used to highlight the frequency and duration of the agro-climatic heat stress, namely: i) heat stress days (HSD), defined as days when the critical threshold Tx_{32} is reached or overpassed; ii) heat stress degree-days (HSDD), expressed as degree-days with a daily maximum temperature in excess of the critical threshold Tx_{32}, which are considered a measure of the seasonal extreme heat load; iii) heat stress spells frequency (HSSfr). Herein, a heat stress spell event is defined by considering a minimum sequence of at least three consecutive days when daily Tx is exceeding the critical threshold Tx_{32}; iv) heat stress spell maximum duration (HSSdurmax), which depicts the maximum time-span of an individual heat spell event.

Statistical model fitting. Crop yield sensitivity to extreme heat was investigated using regression and correlation analyses. The associations between seasonal heat stress metrics (as independent variables) and crop yield anomalies (dependent) were tested over the 1990–2013 period for all 15 counties and for each of the three crop types, in relation to the following statistics: Pearson correlation coefficient (r – the measure of strength and direction of the correlation between the predictand and predictors), squared correlation coefficient (r^2 – the proportion of variance of the predictand explained by predictors) and p value ($p<0.01$ – as indicator of the significance level so that the null hypothesis to be rejected or accepted against the alternative hypothesis).

Trend analysis. The non-parametric Mann-Kendall test (MK) was used to test the local significance of trends summer temperature and heat stress indices. Slope coefficients were estimated using the Kendall-Theil method (Theil-Slope estimate) and are expressed in corresponding units (°C, days), decennial (decade^{-1}) or relative to the length of the study period (e.g. °C period $^{-1}$). In this study, the significance level was fixed at 5% (two-tailed test).

4. RESULTS

4.1. Observed temperature change and frequency of hot summers

Southern Romania is experiencing a notable warming, but with non-homogeneous or spatially consistent changes in precipitation regime (e.g., Busuioc *et al*., 2010; Croitoru and Piticar, 2012; Dumitrescu *et al*., 2015).

Over 1961–2013, mean temperatures were steadily increasing since the mid-1980s or the early 1990s. Comparing the local trends, magnitudes throughout the study region, 2001–2013 emerges as a time-interval of intensified regional climate warming. This interval concentrates six of the warmest years of the period throughout both agricultural regions, with annual averages of over 12°C. Relative to the previous decades, this time interval had the greatest upwards (0.11–0.22°C decade^{-1}), especially in contrast to the 1971–80, the coldest decade since 1961. In terms of mean temperatures, regionally-wide, climate warming is observable in most seasons except autumn (the most stable season). In summer, warming is the strongest, with magnitudes of up to 0.43–0.49°C decade^{-1} in Muntenia and 0.37–0.45°C decade^{-1} in Oltenia. By contrast, winter warming is the weakest (below 1.0°C in both regions).

The changes in extreme temperatures are particularly important for farming activities since they do greatly influence the physiological processes responsible for final crop yields. In southern Romania, such changes have been observed both daytime (Tmax) and night-time (Tmin) in all seasons. In summer, temperature increase is generally faster and stronger during the day than at night in both regions. Estimated warming magnitudes of Tmax exceeded 0.47°C decade^{-1} in most areas or even 0.56°C decade^{-1} in some areas of Muntenia (Fig. 4). During the extended summer season (May–September), the corresponding trend slopes of Tmax are commonly below 0.37°C decade^{-1}, reaching 0.43°C decade^{-1} only in the south-easternmost areas of Muntenia (Feteşti and Călăraşi). Regionally, daytime summer warming is stronger in Muntenia, especially in the Danube Floodplain areas (e.g., Zimnicea, Giurgiu, Călăraşi, Feteşti).

July and August, the months of maximum water and radiative demand, have the greatest contribution to the overall seasonal warming, especially in the southernmost agricultural areas, where trend slopes exceed 0.50–0.56°C decade^{-1}.

Smoothed time-series of regionally average air temperature anomalies for the two agricultural regions are illustrated in Figure 5, capturing the ongoing warming process and the effects of the recent extreme warm weather. Since 1986–1987, in both cropping regions, there is a visible concentration of positive anomalies with up to eight consecutive summers in a row over 2006–2013. This time-slice is also recognized as particularly warm at European scale. Luterbacher *et al*. (2016) showed that Europe had experienced a marked summer warming (June–August) of about 1.3°C over the 1986–2015 period. Some recent summers (2003, 2010, 2015) proved unusually warm in most European regions, moreover so in the context of the last two millennia. Analysing the European summer temperatures since Roman times, Luterbacher *et al*. (2016) also provided evidence that there were no 30-year periods in either reconstruction to exceed the mean average European summer temperature of the last three decades (1986–2015 CE). Associated to this, the likelihood of occurrence of warm and hot summers has risen significantly in the first part of the 21st century over large parts of the Continent, some scholars considering such a trend as a response to anthropogenic forcing (e.g., Stott *et al*., 2004; Russo *et al*., 2015; Christidis *et al.*, 2015).

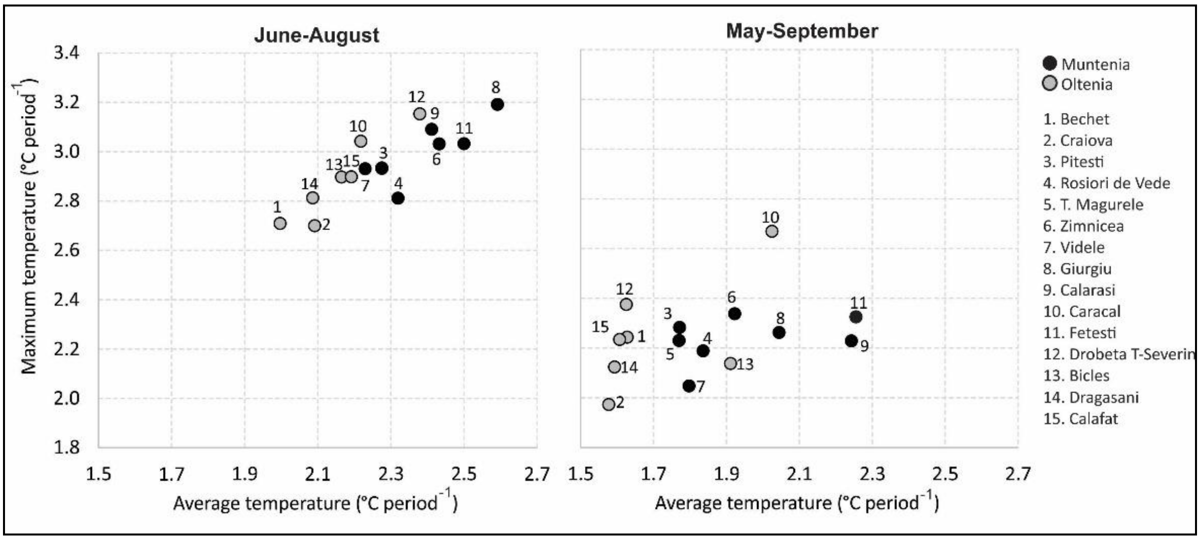


Fig. 4 – Estimated MK slope coefficients (°C/period) of seasonal air temperature trends in Oltenia and Muntenia cropping regions

Despite the clear and significant warming signal over 1961–2013, in southern Romania, the frequency of hot summers (two-to-three standard deviations) is limited to up to 2–4 cases/period (Table 1). It is worthy of note that the summers of 2007 (two standard deviation in all locations) and 2012 (two standard deviation and even three standard deviation in some locations – e.g. Drăgăşani, Craiova, Piteşti, Roşiori de Vede, Giurgiu) were the hottest in both cropping regions, with large positive anomalies relative to the climatological norm of the period, ranging from 2.5 to 2.9°C in 2007 and reaching up to 3.2°C in 2012. The agricultural seasons of 2006–07 and 2011–12 were also the driest in record over the 1961–2013 period, especially in July.

Table 1

Hot and warm summers in the southern agricultural regions of Romania over 1961–2013 and the range of seasonal temperature anomalies

Variables	Hot summers (two-to-three σ)	Warm summers (one σ)
Cases	2012, 2007 (all over the region) 2000, 2003 (in very few locations)	1998–2003, 2008–2010, 2013; 1963, 1988, 1993 (only by Tmax)
Temperature anomalies (Tavg)	2.9–3.2°C	0.9–2.1°C
Temperature anomalies (Tmax)	2.7–4.2°C	0.8–2.2°C

A previous study on changes in summer modes across the Romanian Plain region based on the behaviour of joint temperature-precipitation quantiles (Micu *et al*., 2014), indicated an increasing prevalence of dry-warm summers all over the region, most visible after 1985. Moreover, the frequency and duration of tropical heat-dry spells was found to be on a significant increase, particularly due to the intensification of the daytime tropical heat stress (mostly visible after 1990).

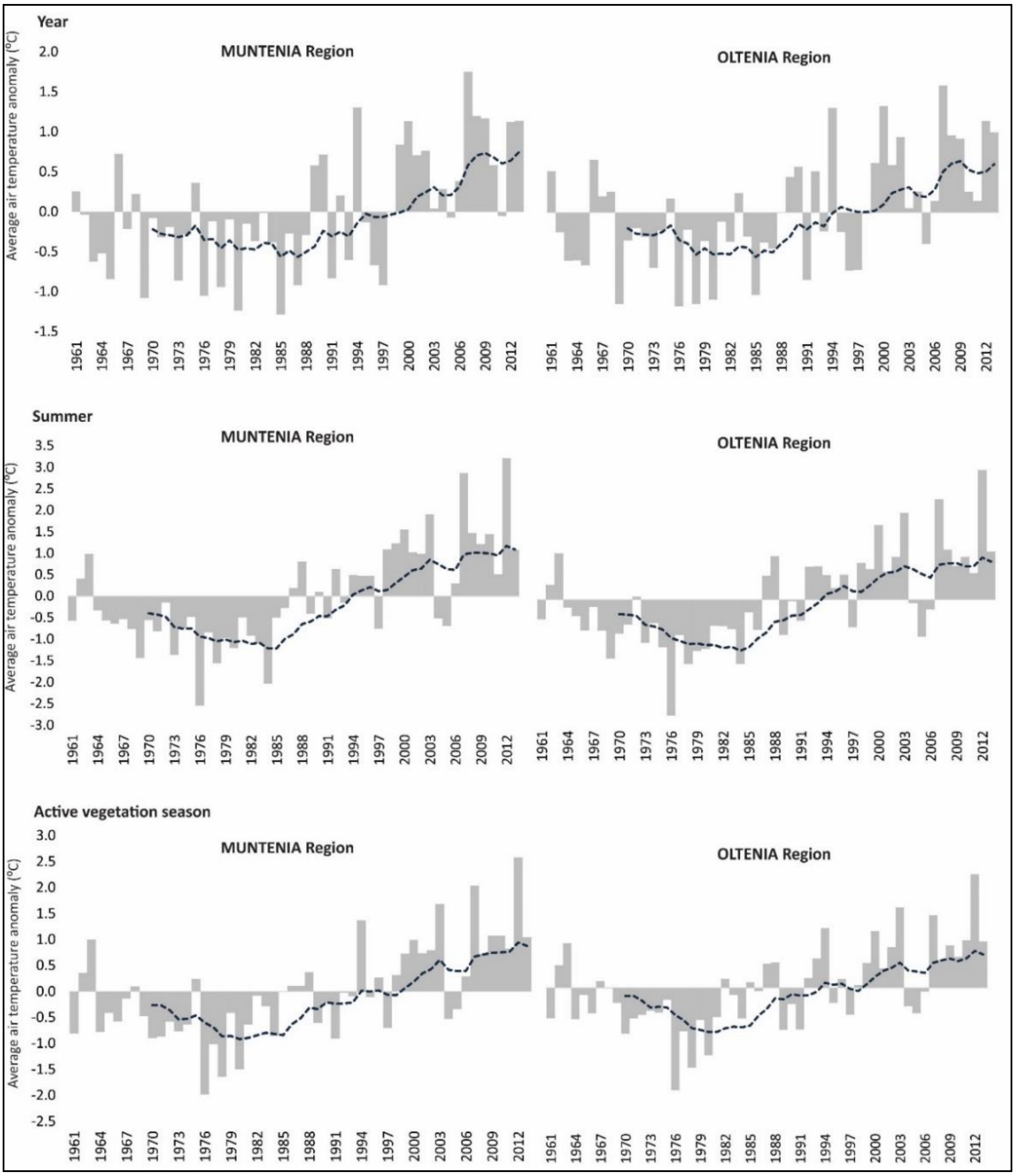


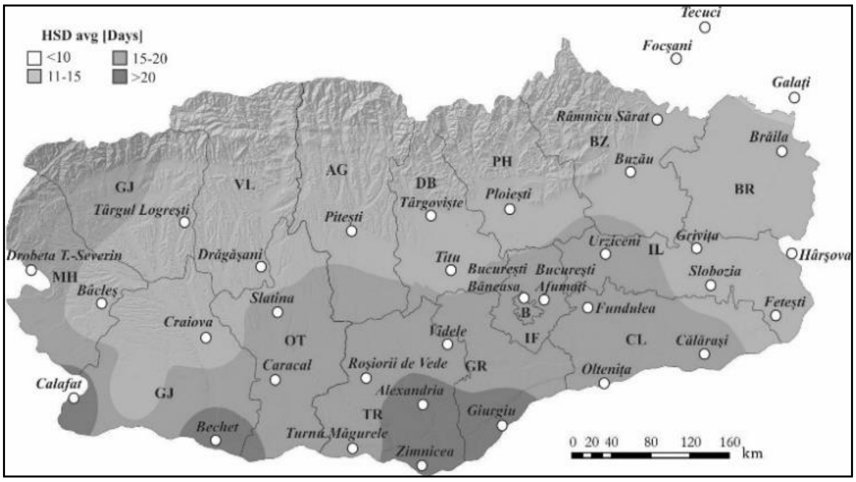
Fig. 5 – Average air temperature anomalies from 1961 to 2013 in the Muntenia and Oltenia cropping regions. Running 10-year regional running averages are shown with the black dashed line

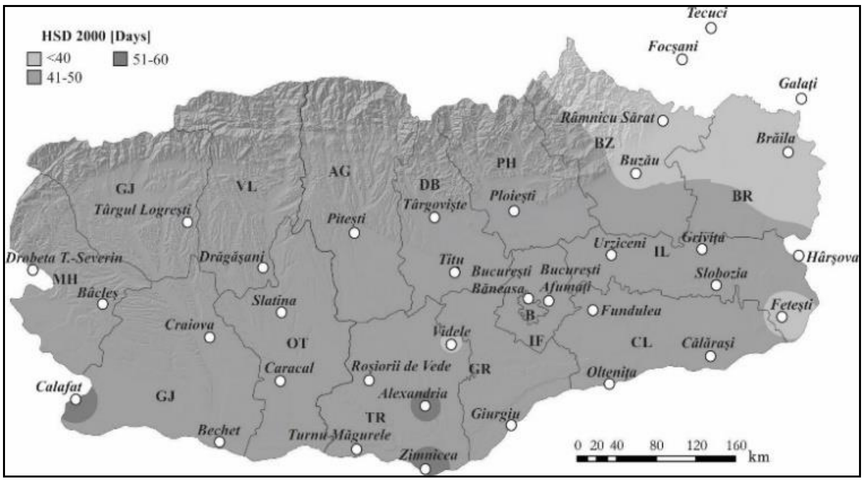
Investigating the mechanisms of controlling hot summer occurrence in Romania, Busuioc *et al*. (2007) showed that the strong summer temperature anomalies in recent years (e.g., 2000, 2003, 2007) were associated to the increased frequency of high-pressure systems at atmospheric heights of 500 hPa. The authors also revealed a good correlation with the positive temperature anomalies at 850 hPa level, especially above the South-East European territory, in terms of both spatial extension and anomalies.

4.2. Agro-climatic heat stress: regional climatology and associated trends over 1961–2013

This section presents an overview on the heat stress characteristics (frequency and duration) and corresponding trends in the cropping Muntenia and Oltenia regions.

Frequency of heat stress days (HSD). The average number of HSD shows a general north-to-south increase across the study region, with a maximum in the central and southernmost floodplain areas (above 21–26 days season^{-1}). These areas emerge as distinct hot-spot areas under the intensified climate warming in the recent decades. By contrast, the northern and northeastern cropping areas are less exposed to heat stress days (below 10–15 days season^{-1}). Regionally, seasonal HSD ranges between 12 days at Fundulea (Muntenia) and 30 days at Calafat (Oltenia). At monthly level, peak HSD frequencies are specific to the July–August interval across both regions with over 7–8 days/month compared to June – the summer month with the lowest load of high-temperature days (3–4 days per month). In terms of intra-seasonal HSD variability, 2000, 2007 and especially, 2012 were the warmest seasons on record across both agricultural regions, with maximum HSD of 50–75 days season^{-1} in Oltenia and over 48–70 days season^{-1} in Muntenia. Figure 6 depicts the spatial distribution patterns of seasonally averaged HSD and maximum HSD in the warmest seasons of the study period across both agricultural regions.





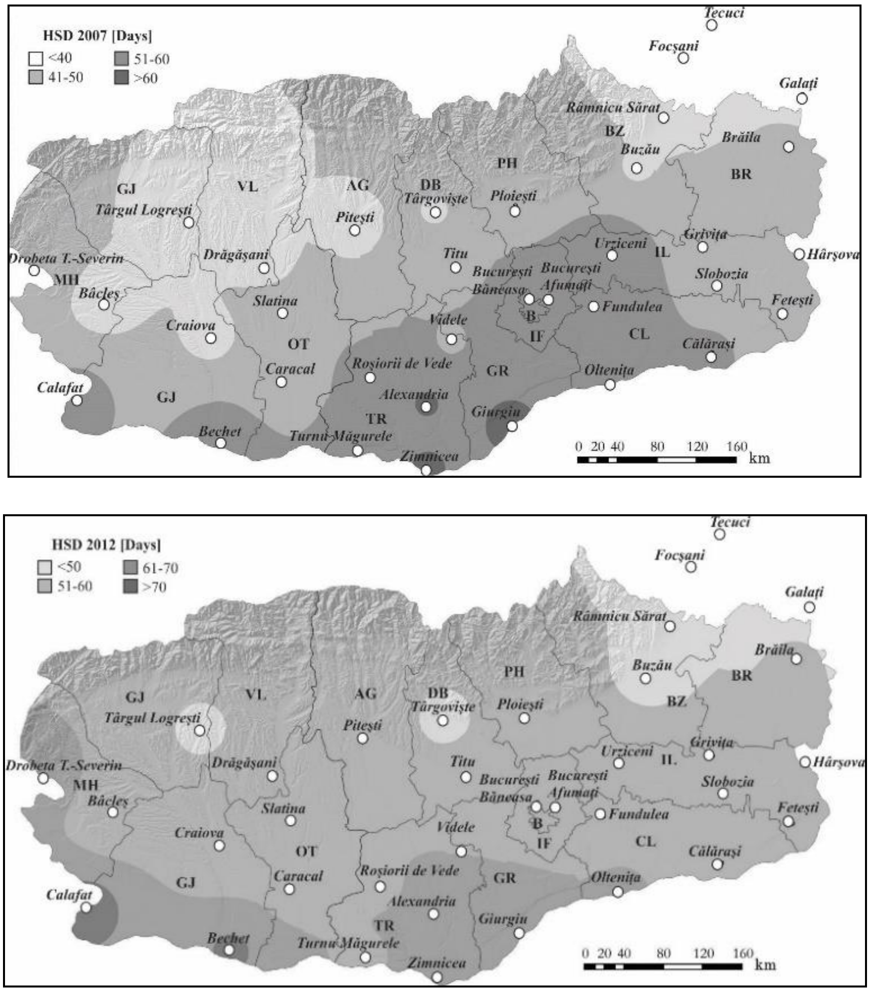


Fig. 6 – Spatial distribution of seasonal HSD in the lowlands of the Muntenia and Oltenia cropping regions: average values (*upper left graph*) and maximum values of 2000, 2007 and 2012 (*the other graphs*)

Trend analysis of seasonal HSD provides clear indication of an increasing heat stress across the two agricultural regions, especially since the mid-1980s ($p<0.05$) (Fig. 7). The change in the seasonal HSD is consistent and highly statistically significant ($p<0.001$) across both regions, with fairly comparable regional magnitudes: +5.1 days decade^{-1} (27 days period^{-1}) in Oltenia and +4.52 days decade^{-1} (24 days period^{-1}) in Muntenia. Regardless the region, the July–August interval shows a great increase in HSD frequency (+9–10 days period^{-1}) relative to the June increase, limited to only 0.75 days decade^{-1} (4 days period^{-1}). In the rest of the months, MK slope coefficients did not reach statistical significant levels.

The seasonal heat stress load through accumulation of temperatures above the critical biological threshold Tx_{32} is well expressed by the *heat stress degree-days* index (HSDD). On average, the seasonal heat stress load is substantial (above 20 degree-days) over most of the Oltenia region, as well as in the central plain and southern floodplain areas of Muntenia (e.g. 29 degree-days at Alexandria, Bechet, Zimnicea) (Fig. 8). The eastern and northern plain areas of Muntenia are less exposed to heat stress accumulation. At monthly level, the July–August interval has the greatest contribution to the overall seasonal heat stress load in both regions (77% in Oltenia and 74% in Muntenia).

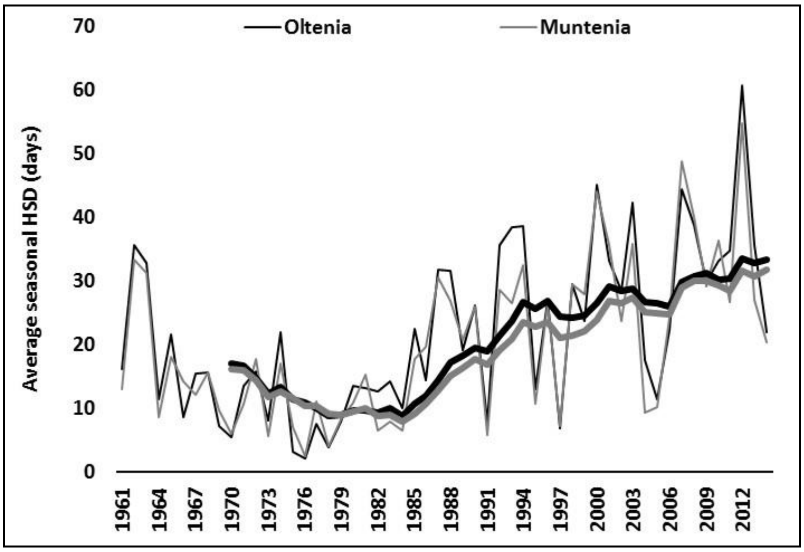
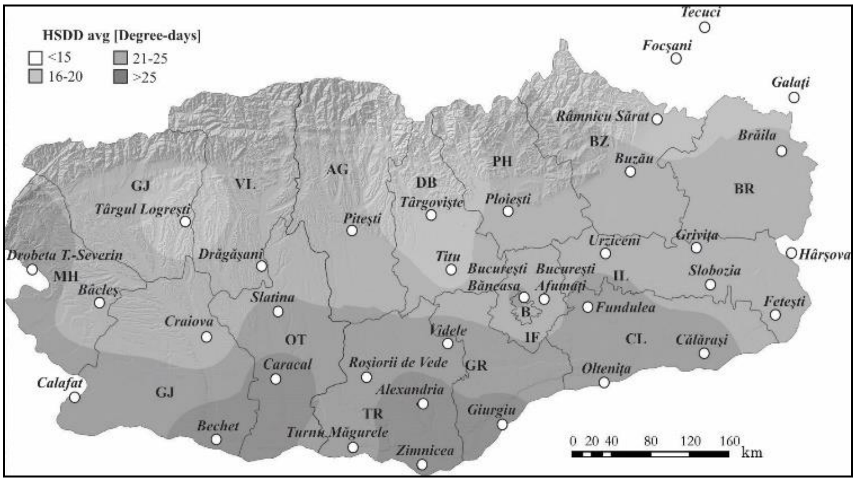
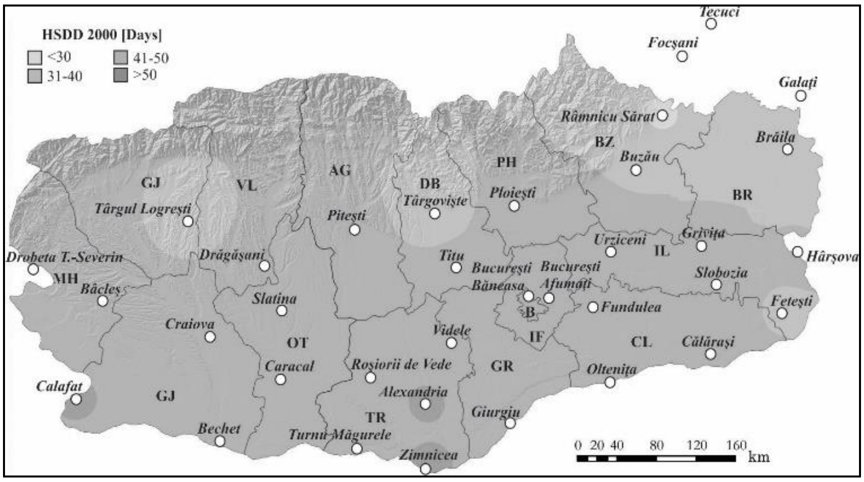


Fig. 7 – Trends in seasonal HSD in the southern agricultural lowlands of Romania: temporal variability with a 10-year low-pass Gaussian filter (solid lines)





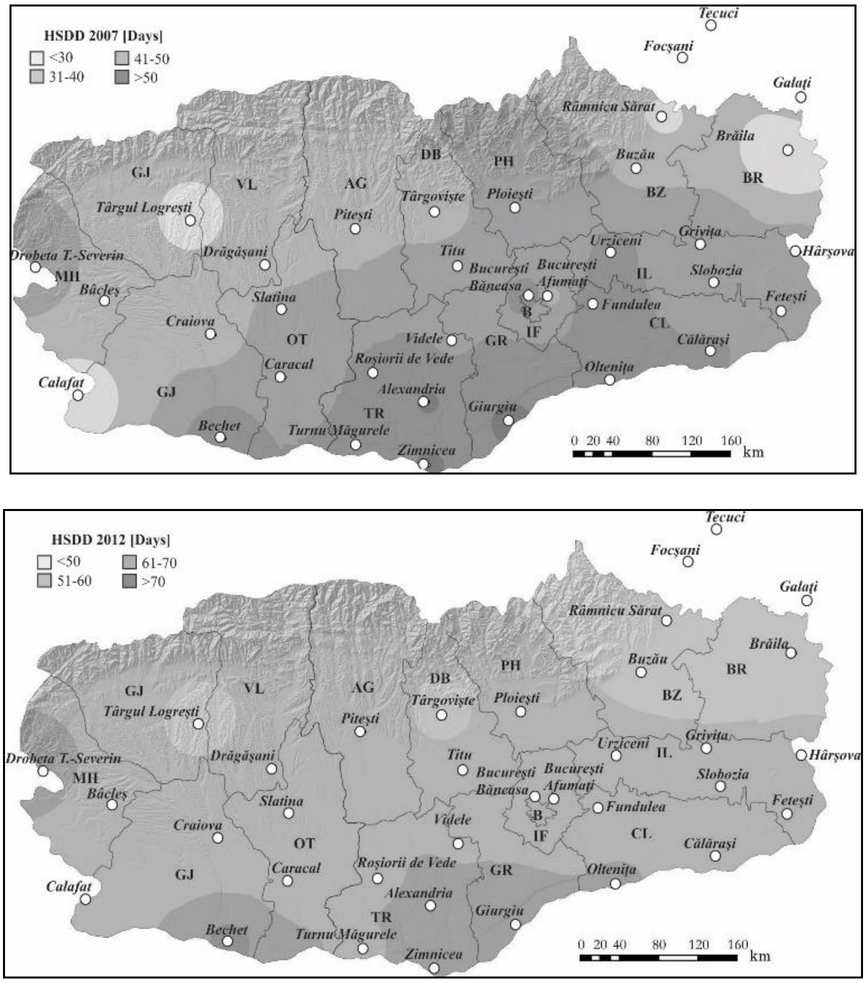


Fig. 8 – Spatial distribution of HSDD in the lowlands of the Muntenia and Oltenia cropping regions: average values (*upper left graph*) and maximum values of 2000, 2007 and 2012 (*the other graphs*)

The number of HSDD increased across both regions, especially after the late 1980s or early 1990s (Fig. 9). This increase is significant ($p<0.05$ to 0.001) at all selected weather stations, with slope coefficients ranging between 3.8 and 5.7 degree-days decade^{-1} (20–30 degree-days period^{-1}) in Oltenia and between 2.5 and 5.8 degree-days decade^{-1} (13–31 degree-days period^{-1}) in Muntenia. Regionally averaged, the change magnitude is slightly higher in Oltenia than in Muntenia (23.2 degree-days period^{-1} and 22.7 degree-days period^{-1}, respectively). Particularly hot seasons, with peak heat stress load, occurred in 2000, but especially in 2007 and 2012, when the HSDD exceeded 50 degree-days over extended areas across the two regions.

Prevailing extreme high temperatures in a row of several days (at least three in this case) were found to be an important impact factor on the quality and quantity of harvests, determining record yield losses and increase production costs in several agricultural regions of Europe, especially in the Central and Southern ones (e.g. UNSDIR, 2003; Ciais *et al*., 2005; Olesen *et al*., 2011). In Romania, the southern plain regions, frequently exposed to persistent hot and dry summer airflows of North-African origins (Barbu *et al*., 2014), are among the most affected by heat spells in summer. The variability of summer maximum temperatures at the weather stations of Oltenia and Muntenia regions shows that the persistent episodes of extreme heat have become a more common feature of the summer climate in the recent years.

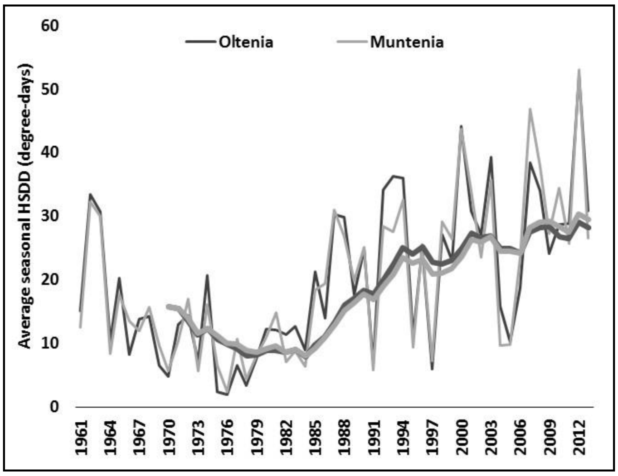


Fig. 9 – Trends in seasonal HSDD in the southern agricultural lowlands of Romania: temporal variability with a 10-year low-pass Gaussian filter (solid lines)

The analysis of heat stress associated to heat spells when the critical biological thermal threshold was systematically reached and/or overpassed at least in three consecutive days shows that the maximum *frequency of heat stress spells* (HSSfr) have a fairly similar value range between the two agricultural regions: 6 cases at Craiova (1990) to 10 cases at Calafat, Caracal and Slatina (2003) in the Oltenia region; 5 cases at Feteşti (1992 and 2000) to 11 cases at Zimnicea (2012). The total HSSfr exceeding 200 cases/period, indicates the emergent "hot-spot areas" across the two agricultural regions, where the agro-climatic heat stress is much recurrent. These areas are located in the Danube floodplain: Bechet (210), Calafat (205), Zimnicea (202). The rest of the areas remain also exposed to heat stress, but the total number of heat stress spell occurrences is limited to less than 150–170 cases/period. In respect to the intra-seasonal variability, there is an evident concentration of high-frequency heat stress spell seasons over the last few decades, especially after 2000 (Fig. 10). Regionally-wide, the warmest seasons in terms of HSSfr were 2000, 2007 and 2012, also known for their prominent soil water deficits and severe droughts.

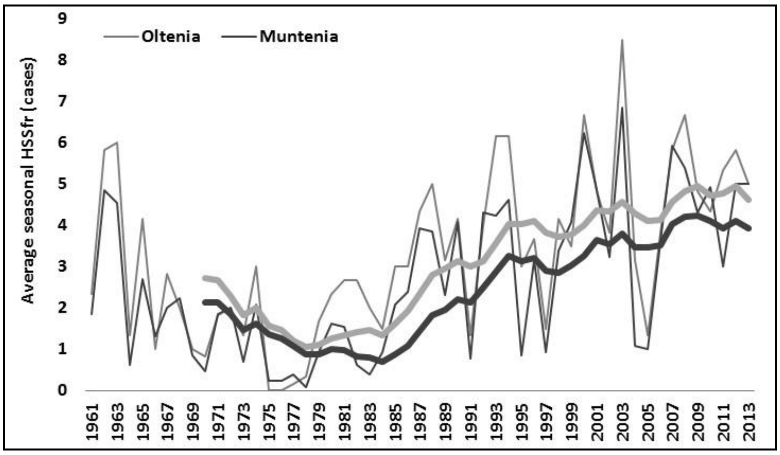


Fig. 10 – The variability of average seasonal frequency of heat stress spells in Oltenia and Muntenia regions. The solid lines depict the observed upwards revealed by a 10-year low-pass Gaussian filter.

The trend analysis of HSSfr has revealed an increasing frequency of heat stress across both regions, slightly more evident in Oltenia (up to 0.75 days decade^{-1} or 4.0 days period^{-1}) than in Muntenia (0.66 days decade^{-1} or 3.5 days period^{-1}) when considering the average regional slopes. At local scale, the MK statistics returned highly significant changes in this heat stress index ($p<0.001…0.05$) in all locations. The areas which experienced large change magnitudes (more than 4.0 days period^{-1}) are Calafat and Zimnicea. Along with other central plain and southern floodplain areas were found highly exposed to large increases in HSSfr (at least 3.5 days period^{-1}): Bechet, Drobeta Turnu-Severin, Caracal, Călăraşi, Giurgiu, Titu and Videle.

The *maximum persistence of each individual heat spell* is a valuable metric of heat stress intensity (*HSSdurmax*). In the study region, the record duration of a heat spell was recorded in the Oltenia region, at Calafat, from July 31 to September 1st, 1992 (33 days), when maximum temperatures ranged between 32.4 and 38.1°C. In Muntenia, the peak HSSdurmax was of 23 days at Giurgiu, during a heat spell which lasted from July 19 to August 10, 2012. In this case, the value range of daily maximum temperatures was more extended (32.0–42.9°C) than in the previous example. Table 2 displays the characteristics of the first five most persistent heat stress spells which affected Oltenia and Muntenia agricultural regions during the extended summer season from 1961 to 2013. All the events were found outstandingly extreme relative to the local and regional climatology of heat spell duration (generally over 20 days, with return periods of over 100–150 years) and daily maximum temperature range during the heat spells (greatly exceeding the critical biological thermal threshold by up to 8–10°C, especially in Muntenia). Throughout the study region, such heat stress events had an occurrence probability below 4% (Fig. 11).

Table 2

Top 5 of the most persistent heat stress spells in the southern agricultural lowlands of Romania (1961–2013)

Oltenia				**Muntenia**			
Location	**HSSdurmax (days)**	**Time interval**	**Tmax range (°C)**	**Location**	**HSSdurmax (days)**	**Time interval**	**Tmax range (°C)**
Calafat	33	31.07–01.09.1992	32.4–38.1	Giurgiu	23	19.07–10.08.2012	32.1–42.9
Bechet	25	08.08–01.09.1992	32.2–37.1	Bucureşti–Băneasa Feteşti Olteniţa	22 22 22	19.07–09.08.2012 19.07–09.08.2012 19.07–09.08.2012	30.0–40.8 32.2–40.9 32.4–42.1
Caracal	23	19.07–10.08.2012	32.0–40.1	Ploieşti Titu	21 21	20.07–09.08.2012 20.07–09.08.2012	32.2–40.2 32.0–40.7
Slatina	22	19.07–09.08.2012	32.0–39.7	Feteşti	18	31.07–17.08.2012	32.3–37.7
Bechet	19	13–31.08.2003	32.3–39.1	Olteniţa Giurgiu Roşiori de Vede	17 17 17	31.07–16.08.2010 15–31.07.2007 15–31.07.2007	32.0–37.7 32.5–42.8 32.0–42.7

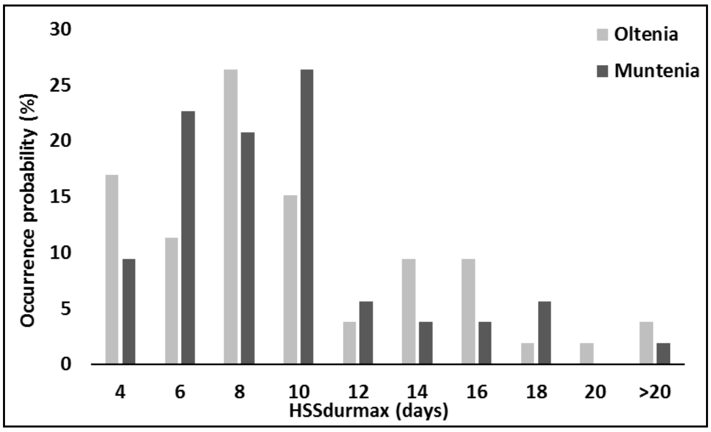


Fig. 11 – Occurrence probability of heat stress spells with different maximum durations in the Oltenia and Muntenia cropping regions.

Complementary to the significant increasing frequency of heat stress spells, southern agricultural lowlands are also under a visible lengthening of the duration of these hot-weather extremes (Fig. 12). This change signal is spatially consistent across the study region and all the trends were found statistically significant ($p<0.001…0.05$). The maximum length of heat stress spells is on increase by approximately 9 days period^{-1} (1.69 days decade^{-1}) in Oltenia and 8 days period^{-1} (1.51 days decade^{-1}) in Muntenia. At local scale, the largest change magnitudes were estimated for some Danube floodplain areas in Oltenia (over 7 days period^{-1}): Calafat (8.5), Bechet (8.0), Drobeta Turnu-Severin (8.0) and Zimnicea (7.1).

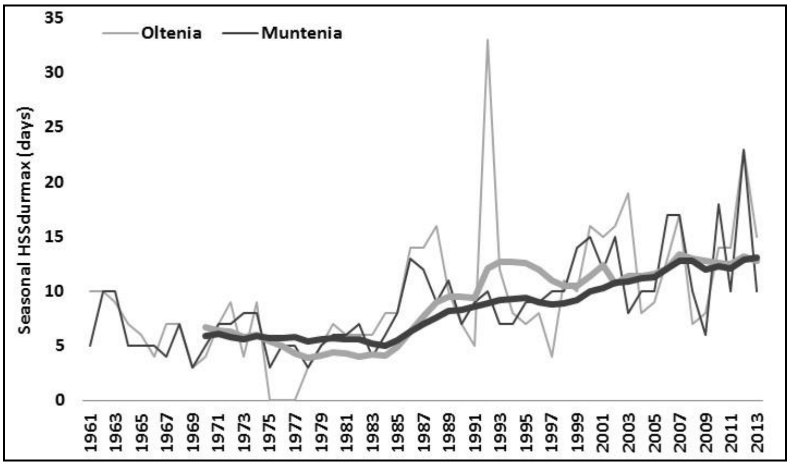


Fig. 12 – Variability of seasonal maximum duration of heat stress spells in Oltenia and Muntenia regions. The solid lines depict the observed upwards revealed by a 10-year low-pass Gaussian filter.

Table 3 summarizes the key findings on the changing of extreme heat conditions at county level, which suggest a gradual intensification of heat stress during the extended summer season in both agricultural regions.

Table 3

MK estimates of significant trends in seasonal agro-climatic heat stress at county level over the 1961–2013 period (statistically significant cases are marked in **bold**)

Agricultural regions	Counties	Statistical significance (*p* values) and/slope coefficients (unit/53 years)			
		HSD	**HSDD**	**HSSfr**	**HSSdurmax**
Oltenia	Mehedinţi	<**0.001**/+26.50	<**0.001**/+25.5	<**0.001**/+8.0	<**0.001**/+7.95
	Dolj	<**0.001**/+29.51	<**0.05**/+21.0	<**0.001**/+7.9	<**0.001**/+8.11
	Gorj	<**0.001**/+21.20	<**0.001**/+17.7	<**0.05**/+2.65	<**0.05**/+4.18
	Olt	<**0.001**/+26.17	<**0.001**/+26.5	<**0.001**/+5.7	<**0.001**/+5.92
	Vâlcea	<**0.001**/+22.84	<**0.001**/+22.7	<**0.001**/+3.45	<**0.05**/+5.30
Muntenia	Argeş	<**0.001**/+21.06	<**0.001**/+21.06	<**0.001**/+2.04	<**0.001**/+3.93
	Dâmboviţa	<**0.001**/+23.96	<**0.001**/+19.14	<**0.001**/+3.31	<**0.001**/+5.30
	Prahova	<**0.001**/+21.20	<**0.001**/+21.20	<**0.001**/+3.53	<**0.001**/+4.61
	Buzău	<**0.001**/+20.66	<**0.001**/+17.67	<**0.001**/+2.80	<**0.05**/+3.92
	Brăila	<**0.05**/+21.20	<**0.01**/+13.79	<**0.001**/+2.76	<**0.001**/+4.92
	Teleorman	<**0.001**/+28.31	<**0.001**/+27.24	<**0.05**/+3.84	<**0.001**/+5.83
	Giurgiu	<**0.001**/+29.44	<**0.001**/+30.01	<**0.05**/+3.79	<**0.05**/+4.82
	Ilfov	<**0.001**/+26.50	<**0.001**/+25.59	<**0.001**/+3.55	<**0.001**/+5.67
	Bucharest	<**0.001**/+25.34	<**0.001**/+25.01	<**0.05**/+2.94	<**0.05**/+4.58
	Călăraşi	<**0.001**/+25.88	<**0.001**/+24.81	<**0.001**/+3.53	<**0.05**/+5.47
	Ialomiţa	<**0.001**/+23.01	<**0.001**/+20.82	<**0.05**/+2.41	<**0.001**/+5.48

4.3. Heat stress-crop yield relationships: interpretation and attribution

Crop production is affected by numerous factors (social, economic, political and climatic), which are complexly interrelated at different spatial and temporal scales (Entwisle and Stern, 2005). In Romania, the cultivated area and the plant production were strongly influenced by the socio-economic and political conditions of the post-communist period. This influence depended on farming practices (the absence of functional irrigation systems, fewer natural and chemical fertilizers, poor mechanization), inadequate farm structure and agricultural policies. Yields vary greatly from one farm to another, depending on their financial resources, as well as on the quantity and the quality of inputs.

Over 1990–2000, the production of wheat, maize and sun flower crops was on a continuous decrease due to the reduction of cultivated surfaces and technological regression. After 2000, as a result of reducing the fragmentation of agricultural land, the implementation of Common Agricultural Policies (CAP) and the presence of subsidies in agriculture, average yields, especially of maize, sunflower, sugar-beet, potatoes and vegetables have improved.

The changes in the present climate and extreme events (e.g. heat waves, drought, floods, hail) are recognized as a major stressor for crop yields and livestock productivity, especially in rainfed systems (e.g. Rojas-Downing *et al*., 2017; Iizumi and Ramankutty, 2015; Siebert and Ewert, 2014). In southern Romania, the years of 2000 and 2007 emerged as years of failed crop yields for sunflower and maize and 2002–2003 interval for wheat yields (Table 4). The levels of failed crop yields are considered dramatically low relative to the average crop yields over the 1990–2013 period: 60 to 90% for maize, 58 to 98% for wheat and 37 to 83% for sunflower. Reported decreases in agricultural production, especially in the southern and south-eastern lowlands of Romania, were found associated to significant precipitation deficits, persistent atmospheric and pedological drought and extreme heat recorded in some of the driest and hottest years of the examined period (2000, 2007 and 2012) (*Cod de bune practici agricole în contextul schimbărilor climatice actuale şi previzibile*, 2014). In these extreme years, the gross added value from agriculture was generally negative e.g. –18.4 (2000), –15.3 (2007), –21.6 (2012).

Table 4

Failed crop yields of maize, wheat and sunflower crops in the agricultural lowlands of Oltenia and Muntenia cropping regions over the 1990–2013 interval and the corresponding share of effectively irrigated area per total irrigable area

Agricultural regions	Counties	Lowest crops yields (kg/ha/y)/record year			Irrigated area during the low crop yield years (% of the total area equipped for irrigation)
		Grain maize	Winter wheat	Sunflower	
Oltenia	Mehedinţi	317.9/2007	605.7/2007	181.1/2007	0.0
	Dolj	346.7/1993	261.4/2002	138.2/2002	N/A
	Gorj	1182.0/2000	1012.0/2002	443.0/2000	0.2
	Olt	515.4/2000	832.2/2007	408.4/2007	4.3
	Vâlcea	1243.0/2012	1181.0/2002	333.0/2000	0.0
Muntenia	Argeş	1366.0/2000	1110.0/2003	503.0/2000	2.9
	Dâmboviţa	1033.0/2000	1106.0/1996	395.0/2000	3.7
	Prahova	1327.0/2000	697.0/2002	651.0/2007	3.4
	Buzău	709.0/2007	51.0/2003	511.0/2002	4.8
	Brăila	1203.1/2007	798.2/2003	923.5/2007	29.5
	Teleorman	303.0/1993	718.9/2003	450.3/2000	N/A
	Giurgiu	353.4/2000	1099.0/2003	211.8/2007	4.1
	Ilfov	541.0/2000	707.0/2003	401.0/2007	1.6
	Călăraşi	695.7/2007	403.5/2003	364.3/2007	13.3
	Ialomiţa	426.6/2007	264.5/2003	425.0/2007	12.6

The great yield losses recorded at county level (over 50% of the average production relative to the previous year), were a consequence of the cumulative adverse effects of extreme heat stress, subsequent intense evapotranspiration and limited water compensations though irrigation, most of them non-operational. The total arable area of the Oltenia and Muntenia regions, which was effectively irrigated had a fraction of only 6.1% to 11.1% in the total surface equipped with irrigation systems. During the years of failed crops, the effective irrigated areas accounted for only up to 2.8% in Oltenia and 7.0% in Muntenia in the total irrigable area (Fig. 13). The lack of efficient irrigations was found responsible for up to 57% (2007) of the low record yields of maize (74% in Oltenia and 71% in Muntenia), wheat (53% in Oltenia and 50% in Muntenia) and sunflower (61% in Oltenia and 62% in Muntenia).

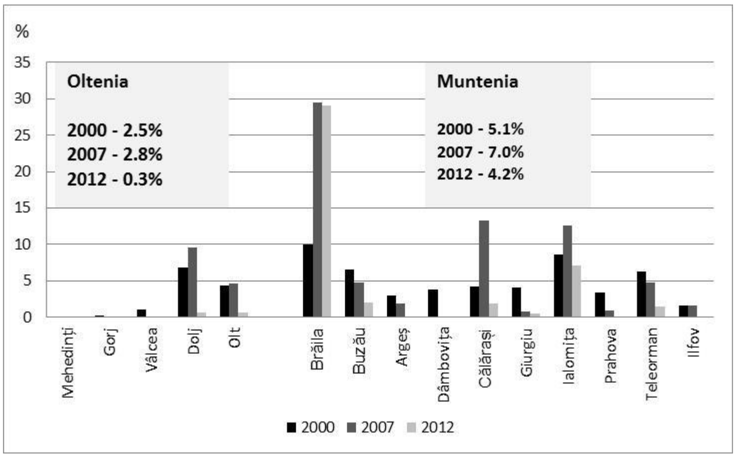


Fig. 13 – Dynamics of effectively irrigated area at county level in the Oltenia and Muntenia cropping regions (% of the total area equipped for irrigation)

In 2000, the most affected crops in the southern agricultural lowlands of Romania were maize and sunflower. Relative to the previous year, maize recorded the most important production losses (over 80%), especially in the counties situated in the western half of the study region: Teleorman 90%, Giurgiu 89%, Olt and Ilfov 87%, Dolj 86%, Mehedinți 82%, Gorj 72%. The losses in sunflower production were also high (over 50–60%), mainly in Olt (66%), Teleorman (61%), Vâlcea (61%), Dolj (60%), Mehedinți (56%), Dâmbovița and Giurgiu counties (53%). Losses in wheat production were lower, of up to 23% only in some counties located in the north-eastern part of the study region (Brăila, Buzău, Ialomița) (Fig. 14).

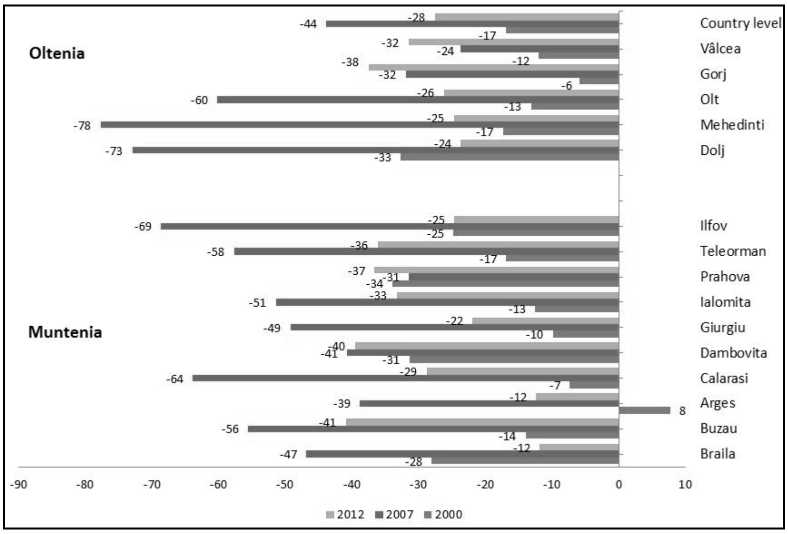


Fig. 14 – Wheat yield losses (% reduction) in the southern agricultural lowlands of Romania, in heat stress representative years: for 2000 versus 1999, 2007 *versus* 2006 and 2012 versus 2011

The heat stress and drought of **2007** had a great impact mainly on sunflower and maize production. Peak losses in maize crop production (up to 90% relative to the previous year) were recorded in Oltenia, with very low yields in Mehedinţi (318 kg/ha), Olt (531 kg/ha) and Dolj counties (549 kg/ha). Muntenia region was also significantly affected, Ialomița (425 kg/ha) and Giurgiu (539 kg/ha) counties facing the most important losses in maize production (80–87% relative to the earlier year). Generally, in that year, the counties lying in the eastern half of the study region registered the steepest declines in the average yields for all the three crops (Fig. 15).

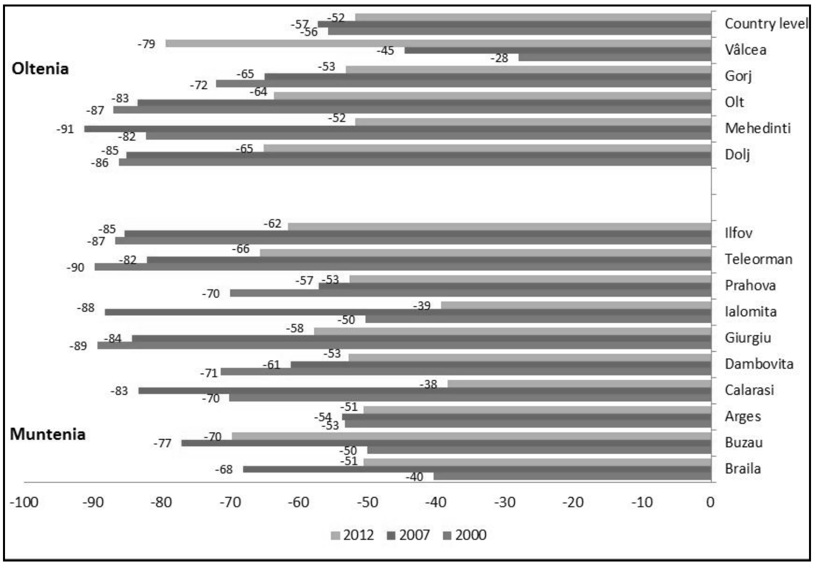


Fig. 15 – Maize yield losses (% reduction) in the southern agricultural lowlands of Romania, in heat stress representative years: for 2000 versus 1999, 2007 *versus* 2006 and 2012 versus 2011

In **2012**, most counties of the Romanian Plain, except for Călăraşi and Ialomița, recorded 50% lower average maize productions compared to 2011 (exceptionally, the decline in Buzău exceeded 70%). For the rest of the crops, yield losses were limited to 12–40% for wheat and sunflower (Fig. 16).

Variations in the annual production of wheat, maize and sun flower crops were investigated in relation to heat stress characteristics during the extended summer season (May–September) over 1990–2013, in order to decompose the detrimental effects of extreme heat alone. Table 5 presents the summarized statistics of the correlation analysis extended to regional averages of the observed crop yields and heat stress condition metrics at county level in the Oltenia and Muntenia cropping regions.

Maize, the crop with the largest yield area across southern Romania, showed the greatest sensitivity to extreme summer heat, with regionally-wide statistically significant and negative relationships. Heat stress days (HSD) and heat stress degree-days (HSDD) were found as best predictors of changes in maize production across both regions, in the range of 36 up to 61% (Table 5). The maximum duration of heat stress spells (HSSdurmax) was found to explain only 24 up to 36% of the decrease in annual maize yield and only sparsely, in Mehedinţi, Dolj, Teleorman and Călăraşi counties.

For the other crops, the correlation coefficients were limited in describing the association between crop production and heat stress indices in most counties and no discernible patterns were found in the behaviour of these variables in a cause-effect relationship. Heat stress is globally considered as one of the most important limiting factors of wheat yields, except for some regions (e.g. China, India) where water stress was found to be a more important predictor (Zampieri *et al*., 2017). In Muntenia and Oltenia, heat stress is not a prominent factor to explain the variability of winter wheat yields. Exceptionally, regression analysis revealed that it is only persistent episodes of heat stress spells (HSSdurmax) that could explain 17% to 24% of crop yield anomalies in a few distinct counties such as: Mehedinţi, Dolj, Teleorman and Călăraşi. The weak predictive role of extreme high temperatures could be generally justified by the early ripening-harvesting stage of this crop, which takes place during the July–August interval when heat in southern Romania is highly recurrent and persistent.

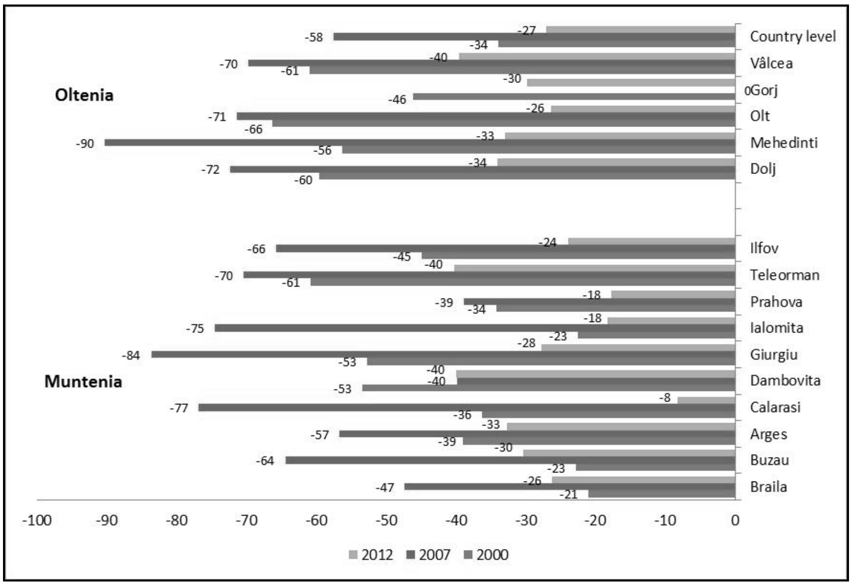


Fig. 16 – Sunflower yield losses (% reduction) in the southern agricultural lowlands of Romania, in heat stress representative years: for 2000 *versus* 1999, 2007 versus 2006 and 2012 versus 2011

In the case of sunflower, the production was found responsive to seasonal heat stress load (HSDD) only in Dolj and Buzău counties (16–18%), as well as to the frequency of heat stress spells, but only in Olt and Dâmboviţa counties (14–22%). Persistent heat stress spells (HSSdurmax), which in southern Romania lasted at least 12 up to 22 consecutive days, were identified as best predictor of sunflower yield variations (13–26%) in five out of the total 15 counties for which the regression analysis was conducted (Mehedinţi, Olt, Dâmboviţa, Buzău and Ilfov).

Table 5 shows that extreme daytime temperatures had a detrimental effect on the final crop yields in most counties of the two agricultural regions. The correlations are mostly negative, indicating a general decrease in crop production in response to the increasing seasonal heat stress, particularly with the contribution of the heat stress representative years (2000, 2007 and 2012), when irrigations were not used at full capacity.

Filtering the data to exclude the effects of potential outliers from the regression analysis (namely, the influence of the very warm and droughty summers of 2000, 2007 and 2012), some relevant changes in the heat stress-crop yield relationship were observed across both regions. The heat stress-maize yield relationship maintained its direction (negative) for all crops and for each county of the two regions, but decreased in strength and significance. These changes were particularly obvious for maize crops:

– The average loss in strength for both regions were 12 to 20%. Greatest decreases were recorded for the HSDD (up to 34–35% in Muntenia – Buzău and Argeş counties; up to 41% in Oltenia – Vâlcea County) and HSD predictors (up to 27–28% in Dâmboviţa, Teleorman and Vâlcea counties). For the other predictors, decreases in strength were limited in general to 20%, with the exception of

Dâmboviţa and Prahova counties for HSSfr (29–32%) and of Vâlcea, Olt, Gorj, Argeş, Dâmboviţa and Călăraşi for HSSdurmax (21–31%). Generally, the greater the decrease in the strength of heat stress-maize yield relationship, the greater the contribution of the heat stress to the crop yield losses during the hot and dry summers of 2000, 2007 and 2012.

Table 5

Regression analysis results on the relationships between annual crop yields and heat stress indices during the extended summer season at NUTS3 level for the Oltenia and Muntenia cropping regions (ns – not significant)

Crop	Counties	HSD (days)		HSDD (days)		HSSfr (cases)		HSSdurmax (days)	
		R^2	pvalue	R^2	pvalue	R^2	pvalue	R^2	pvalue
Wheat	Mehedinţi	.10	ns	.10	ns	.01	ns	**.17**	**<0.05**
	Dolj	.09	ns	.13	ns	.01	ns	**.17**	**<0.05**
	Olt	.10	ns	.10	ns	.11	ns	.07	ns
	Vâlcea	.02	ns	.09	ns	.02	ns	.06	ns
	Gorj	.02	ns	.03	ns	.02	ns	.03	ns
	Argeş	.02	ns	.02	ns	.02	ns	.03	ns
	Dâmboviţa	.04	ns	.09	ns	.03	ns	.06	ns
	Prahova	.02	ns	.07	ns	.02	ns	.02	ns
	Buzău	.02	ns	.01	ns	.01	ns	.03	ns
	Teleorman	.11	ns	.14	ns	.02	ns	**.20**	**<0.05**
	Brăila	.12	ns	**.31**	**<0.001**	**.15**	**<0.05**	.02	ns
	Giurgiu	.02	ns	.03	ns	.05	ns	.02	ns
	Ilfov	.03	ns	.03	ns	.02	ns	.01	ns
	Călăraşi	.13	ns	.13	ns	.04	ns	**.24**	**<0.05**
	Ialomiţa	.09	ns	.07	ns	.02	ns	.02	ns
Maize	Mehedinţi	**.36**	**<0.001**	**.36**	**<0.001**	**.18**	**<0.05**	**.37**	**<0.001**
	Dolj	**.33**	**<0.001**	**.45**	**<0.001**	**.27**	**<0.01**	**.24**	**<0.05**
	Olt	**.41**	**<0.001**	**.46**	**<0.001**	**.32**	**<0.001**	**.28**	**<0.001**
	Vâlcea	**.40**	**<0.001**	**.52**	**<0.001**	**.25**	**<0.05**	**.30**	**<0.01**
	Gorj	**.47**	**<0.001**	**.55**	**<0.001**	**.45**	**<0.001**	**.39**	**<0.001**
	Argeş	**.32**	**<0.001**	**.45**	**<0.001**	**.43**	**<0.001**	**.36**	**<0.001**
	Dâmboviţa	**.39**	**<0.001**	**.39**	**<0.001**	**.42**	**<0.001**	**.25**	**<0.05**
	Prahova	**.54**	**<0.001**	**.40**	**<0.001**	**.44**	**<0.001**	**.39**	**<0.001**
	Buzău	**.30**	**<0.001**	**.48**	**<0.001**	**.23**	**<0.05**	.14	ns
	Teleorman	**.46**	**<0.001**	**.36**	**<0.001**	**.33**	**<0.001**	.14	ns
	Brăila	**.37**	**<0.001**	**.43**	**<0.001**	**.37**	**<0.01**	**.17**	**<0.05**
	Giurgiu	**.19**	**<0.001**	**.19**	**<0.05**	.09	ns	.02	ns
	Ilfov	**.56**	**<0.001**	**.61**	**<0.001**	**.30**	**<0.01**	**.46**	**<0.001**
	Călăraşi	**.47**	**<0.001**	**.47**	**<0.001**	**.31**	**<0.001**	**.27**	**<0.05**
	Ialomiţa	**.44**	**<0.001**	**.39**	**<0.001**	.02	ns	.02	ns
Sunflower	Mehedinţi	.09	ns	.09	ns	.02	ns	**.14**	**<0.05**
	Dolj	.05	ns	**.18**	**<0.05**	.04	ns	.09	ns
	Olt	.14	ns	.12	ns	**.14**	**<0.05**	**.13**	**<0.05**
	Vâlcea	.09	ns	.09	ns	.08	ns	.09	ns
	Gorj	.08	ns	.06	ns	.02	ns	.05	ns
	Argeş	.02	ns	.02	ns	.09	ns	.07	ns
	Dâmboviţa	.07	ns	.10	ns	**.22**	**<0.05**	**.26**	**<0.05**
	Prahova	.07	ns	.07	ns	.12	ns	.02	ns
	Buzău	.13	ns	**.16**	**<0.05**	.07	ns	**.22**	**<0.05**
	Teleorman	.08	ns	.11	ns	.08	ns	.03	ns
	Brăila	.03	ns	.09	ns	.04	ns	.01	ns
	Giurgiu	.02	ns	.02	ns	.01	ns	.01	ns
	Ilfov	.05	ns	.05	ns	.03	ns	**.15**	**<0.05**
	Călăraşi	.07	ns	.07	ns	.04	ns	.06	ns
	Ialomiţa	.06	ns	.05	ns	.01	ns	.02	ns

– Heat stress-maize yield relationship showed most widespread decreases in statistical significance (10 out of the total 15 counties), associated to the predictor referring to the persistent heat stress spells (HSSdurmax). The results of the regression analysis after filtering procedure suggest that this heat stress predictor could produce little detrimental effects on maize yields in Dâmboviţa, Buzău, Brăila, Teleorman and Ialomiţa. An opposite situation was found for the HSDD predictor, for which there were only few counties showing losses in the statistical significance of heat stress-maize crop response (Argeş, Dâmboviţa and Giurgiu).

5. CONCLUSIONS

We have analysed the changes in heat stress characteristics (frequency and duration) in the warming seasonal climate of 1961–2013 and their effects on the annual yield anomalies of three major crops recorded between 1990 and 2013 in the Oltenia and Muntenia cropping regions. Both regions are under a clear and statistically significant summer warming, which was estimated faster and stronger by maximum temperature values (daytime) at rates of over 2.5°C/53 years. The most affected cropping region is Muntenia, especially in some areas in the Danube Floodplain (e.g. Zimnicea, Giurgiu, Călăraşi and Feteşti). July and August were found the largest contributors to seasonal warming by their maximum temperature values (2.7–3.0°C/53 years). The frequency of hot summers (two-to-three standard deviations) in southern Romania amounted 2–4 cases/period: 2012 and 2007 (throughout the study region); and 2000 and 2003 (in some areas). These summers were also among the driest in record in both regions.

In the recent years, persistent episodes of extreme heat have become a common weather feature in summer. The trends analysis of heat stress characteristics over 1961–2013 shows an increase in the frequency and duration of extreme summer heat in both cropping regions, mainly in their southernmost areas. All trends are highly statistically significant ($p<0.01$–0.001). The seasons of significant heat stress by means of all four selected indices, were 2000, 2007 and 2012, also known for their prominent soil water deficits and severe droughts. At monthly scale, increasing trend values were particularly large in July and August (the months of high heat stress sensitivity for maize and sunflower and of peak water demand for maize), threatening the yields of crops with harvesting in fall (maize and sunflower). Here are the counties where the estimated slopes of heat stress trends are in general the largest: Dolj, Olt, Teleorman and Giurgiu.

This analysis shows different and spatially variable crop yield sensitivities to extreme heat. Fitting the statistical relationships between crop production and the four selected heat stress metrics to decompose the detrimental effects of extreme heat, we aimed to estimate the strength and direction of the corresponding relationships at county scale (NUTS3). The main conclusions are summarized below:

– There is a good correspondence between the negative crop yield anomalies and the warm (and dry) character of the extended summer season (May–September), highly visible during the hot and dry years of 2000, 2007 and 2012. The counties which experienced substantial crop yield failures during those years were Mehedinţi, Dolj, Gorj, Olt, Teleorman and Giurgiu;

– *Summer heat stress* is a key yield *limiting factor* in the *crop production of maize* in most counties. Selected heat stress indices allowed explaining 17 to 55% (on average) of the annual variability of yields at county level. Among heat stress indices, HSD and HSDD were found as best predictors (19 up to 61%), followed by HSSfr (18–45%), while HSSdurmax was found to explain 24 up to 36% and only sparsely (in the Mehedinţi, Dolj, Teleorman and Călăraşi);

– During the hot and droughty summers of 2000, 2007 and 2012, the detrimental effect of heat stress on crop yields was worsened by the lack of efficient water compensations through irrigations (generally below 5% in Oltenia and 7% in Muntenia). Rehabilitation of the existing irrigation infrastructure emerges as an important adaptation measure to reduce the vulnerabilities and future impacts of heat stress on national food security;

– There is a strong (good-to-excellent in the case of maize and fair-to-good for sun flower and wheat) and negative relationship between the annual production and seasonal the heat stress over 1990–2013;

– Heat stress could be considered an important predictor of crop yield failures, especially for maize crops. After filtering the data to exclude the influence of the very warm and droughty summers of 2000, 2007 and 2012, the heat stress-maize yield relationship maintained its direction (negative) for all crops and in all counties of the two regions, but decreased in its strength and significance. These changes were particularly obvious for maize crops, mostly by means of HSD and HSDD heat stress predictors. HSSdurmax factor was found to produce the weakest effects on maize yields, especially in Dâmboviţa, Buzău, Brăila, Teleorman and Ialomiţa counties;

– High daytime temperatures showed less detrimental influences on the yields of summer harvesting crops (winter wheat) and good high temperature and drought resistance (sunflower).

Our results confirm previous findings of regional disparities in climate change impacts on crop production. However, as temperature thresholds are well-defined and distinct for each crop plant, further investigations on the mechanisms and processes involved in the key development stages of crops, which could influence statistical correlations between extreme heat and the final crop yield, remain as a perspective work. Further analyses at finer spatial and temporal scales, using longer time-series of crop production and climate data, would be also beneficial to improving our current results, for better distinguishing and decoupling climate change effects from the broad socio-economic context within which the crop yield gains and losses evolved.

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REFERENCES

Balotă, M., Rees, D., Reynolds, M.P. (1997), *Chlorophyll fluorescence parameters associated with spring wheat yield under hot, irrigated conditions*, Proceedings of Int. Sym. Of Drought and Plant Production, Belgrade (Sept. 17–20): 373–382.

Barbu, N., Feorgescu, F., Ştefănescu, V., Ştefan, S. (2014), *Large-scale mechanisms responsible for heat waves occurrence in Romania*, Rom. J. Phys., 59 (9–10): 1109–1126.

Bojariu, R., Bîrsan M.-V., Cică, R., Velea, L., Burcea, S., Dumitrescu, Al., Dascălu, S.I., Gothard, M., Dobrinescu, A., Cărbunaru, F., Marin, L. (2015), *Schimbările climatice – de la bazele fizice la riscuri şi adaptare*, Edit. Printech, Bucureşti, 200 p.

Busuioc, A., Caian, M., Cheval, S., Bojariu, R., Boroneanţ, C., Baciu, M., Dumitrescu, Al. (2010), *Variabilitatea şi schimbarea climei în România*, Edit. Pro Universitaria, 226 p.

Busuioc, A., Dumitrescu, Al., Soare, E., Orzan, A. (2007), *Summer anomalies in 2007 in the context of extremely hot and dry summers in Romania*, Romanian Journal of Meteorology, **9**, *1–2*.

Busuioc, A., Dobrinescu, A., Bîrsan, M-V., Dumitrescu, A., Orzan, A. (2015), *Spatial and temporal variability of climate extremes in Romania and associated large-scale mechanisms*, Int. J. Climatol., 35: 1278–1300.

Ciais, P., Reichstein, M., Viovy, N., Granier, A., Ogée, J., Allard, V., Aubinet, M., Buchmann, N., Bernhofer, C., Carrara, A., Chevallier, F., De Noblet, N., Friend, A.D., Friedlingstein, P., Grünwald, T., Heinesch, B., Keronen, P., Knohl, A., Krinner, G., Loustau, D., Manca, G., Matteucci, G., Miglietta, F., Ourcival, J.M., Papale, D., Pilegaard, K., Rambal, S., Seufert, G., Soussana, J.F., Sanz, M.J., Schulze, E.D., Vesala, T., Valentini, R. (2005), *Europe-wide reduction in primary productivity caused by the heat and drought in 2003,* Nature, 437: 529–533.

Chimenti, CA., Hall, AJ., López, MS. (2001), *Embryo-growth rate and duration in sunflower as affected by temperature*, Field Crops Res., 69: 81–88.

Christidis, N., Jones, GS., Stott, PA. (2015), *Dramatically increasing chance of extremely hot summers since the 2003 European heatwave*, Nature Climate Change, 5: 46–50.

Cod de bune practici agricole în contextul schimbărilor climatice actuale şi previzibile (2014), Ministerul Agriculturii şi Dezvoltării Durabile, Bucureşti: 171 p.

Croitoru, A.E., Piticar, A. (2012), *Changes in daily extreme temperatures in the extra-Carpathians regions of Romania*, International Journal of Climatology, 33 (8): 1987–2001.

Croitoru, A.E, Holobaca, IH, Lazar, C, Moldovan, F, Imbroane, A. (2012), *Air temperature trend and the impact on winter wheat phenology in Romania*. Climatic Change. 111: 393–410.

Croitoru, A.E., Piticar, A., Dragotă, C.S., Burada, D.C. (2013), *Recent changes in reference evapotranspiration in Romania*, Global and Planetary Change, 111: 127–36.

De la Haba, P., De la Mata, L., Molina, E., Agüera, E. (2014), *High temperature promotes early senescence in primary leaves of sunflower* (*Helianthus annuus* L) plants, Can. J. Plant. Sci. 94: 659–669.

De la Mata, L., De la, Haba P., Alamillo, JM., Pineda, M., Agüera, E. (2013), *Elevated CO2 concentrations alter nitrogen metabolism and accelerate senescence in sunflower (Helianthus annuus L) plants*. Plant Soil Environ., 59: 303–308.

Deryng, D., Conway, D., Ramankutty, N., Price, J., Warren, R. (2014), *Global crop yield response to extreme heat stress under multiple climate change futures*, Environmental Research Letters, 9(3).

Dumitrescu, A., Birsan, M.-V. (2015), *ROCADA: a gridded daily climatic dataset over Romania (1961–2013) for nine meteorological variables*, Natural Hazards, 78(2): 1045–1063.

Dumitrescu, A., Bojariu, R., Bîrsan, M.-V., Marin, L., Manea, A (2015), *Recent climatic changes in Romania from observational data (1961–2013)*, Theor. Appl. Climatol., 122 (1–2): 111–119.

Entwisle, B., Stern, P.C., (Eds.) (2005), *Population, land use and environment: research directions*, National Research Council (US) Panel on New Research on Population and the Environment, National Academies Press, Washington DC., 330p.

Fabian, G., Gomoiu, E. (1981), *Relaţia dintre capacitatea de asimilare şi unii factori de stres ecologic la porumb*, Probleme de genetică teoretică şi aplicată, XIII, 2: 81–96.

Harris, HC., McWilliams, JR., Mason, WK. (1978), *Influence of temperature on oil content and composition of sunflower seed*. Aust J Agric Res 29: 1203–1212.

Hatfield, JL., Prueger, JH. (2015), *Temperature extremes: Effect on plant growth and development*, Weather Clim. Extremes 10: 4–10.

Iizumi, T., Ramankutty, N. (2015), *How do weather and climate influence cropping area and intensity?*, Global Food Security, 4: 46–50.

IPCC AR5 (2014), *Climate change 2014: Synthesis Report*. Contribution of Working Groups I, II, III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland: 151 p.

Kottek, M., Grieser, J., Beck, C., Rudolf ,B., Rubel, F. (2006), *World map of Köppen-Geiger climate classification updated*, Meteorologische Zeitschrift, 15(3): 259–263.

Lazăr, C., Lazăr, D.A. (2010), *Simulation of temperature increase on winter wheat yields and development in south–eastern Romania*. Romanian Agric Res 27:7–15.

Lobell, D.B., Schlenker, W., Costa-Roberts, J. (2011), *Climate trends and global crop production since 1980*, Science, 333(6042): 616–620.

Luterbacher, J., Werner, J.P., Smerdon, J.E., Fernández-Donado, L., González-Rouco, F.G., Barriopedro, D., Ljungqvist, F.C., Büntgen, U., Zorita, E., Wagner, S., Esper, J., McCarroll, D., Toreti, A., Frank, D., Jungclaus, J.H., Barriendos, M., Bertolin, C., Bothe, O., Brázdil, R., Camuffo, D., Dobrovolný, P., Gagen, M., García-Bustamante, E., Ge Q., Gómez-Navarro, J.J., Guiot, J., Hao, Z., Hegerl, G.C., Holmgren, K., Klimenko, V.V., Martín-Chivelet, J., Pfister, C., Roberts, N., Schindler, A., Schurer, A., Solomina, O., von Gunten, L., Wahl, E., Wanner, H., Wetter, O., Xoplaki, E., Yuan, N., Zanchettin, D., Zhang, H., Zerefos, C. (2016), *European summer temperatures since Roman times*, Environmental Research Letters, 11.

Meluţ, L.C., Dincă, V., Mihai, T. (2014), *Aspecte privind conceptul de stres, arşiţă şi secetă la cultura de porumb*, Agricultura Transilvăneană, 21.

Micu, D., Havriş, L.-E., Dragotă, C.-S., Mărculeţ, C. (2014), *Changes in summer types in relation to drought occurence in the Romanian Plain region*, Aerul şi apa – componente ale mediului/ Air and water components of the environment, Edit. Casa Cărţii de Ştiinţă, Cluj-Napoca: 118–125.

Moriondo, M., Giannakopoulos, C., Bindi, M. (2011), *Climate change impact assessment: the role of climate extremes in crop yield simulation*. Clim Change 104: 679–701.

Neacşa, O., Berbecel, O. (1979), *Climatologie şi agrometeorologie*. Editura Didactică şi Pedagogică, Bucureşti.

Olesen, J.E., Trnka, M., Kersebaum, K.C., Skjelvåg, A.O., Seguin, B., Peltonen-Sainio, P., Rossi, F., Kozyra, J., Micale, F. (2011), *Impacts and adaptation of European crop production systems to climate change*, Europ. J. Agronomy, 34: 96–112.

Păltineanu, C., Mihăilescu, I.F., Seceleanu, I., Dragotă, C., Vasenciuc, F. (2007), *Using aridity indexes to describe some climate and soil features in Eastern Europe: a Romanian case study*, Theoretical Appl. Climatology, 90(3–4): 263–274.

Peltonen-Sainio, P., Jauhiainen, L., Trnka, M., Olesen, J.E., Calanca, P.L., Eckersten, H., Eitzinger, J., Gobin, A., Kersebaum, K.C., Kozyra, J., Kumar, S., Marta, A.D., Micale, F., Schaap, B., Seguin, B., Skjelvåg, A.O. & Orlandini, S. (2010), *Coincidence of variation in yield and climate in Europe*. Agriculture, Ecosystems and Environment, 139: 483–489.

Petcu, E., Georgescu, F., Arsintescu, A., Stanciu, D. (2001), *The effects of hydric stress on some characteristics of sunflower plants*, Romanian Agricultural Research, 16: 15–22.

Piticar, A., Croitoru, AE., Ciupertea, FA., Harpa, G.V. (2017), *Recent changes in heat waves and cold waves detected based on excess heat factor and excess cold factor in Romania*, Int. J. Climatol., doi: 10.1002/joc.5295.

Porter, J.R., Gawith, M. (1999), *Temperatures and the growth and development of wheat: a review*, Eur. J. Agron. 10: 23–36.

Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B., Travasso, M.I. (2014), *Food security and food production systems*, in *Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects*: 485–533. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, and New York, USA, Cambridge University Press.

Prăvălie, R., Patriche, C.V., Sîrodoev, I., Bandoc, G., Dumitraşcu, M., Peptenatu (2017), *Water deficit and corn productivity during post-socialist period. Case study: Southern Oltenia drylands, Romania*, Arid Land Research and Management, 30(3): 239–257.

Rojas-Downing, M.M., Nejadhashemi, P.A., Harrigan, T., Woznicki, S.A. (2017), *Climate change and livestock: impacts, adaptation and mitigation*, Climate Risk Management, 16: 145–163.

Rondanini, D., Savin, R., Hall, A.J. (2003), *Dynamics of fruit growth and oil quality of sunflower (Helianthus annuus L) exposed to brief intervals of high temperature during grain filling*, Field Crops Res 83: 79–90.

Rondanini, D., Mantese, A., Savin, R., Hall, A.J. (2006), *Responses of sunflower yield and grain quality to alternating day/night high temperature regimes during grain filling: effects of timing, duration and intensity of exposure to stress*, Field Crops Res 96: 48–62.

Russo, S., Sillmann J., Fischer E.M. (2015), *Top ten European heatwaves since 1950 and their occurrence in the coming decades*, Environ. Res. Lett., 10.

Sandu, I., Mateescu, E., Vătămanu, V. (2010), *Schimbări climatice în România şi efectele asupra agriculturii.* SITECH Publishing House, Craiova: 406 p.

Sandu, I., Mateescu, E. (2014), *Schimbări climatice actuale şi previzibile în România,* în volumul Schimbări climatice – provocare majoră pentru cercetarea agricolă, Editura Academiei Române, Bucureşti: 17–36.

Semenov, M., Shewry, P.R. (2011), *Modelling predicts that heat stress, not drought, will increase vulnerability of wheat in Europe*, Nat. Sci. Rep. **1** 66.

Siebert, S., Ewert, F. (2014), *Future crop production threatened by extreme heat*, Environmental Research Letters 9.

Stott, P.A., Stone, D.A., Allen, M.R. (2004), *Human contribution to the European heatwave of 2003*, Nature, 432.

Strategia Naţională pentru Schimbări Climatice 2013–2020 (2013), Ministerul Mediului şi Schimbărilor Climatice (http://mmediu.ro/app/webroot/uploads/files/Strategia-Nationala-pe-Schimbari-Climatice-2013-2020.pdf, accesat în data de 05.10.2017)

Ţerbea, M., Vrânceanu, A.V., Petcu, E., Craiciu, D.S., Micuţ, G. (1995), *Phsyhological response of sunflower plants to drought*, Romanian Agricultural Research, 3: 61–67.

Vlăduț, A, Onțel, I. (2013), *Summer air temperature variability and trends within Oltenia Plain,* Journal of the Geographical Institute "Jovan Cvijic" SASA, Vol. 63/ no.3 DOI: 10.2298/IJGI1303371V. UDC: 551.524. pp. 371–381, ISSN 0350-7599.

UNSDIR (2003), *Impact of summer 2003 heat wave in Europe*, on-line report (www.unisdr.org/files/1145_ewheatwave.en.pdf, accessed on July 21, 2017).

Zampierin N., Ceglarn A., Dentenern F., Toretin A. (2017), *Wheat yield loss attributable to heat waves, drought and water excess at global, national and subnational scales*, Environmental Research Letters, 12(6).

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THE EFFECT OF PRECIPITATION ON RIVER RUNOFF IN ROMANIA'S REPRESENTATIVE BASINS

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Key-words: representative basins, runoff coefficient, natural background: geology, soil texture, slopes, forest-cover coefficient.

L'effet des précipitations sur l'écoulement de rivières dans les bassins représentatifs en Roumanie. Le document présente les principales réalisations dans le domaine du débit de l'eau, dans les petits bassins – dessous 50 km^2, montrant les résultats concernant l'influence des principaux facteurs de l'environnement naturel: géologie, relief (le versant du bassin), boisement, le type de sol, sur les caractéristiques de l'écoulement de l'eau de la rivière. Ces résultats ont été obtenus par des méthodes spécifiques: dans le cas de l'influence de la structure géologique, l'on a utilisé la méthode des marquages avec traceurs, la méthode hydrométrique et la méthode hydrologique. L'influence sur l'écoulement de surface d'autres facteurs (la topographie, la texture du sol, le boisement) a été mise en évidence par des relations de synthèse du coefficient de ruissellement dans les différentes conditions sur les précipitations qui ont généré l'écoulement, P(mm), et des précipitations précédentes, API_{10}(mm). Pour d'autres facteurs (la topographie, la texture du sol, le boisement) leur influence sur l'écoulement de surface, a été mis en évidence par des relations de synthèse du coefficient de ruissellement dans les différentes conditions sur les précipitations qui ont généré l'écoulement, P(mm), et des précipitations précédentes, API_{10}(mm). La dernière partie de cet article présente le rôle du coefficient de ruissellement dans la practique hydrologique, en particulier dans le calcul maximal du débit d'écoulement par de recommandations des méthodes appropriées: la méthode "rationnelle" et la méthode "q5".

1. INTRODUCTION

The river runoff is the result of some complex influences exerted by several factors, among which the most important ones are precipitation generating factors and air temperature. Also, an important influence on the runoff process have the conditioning factors: the nature of the geological subsoil, the area's relief, the soil and vegetation, which represent runoff conditions of the basin.

The formation process of runoff in small catchments is different from that in medium-sized and large ones. In the case of small river basins, the role of the physical-geographical factors, conditioning factors, on river runoff increases to a great extent.

The main objective of this paper is to present synthesis relations and tables containing runoff coefficient values under different conditions (rainfall, soil humidity, forest-cover coefficient, basin slope and soil texture), and to show how the results obtained could be used for practical applications and maximum discharge estimation in small basins by means of the genetic methods approach.

The results yielded by studies in Romania on small representative basins highlight their influence on the surface runoff of the main natural factors: topography, soil, vegetation, and geology (Miţă *et al.*, 2005; Miţă and Mătreaţă, 2003, 2005).

The representative basins (R.B.) are small river basins, with a surface of 40–50 km^2, in which the characteristics of the natural background – geology, relief, soil, and vegetation – including precipitation, can be found in other large river basins, too.

Being located in all the physical and geographical areas of Romania (Fig. 1), representative basins show a great diversity of geological, soil, relief, and vegetation conditions, and can therefore be used to determine surface-water runoff characteristics.

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Obtaining some correct values of runoff elements in small basins is also favoured by the fact that in such basins, not only natural background factors are determined with great accuracy, but also the triggering factor, that is precipitation.

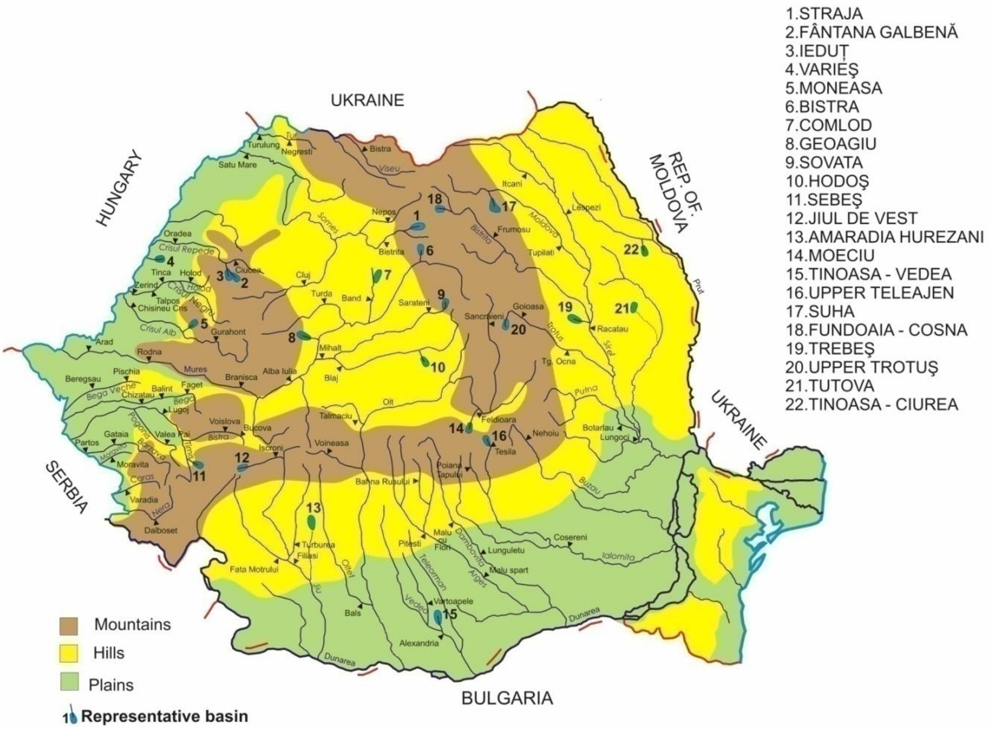


Fig. 1 – The map of representative basins in Romania (1988).

This aspect is important because the main syntheses of hydrological elements were made in the conditions of various characteristics of precipitation – quantity, intensity (Miţă and Mătreaţă, 2016).

2. THE INFLUENCE OF THE NATURAL BACKGROUND ON RUNOFF

2.1. The influence of geological structure

Studying the influence of geological structure on surface runoff became necessary especially in some areas where it was significantly reduced, or would completely disappear in the underground. In these areas it is mostly the water supply to localities and irrigation that are negatively affected.

The anomalies observed in the runoff regime are important also for the hydrological activity, due especially to the influence of the ecological structure on the hydric balance of those basins. A more detailed study was carried out on 10 representative basins.

The influence of karst on surface runoff in the Moneasa R.B.

In this paper, the geological structure of karst is taken into consideration, because it has occasionally a strong influence on the regime of some river surface runoff.

In what follows, the analysis focusses on the influence of karst on surface runoff in the Moneasa representative basin. The approach is similar also for their representative basins (Miţă and Mătreaţă, 2010).

The following methods underlie our analysis:

- research of the area to establish karst characteristics;
- hydrometrical measurements of discharges upstream and downstream of the obvious karst areas;
- tracer-marking to establish groundwater direction;
- hydrological synthesis relations.

Figure 2 presents the map of the Moneasa Basin, a tributary of the Crişul Alb river basin, as well as the Brătcoaia River, a tributary of the Crişul Negru river basin.

Tracer-markings with (fluorescein, rhodamine, etc.) and hydrometric measurements indicated that the losses reported in the Izoi Depression (Crişul Alb river basin), and in the Brătcoaia Depression (Crişul Negru river basin), alongside other losses (Fig. 2), are connected mainly with the Grota Ursului Spring (Fig. 3) (Miţă *et al.*, 2005).

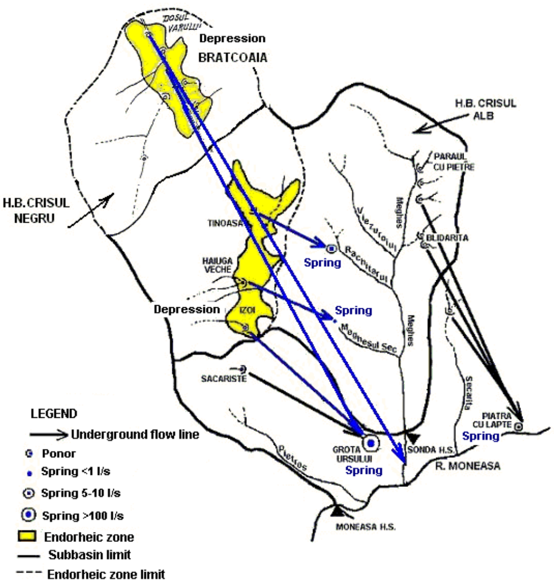


Fig. 2 – The Moneasa – Brătcoaia karst area. Underground trails from the Megheş – Moneasa hydrographic area (the Crişul Alb) – Brătcoaia (the Crişul Negru).

Fig. 3 – The Grota Ursului Spring –Moneasa R.B., where infiltrations from the Izoi and Brătcoaia depressions outflow.

In this way, the main areas of water infiltration in the underground and the trails of underground runoff were identified (Fig. 2).

At the same time, the synthesis relation between specific multiannual average discharge, q_{med}(l/s km^2) and basin average altitude, H_{med}(m), yielded the natural runoff regime, anomalies being quantitatively assessed in terms of a diminishing runoff for the karst-influenced sub-basins (eg. Megheş r.–Sonda h.s.), or the share of discharges (eg. r. Moneasa–Moneasa h.s.) (Fig. 4).

At the same time, the synthesis relation, detailed out for the Megheş sub-basin (Fig. 5), emphasizes the following:

- in the case of Sonda h.s., q_{med} value in the sythesis relation corresponding to H_{med}=681 m, results in q_{med}=18 l/skm^2. Thus $Q_{med}=q_{med}$ x F = 18x10=180 l/s.

The real value of discharge, resulting from the measurements made over a period of 33 years (1975–2008), is Q_{med}=84 l/s.

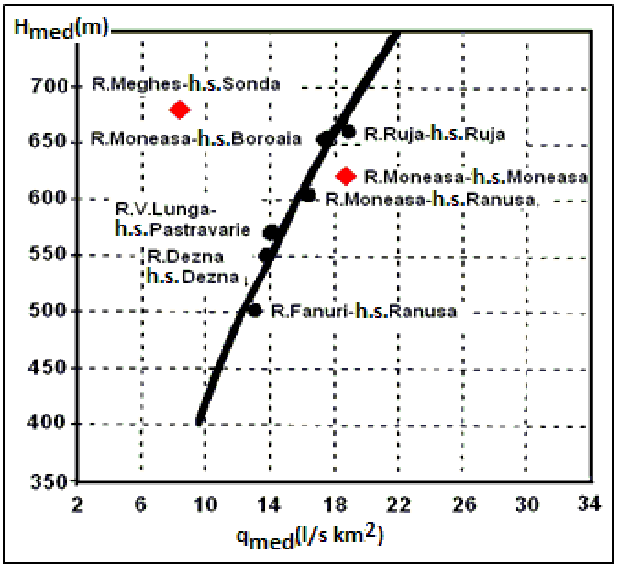


Fig. 4 – Relation q_{med} – H_{med} for the Moneasa – Dezna hydrographic space.

Thus, there is a deviation of 96 l/s of the recorded discharge value, that would have existed in normal runoff conditions (i.e. in the absence of karst):

$\Delta Q = Q_{med\ synthesis\ relation} - Q_{med\ true} = 180–84 = 96$ l/s

- in the case of the Izoi Depression (surface F=4.2km^2; average altitude H_{med}=800 m), the value in relation q_{med} (l/s km^2), corresponding to H_{med}=800 m, results in q_{med}=24.5 l/s km^2; consequently, Q_{med} = 103 l/s (Q_{med}=24.5 x 4.20).

The real value is **zero**, because the Izoi Depression is an endorheic karst region, the runoff being totally drained underground. The difference of current discharge versus the discharge that should correspond to the surface, is of 103 l/s, a discharge that would have been recorded, had the karst not existed.

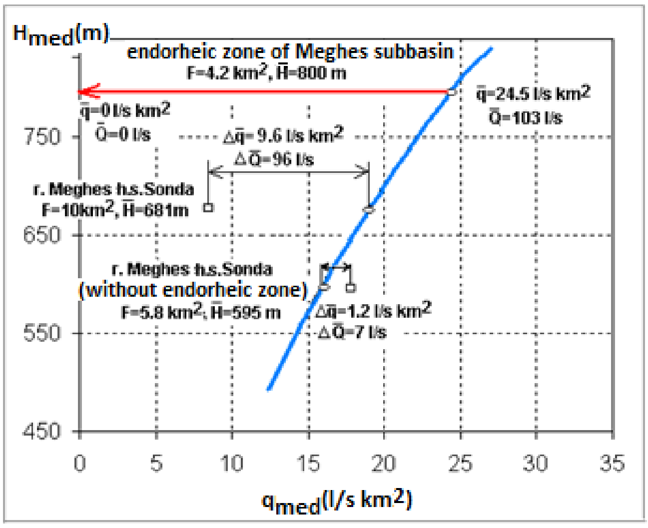


Fig. 5 – Water balance in Moneasa R.B., the Megheş sub-basin.

The discharge of 96 l/s, which is lower to what should have been under normal runoff conditions, recorded at Sonda h.s. can be explained by the absence of the share of discharge from the Izoi Depression, which is totally drained underground by various characteristic karst formations. This fact is also confirmed by establishing the discharge corresponding to surface $F=5.80km^2$, meaning Sonda h.s without the share of the Izoi Depression ($F=4.20km^2$). The value of 5.80 km^2 corresponding to this surface is $H_{med}=575$ m, the respective discharge being Q=q x F = 15 x 5.80= 87 l/s.

This value corresponding to what was recorded at Sonda h.s, confirms that the Izoi Depression was not involved in runoff.

2.2. The influence of relief on surface runoff

The influence of basin slope on the runoff coefficient. Relations highlighting this influence

The modality to demonstrate the influence of basin slope on runoff involved comparing the values of the runoff coefficient, α, recorded in basins that were differentiated in this respect.

Normally, values were compared by some rainfall quantities equal in all the basins. Also, the basins were considered to be similar in terms of soil texture, and vegetation, only the slope was different.

The basic relations obtained at all hydrometric stations within the representative basins, is

$$\alpha = f(P, API_{10})$$

where:

α – runoff coefficient;

P – the rainfall that generated the runoff (mm);

API_{10} – the rain fallen in the previous 10 days, calculated by the API model (the previous rain index) – that replaces soil humidity before runoff occurs (mm).

This type of relation (Fig. 6), highlights the influence of basin slope on the runoff coefficient, in the case of some basins with a different basin slope, but similar according to other natural background factors e.g. the soil texture and forest-cover coefficient.

The exemples refer to two hydrometric stations: Şendroaia (the Straja representative basin), and Moneasa (Moneasa representative basin).

The river basins corresponding to the two hydrometric stations are characterized by close forest-cover coefficient values, Cp (%): Cp=82% in the case of Şendroaia h.s and Cp=90.5% in the case of Moneasa, but also by a similar soil texture (medium texture).

The basin slope, Ib (%) is significantly different for the two basins (Ib=40.9% for the Moneasa river basin and only 12.9% for the Şendroaia one).

This difference represented also the reason for analysing its role in the variation of the runoff coefficient.

In Figure 6, the difference is noted of the two stations, and the basic relation $\alpha = f(P, API_{10})$.

In the case of some equal rainfall quantities (P=120 mm) that generated the flash-flood, for example, in the case of both basins, and of some rainfall quantities previously fallen ($API_{10}=40$ mm), value α=0.552 for the Moneasa h.s., with a basin slope Ib=40.9%; and of only 0.460 for the Şendroaia h.s., value α=0.460 with a basin slope Ib=12.9%. Thus, there is a difference of $\Delta\alpha=0.092$.

Synthesis relation α = f(Cp, Ib)

This relation was obtained based on the data yielded by the representative basins; it holds for the main soil textures – heavy, medium, and light – provided P=125 mm and $API_{10}=40$ mm (Fig. 7).

In the case of such relations, even greater differences between values α occur due to the differences between basin slope values.

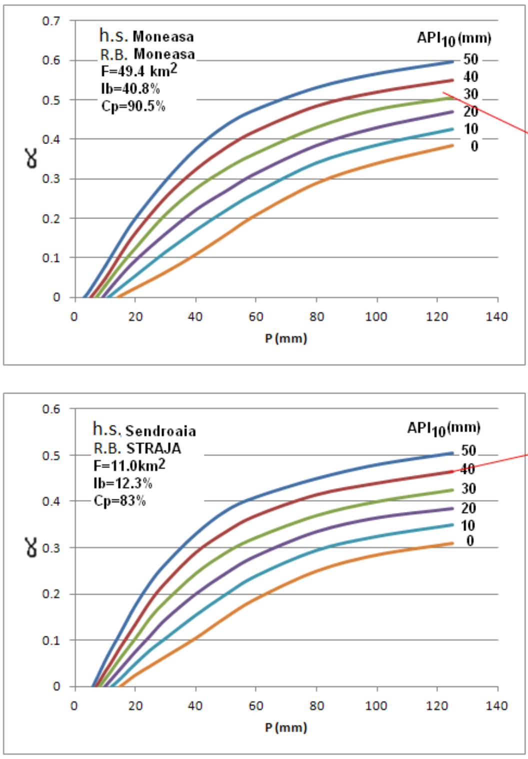


Fig. 6 – Relation α = f(P, API_{10}) for the Moneasa and Şendroaia basins, under a medium soil texture.

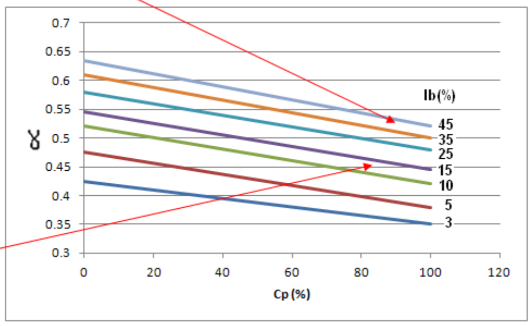


Fig. 7 – Synthesis relation α = f(Cp, Ib) for a medium soil texture provided P=125 mm and API_{10}=40 mm.

Thus, in the synthesis relation (Fig. 7), referring to a medium soil texture, provided the forest-cover coefficient is Cp=0%, the resulting value is α=0.635 for a slope Ib=45% and α of only 0.423 for a slope Ib=3%. Thus, a difference of Δα=0.212, which means an α values by 33.5% lower in the case of Ib=3%, compared to α value in the case of Ib=45%.

The synthesis relation in Figure 7 also confirms the veracity of values α obtained at the hydrometric stations, because these values are within the limits of the forest-cover coefficient – Cp(%) and of the basin slope – Ib(%) corresponding to these basins.

In the Moneasa basin α=0.530, with slope limits between 35% and 45% and Cp=90.4%; also in the Şendroaia basin α=0.453, within slopes limits between 10% and 15% and Cp=82%.

2.3. The influence of soil texture on runoff coefficient variation. Relations highlighting this influence

Relations highlighting the influence of soil texture on the runoff coefficient in the particular case of some river basins

Highlighting the role that the soil texture has on the runoff coefficient was made by relation α = f(P, API_{10}) elaborated for several basins characterized by certain soil textures.

This time, the analysis covered the data obtained from groups of basins with a close forest-cover coefficient, Cp(%) and a basin slope, Ib(%), but distinguished by the soil texture.

Figure 8 exemplifies relation α = f(P, API_{10}) for the Lipova River at Lipova h.s. (Tutova representative basin), which has a medium-heavy soil texture, and the same type of relation for the hydrometric station upstream Căpriţa h.s., on the Ieduţ River, the Ieduţ R.B., featuring a light soil texture. Morpho-hydrographic characteristics are shown in the respective graphs.

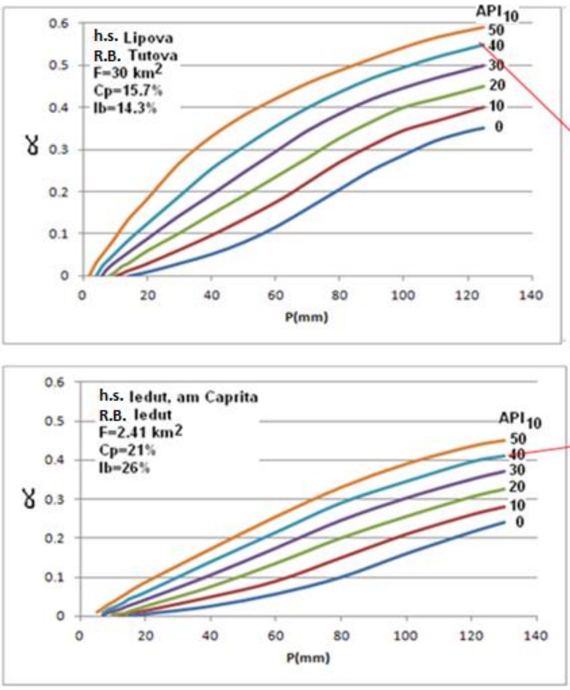


Fig. 8 – Relation α = f(P, API_{10}) for two basins with close slopes, but different soil textures: Lipova h.s. (medium-heavy texture), Ieduţ h.s. (light texture).

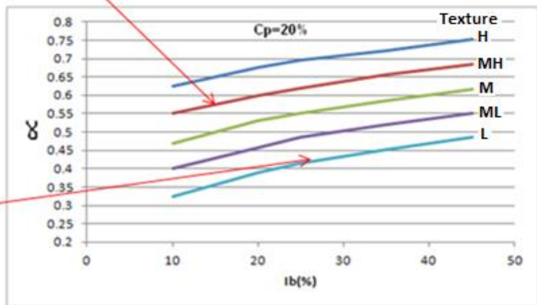


Fig. 9 – Sythesis relation α = f(Ib, Cp) for several soil textures, provided P=125 mm, API_{10}=40 mm (H-heavy texture, MH-medium-heavy texture, M-medium, ML-medium light texture, L-light texture).

In the case of the two basins, the values of the forest-cover coefficient, Cp(%), and of the basin slope, Ib(%), are quite close, as is the difference of soil texture: medium-heavy in the representative Tutova R.B., and light in the Ieduţ R.B.

With values of P=125 mm and API_{10}=40 mm, there is a value difference of α determined by the different soil texture: α=0.560 for the Tutova basin (the Lipova River – Lipova h.s.) with a medium – heavy texture and α=0.410 for the Ieduţ basin (the Ieduţ River – h.s. upstream Căpriţa h.s.), which has a light texture. Thus, a significant difference between α values (Δα=0.150) does exist.

Highlighting the manner in which soil texture influences runoff, and implicitly the runoff coefficient, was made by comparing values α corresponding to some basins, with a more favourable texture, to the runoff (medium-heavy, in the case of the Lipova sub-basin), with values α corresponding to some basins with a less favourable texture (light in the case of the Ieduţ basin).

Also, in this case, the values obtained in the conditions of the representative basins Lipova and Ieduţ are correctly inserted into the synthesis relations (Fig. 9): the medium-heavy texture of the Lipova basin α=0.560, and the light texture of the Ieduţ basin α=0.410.

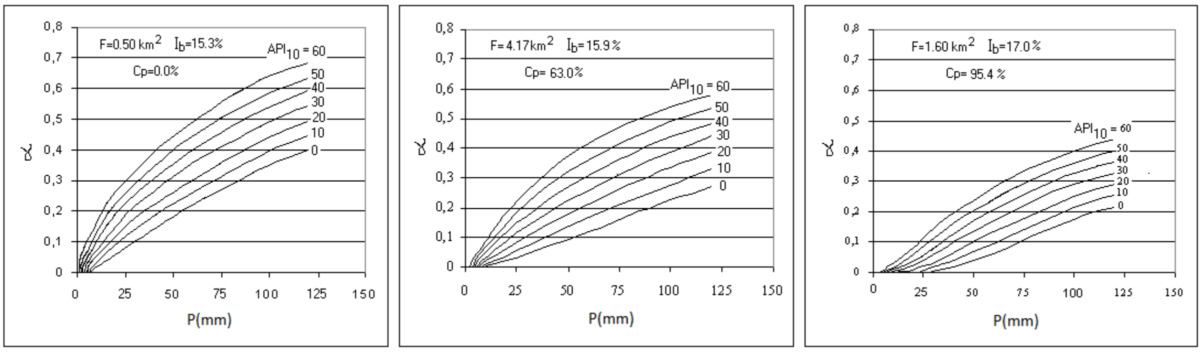
2.4 The influence of forest cover on the runoff coefficient

The influence of afforestated areas on the runoff coefficient is a most complex one, because several forest components, all in the runoff, participate in diminishing it (Abagiu, 1979; Miţă and Crângaşu, 1986). Thus, a synthesis was made of the following types of retentions (Miţă and Mătreaţă, 2008; Stan *et al.*, 2014):

- *the retention of rainfall in the tree crowns* Rc(mm);
- *the retention of rainfall in the forest litter* Rl(mm);

- *the retention of rainfall in the process of vegetation development;*
- *the retention of rainfall in forest soil* Rs(mm).

In the conditions in which the other characteristics of the natural background – soil type and basin slope – are very close, the values of the runoff coefficient, α, are clearly hightlighted in the case of some equal rainfall values, hc(mm) (Fig. 10). Thus, very high values of α are observed for the Bolovani sub-basin, completely deforested, while in the Humăria sub-basin, the higher forest-cover coefficient, Cp=95.4%, lowest runoff coefficient values are recorded.



Bolovani sub-basin *Tinoasa sub-basin* *Humăria sub-basin*

Fig. 10 – Relations α = f(P, API_{10}) in the Tinoasa – Ciurea representative basin.

But, the runoff coefficient, determined for these flash-floods, indicates the global influence of forest components on the runoff, that is, the influence of rainfall retention in the tree crowns – Rc(mm), and in the forest litter – Rl(mm), including infiltration in the forest soil which has a great water storage capacity – Rs(mm) (Fig. 10).

A detailed analysis of the forest components water retention capacity is given in Figure 11, the results showing that forest soil retention is the most important interception recorded in the afforestated areas (Miţă and Mătreaţă, 2004).

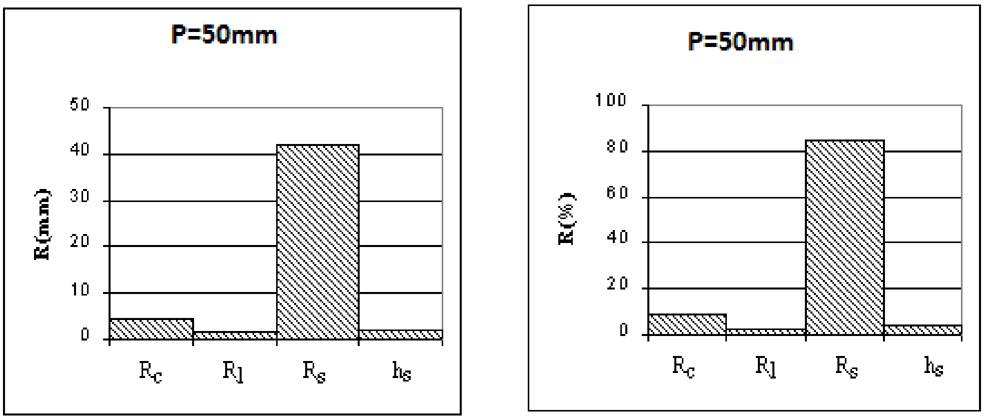


Fig. 11 – Interception (mm%)in the crown, litter, soil and the drained layer (hs) in the case of a 50 mm rainfall (API_{10}=0mm) – Humăria h.b. (C_p=95.4%).

It is worth-mentioning that the interception role of rainfall by the forest is maintained for a period of several years, even after the forest had been cut.

This is due to the main interception factors (the soil and the radicular systems), which favour infiltration, preserve their influence in deforested areas. At the same time, it must be underlined that maintaining deforestation lasts for a long period of time, repeated flash-floods, may produce soil washing, ravines occurring that may lead to soil degradation as the forest loses its protective role.

Synthesis relations highlighting the influence of the forest on the runoff coefficient α = f(Cp, Ib)

This type of relations (Fig. 12), obtained from representative basins in Romania, underscore lower runoff coefficient values, as the forest-cover coefficient increases.

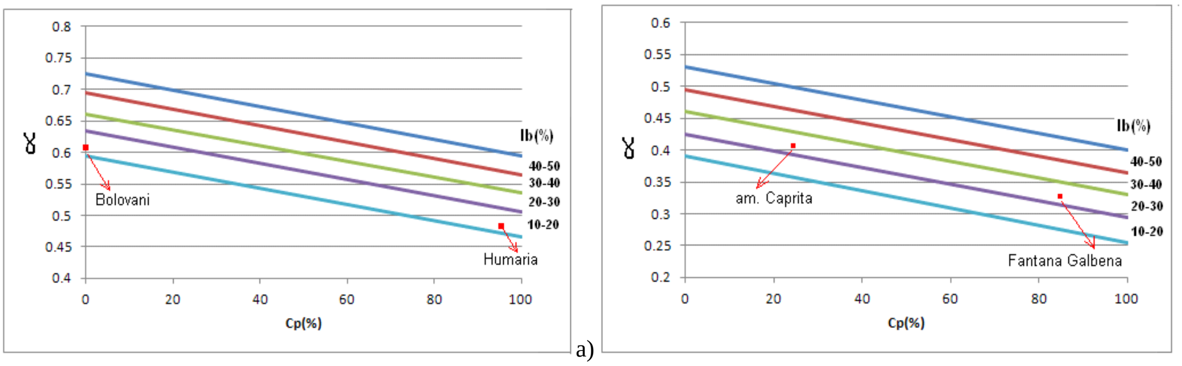


Fig. 12 – Relations α = f(Cp, Ib) provided P=125mm, API_{10}=40mm for basins with medium-heavy texture a) and basins with light texture b).

Noteworthy, the values of the runoff coefficient corresponding to average-heavy texture basins (Humăria α=0.610 and Bolovani α=0.480) are in the Ib=10–20% slope category (Fig. 12a), while values corresponding to light-texture basins (Ieduţ am. Căpriţa α=0.410 and Fântâna Galbenă α=0.325) are in the Ib=20–25% slope category (Fig. 12b).

3. COAXIAL RELATIONS AND SYNTHESIS TABLES TO DETERMINE THE RUNOFF COEFFICIENT

As shown in the previous chapters, the basic relations obtained in the particular case of a river basin of α = f(P, API_{10}) (Fig. 13), helped obtaining synthesis relations similar to those given in the analysis of the main natural background factors that influence surface runoff.

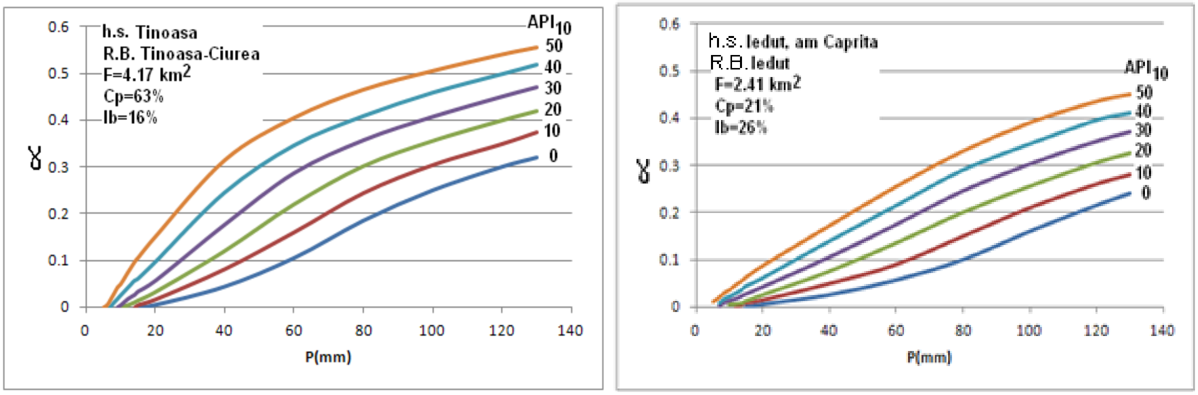


Fig. 13 – Relations α = f(P, API_{10}) for the representative basins: Ciurea (medium-heavy texture) and Ieduţ (light texture).

Also, based on all the previously-mentioned relations, COAXIAL RELATIONS were elaborated to determine the runoff coefficient under different conditions, such as rainfall quantity, P(mm), precipitation fallen on the previous 10 days, API_{10} (calculated by the API model), basin slope, Ib(%), forest-cover coefficient, Cp(%), and soil texture (Fig. 14).

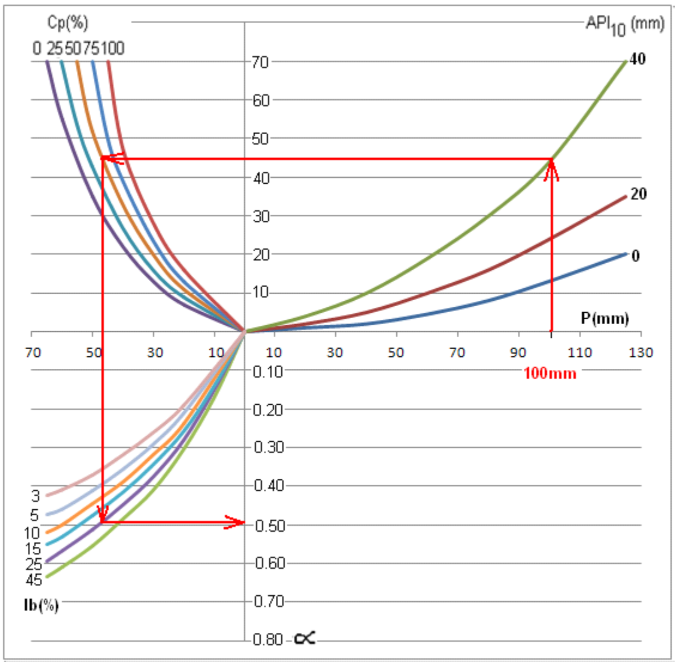


Fig. 14 – The coaxial relation for determining the runoff coefficient on all medium texture river basins.

In the example given in Fig. 14, the value of the runoff coefficient is α = 0.500 for P=100 mm, API_{10}=40 mm, Cp=50%, Ib=25%.

Continuing the analysis on river basins, synthesis tables of runoff coefficient values were elaborated for different situations: rainfall P(mm), API_{10}(mm), Cp(%), Ib(%) and soil texture (Miţă, 2017).

The runoff coefficient values provided P=125 mm, API_{10}=40 mm for different soil textures, are specified in the table 1.

Table 1

Runoff coefficient values provided P=125 mm, API_{10}=40 mm.

HEAVY TEXTURE

Cp(%)/ Ib(%)	**0**	**25**	**50**	**75**	**100**
1	0.370	0.340	0.313	0.282	0.262
3	0.525	0.500	0.472	0.440	0.417
5	0.590	0.560	0.533	0.500	0.470
10	0.640	0.612	0.577	0.550	0.520
15	0.680	0.652	0.612	0.585	0.550
25	0.725	0.695	0.660	0.625	0.590
35	0.760	0.730	0.696	0.662	0.620
45	0.790	0.760	0.726	0.690	0.650
60	0.830	0.795	0.765	0.730	0.685

MEDIUM TEXTURE

Cp(%)/ Ib(%)	**0**	**25**	**50**	**75**	**100**
1	0.273	0.257	0.244	0.235	0.222
3	0.423	0.408	0.390	0.370	0.350
5	0.470	0.451	0.430	0.405	0.380
10	0.520	0.495	0.475	0.448	0.420
15	0.547	0.530	0.503	0.476	0.446
25	0.580	0.562	0.536	0.510	0.480
35	0.610	0.587	0.561	0.530	0.500
45	0.635	0.610	0.582	0.553	0.520
60	0.670	0.635	0.605	0.570	0.537

LIGHT TEXTURE

Cp(%)/ Ib(%)	**0**	**25**	**50**	**75**	**100**
1	0.215	0.204	0.190	0.180	0.158
3	0.340	0.327	0.310	0.290	0.265
5	0.378	0.365	0.345	0.323	0.303
10	0.418	0.397	0.380	0.355	0.335
15	0.447	0.430	0.407	0.380	0.360
25	0.472	0.452	0.435	0.403	0.380
35	0.492	0.470	0.452	0.425	0.400
45	0.510	0.487	0.467	0.443	0.418
60	0.530	0.505	0.480	0.460	0.430

The values in this table are a very useful tool for assessing maximum discharges in small basins, by using the genetic methods of calculation.

Coaxial relations of the same type and synthesis tables were also elaborated for different agricultural crops (Miţă and Ene, 1985; Miţă, 2017).

4. THE ROLE OF THE RUNOFF COEFFICIENT IN CALCULATING MAXIMUM DISCHARGES

The study of the runoff coefficient is important when it is included in the structure of the genetic methods of calculating maximum discharges.

One of the methods most often used in Romania is the “rational” method, and the method of specific maximum discharge “q5”.

The “rational” method is used to determine maximum discharges in basins with surfaces below 5 km^2:

$$\mathbf{Q_{max1\%} = 16.67 * i_{p1\%} * \alpha * F \ m^3/s}$$

where,

$Q_{max1\%}$ – maximum discharge 1% exceeding probability (m^3/s);

α – runoff coefficient;

$i_{p1\%}$ – rain intensity probability 1% (mm/min);

F –catchment surface (km^2);

16.67 – conversion coefficient from mm/min (for $i_{p1\%}$) and km^2 (for F) to m^3/s for Q_{max}.

The method of maximum discharge per unit area “q5” is useful for determining maximum discharges in small basins with a surface between 5 and 50 km^2. It was proposed by P. Miţă in 1992 and included in the paper "Instructions for the calculation of the maximum runoff in small basins" (Miţă, 1997):

$$\mathbf{Q_{max1\%} = q_{5max1\%} * F^{n} * 10^{3}\ m^{3}/s}$$

where,

$Q_{max1\%}$ – maximum discharge 1% exceeding probability (m^3/s);

$q_{5max1\%}$ – is the specific maximum discharge 1% exceeding probability, corresponding to a 5 km^2 area (l/s km^2);

F –surface catchment (km^2);

n –reduction coefficient of the maximum discharge in terms of basin surface.

This method starts by using the "rational" approach.

The method is especially recommended for homogeneous areas in terms of facies, and is useful when, within a hydrographic area, determining discharges in several basins with the surfaces between 5 and 50 km^2 is required.

Using this method is quite simple. First, $Q_{max1\%}$ (implicitly $q_{max1\%}$) is determined for a reference basin surface of 5 km^2, or a value close to it. This is normally done by the "rational" method.

According to the rational method, once $q_{5max1\%}$ obtained (which corresponds to a 5–km^2 surface, $Q_{max1\%}$ is determined for any basin with a surface between 5 and 50 km^2, using for F reduction coefficient n values (Table 2).

Table 2

The values of reduction coefficient "n".

F(km^2)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
5	1.00	0.994	0.989	0.984	0.979	0.974	0.970	0.968	0.965	0.963
6	0.959	0.957	0.954	0.952	0.950	0.948	0.946	0.944	0.942	0.940
7	0.939	0.937	0.935	0.933	0.929	0.927	0.925	0.923	0.921	0.919
8	0.917	0.916	0.915	0.914	0.913	0.912	0.910	0.908	0.906	0.904
9	0.902	0.901	0.900	0.898	0.897	0.896	0.894	0.893	0.892	0.890
10	0.886	0.881	0.874	0.864	0.854	0.844	0.838	0.834	0.829	0.824
20	0.818	0.815	0.811	0.807	0.803	0.800	0.796	0.793	0.790	0.786
30	0.782	0.780	0.778	0.776	0.773	0.771	0.768	0.766	0.764	0.761
40	0.760	0.759	0.758	0.757	0.756	0.755	0.753	0.751	0.749	0.747
50	0.746	0.745	0.744	0.743	0.742	0.740	0.739	0.738	0.737	0.735

It is worth-mentioning that reduction coefficient values of maximum discharge, in terms of basin surface "n", were determined such that they are continually decreasing from value 1 (of F with $Q_{max1\%} = 16.7*\alpha*i*F$), as basin surface increases.

Choosing the reference surface is also very important, so as to correspond as much as possible to the fascies throughout the study area.

5. CONCLUSIONS

The variation of water runoff was determined in a multitude of conditions, regarding both the characteristic rainfall and the physical and geographical factors.

The analysis of runoff formations in terms of different characteristic values was made by using historical monitoring data from the representative river basins situated in various particular conditions.

The results obtained were also due to the methods used, which were the most adequate for this kind of study.

The influence of geology was emphasised by analysing the influence of karst on the runoff processes within the Moneasa river basin, the results showing both reduced discharge in some river sectors, but also significant increase of discharge in other sectors.

Estimating the runoff coefficient under different conditions (basin slope, forest cover coefficient, soil type), for a certain precipitation amount and initial soil humidity, important variations of this parameter were obtained:

– In case of basins with a medium soil texture and no forest cover, the runoff coefficient is by 33.5% smaller for a basin slope of 3%, than the values obtained for a basin slope of 45%.

– In case of a medium soil texture and 25% basin slope, the runoff coefficient is by 17% smaller if the basin is fully forest-covered, compared to a no-forest-cover basin.

– In case of basins with a slope of 25% and forest cover coefficient of 50%, the runoff coefficient is by 34% smaller for a light soil texture than for a heavy soil texture.

The practical importance of runoff characteristics, especially of the runoff coefficient, results from using it in the computation of maximum runoff in small basins, being found in all genetic methods of assessing the runoff variable parameters.

REFERENCES

Abagiu, P. (1979), *Cu privire la capacitatea de retenţie a pădurii*, Buletinul informativ al ASAS, Bucureşti.

Miţă, P. (1997), *Instrucţiuni pentru calculul scurgerii maxime în bazine mici*, INHGA, Bucureşti.

Miţă, P. (2017), *Coeficientul de scurgere*, INHGA, Bucureşti.

Miţă, P., Ene, Al. (1985), *În problema scurgerii în cazul suprafeţelor acoperite cu diverse culturi agricole*, Sesiunea Anuală de Comunicări Ştiinţifice a INMH, Bucureşti.

Miţă, P., Crângaşu, Ştefania (1986), *Runoff modifications in forested areas*, Zeitcliff fur Geomorphologie supl. Bd. **59**, Stuttgard.

Miţă, P., Mătreaţă, Simona (2003), *Rolul zonelor împădurite asupra variaţiei scurgerii de suprafaţă*, Analele Universităţii Spiru Haret, No. **6**, pp. 17–24.

Miţă, P., Mătreaţă, Simona (2004), *Aspecte privind rolul hidrologic al pădurii,* Revista Pădurilor, No. **1**, pp. 36–40.

Miţă, P., Mătreaţă, Simona (2005), *Rezultate privind influenţa principalilor factori ai cadrului natural asupra scurgerii de suprafaţă.* Comunicări de Geografie, vol. **IX**, Edit. Universităţii, Bucureşti, pp. 293–297.

Miţă, P., Mătreaţă, Simona (2008), *Rolul diferit pe care-l are pădurea în cazul diverselor faze de regim ale scurgerii apei*, Silvologie, Vol. **VI**, Edit. Academiei Române, Bucureşti, pp. 239–264, ISBN 978-973-27-1702-8.

Miţă, P., Mătreaţă, Simona (2010), *Modificări semnificative ale scurgerii de suprafaţă semnalate în areale cu structuri geologice deosebite*, Revista Geografică, T. **XVII**. pp. 10–15, ISSN 1224-256 X.

Miţă, P., Mătreaţă, Simona (2016), *Representative basins in Romania. Synthesis of research results*, Edit. Didactică şi Pedagogică, Bucureşti, România, ISBN 978-606-31-0296-7.

Miţă, P., Orăşeanu, I., Corbuş, C. (2005), *Modalităţi de stabilire a influenţei cantitative a carstului asupra variaţiei scurgerii de suprafaţă în bazinul reprezentativ Moneasa*, Hidrotehnica, vol. **50**, No. *6*, Bucureşti, pp. 7–14.

Stan, F., Neculau, G., Zaharia, L., Toroimac, Ioana G. (2014), *Evapotranspiration variability of different plant types at Romanian experimental evapometric measurement station.* Climatologie, vol. **11**., pp. 85–90.

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CHANGING TEMPERATURE EXTREMES IN THE NORTHWEST HIMALAYAS

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Key-words: Himalayan region; North Kashmir river catchment region; Climate variability; Trend detection; Kashmir Valley.

Abstract. Fluctuation in Earth's climate occurs on different time-scales. The climate system is changing in response to both natural and human variables. The impacts of climate warming in mountainous regions are variable, because of large variations in altitude within small distances. The study focuses on a Himalayan region which is more susceptible to temperature fluctuations as has been reported by many studies. Moreover, the region is ecologically more sensitive to climatic fluctuations which could affect the eco-system services of the region. The entire water resource of the Kashmir Valley is a progeny of the Himalayas. The present paper aims to investigate the highest maximum temperature trend in the North Kashmir river catchment region from 1977 to 2011, using the Mann-Kendall and Sen Slope statistic which are robust statistical methods for calculating the trend in hydrometeorological parameters. The data have shown an upward trend for all the stations at α 0.001, 0.01, 0.05 and 0.1. The Pahalgam Station, which happens to be the highest altitude station taken up for the study, shows a rise in temperature extremes for the entire season. The increasing temperature extremes have resulted in the reduction of the snow and glacial cover which, in turn, has affected the hydrological characteristics of the river network in the study-area. The trend is more intense in the eastern part of the study-area, which happens to be the abode of large glaciers and snow fields.

1. INTRODUCTION

The first decade of the 21st century was the warmest recorded since modern measurements have been in place (1850). This was marked by dramatic climate and weather extremes, such as the European heat wave of 2003, the 2010 floods in Pakistan, the hurricane *Katrina* in the United States of America, the cyclone *Nargis* in Myanmar and long-term droughts in the Amazon Basin, Australia and East Africa (WMO, 2013). The mountains and the cold climate regions act as a primary indicator of climate change. Large-scale climate variability is generally exhibited by the more extended mountainous regions, such as the Himalayas, the Alps, the Andes, the Rockies, etc. (Beniston *et al.*, 1997). The world's major river systems owe their origin and stability to the high-altitude mountainous regions which drives the global hydrological cycle. In the regional context, the Himalayas play a critical role in the hydro-meteorological aspects of the major river basins in South Asia (Fowler and Archer, 2005; Singh, Arora, 2007). The high-altitude regions show a greater sensitivity to climatic warming as indicated by the temperature records from Nepal (Shrestha *et al.*, 1999) and China (Liu and Chen, 2000). The trends in climatic elements like temperature, seasonal total snowfall amount and seasonal total snow-water equivalent on a regional scale over the Northwestern Himalayas have not been adequately addressed (Bhutiyani *et al*., 2007, 2009; Shekhar *et al.*, 2010; Dimri and Das, 2011). Consistent with increasing surface air temperatures in the Northwestern Himalayas (Pant and Borgaonkar, 1984; Li and Tang, 1986; Seko and Takahashi, 1991; Shrestha *et al.*, 1999; Thompson *et al.*, 2000; Kang *et al.*, 2010), Many studies have reported that maximum and minimum temperatures have shown an upward trend during recent decades (Bhutiyani *et al.*, 2007, 2009), which is equally true for other large mountain ranges too (Beniston *et al.*, 1997; Diaz and Bradley, 1997; Beniston, 2003). Several studies made by researchers have confirmed the fact that the rate of warming is higher in the Himalayan region than the global

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average and temperature differences are higher during winter and autumn than in summer (Shrestha *et al.*, 1999; Liu and Chen, 2000; New *et al.*, 2002; Xu *et al.*, 2009). Trend detection studies conducted in the Indian sub-continent and the Himalayan region have revealed temperature warming (Arora *et al.*, 2005; Fowler and Archer, 2006; Bhutiyani *et al.*, 2007; Jaswal, 2010; Pal and Tabbaa, 2010). The Brahmaputra Basin witnessed an increase of 0.6°C from 1900 to 2000 (Immerzeel, 2008) The Himalaya mountainous region and the Tibetan Plateau experienced a warning of 1.0°C and 1.1°C respectively, during the pre-monsoon period. The study conducted by Jhajharia and Singh (2010) contradicted the findings of Immerzeel (2008) regarding the air temperature trend in the eastern Himalayas during the pre-monsoon period. However, the findings of Jhajharia, and Singh (2010) are in complete agreement with the findings of Immerzeel (2008) as both studies have identified a warming in the monsoon and post-monsoon seasons alike. Since for a couple of decades, temperature extremes intensifying almost throughout the Himalayan region, its water resource has been badly affected. There has been a shift in land-use practices owing to the deteriorating water resources in the study-area. The study was intended to add a quantitative dimension to the increasing trends in temperature extremes.

2. STUDY-AREA

Spatially, the North Kashmir river catchment region lies between 34º 12′ 09″ to 34º 41′ 55″ north latitude and 73º 54′ 37″ to 75º 35′ 10″ east longitude as shown in Figure 1. The study-area is a northwestern Himalayan region. The eastern part is the abode of a few important glaciers which play a crucial role in the hydrology of the River Sind. The central and western catchments are rain-fed, thus, having a strong seasonal effect on the waterflow. The North Kashmir Rivers have carved their valleys draining the southern slopes of the North Kashmir Himalaya, which is a massive topographic barrier. It encloses the Kashmir Valley on the north and north-east.

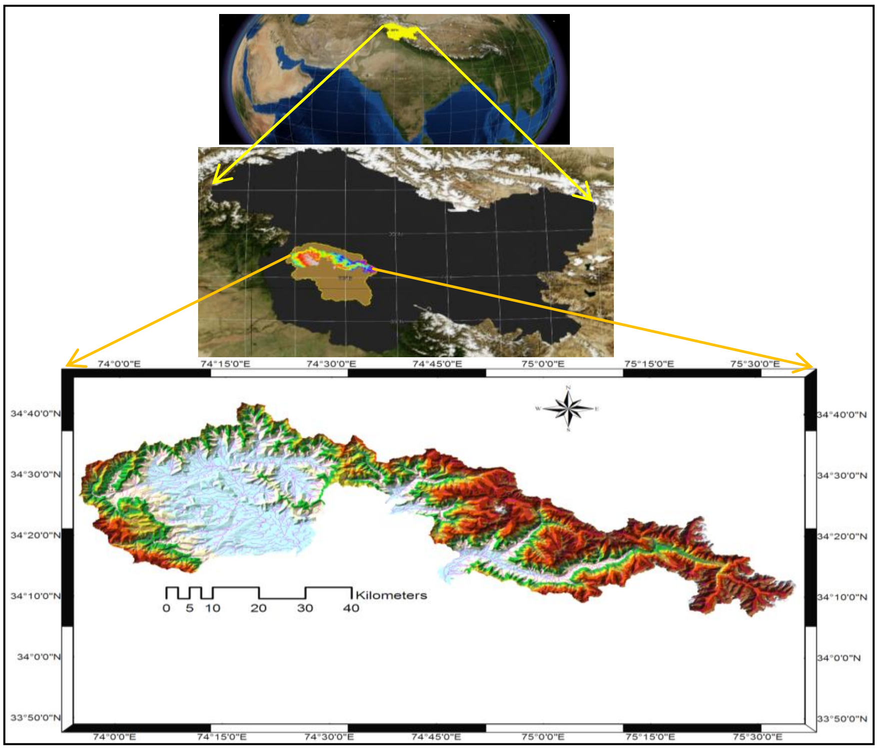

Fig. 1 – Location of the study area.

Four major tributaries of the River Jhelum and the Wular Lake, namely Sind, Ein, Madhumati and Pohru make up the North Kashmir river catchment region. Although it rains throughout the year, rainfall is not uniformly distributed. Most rainfall is concentrated in the spring season.

3. DATASETS AND METHODOLOGY

The North Kashmir river catchment region does not have an adequate number of meteorological stations. Only one meteorological station, Kupwara, exists within the study-area. The Thiessen polygon method has been used to identify the representative stations for different parts of the study-area. The western part is represented by the Kupwara Station. The central and the eastern parts are represented by the Srinagar and Pahalgam stations, respectively (Fig. 2). The highest maximum temperature data from 1977 to 2011 were acquired from IMD, Pune. The trend analysis has been performed using the non-parametric Mann-Kendall test along with the Sen Slope Estimator. The Mann-Kendall test identifies only the trend, but the Sen Slope is a good estimator of the trend magnitude. The statistical tests were carried out using VB Macro developed by the Finnish Meteorological Institute, Finland.

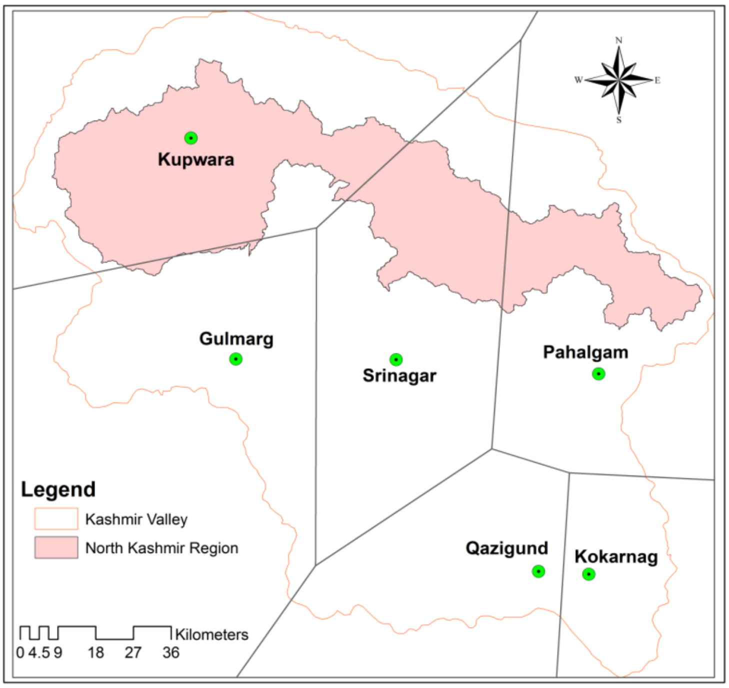

Fig. 2 – Representative meteorological stations with Thiessen polygons.

3.1. Mann-Kendall Test

The Mann-Kendall test can be viewed as a non-parametric test for zero slope of the linear regression of time-ordered data versus time as illustrated by Hollander and Wolfe (1973, p. 503). The test is applicable if the time series obeys the linear model:

$$x_i = f(\mathrm{t}_i) + \varepsilon_i \qquad (1)$$

Where *f (t)* is a continuous monotonic increasing or decreasing function of time and the residuals ε_i can be assumed to be from the same distribution with zero mean. It is therefore, assumed that the variance of distribution is constant in time.

If n is 40 or less, the following procedure may be used. When n exceeds 40, the normal approximation test is used (Gilbert, 1987). The following procedure is applied when there is only one datum per time unit is taken, which may be a day, a week, a month, and so on.

Let $Sgn\left(x_j - x_k\right)$ be an indicator function that takes on the values 1, 0 or -1 according to the sign:

$$\mathrm{sgn}(\mathrm{x}_j - \mathrm{x}_k) = \begin{bmatrix} 1 & \mathit{If}\,(\mathrm{x}_j - \mathrm{x}_k) > 0 \\ 0 & \mathit{If}\,(\mathrm{x}_j - \mathrm{x}_k) = 0 \\ -1 & \mathit{If}\,(\mathrm{x}_j - \mathrm{x}_k) < 0 \end{bmatrix} \qquad (2)$$

The Mann-Kendall statistic is computed as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k=1}^{n} \mathrm{sgn}(\mathrm{x}_j - \mathrm{x}_k) \qquad (3)$$

Where x_j and x_k are the annual values in years j and k, $j > k$, respectively

When n is above 40, the normal approximation test described given below is used. Actually, Kendall (1975, p. 55) proposes that this method may be used for n as small as 10 unless there are many tied groups. In order to apply the normal approximation test to the time-series data, the first step is to compute the variance of S, which is done by the following equation:

$$VAR(\mathrm{S}) = \frac{1}{18}\left[n(\mathrm{n}-1)(2\,\mathrm{n}+5) - \sum_{p=1}^{q} t_p(\mathrm{t}_p - 1)(2\,\mathrm{t}_p + 5) \right] \qquad (4)$$

Here q is the number of tied groups and t_p is the number of data-values in the p^{th} group

The values of S and $VAR(S)$ are used to compute the test statistic Z as follows:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(\mathrm{S})}}\,\mathit{If} \quad S > 0 \\ 0 \quad \mathit{If} \quad S = 0 \\ \dfrac{S+1}{VAR(\mathrm{S})}\,\mathit{If} \quad S < 0 \end{cases} \qquad (5)$$

The presence of a statistically significant trend is evaluated using Z value. A positive (negative) value of Z indicates an upward (downward) trend. Statistic Z has a normal distribution. To test for either an upward or downward monotone trend (a two-tailed test) at α level of significance, H_0 is rejected if the absolute value of Z is greater than Z_1-$\alpha/2$, where Z_1-$\alpha/2$ is obtained from the standard normal cumulative distribution tables. The statistical tests used in the macro computes the trend at 0.001, 0.01, 0.05 and 0.1 significance levels of α.

3.2. Sen's Method

Sen Slope is a non-parametric method that gives the magnitude of the slope (Change per time unit). It is used in cases in which the trend is assumed to be linear. This means that $f\,(t)$ in equation (1) is equal to

$$f\,(\mathrm{t}) = \mathrm{Qt} + \mathrm{B} \qquad (6)$$

Where Q is the slope and B is a constant.

To get the slope estimate *Q* in equation (6) we first calculate the slopes of all data-value pairs by using the formula:

$$Q_i = \frac{x_j - x_k}{j-k} \qquad (7)$$

Where x_j and x_k are data-values at times (or during time periods) j and k, respectively and where j > k and N is the number of data-pairs for which j > k. The median of these N values of Q is Sen's estimator of slope. If there is only one datum in each time-period, then N' = n (n -1)12, where n is the number of time-periods.

If there are *n* values x_j in the time series, we get as many as $N = n(n-1)/2$ slope estimates (Q_i). Sen's estimator of slope is the median of these *N* values of *Qi*. The *N* values of *Qi* are ranked from the smallest to the largest and Sen's estimator is:

$$Q = Q_{[(N+1)/2]} \; if \quad N \quad is \quad Odd$$
$$Q = \frac{1}{2}\left(Q_{[N/2]+Q[(N+2)/2]}\right) if \quad N \quad is \quad even \qquad (8)$$

The procedure in VB macro computes the confidence interval at two different confidence levels; α = 0.01 and α = 0.05, resulting in two different confidence intervals. A 100 (1-α) % two-sided confidence interval about the true slope may be obtained by the non-parametric technique given by Sen (1968b). The procedure given above is based on the normal distribution which is valid for n as small as 10 unless there are many ties. This procedure is a generalization of that given by Hollander and Wolfe (1973, p. 207) when ties and/or multiple observations per time period are present.

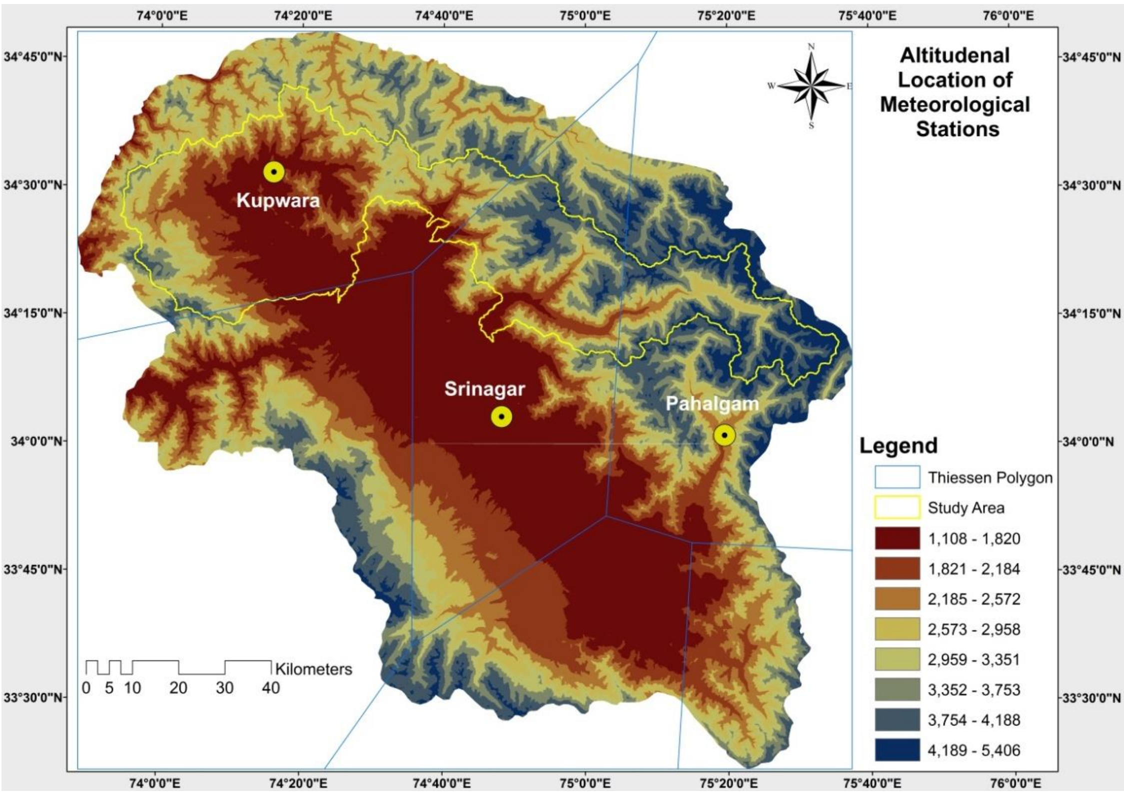

Fig. 3 – Altitudinal location of representative meteorological stations.

At first we compute:

$$C_\alpha = Z_{1-\alpha/2}\sqrt{VAR(\mathrm{S})} \qquad (9)$$

Where $VAR(S)$ was defined in equation (4) and $Z_{1-\alpha/2}$ is obtained from the standard normal distribution.

Next $M_1 = (N - C_\alpha)/2$ and $M_2 = (N + C_\alpha)/2$ are computed. The lower and upper limits of the confidence interval, Q_{min} and Q_{max} are the M_1^{th} largest and the $(M_2 + 1)^{th}$ largest of the N-ordered slope estimates Q_i. If M_1 is not a whole number, the lower limit is interpolated. Correspondingly, if M_2 is not a whole number, the upper limit is interpolated.

4. RESULTS

The test statistic related to the long-term seasonal highest maximum temperature (1977–2011) for the Kupwara, Pahalgam and Srinagar stations is given in Table 1.

Table 1

Test statistic for highest maximum temperature.

	Season	Z Value	Level of Significance (α)	Sen Slope
Kupwara	Winter	2.70	0.01	0.05
	Spring	3.41	0.001	0.08
	Summer	1.61	Nil	0.03
	Autumn	3.84	0.001	0.06
Pahalgam	Winter	2.98	0.01	0.09
	Spring	2.86	0.01	0.07
	Summer	2.03	0.05	0.02
	Autumn	3.55	0.001	0.04
Srinagar	Winter	2.68	0.01	0.05
	Spring	2.29	0.05	0.05
	Summer	-0.58	Nil	-0.01
	Autumn	2.50	0.05	0.04

Kupwara Station

The statistics calculated from the Mann-Kendall and the Sen Slope Estimator is given in Table 1. The highest maximum temperature in the winter season is showing an increasing trend with a Z value of 2.70 and slope value of 0.05.

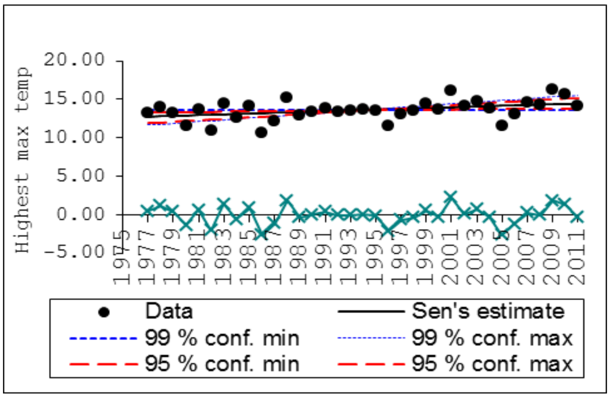

Fig. 3 – Winter Highest Maximum Temperature.

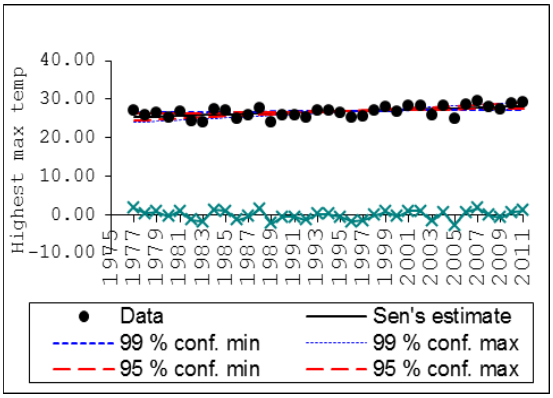

Fig. 4 – Spring Highest Maximum Temperature.

The trend is increasing statistically at the 99 percent level of confidence. The narrow angle between the confidence limits at 95 and 99 percent also confirms the fact that the trend is increasing at the significant statistical level of confidence (Fig 3). The autumn season indicates an increasing trend in the highest maximum temperature at the Kupwara Station from 1977 to 2011 (Fig. 6). The trend is positive at α 0.001. The statistical tests have calculated an increasing trend at the 99.9 percent confidence level.

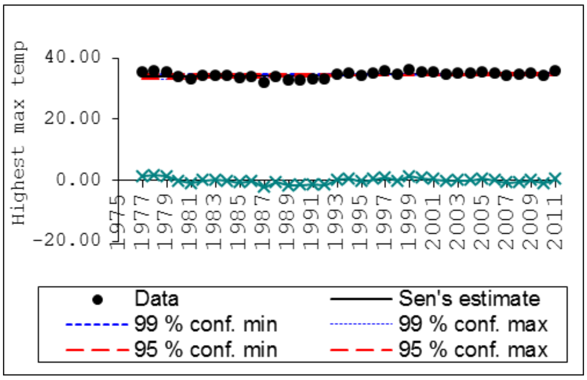

Fig. 5 – Summer Highest Maximum Temperature.

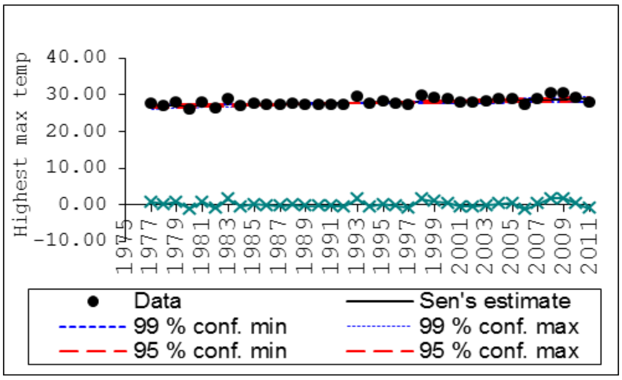

Fig. 6 – Autumn Highest Maximum Temperature.

Though the summer highest maximum temperature shows an increasing trend, it is not statistically significant (Table 1 and Fig. 5). The Z value is 1.61, which is very close to the normal distribution value of 1.64 at 90 percent confidence level. The autumn season also shows an increasing trend with a Z value of 3.84. The trend is significant at α 0.001. Almost, all data points fall within the confidence limits as it is obvious from Figure 6. The spring season has also shown an increasing trend in temperature extremes recorded at Kupwara Station, with a slope magnitude of 0.08, which is by no means a small increase in temperature.

Pahalgam Station

Pahalgam Station registered an increasing trend in the highest maximum temperature recorded from 1977 to 2011 for all the seasons. The winter highest maximum temperature reveals a positive trend with a Z value of 2.98. The trend is significant at α 0.01, which means a linear trend of data at 99 percent confidence level. Almost all data points fall within the confidence limits except for a few data-values at the beginning of the time-series (Fig. 7).

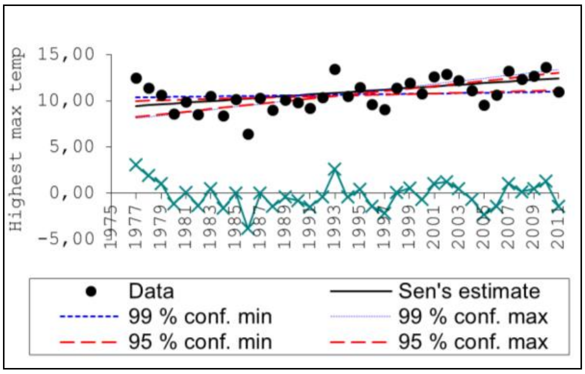

Fig. 7 – Winter Highest Maximum Temperature.

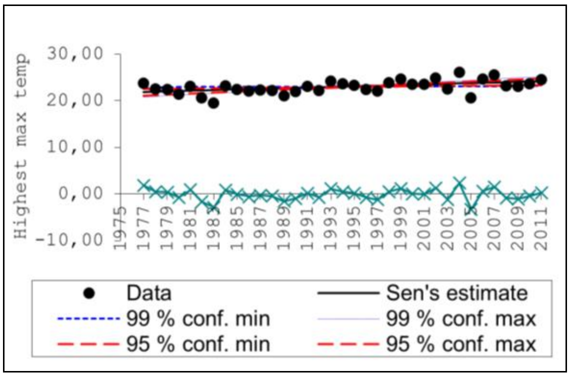

Fig. 8 – Spring Highest Maximum Temperature.

The slope of the trend line is 0.09. Spring and summer also show an increasing trend with 99 percent confidence level. The Z value for the spring and summer seasons, as calculated by the Mann-Kendall test, is 2.86 and 2.02, respectively. The Sen Slope test estimates a slope value of 0.07 for the spring season and of 0.02 for the summer season (Table 1).

The autumn season projects a trend at 99.9 percent confidence level, but the trend magnitude is not very high. Similarly, the summer season reveals a soft positive trend as compared to the winter and spring season. The linear model applied to the time-series befits the data shown in Figures 9 and 10.

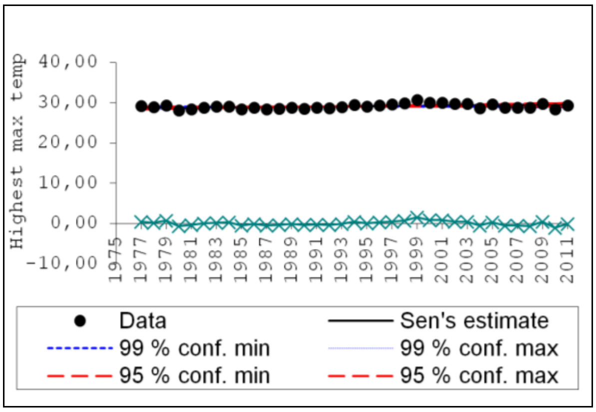

Fig. 9 – Summer Highest Maximum Temperature.

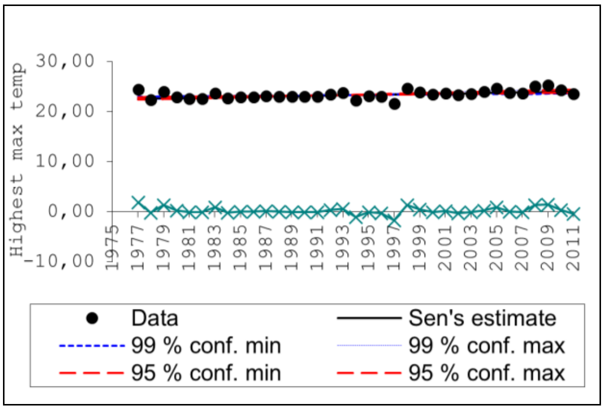

Fig. 10 – Autumn Highest Maximum Temperature.

Srinagar Station

The winter highest maximum temperature witnessed an increasing trend from 1977 to 2011 (Table 1 and Fig. 11). The data observed at Srinagar Station depict an increasing trend with a confidence level of 99 percent. Figure 11 clearly shows that the absolute values of the highest maximum temperature increased during the later part of the time-series with a slope trend of 0.05.

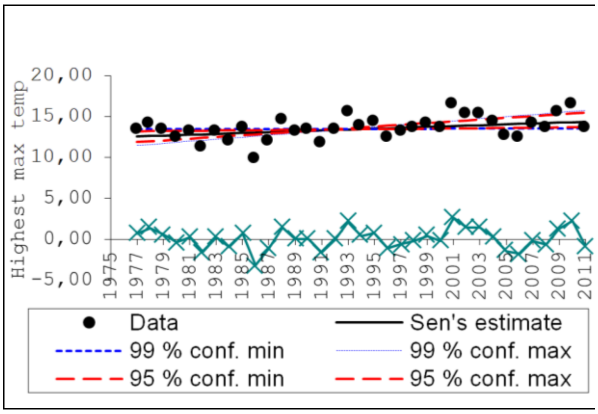

Fig. 11 – Winter Highest Maximum Temperature.

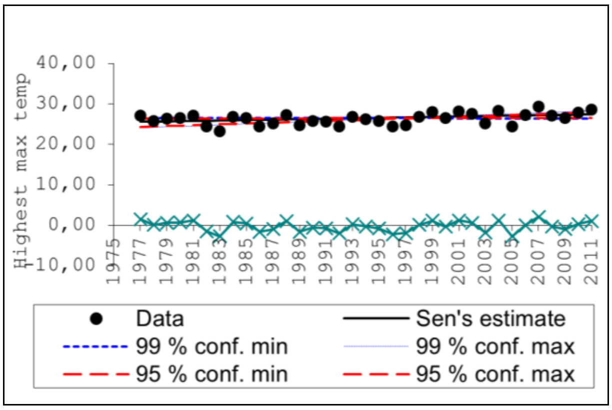

Fig. 12 – Spring Highest Maximum Temperature.

The spring season also reveals an increasing monotonic trend at 95 percent level of confidence with a slope of 0.05.

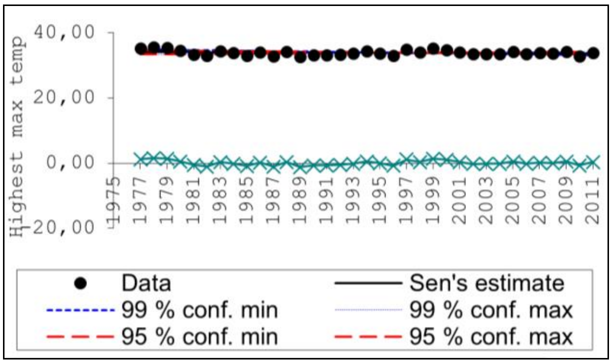

Fig. 13 – Summer Highest Maximum Temperature.

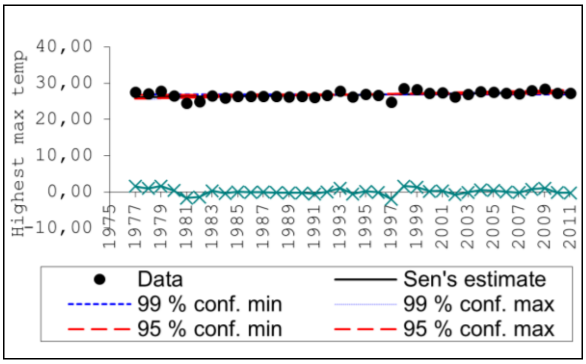

Fig. 14 – Autumn Highest Maximum Temperature.

The trend is missing in the summer season, but the autumn season shows up a trend at 95 percent level of confidence with a slope of 0.04.

5. DISCUSSION

The meteorological stations taken up for the study are located in different altitudinal zones (see Fig. 3). The increasing temperature in the high-altitude areas could be disastrous for the already degrading water-resource of the region. The eastern part of the study-area has some important glaciers and snow fields which regulate the hydrological regime of the Sind River that drains the area. An increasing winter temperature would mean a decrease in snowfall. Spring-time warming accelerates the snowmelt process in the higher reaches, badly affecting the discharge pattern of the streams. The unprecedented warming of the high-altitude regions in the study-area has further resulted in frequent cloudbursts and incessant rains. The diminishing water resource may start up a process of land-use transformation in the region which is indeed happening at a small scale. The study does not point to any specific altitude-related trends as all high-and-low-altitude stations are projecting somewhat a similar behaviour with regard to the extreme temperature trends, but the magnitude of the trend is a bit higher at the comparatively high-altitude stations.

6. CONCLUSIONS

The study was aimed at investigating the trends in highest maximum temperature in North Kashmir river catchment region from 1977 to 2011. The study-area is covered by three meteorological stations, namely, Kupwara, Pahalgam and Srinagar which are located in different altitudinal zones. The dynamics of hydrology in glacierised basins is closely associated with the air temperature. In the Himalaya, July and August are generally the warmest months (Thayyen & Gergan, 2010), when there is enough heat energy available for melting the winter-time snowpack and glacial ice. The decreasing temperature with altitude sets perfect conditions for the formation of glaciers and snow fields. The increasing temperature in the winter season reduces the extent of glacier areas. The Srinagar, Shimla and Leh stations in the north-west Himalayas had shown a warming trend in the last century (Bhutiyani *et al.*, 2007). The Himalayas experienced rising temperature trends in the 20^{th} century (Shrestha *et al.*, 1999; Immerzeel, 2008) which accelerated the melting process of the winter snowpack and of glacier ice. The high-altitude regions show greater data variability than the low-altitude ones. The stations identified for the study, except for Srinagar, do not have long-term datasets available, which makes it difficult to assess the long-term climate dynamics in the study-area. However, the recent increase in the extreme air temperature is highly consequential to the number of ecosystem services in the Himalayan region.

REFERENCES

Arora, M., Goel, N.K., Singh, P. (2005), *Evaluation of temperature trends over India*, Hydrol. Sci. J., **50**, *1*, pp. 81–93.

Beniston, M. (2003), *Climatic change in mountainous regions: A review of possible impacts*, Clim. Change, **59**, pp. 5–31.

Beniston, M., Diaz, F.D., Bradley, R.S. (1997), *Climatic change at high elevation sites: An overview*, Clim. Change, **36**, pp. 233–251.

Bhutiyani, M.R., Kale, V.S., Pawar, N.J. (2007), *Long-term trends in maximum, minimum and mean annual air temperatures across the northwestern Himalaya during the twentieth century*, Clim. Change, **85,** pp. 159–177.

Bhutiyani, M.R., Kale, V.S., Pawar, N.J. (2009), *Climate change and the precipitation variations in the northwestern Himalaya*, 1866–2006; Int. J. Clim., **36**, pp. 535–548.

Diaz, H.F., Bradley, R.S. (1997), *Temperature variations during the last century at high elevation sites*, Clim. Change, **36**, pp. 253–279.

Dimri, A.P., Das, S.K. (2011), *Wintertime climatic trends in the western Himalayas*, Clim. Change, **111**, pp. 775–800.

Fowler, H.J., Archer, D.R. (2005), *Hydro-climatological variability in upper Indus basin and implications for water resources*, In: Regional hydrological impacts of climate change – impact assessment and decision making (eds) Wagner T *et al*., Proceedings of Symposium S6 held during the Seventh IAHS Scientific Assembly at Foz do lguacu, Brazil, IAHS Publ., **295**, pp. 131–138.

Fowler, H.J., Archer, D.R. (2006), *Conflicting signals of climatic change in the Upper Indus Basin*, J. Climate, v. **19**, pp. 4276–4293.

Gilbert, R.O. (1987), *Statistical methods for environmental pollution monitoring*, Van Nostrand Reinhold, New York.

Immerzeel, W. (2008), *Historical trends and future predictions of climate variability*, International Journal of Climatology. **28**, pp. 243–254.

Jaswal, A.K. (2010), *Recent winter warming over India–spatial and temporal characteristics of monthly maximum and minimum temperature trends for January to March*, Mausam, v. **111**. Pp. 45–66.

Jhajharia, D., Singh, V.P. (2010), *Trends in temperature, diurnal temperature range*, International Journal of Climatology.

Kang, S., Xu, Y., You, Q., Flugel, W.A., Pepin, N., Yao, T. (2010), *Review of climate and cryospheric change in the Tibetan Plateau*, Environ. Res. Lett. **5**, doi: 10.1088/1748-9326/5/1/015101.

Li, C., Tang, M. (1986), *Changes of air temperature of Qunghai–Xizang plateau and its neighborhood in the past 30 years*, Plateau Meteorol. **284**, pp. 2156–2159.

Liu, X., Chen, B. (2000), *Climate warming in the Tibetan Plateau during recent decades*, Int. J. Climatol, v. **20**, pp. 1729–1742.

New, M., Lister, D., Hulme, M., Makin, I. (2002), *A high resolution data set of surface climate over global land areas*, Climate Research, v. **21**, pp. 1–25.

Pal, I., Al-Tabbaa, A. (2010), *Long-term changes and variability of monthly extreme temperatures in India*, Theor. Appl. Climatol., v. **100**, pp. 45–46.

Pant, G.B., Borgaonkar, H.P. (1984), *Climate of the hill regions of Uttar Pradesh*, Him. Res. Develop. **3**, pp. 13–20.

Seko, K., Takahashi, S. (1991), *Characteristics of winter precipitation and its effects on glaciers in Nepal Himalaya*, Bull. Glacier Res., v. **9**, pp. 9–16.

Shekhar, M.S., Chand, H., Kumar, S., Srinivasan, K., Ganju, A. (2010), *Climate change studies in the western Himalaya*, Ann. Glaciol., **51**, pp. 105–112.

Shrestha, A.B., Wake, C.P., Mayewski, P.A., Dibb, J.E. (1999), *Maximum temperature and trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal from period 1971–94*, Journal of Climate, v. **12**, pp. 2775–2787.

Singh, P., Arora, M. (2007), *Water resources potential of Himalayas and possible impact of climate change*, Jalvigyan Sameeksha, v. **22**, pp. 109–132.

Thompson, L.G., Yao, T., Thompson, E.M., Davis, M.E., Handerson, K.A., Lin, P.N. (2000), *A high resolution millennial record of the South Asian monsoon from Himalayan ice cores*, Science **289**, pp. 1916–1919.

Xu, J., Grumbine, E.R., Shrestha, A., Eriksson, M., Yang, X., Wang, Y., Wilkes, A. (2009), *The melting Himalayas: Cascading effects of climate change on water, biodiversity, and livelihoods*, Conservation Biology, v. **23**, vo. *3*, pp. 520–530.

Hollander, M., Wolfe, D.A. (1973), *Nonparametric Statistical Methods*, John Wiley and Sons, New York, 503 p.

Thayyen, R. J., Gergan, J.T. (2010), *Role of glaciers in watershed hydrology: preliminary study of a "Himalayan catchment"*, The Cryosphere **4**, pp. 115–128.

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ALEXANDRU UNGUREANU À 75 ANS

Né le 22 juillet 1941 à Piatra-Neamţ dans une famille dont les racines paternelles avaient une ancienne origine transylvaine, Alexandru Ungureanu est de nos jours un géographe emblématique pour la communauté géographique roumaine. Les ancêtres paternels étaient descendus de la vallée de Bârgău vers 1770 dans la moyenne vallée de la Bistrița Moldave. Son père, Gheorghe Ungureanu, licencié en droit, historien archiviste et sa mère, Valeria-Margareta (née Străjescu), licéncié en mathématiques, professeur de lycée et lecteur à l'Institute Polytéchnique „Gheorghe Asachi" de Iaşi étaient des intellectuels remarquables. En 1966 il était marié avec Irina-Brânduşa (néé Nicolae), géographe aussi et éminent professeur à l'Université „Alexandru Ioan Cuza" de Iaşi. Sa fille, Maria Marion-Ungureanu, médecin psychiatre, vit en Roussillon, à Perpignan, dans le Midi français.

Liè à son village ancestral, Hangu depuis l'enfance, il a dû suivre sa famille dans les temps turbulents de la deuxième guerre mondiale, de Piatra Neamț à Iaşi et en 1944 il fut marqué par le refuge en Olténie (à Săcelu, département de Gorj) et à Râmnicu Sărat. En 1945, la fin de la conflagration permet le retour de la famille à Iaşi où il suivit tout le parcours scolaire. Les études lyceales, suivies dans l'un des écoles d'ancienne tradition de la ville, e lycée de garçons no. 2 („Costache Negruzzi") et accomplies par le soutien de l'examen de maturité (bacalauréat) avec les meilleurs résultats ont permis l'inscription, pendant la même année, à l'Université „Alexandru Ioan Cuza" où il avait choisi la faculté de Biologie-Géographie-Géologie, la filière Géographie. Soutenu en 1962, l'examen d'état (la licence), dont le sujet visait l'un des plus importants domains d'interêt géographique, la géomorphologie, avait attesté les qualités professionnelles et surtout la capacité de réflection scientifique. Ainsi, l'occupation d'un poste de préparateur dans le département de Géographie de la prestigieuse université de Iaşi, n'était qu'une première reconnaissance de son potentiel académique.

Promu assistant suppléant une année plus tard et assistant titulaire en 1967 il s'inscrit pendant la même année au doctorat sous la direction du professeur Ioan Şandru, l'objet de sa thèse visant l'étude géographique des villes de Moldavie. Finalisée en 1976 et publiée en 1980 sous le titre „Oraşele din Moldova. Studiu de geografie economică" et éditée sous l'égide de l'Académie Roumaine ce travail confirmait la valeur de ses recherches, orientées dans le champ scientifique de la géographie humaine. Maître assistant titulaire depuis 1971, dans une période où la promotion était très dificile, au caprices du régime totalitaire, le jeune chercheur Alexandru Ungureanu avait entrepris plusieurs une ample documentation dans le archives, dans le bibliothèques et directement sur le terrain en obtenant ainsi une connaissance presque exhaustive de la réalité géographique roumaine. L'horizon ouvert par les stages de spécialisation faits en France (décembre 1967 – juillet 1968, 1975), en Autriche (1969, 1975), en Suisse (1975) et en Allemagne (1973, 1975) survenus dans la courte période de reprise des rélations académiques avec l'Occident au début du régime Ceauşescu, et qui seront matérialisés non seulement par l'acquis des théories et des modèles d'analyse géographique les plus avancés mais aussi par des contacts avec les géographes (surtout français) les plus réputés de l'époque avec lesquels il avait entretenu un échange d'idées et de connaissances qui ont permis la mise à jour de la pratique scientifique, malgré l'isolement du régime totalitaire.

Les contraintes de l'époque ont bloqué l'ascension professionnelle et seulement la chute du régime en décembre 1989 permettra l'accés, par concours, au statut de maître de conférences (1990) et professeur universitaire (1993). Depuis 1994 il reçoit aussi le droit de diriger des travaux de doctorat. L'ouverture suivie par la chute du régime avait aussi permis la reprise des stages de documentation et de spécialisation à l'étranger, avec des visites succesives en Italie, Grèce, Bulgarie, Hongrie, Autriche, République Tchéque, Allemagne, France, Bélgique, Royaume Uni, Suède etc., sans oublier les fréquentes stages effectués en République de Moldavie. Ces stages, favorisés par la maîtrise parfaite de plusieurs langues etrangères, appropriées surtout en autodidacte.

Rev. Roum. Géogr./Rom. Journ. Geogr., **61**, (2), p. 217–221, 2017, Bucureşti.

Depuis 1 octobre 2006, le professeur Alexandru Ungureanu avait reçu le statut de professeur consultant et en 2007 celui de professeur émeritus, signe de réconnaissance au sein de la communauté géographique de l'université où il s'est formé et avait activé pendant presque 5 décennies.

La longue activité scientifique, qui n'avait pas cessé avec la retraite survenue en 2006, fut véritablement prodigieuse, l'énumération de ses récherches ne peut pas être complète. Ses domaines d'intérêt s'inscrivent dans le large horizon de la géographie humaine avec une visible ouverture interdisciplinaire. Enumérer ces domaines dans l'ordre de la fréquence des études publiées serait difficile vu leur interférence.

On peut commencer avec la géographie urbaine, domaine qui avait constitué l'objet d'étude de la thèse de doctorat et de nombreuses articles scientifiques apparues dans les revues roumaines ou étrangères et où les principales contributions ont visé la détermination des zones d'influence et de l'hiérarchie urbaine, l'analyse du processus d'urbanisation dans une perspective crono-spatiale dans tous ses formes de manifestation (évolution territoriale, phases et cycles d'évolution, les connexions avec le processus d'industrialisation et avec la mobilité de la population etc.). Les connexions inhèrentes avec la géographie rurale se sont finalisées avec une succésion d'études visant l'évolution des réseaux d'habitat rural et des systèmes agraires, notamment au nord-est de la Roumanie (spécialisation agricole, utilisation des terrains en corrélation avec la morphologie de l'habitat rural etc.). L'utilisation d'une méthodologie avancée, malgré les vicissitudes de l'époque totalitaire, l'adaptation des modèles utilisés aux situations concrètes et la création d'indices et d'indicateurs statistiques (souvent de type synthétique comme l'indice de la spécialisation agricole ou l'indice d'adéquation de l'utilisation des terrains aux conditions naturelles de favorabilité) lui assure une place de premier plan au moins au niveau national.

Les études de géographie urbaine ou rurale se sont entrecroisées d'une manière inhérente avec la géographie de la population, dont les résultats ont visé surtout le processus de peuplement, l'analyse de la transition démographique en Roumanie depuis les premiers enregistrements statistiques, la causalité et les formes de manifestation de la mobilité territoriale de la population, les transformations structurales et leur relation avec le marché d'émploi etc. Dans le même contexte il ne faut pas oublier les contributions visant la structure etno-linguistique de la population, surtout celles concernant la République de la Moldavie, ouvrant des liaisons vers les domaines de la géographie politique et historique.

La géographie économique ne pouvait pas être évitée, les relations entre le processus d'urbanisation et celui de l'industrialisation, extrêmement active avant 1989, incitant des études visant aussi les activités productives que les services dont une attention particulière fut accordée au réseau de communications. L'adaptation des indices de connexion et de connectivité au niveau de la Roumaine reste une contribution notable et mémorable. Dans ce contexte il ne manquent pas les contributions concernant l'utilisation touristique de l'espace ou l'utilisation des ressources naturelles.

La géographie régionale se retrouve souvent d'une manière synthètique dans les contributions visant l'analyse de certaines thèmes d'intérêt scientifique au niveau des régions ou des microrégions géographiques. La maîtrise parfaite de la géographie physique, du point de vue théorique mais aussi méthodologique avait favorisé les connexions avec la géographie humaine et la création de synthèses notables souvent insérées dans les ouvrages collectives considérées encore un étalon de la recherche géographique roumaine (tel lé traité de Géographie de la Roumanie édité pendant les années 1980 par l'Acadèmie Roumaine).

Apparentées, les domaines particuliers de la géographie historique, la géographie politique et surtout la toponomastique constituent un autre volet de contribution remarquables par leur originalité, expression d'une vaste culture scientifique et humaniste, preuve d'une formation encyclopédique dans un esprit classique.

Tous ces domaines d'intérêt mentionnés ont fait aussi l'objet d'un effort de systhématisation sous la forme de cours universitaires dont la structure originale et la clareté de l'exposition de l'information ont reçu l'appréciation unanime. De ce point de vue on peut affirmer que le professeur Alexandru Ungureanu est le géographe humaniste complet par excellence.

Dernièrement, il ne faut pas oublier l'effort de réveler des sources documentaires et cartographiques rares visant le territoire de la Roumanie, souvent oubliées dans les archives étrangères (françaises et autrichiennes surtout) et l'accumulation d'une vaste documentation photographique, pour la plupart originale, témoignage d'une vaste expérience du terrain.

L'activité scientifique s'est concentrée dans les quelques 20 volumes d'auteur ou publiées en collaboration, y compris à l'étranger et dans une centaine d'articles et études publiés dans les périodiques de spécialité ou dans les volumes collectifs de certaines manifestations scientifiques dont il est difficile de faire un classement. A côté des publications nationales (*Revue Roumaine de Géographie, Analele Ştiinţifice ale Universităţii „Alexandru Ioan Cuza" din Iaşi, Revista Arhivelor, Lucrările Seminarului Geografic „Dimitrie Cantemir", Terra, Anuarul Institutului de Istorie şi Arheologie „A. D. Xenopol", Lucrările Staţiunii de Cercetări Biologice, Geologice şi Geografice „Stejarul", Analele Universităţii de Vest Timişoara, Geographica Timisiensis, Revista Română de Geografie Politică* etc.) on peut mentionner les publications étrangères (*Annales de Géographie, Rivista Geografica Italiana Revue Géographique de l'Est, Acta Geographica, Deutschland und Rumänien im Spiegel ihrer Schulbücher, Europa Regional* etc.). Il faut pas ignorer les nombreuses contributions présentées aux conférences et congrès scientifiques internationaux, pas encore publiées et les travaux élaborés dans le cadre des projets de recherche à financement national ou étranger (à mentionner seulement les collaboration avec l'Institut de Géographie Régionale de Leipzig, l'Institute de Géographie de Lausanne et l'Université de Freiburg im Brisgau).

Le prestige au sein de la communauté académique est illustré aussi par les nombreux articles de chronique scientifique, anniversaires ou commemoratifs et surtout par les grand nombre de compte-rendus publiés, expression de la sollicitude, l'objectivité et la probité professionnelle caractéristiques. Ceci se manifeste aussi dans le nombre impressionant de travaux préfacés et les fréquentes sollicitations de révision scientifique aussi de la part des publications que de la part des maisons d'édition, y compris pour des matériaux didactiques et cartographiques.

Les résultats de la recherche scientifique se sont concrétisés aussi dans les nombreuses conférences scientifiques soutenues en qualité de professeur invité, concernant notamment la problématique géographique de la population et de l'habitat, dans les universités étrangères: à Lausanne (en 1991), à l'Institut de Géographie de Leipzig, à l'Université de Halle et à l'Institute d'Etudes Sud-Est Européennes de Munich (en 1993), à l'Université de Padoue, à l'Institute de Rencontres Cultureles Central-Européen de Gorizia, à l'Institute Roumain de Venise, à l'Université de Linköping (en 2001), à l'Université de Dijon (en 2003) etc.

Une importante composante de l'activité scientifique du professeur Alexandru Ungureanu est constituée par la direction des thèses de doctorat, activité déroulée depuis 1995. Entre 2004 et 2008 il a été le directeur exécutif de l'Ecole Doctorale de la Faculté de Géographie et Géologie. Un nombre de 16 doctorants ont élaboré et soutenu leurs thèses sous sa direction, la plupart travaillant dans divers centres universitaires, y compris dans la République de Moldavie. On peut y ajouter la direction des thèses postdoctorales dans le cadre du programme de bourses "Eugène Ionesco", dont les bénéficiaires en sont des doctorants des pays francophones d'Afrique notamment. Cette activité est complétée par la participation en qualité de référent dans des nombreux jurys de thèse (à Bucarest, Cluj, Iași, Chișinău, Paris etc.). Pendant une longue période il fut aussi le président du comité de spécialité de la C.N.A.T.D.C.U., l'office ministériel de contrôle de l'activité doctorale. La probité morale et le prestige l'ont recommandé pour la participation à des nombreux comités de concours de promotion dans les universités roumaines.

Les résultats scientifiques exceptionnels et ses qualités administratives ont recommandé l'élection dans le poste de directeur du Centre Universitaire de Géographie Humaine et d'Aménagement du Territoire, fonctionnant au sein de la Faculté de Géographie et Géologie et distingué avec un diplôme d'excellence par le Ministère de l'Education en 2005. L'expertise l'avait recommandé aussi en qualité d'évaluateur dans la C.N.C.S.I.S., l'institution qui gère l'activité de recherche en Roumanie et il fut aussi expert en problèmes de population dans le programme ESPON, financé par l'Union Européenne. La même expertise l'avait recommandé à participer dans divers comités d'évaluation des projets de recherche financés par l'Académie Roumaine.

Il ne faut pas négliger l'assistance scientifique de spécialité accordée souvent directement au terrain d'étude pour des nombreux géographes et divers spécialistes étrangers (provenant de France, Suisse, Italie, Etats-Unis, Allemagne, Japon, Inde, Suède, Royaume Uni, Fédération Russe, R.P. de Chine, Ukraine, Pologne, Hongrie, République Tchèque, Sénégal, Cameroun etc.

En ce qui concerne l'activité didactique, essentielle dans l'enseignement universitaire, le professeur Alexandru Ungureanu a eu de nombreuses contributions de haute qualité. Bientôt après le début il avait commencé soutenir les premières conférences (depuis 1964), partie des cours universitaires où il s'est remarqué par les contributions originales et la grande diversité des thématiques enseignées (visant aussi des cours généraux que des cours de géographie régionale ou spécialisés), y compris en langue française depuis la création d'une filière francophone dans la faculté (en 1996). Après 1992 il avait soutenu des cours aussi à l'Académie de Sciences Economiques de Chişinău. Des dizaines de générations d'étudiants ont bénéficié des cours soutenus avec responsabilité, la plupart étant publiés aussi dans diverses maisons d'édition roumaines. La création du déuxième cycle universitaires (intitulé d'abord études approfondies, ensuite master) à élargi la palette de cours présentés, de même que l'institutionalisation du troisième cycle, celui de doctorat, après l'application des principes de Bologna (depuis 2003).

L'activité didactique ne s'est pas limitée seulement aux cours académiques, il avait dirigé un grand nombre de mémoires de licence, de maîtrise et des travaux de promotion des professeurs de l'enseignement préuniversitaire. L'organisation de nombreuses applications de terrain complète l'image de l'activité didactique. On remarque surtout les applications organisées pour les étudiants étrangers, suite à des accords de collaboration avec les universités Paris VII, Lublin, Salzburg, Tiraspol, contribuant à la création d'une image objective de notre pays. Il s'est impliqué aussi, en qualité de conférencier, secrétaire et organisateur des applications de terrain au sein des cours internationaux d'été à l'Université "Alexandru Ioan Cuza" depuis 1972. On peut aussi ajouter la présidence de nombreux concours scolaires (olympiades de spécialité surtout) qui atteste l'ouverture vers l'éducation, à tous ses niveaux.

L'activité didactique ne serait pas complète sans évoquer la participation dans le comité national de sélection des manuels scolaires où il avait imposé la nécessité d'une meilleure représentation de la Roumanie, y compris dans les manuels d'histoire, avec des partenaires étrangers (allemands à Braunschweig en 1973, 1978, 1986, à Bucarest en 1974, à Suceava en 1976 et à Sibiu en 1980 et autrichiens, à Vienne en 1976). Il avait aussi représenté la delégation roumaine à la Conférence du Conseil de l'Europe concernant l'enseignement supérieur privé, organisé à Prague en 1994. Tous ces activités démontrent les compétences en matière d'éducation et la forte disponibilité pour l'amélioration de la qualité à tous les niveaux de l'enseignement.

Les activités didactiques et scientifiques s'entrecroisent avec les responsabilités administratives. Membre du Sénat de l'Université pendant 12 ans, secrétaire scientifique de cette structure académique et membre du Conseil d'Honneur de l'Université depuis 1997, le professeur Alexandru Ungureanu avait promu la géographie au niveau institutionnel, ayant une longue expérience administrative dans le Conseil de la Faculté (depuis 1972) ou en qualité de doyen de la faculté (1992–1996) et secrétaire scientifique (1998–2000). Ces responsabilités l'ont impliqué dans les actions menées à compléter la base technique et matérielle de la faculté. L'informatisation des services administratives de la faculté, l'acquisition des matériaux didactiques, l'organisation d'une photo-diathèque, du laboratoire de géographie humaine et d'une bibliothèque de spécialité (avec des donations étrangères) sont quelques exemples démontrant sa capacité administrative.

La riche activité didactique et scientifique l'avait recommandé souvent comme représentant de la communauté universitaire à des diverses manifestations anniversaires, les 125 ans depuis la fondation de l'Université de Cernăuţi et 80 ans depuis la fondation de la Faculté de Géographie de Tiraspol en sont quelques exemples, les deux déroulées en 2008, sont deux exemples illustratifs pour l'ouverture envers la vie académique des roumaines des pays voisins.

Sa prodigieuse activité est illustrée aussi par les nombreuses participations à des émissions radio et télévisées, contribuant à la popularisation de certains problèmes d'intérêt publique ou de certaines régions moins connues, de Roumanie ou de l'étranger.

Les mérites et l'activité prodigieuse furent récompensés par l'élection le 7 février 1995 dans l'Académie Roumaine. En tant que membre correspondant de ce haut forum scientifique il avait été élu président de la Commission de Standardisation des noms géographiques et, depuis 2008, président de la Commission de Toponymie.

Cette haute dignité est complétée par la participation dans divers comités de rédaction des publications de spécialités, la réception du titre de membre d'honneur des associations professionnelles (par exemple, la Société de Géographie de France, depuis 1983, le jury Vautrin-Lud qui accorde les prix internationaux en géographie dans le cadre du Festival de Géographie de Saint-Dié en Vosges, l'Association pour les Relations Culturelles Italo-Roumaine etc.). Cette reconnaissance internationale suivit l'implication dans les activités de la Société de Géographie de Roumanie (membre depuis 1962, vice-président depuis 1998). Le titre Docteur Honoris Causa de l'Université de L'Ouest de Timişoara et de l'Université „Ştefan cel Mare" de Suceava complète la vaste réconnaisance et le préstige du professeur Alexandru Ungureanu.

La riche activité scientifique et didactique, la vaste œuvre et la diversité thématique de ses recherches lui ont apporté de nombreux distinctions et appréciations. On peut mentionner le titre de lecteur universitaire émérite, conféré par le Ministère de l'Education et de l'Enseignement en 1982, l'ordre "Meritul pentru Învățământ" en degré de Commandeur conféré en 2004 et le Prix Opera Omnia accordé par la C.N.C.S.I.S. en 2009. La même reconnaissance explique l'insertion des présentations avec sa vaste et complexe activité dans des ouvrages tels *„Enciclopedia marilor personalităţi din istoria, ştiinţa şi cultura românească de-a lungul timpului şi de pretutindeni"* (Ed. Geneze, Bucarest, 2003, vol. V, p. 464–467) ou *„Dicţionar enciclopedic"* (Ed. Enciclopedică, Bucarest, vol.VII, 2009).

La vaste activité et sa prodigieuse oeuvre presuppose un grand effort, une profonde reflexion et avant tout, un esprit humaniste qu'on retrouve dans tous ses études scientifiques, cours universitaires etc. Tout dialogue avec le professeur Alexandru Ungureanu dénote l'esprit encyclopédique, les vastes connaissances exprimés avec objectivité et modestie. Ceci anime nos appréciations et nos voeux les plus sincères, à l'occasion de son anniversaire.

Ionel Muntele

INTERDISCIPLINARY RESEARCH INTO THE ENVIRONMENT AND SOCIETY CONFERENCE INSTITUTE OF GEOGRAPHY, ROMANIAN ACADEMY

JULY 7, 2017, BUCHAREST, ROMANIA

On July 7, 2017, the Institute of Geography hosted the annual scientific communication session "Interdisciplinary Research into the Environment and Society" devoted to the late Academician Liviu Constantinescu (1914–1997). The event was organised by the Romanian Academy's Institute of Geography, and the "Simion Mehedinţi" Cultural-Scientific Foundation. Prof. Dan Bălteanu, member of the Romanian Academy, took the floor in the Plenary Session, presenting the results of the RO-RISK Project on landslide risk-connected interdisciplinary research.

Proceedings unfolded within three sections: I. Physical Geography – natural hazards; II. Geography of the Environment; III. Human Geography and Regional Development. The papers presented in *the First Section*, focussed on a wide range of subjects, e.g. landslides in Alunu, Vâlcea County; earthquakes-triggered landslides in Vrancea Seismic Region: landslide distribution in the Nemira Mts.; climatic anomalies in the south-west of Romania in the spring of 2017; changes in the evolution of the summer-thermal stress and agricultural production in the lowlands; air-and-soil freeze; *Second Section* papers – Geography of the Environment – had in view the assessment of eco-system services by means of some environment and socio-economic indicators; the dynamics and conservation of forest ecosystems, quantification of socio-economic vulnerability and preliminary evaluation of the population's health state vulnerable to extreme climatic phenomena; spatial modelling of Romania's deforestation actions; irrigations in Romania. *Third Section* papers discussed such issues as changes in the demographic structures of the Southern Carpathians; the humanisation process in the Bălăciţa-Piedmont Tableland; Europe within the current geo-political context; economic characteristics in Sălătrucel Commune; tourism in the Romanian Danube Valley; relationship between the ethnical and confessional structures of the German population in Romania; the geographical spread of the Romanian toponym "obcina" (hillside). The scientific session ended up with a round-table on the subject of *A Dynamic Planet. Transdiciplinary Geographical Research Prospects*. The papers presented followed some major Geography development directions, research-work relying on field investigations, GIS methods, satellyte recordings, etc.

This scientific session was attended by researchers and teaching staff from the Romanian Academy's Institute of Geography in Bucharest, the University of Bucharest – Faculty of Geography, ESRI Romania, Oltenia Meteorological Centre, and Fundulea National Institute of Research-Development in Agriculture.

Mihaela Rodica Persu

Rev. Roum. Géogr./Rom. Journ. Geogr., **61**, (2), p. 223–225, 2017, Bucureşti.

IGU THEMATIC CONFERENCE ON LAND USE/COVER CHANGES, BIODIVERSITY, HEALTH AND ENVIRONMENT, LOCAL AND REGIONAL DEVELOPMENT

SEPTEMBER 11–15, 2017, BUCHAREST AND TULCEA, ROMANIA

Romania, through the Institute of Geography of the Romanian Academy and the Faculty of Geography, University of Bucharest as main organisers, hosted the second IGU Thematic Conference. This type of conference was put into practice after the 33rd International Geographical Congress which was held in Beijing China (August 21–25, 2016) when IGU engaged itself into a new set of conferences planned to be more focused on specific research topics then the regional and global meetings. The *IGU Thematic Conference* was jointly organised under the auspices of IGU, through four Commissions: Land Use/Cover Change, Local and Regional Development, Biogeography and Biodiversity and Health and the Environment thanks to the presence and involvement of 3 steering members from Romania: Dr. Monica Dumitrașcu (Institute of Geography) – Land Use/Cover Change and Biogeography and Biodiversity IGU Commissions; Dr. Ines Grigorescu (Institute of Geography) – Local and Regional Development IGU Commission and Prof. Liliana Dumitrache (Faculty of Geography, University of Bucharest) – Health and the Environment IGU Commission. The Romanian Committee for Future Earth – Research for Global Sustainability and Romanian National Geographical Committee were also partners of this scientific event.

The IGU Thematic Conference took place in Bucharest and Tulcea between 11 and 15 September 2017 and had as main theme ***Land Use/Cover Changes, Biodiversity, Health and Environment, Local and Regional Development***. The main rationale of the *IGU Thematic Conference* was to bring together scientists and stakeholders from various connecting fields to address different effects of ecosystems changes, to set-up mitigation and adaptation strategies and contribute with scientific information to local/regional land use, planning and environmental policies.

The event gathered about 85 participants from 20 countries: Bosnia and Herzegovina, Bulgaria, the Czech Republic, Germany, Hungary, India, Indonesia, Israel, Italy, Japan, Poland, Romania, Russia, Belgium, Serbia, Slovakia, Slovenia, South Africa, Spain and Turkey. The *IGU Thematic Conference* was also attended by outstanding members of the IGU such as: Prof. Yokio Himiyama, President of IGU, actual and former chairs of the involved commissions (Prof. Michael Sofer – Israel, Prof. Ivan Bicik – the Czech Republic, Prof. Jerzy Bansky – Poland, Prof. Matej Gabrovec – Slovenia).

The main topics of this event were related to: Land Use/Cover Change and Land Degradation; Impacts of Land Use/Cover Changes on Biodiversity Loss; Causes and Consequences of Land Use/Cover Changes; Biodiversity Conservation and Management; Extreme Weather Events; Socio-Territorial Vulnerabilities and Impacts on Public Health; Environmental Changes and Human Health: Impacts and Inequalities; Distribution of Health Resources; Access to Health Care and Spatial Justice; Local Resources and Regional Specialization; Local and Regional Development: Socio-economic Disparities; Spatial Development and Territorial Cohesion; Cross-border Cooperation and Neighbourhood Policies; Governance and Policies in Planning; Land Use and Biodiversity.

During the first day of the *IGU Thematic Conference*, four plenary lectures were given by leading geographers form different parts of the world, also known for their prestigious activity within the IGU: *Environmental Change and Regional Development in Romania* given by Prof. Dan Bălteanu (Director of the Institute of Geography, Romanian Academy), *Reorganisation of International Academic Community* by Prof. Yukio Himiyama (President of International Geographical Union), *Ecosystem Services as a Tool for Local and Regional Development* by Prof. Marek Degorski (Director of the Institute of Geography and Spatial Organization, Polish Academy of Sciences) and *The Changing Landscape of the Rural Urban Fringe: An Israeli Case Study* by Prof. Michael Sofer (Bar-Ilan University, Israel).

The second day of the *IGU Thematic Conference* was held in Tulcea, where the largest part of the lectures were presented in nine Panels dedicated to the four IGU Commissions, two thematic sessions on “Spatial Development and Environmental Risks”, one poster session and one roundtable entitled “Transdisciplinary research on environmental issues”. The Roundtable was moderated by prof. Dan Bălteanu and the discussions were held between the governor of the Danube Delta Biosphere Reserve (Mr. Mălin-Matei Mușetescu), a group of scientists and stakeholders from the Danube Delta National Institute for Research and Development (dr. eng. Iulian Nichersu, dr. eng. Ion Năvodaru), the Institute of Geography, Romanian Academy (dr. Monica Dumitraşcu, dr. Diana Dogaru), the Romanian Geographical Society – Tulcea branch (prof. Gheorghe Băisan) and several local actors.

The Conference Agenda also included the business meetings of two of the involved IGU Commissions: Local and Regional Development and Land Use/Cover Change.

Two types of excursions were organised for the participants during and after the *IGU Thematic Conference*. Thus, during the Conference, a scientific boat trip to the **Danube Delta Biosphere Reserve** was organised on September 13th and a field trip in the **Dobrogea Region and the Black Sea Coast** on September 14th.

After the Conference, between 15 and 16 September, an optional post-conference excursion was organised to the Romanian Carpathian Mountains and the hilly region of the Subcarpathians.

Overall, the main scope of the IGU Thematic Conference was to connect land use and biodiversity in order to understand the relationships between ecosystems and socio-economic systems, ecosystem services, and the potential risks and benefits to regional development and human health and welfare.

Monica Dumitraşcu, Ines Grigorescu

Dan Bălteanu (Ed.) (2017), *Lower Danube Basin. Approaches to Macroregional Sustainability* (Bazinul Dunării Inferioare. Consideraţii cu privire la dezvoltarea durabilă macroregională), The Publishing House of the Romanian Academy, 2017, Bucharest, 227 pages.

The research on the Romanian Danube Valley is part of the Romanian Academy's fundamental project on the *Development Strategy of Romania for the next 20 years (2016–2035)*, this volume grouping the communications held over the four editions of the international symposium "Interdisciplinary Research-Innovation related to the EU Strategy for the Danube Region", organized under the aegis of the Romanian Academy's Council of Research Coordination for the EU Strategy for the Danube Region and the National Committee for Future Earth – Researches for Global Sustainability.

The three parts of this work (the global change context: transdiciplinarity and capacity building; environmental risks and biodiversity: assessments and tools; and local and regional territorial development) group 16 papers (written by 35 authors from Romania and Germany).

The first part is devoted to global change context, the German contributors focusing their interests on the following issues: assessment of the Danube futures under global change conditions (Wolfram Mauser); the necessity of partnerships between high performance computing (HPC) facilities in environmental sciences and the European E-Infrastructure (Anton Frank, Jens Weismüller and Stephan Hachinger), and the IMPACT 2C Web-Atlas, as a strategy for disseminating results of the integrated research in the Danube Basin (Swantje Preuschmann, Andreas Hänsler and Daniela Jacob). This part also depicts aspects of global environmental change in the Romanian Danube Valley (Dan Bălteanu, Monica Dumitraşcu, Bianca Mitrică, Mihaela Sima, Diana Dogaru, Iulian Nichersu, Marta Jurchescu and Ana Popovici).

The second part makes an assessment of the environmental impact of different natural and human hazards and risks. The main results of the study assessing the perception of local communities regarding the possible impact of DANUBIUS-RI (International Centre for Advanced Studies of River Sea Systems) on the state of the Danube Delta environment, as well as the socio-economic development of the region are presented by Manuela Elisabeta Sidoroff, Iris Maria Tuşa, Mihaela Păun and Alexandru Amarioara. The paper on *Danube Floodrisk Atlas*, based on the DANUBE FLOODRISK Project, (author Mary-Jeanne Adler) supports the integration of all Danubian countries and contributes to the flood risk management strategy of the European Union. The Sturgeon 2020 Program represents the topic of two papers, one highlighting the measures aimed at implementing this program in Romania over the next 20 years (Cristina Sandu, Radu Suciu, Juerg Bloesch and Harald Rosenthal) and the other providing a short state-of-the-art scientific concept of river continuum as the groundwork for river basin management, with example of key projects for the Iron Gate hydropower dams and the submerged sill, in order to improuve navigation at the Bala Branch bifurcation on the Lower Danube (Juerg Bloesch). Monica Dumitraşcu, Dan Bălteanu, Mihaela Sima, Ines Grigorescu and Bianca Mitrică approach the socio-economic and environmental indicators for ecosystem services in Romania, proposing 16 socio-economic and 10 environmental indicators for activities related to ecosystem services.

The third part is represented by seven papers which refer to territorial development at macro-regional, national and local level. The concept of *transnational clusters* in the Adriatic – Danubian Macroregion is discussed by Carmen Păuna and Tiberiu Diaconescu, who highlight the results obtained in a South-East Europe Transnational Cooperation Programme. Bianca Mitrică and Claudia Popescu approach the economic development of the Romanian Danube Valley, pointing out some trends of the Danubian economy, such as the historical imbalance of development between Romania's eastern and western parts, the economic decoupling of some traditionally underdeveloped zones from the country's northern and eastern areas, as well as those alongside the Danube River. The following two contributions by Radu Săgeată and a group of authors (Liliana Popescu, Oana Ionuş, Amalia Badiţă, Daniel Simulescu, Cristina Şoşea and Sandu Boengiu) emphasize the characteristics of cross-border Euroregions and cross-border tourism development, respectively. Vasile Meiţă, Raluca Petre, Jianca Ştefan-Gorîn, Alexandru-Ionuţ Petrişor present the contribution of NIRD URBAN-INCERC to the territorial research of the Danube area. The paper by Nicoleta Damian and Paul Şerban is focused on water-transport and the main types of traded goods, thus providing an overall image of Romania's commercial flows, with the Danube Corridor as a central transport axis. The importance of the institutions involved in the development of the Danubian area and for the implementation of the European Union Strategy for the Danube Region is underlined by Liviu Gabriel Muşat.

This volume is addressed to a wide readership, both specialists and decision-makers, to eventually raise awareness of the importance and rational use of natural resources.

Irena Mocanu

Ana-Maria Taloş (2017), *Stilul de viaţă şi impactul acestuia asupra stării de sănătate a populaţiei. Studiu de caz: judeţul Ialomiţa* (*The life-style impact on the health condition of the population. Case-study: Ialomiţa County*), University of Bucharest Publishing House, 193 p., 85 figures, 11 tables.

This work presents the results contained in the author's Ph.D Thesis (co-ordinator: Prof. Liliana Dumitrache) delivered at the Faculty of Geography, University of Bucharest. Mrs. Taloş makes a new approach and contribution to this little discussed subject of connection between health and life-style, offering a comprehensive analysis of the population's state of health and the factors affecting it. A knowledge of people's health condition and life-style has a major influence on the formation and the development of a community's human capital, given that significant differences between townsmen and countrymen were found to exist.

The book has a brief, but consistent introduction, four chapters, a rich bibliography, a list of tables and a list of figures.

Chapter One – *General consideration on life-style* is a conceptual and theoretical discussion of life-style and its main component elements (food, physical effort, stress, drinking and smoking) and of the connection between it and people's state of health. The chapter ends with a theoretical life-style model.

Chapter Two analyses in detail the geography, demography, sanitation, education and technical-urbanistic infrastructure of this county. Calculating numerous indicators and indexes, she highlights *The health conditions of the Ialomiţa County population*, which considers unsatisfactory in some cases, proceeding therefore to analysing another element related to *life-style* that makes the object of a new chapter – *The life-style of the Ialomiţa County population*. This second to last chapter is based on field investigation results, Mrs. Taloş having devised 212 questionnaires, requiring respondees to answer, beside the component elements included in Chap. One, also questions referring to their own sanitary behaviour. The results have shown major disparities in the perception of town and village dwellers, the former perceiving it as *good*, the latter having a divided opinion, some viewed as *bad*, others as *good*.

The last chapter looks at *The impact of people's life-style in Ialomiţa County on their health*, also establishing life-style typologies by categories of responsibilities within the county. Finally, the correlations and regressions made by the author emphasize the influence of determining factors on health condition and the main life-style predictors.

The geographical and cartographic representations have been achieved by Mrs. Taloş after processing a series of statistical data and using them in Quantum GIS 2.8 Programme, the cartographic material augmenting the value of this work.

Nicoleta Damian