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An Overview of Population Dynamics in Romanian Carpathians (1912–2021): Factors, Spatial Patterns and Urban–Rural Disparities

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Abstract: Our paper aims to analyze the tendencies of population dynamics in the area of the Romanian Carpathians, as well as the factors and spatial processes that can explain the disparities, discontinuities and tensions of demographic evolution. Starting from the hypothesis of an existing set of well-known particularities of the three areas of the Romanian Carpathians (Eastern, Southern and Western), in close connection with the specific manner of using natural and human resources of each area, the main objective of our study is to pinpoint the significant aspects of depopulation and population redistribution. The database was established resorting to censuses from 1912 to the present time. Coupled with a typology of population evolution, a regression analysis was used to assess the relationship between population size changes through time and other variables. The results highlight the contrast between the sustained dynamic in the first part of our study period and the subsequent decline, particularly in the case of establishments specialized in industrial extraction activities. Despite all this, clear signs and tendencies of revitalization and dynamism can be observed, especially where urban and rural settlements are well adapted to the natural environment and can benefit from a significant tourism potential.

Keywords: population decline; regional disparities; vulnerabilities; Carpathians; policy planning

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1. Introduction and Literature Review

Similar to most Eastern European countries, after 1989, Romania experienced a deep demographic crisis resulting from the combination of a negative natural balance and massive emigration of the workforce, especially after the liberalization of the movement of persons in 2001. The Carpathian mountain area is no exception. Representing one-third of Romania's territory, crossing it in the middle, being the area of origin for the main waterways and having a major role in the transport and communication system, the Carpathian area can be considered illustrative. At the same time, due to its physical-geographical peculiarities and the evolution of the population process, it differs significantly from other regions of the country, the historical, political and ethnographic context playing a significant role in this region. Traditionally more sparsely populated, the Carpathian Mountains regions of Romania have predominantly been the domain of pastoral communities, especially in the higher massifs. In the vast depressions of the Eastern Carpathians, Saxon or Szekler communities settled early on and adapted to the physical-geographical conditions, basing their existence on agriculture, timber exploitation and crafts. In the 18th–19th centuries, in the regions that belonged to the former Habsburg Empire, various communities were colonized in order to exploit mineral resources: Germans from the Zips County in Maramures, Czechs in the Banat Mountains, Slovaks in the Plops Mountains or Poles in Bucovina [1]. They often created a veritable ethnographic mosaic, introducing new forms of spatial organization and resource exploitation. The world conflagrations of the 20th

century have strongly affected these communities, particularly the German ones, with the effects being felt in the fluctuations in the population growth rate.

While during the communist period it benefited from massive investment in the exploitation of resources and the preservation of traditional agrarian structures, most of the mountain regions in Romania were not turned to the cooperative system. After 1990, adapting to the market economy led to a sharp decline in activities, especially in the single-industry urban centers and mining areas, as well as in the many spa resorts. Hopes of recovery were dashed by the adverse effects of population decline, which were reaching the critical threshold of depopulation. New territorial disparities were developing, leading, locally or regionally, to increased depopulation in both urban and rural areas, with the risk of becoming a major obstacle to developing a viable economic system.

The issue of depopulation has a long tradition in the analysis of demographic change as the trend of population agglomeration in metropolitan areas has led to the emergence of vast areas marked by underpopulation [2]. However, some authors consider that the advantage of population growth is relative, that there is no direct correlation between this and economic growth [3], and educational factors are more important [4]. From this point of view, depopulation trends are also manifested by the difficulty of providing access to education which can deepen the adverse effects of population decline.

More often than not, depopulation is seen as a process of drastic reduction in population numbers, with no prospect of recovering to previous peaks [5]. It is merely a result of population redistribution, accentuated by the trend towards metropolitan concentration. From this perspective, the Romanian Carpathians, against the background of a predominantly agrarian economy and the delay in the demographic transition, which only became effective in the second part of the 20th century, were relatively spared from this process [6,7]. There are nuances in the case of some massifs, especially in the Western Carpathians, marked by the extent of mining in the past proved more fragile, entering early into a demographic decline that led to the effective depopulation of some areas [8]. As in other Eastern European countries, the transition to a market economy accentuated depopulation trends [9], whereas they had been strongly manifest in some regions since the communist period [10]. Current studies show that the forms of manifestation of this process, evidenced by the general population dynamics, are specific to the Carpathian area in Romania and continue in neighboring states, either towards Central Europe or towards the Balkan states. Thus, some studies from Ukraine and Poland show developments that seem close to those in the Eastern Carpathians [11,12] while advanced analyses using remote sensing or quantitative demographic potential analysis seem to confirm the cross-border manifestation of some processes [13,14]. The earlier manifestation of the depopulation phenomenon in the Western Carpathians appears to be in continuity with the developments in the Carpathian area of Serbia, correlated with similarities in the way of habitat organization and the specificity of economic activities [15]. There is much controversy surrounding the economic and social effects of depopulation. The weakening of productive capacity through the numerical reduction in labor force, diminished innovation potential [16] or the ability to adapt to change and the difficulties of maintaining an acceptable quality of life [17] are often mentioned. Depopulation is not only a demographic problem, adjustable through the mechanism of recovery of fertility indicators [18] but, first and foremost, a problem of integration into the circuits of globalization that often exclude marginal areas, such as mountain areas, which often lack the chance of revitalization. The emergence of strong disparities in terms of living standards [19] leads to economic dependence and massive migration, keeping peripheral areas in the throes of depopulation, limiting a more optimistic outlook [20]. In the Romanian Carpathian area, cases of agricultural abandonment have already been documented [21], next to the shrinking of the settlement network through population concentration along valleys, that can take the form of peri-urbanization near larger cities, often by stimulating tourism activities [22,23] or changes in the lifestyle of certain categories of urban population [24,25]. In the mountainous areas of Romania, the absence of coherent strategies for well-founded territorial development only accen-

tuates the disparities induced by these phenomena and generates dysfunctions in the management of certain public services. As in the lower relief areas, here too there is a combination of two phenomena generated by the economic and social shock of the fall of the communist regime: the decline of the urban population [26] and the retreat of a large part of this population to rural areas, even the most isolated ones. The phenomenon of urban depopulation (shrinking cities) is particularly visible in the Carpathian area and is included among the trends observed in the past in Western countries as well, against a background of a generalized crisis of traditional industries [27,28]. This development should not be seen in a negative sense if there is a judicious approach by the authorities to turn it into an instrument for revitalizing rural areas affected by depopulation [29,30]. Unfortunately, ignoring the urgency of developing a modern infrastructure together with diversifying the supply of jobs has drained much of this urban population's reflux towards international migration [31], with some mountain areas, especially in the northern Eastern Carpathians, being pioneers in this respect. In part, this state of affairs is endemic, the poverty of the Romanian village being an expression of the state's inability to transform peasant agriculture into a productive and diversified activity [32]. Such developments have been recorded in other former communist states, such as Poland, since 1979 [33], but the trends after 1989 have manifested themselves differently, making it difficult to find a model for comparative analysis that integrates development indicators [34–36].

It should be stressed that preventing depopulation is not only a difficult task but also a very costly one that requires laborious support policies, constantly undertaken by the state [37]. Added to this is an essential, equally costly spatial planning that can mitigate or reverse depopulation trends [38,39]. Within media culture, the responsible stakeholders in Romania touch upon this issue solely at a declarative level, completely lacking any rigorous framework, with concrete objectives resulting from a comprehensive diagnosis [40].

Having these theoretical premises, the present study proposes a broad analysis of the evolution of the population in the Romanian Carpathians, detailed in chronospatial profile, since 1912, using all censuses conducted to date. Relying on descriptive, cluster and factorial analysis, this study highlights local and regional particularities, with the depopulation process at the center. The research has a rather methodological character, aiming to identify, diagnose and evaluate some potentially important factors in the evolution of the depopulation process. The chronospatial approach to the phenomenon can indicate the level of relevance of these factors and constitutes a starting point for further analysis of the depopulation process at various scales of analysis. The general objective of this study is to analyze the depopulation process in the Romanian Carpathians in the last century, both in urban and rural areas, in spatial and temporal development and in correlation with a series of explanation factors. This study covers a long period and is conducted at a spatial level of great detail (locality level), producing evidence of some phenomena discussed only at a general level and without such consistent statistical support.

Based on this general objective, a number of specific objectives have been developed: to follow the process of redistribution of the population by large relief units; to highlight the incidence of the accelerated industrialization process during the communist period, which is likely to generate contradictory trends; to observe the role of the maintenance of traditional agricultural systems in the evolution of the population during the same period; to highlight the impact of the decline of industrial activities during the transition period; to observe the trend of peri-urbanization, correlated with the decline of the urban population; to observe the incidence of the development of agro-tourism, in contrast with the accentuation of isolation in the deeply rural mountain areas.

On the basis of these objectives, partly derived from the analysis of the literature reviewed, a general hypothesis was issued: the three Romanian Carpathian divisions (eastern, southern and western), well personalized from a physical-geographical and anthropic point of view, are marked by strong particularities in terms of population dynamics over the last century, in close correlation with the specific use of natural resources and the evolution of the population system. The limitations of this study are the absence or precariousness of

the information needed for a complete analysis of how general population dynamics can capture elements of the depopulation process. Thus, the authors made a selection of those indicators that provide continuity and comparability for the time sequences analyzed and illustrates or supplement the main factors in the population system (dynamic or structural).

2. Materials and Methods

In order to test the proposed hypothesis and meet the proposed objectives, two separate databases (DB) were created and used in specific analyses:

(a) DB1, which contains ten sets of data on the numerical evolution of the population of the 2924 localities in the Romanian Carpathians, according to the 11 censuses carried out between 1912 and 2021 (Appendix A), for the last census, the final results published at the end of May 2023 will be used. The censuses usually recorded the stable population, thus ensuring the comparability of the data, even if the last records, especially those of 2011 and 2021, were heavily distorted by temporary migration abroad. The first set of data is a combination of the results of the census carried out in the Kingdom of Romania on 19 December 1912 and the Austro-Hungarian census of 31 December 1910, with the calculations respecting the somewhat longer time span in the latter case. The calculation of the indicators derived from the database took into account the different amplitude of the interval separating these records from the Romanian census of 29 December 1930, after the integration of the territories that belonged to the Austro-Hungarian Empire.

(b) DB2, which contains information on the explanatory factors used in the factor analysis. Choosing the variables was difficult because at the scale of detail used the information required is insufficient or absent for certain time intervals. For this reason, some variables were used only for certain intervals. Although information on key indicators such as the level of general mobility, and quality of life was needed, we used available statistical information that only partially reflects them. We therefore consider that the use of variables such as the temporary emigration rate, available for the last censuses, or the average income significantly compensates for the lack of more conclusive information. The variables used are shown in the following tables, separately for quantitative and qualitative variables (Tables 1 and 2).

Table 1. Quantitative variables used for multivariate analysis.

Variable	Definition, Measurement Methods	Data Source
IZO	Share of population living in settlements on interfluvial ridges and secondary valleys (% of total population, distinct for each period).	[DTM].
ALT	Average altitude of settlements (meters).	[DTM]
PAD	Degree of afforestation (% of total area, average years 1992–2019, used as invariant for the whole study interval).	[NSI].
FP	Share of area under grassland and meadows (% of total area, average of years 1992–2019, used as invariant for the whole study period).	[NSI].
ARB	Share of arable land (% of total area, average years 1992–2019, used as invariant for the whole study interval).	[NSI].
DH	Gross habitat density (settlements per 100 km^2).	[RECENS 1912...2011] [NSI]
DG	Overall population density at the beginning of the period (loc./km^2), distinct for each period.	[RECENS 1912...2011] [NSI], [ICS].
IV	Population ageing index (Iv = V/T; +60/0–14 years), distinct for each period according to population censuses.	[RECENS 1912...2011] [NSI], [ICS].
URB	Degree of urbanization (% urban population), distinct for each period, according to population censuses.	[RECENS 1912...2011], [NSI].
RUR	Degree of rurality (% population employed in agriculture), distinct for the last three periods according to population censuses. Values from the 1966 census were used as invariant for the first two periods.	[RECENS 1912...2011], [NSI].
EMG	Share of the long-term migrant population in the 2002 and 2011 censuses (% of total population), used for the latter period only.	[RECENS 1912...2011].
SOM	Share of unemployed in the 2002 and 2011 censuses and in 2019 (% of working population), used only for the latter period.	[NSI].
VEN	Average income calculated for the period 2002–2011 (euro/place), based on the average specific wage by industry and social services.	[NSI].

Details of information source: see Appendix A.

Table 2. Qualitative variables used for multivariate analysis.

Category	Variable	Description	Source
Predominant geological structure	CRIST	Predominantly crystalline rocks	[GR]
	CRIST-CC	Crystalline rocks and limestones	
	FLIS	Carpathian flysch	
	SED	Sedimentary rocks	
	VULC	Volcanic rocks	
Economic profile	FOREST	Economic profile based on logging (over 50% of the active population employed)	[NSI] [RECENS...]
	FORTUR	Economic profile based on logging and tourism (over 50% of the active population employed)	
	MINFOR	Economic profile based on logging and mining, including building materials (over 50% of the active population employed)	
	MINTUR	Economic profile based on mining and tourism (over 50% of the active population employed)	
	TUR	Tourism-based economic profile (over 50% of the active population employed)	
Ethnic structure of population	EN	Predominantly Romanian population	[NSI] [RECENS...]
	EN-IUG	Predominantly Romanian population, with South Slavic minorities	
	RO-SLO	Predominantly Romanian population, with Slovak and Czech minorities	
	RO-UC	Predominantly Romanian population with Ukrainian minorities	
	EN-UN	Predominantly Romanian population with Hungarian minorities	
	UN	Predominantly Hungarian population	
	UN-RO	Predominantly Hungarian population with Romanian minorities	

Details of information source: see Appendix A.

These databases were processed to serve the analyses necessary to test the hypothesis formulated. The derived databases were created as follows:

(a) From DB1, 10 series of values were obtained, representing the average annual growth rate, calculated as follows:

$$\text{Rmac} = ((\text{P1} - \text{P0})/\text{t})/((\text{P1} + \text{P0})/2) \times 100,$$

where Rmac is the average annual growth rate, P0 is the population at the beginning of the period, P1 is the population at the end of the period and t is the length of the interval. The derived database was used for descriptive analysis by means of two hierarchical agglomerative clustering: one on a large scale, aggregating the specific values of the 2924 localities in the Romanian Carpathians, six distinct classes, reflecting the main trends of evolution; another on a small scale, after previously aggregating the values for the 49 physical-geographical units (mountain massifs, depressions, major corridors), separated by residence environments, obtaining six distinct classes, the first three being typically urban. The two classifications complement each other, the detailed analysis being doubled by a synthetic one, more expressive from the perspective of the personalization of the three Carpathian ranges. XlStat software was used to produce the classifications, operating with the Euclidean distance and the Ward aggregation method, keeping the dispersion of values between classes as large as possible, in order to ensure internal homogeneity and, consequently, the validity of the typology.

(b) DB2 was constituted at the level of the 2924 localities in the Romanian Carpathians, according to the methodology set out in the tables above. Quantitative values were standardized by the Z-score method, using extreme values as a reference. Subsequently, the values obtained were aggregated at the level of the 49 physical-geographical units that constituted the spatial support for the principal component analyses performed. Qualitative values were estimated at this level based on the prevalence of the features' prevalence. Multivariate principal component analysis was used to test the correlation between the average annual growth rate, considered as the dependent variable, and the 30 explanatory variables (13 quantitative and 17 qualitative). In order to capture the incidence of these

variables in the population dynamics, five distinct periods were separated, corresponding to the specific trends analyzed by the AHC:

- 1912–1930, a period marked by the First World War, the Carpathians constituting a front line, and by the establishment of Greater Romania;
- 1930–1948, a period marked by the amplification of the exploitation of Carpathian resources and by the Second World War;
- 1948–1966, a period during which the installation of the communist regime took place, with the specific features of the Carpathian area (this remained outside the plans for the collectivization of agriculture);
- 1966–1992, a period during which rural exodus peaked at the national level, as well as the extensive development of certain mining activities;
- 1992–2020, marked by the transition to a market economy, which affected the Carpathian area in a specific way through the loss of attractiveness generated by urbanization and increased industrialization. For each of these periods the average annual growth rate was calculated, resulting in five distinct PCAs that capture the differentiated way in which the factors expressed by the explanatory variables acted. The quality of the model was tested by calculating r2 and the analyses were performed in XlStat.

The graphical processing of the results consisted in the production of two cartograms for each AHC analysis, accompanied by the type (class) profile graph. The PCA results were displayed by extracting information on the incidence of each factor from the correlation matrices for each separate period. In addition, standardization plots of the residuals of the multivariate analysis were also entered to track the predictive ability of the model followed.

3. Results

3.1. Typology of Population Dynamics in the Romanian Carpathians (1912–2021)

The first AHC analysis, based on the database of the 2924 localities in the Carpathian area, according to the current administrative–territorial division, proposes a descriptive view on the evolution of the population growth rate, calculated for each intercensal period, highlighting the trends that are differentiated in space and time.

The six separate types (classes) have a distinct profile and are strongly territorialized, closely linked to the predominance of small rural settlements (under 100 inhabitants) in the Western Carpathians and the frequency of large rural settlements (over 1000 inhabitants) in the Eastern Carpathians, especially in the mountain depressions and major valleys. This correlation between the size of the settlements and the evolution of the population, i.e., vulnerability to depopulation, is illustrated in Table 3.

Table 3. Numerical evolution of the population of settlements in the Romanian Carpathians by size categories.

Size Category (Inhabitants)	Number of Localities	Numerical Evolution of the Population (1912 = 100%)									
		1930	1941	1948	1956	1966	1977	1992	2002	2011	2021
0–10	154	99	**105**	98	96	99	40	14	8	4	2
10–100	663	97	**101**	97	95	88	71	50	41	31	25
100–250	538	97	**100**	96	95	93	83	65	58	49	43
250–500	552	99	104	99	103	**106**	99	83	77	68	62
500–1000	479	100	107	103	108	**110**	110	99	95	87	82
1000–2500	364	105	110	106	121	130	**132**	127	122	115	112
2500–10,000	140	106	116	113	134	157	183	**201**	188	175	170
Over 10,000	34	118	140	132	192	265	385	**501**	448	395	371

Data source: see Appendix A. Note: maximum values are highlighted in bold.

According to the table above, the most vulnerable are small rural settlements (under 250 inhabitants), whose decline began before the Second World War and became more marked after 1966, when rural exodus became widespread. Notably, almost half (46%)

of settlements fall into this vulnerable category, with a steeper decline than for large or medium-sized settlements. This evolution is in line with the general trends observed at the national level, but the Romanian Carpathians are much more affected because of the high share of small settlements. The vulnerability of these settlements is enhanced by the isolated position, on the interflows or at the origin of some valleys.

The six classes separated by the AHC analysis largely reflect the correlation between population dynamics and settlement size, with classes marked by a pronounced decline generally located in mountainous areas with small settlements (especially the Apuseni Mountains). The first of the six classes reflects, however, partially the most recent phenomenon manifested in the population dynamics in Romania, the peri-urban concentration, obvious in the area of the Carpathian curvature, superimposed on the peri-urban area of Brasov (Figure 1).

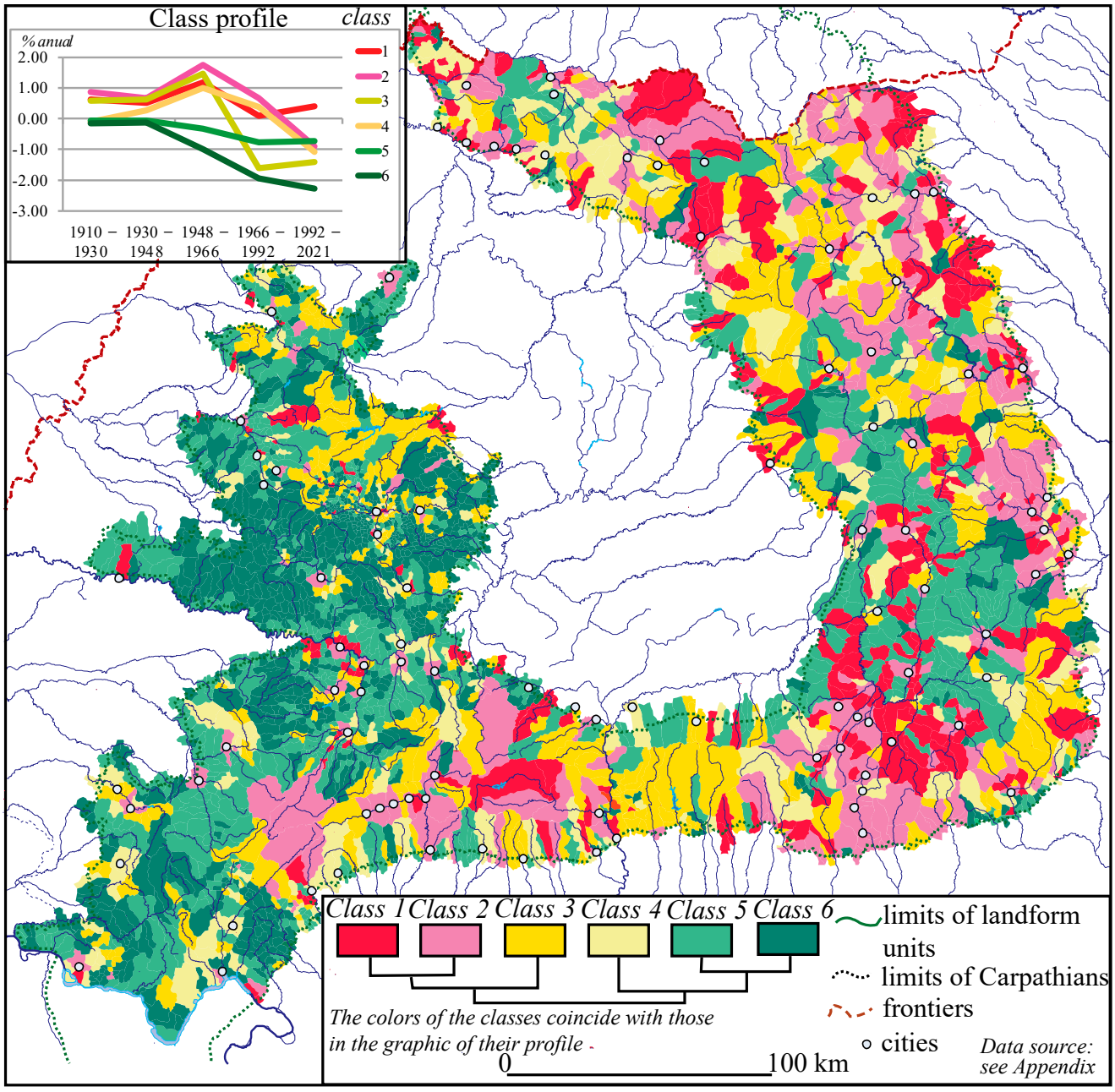

Figure 1. Typology of population dynamics in Romanian Carpathians (1912–2021).

In the northern part of the Eastern Carpathians, however, the dynamic profile of this class, which is the only one that has not experienced a lasting trend of demographic decline, is explained more by the presence of traditional, conservative communities (e.g., neo-protestant communities or communities of Ukrainian ethnic origin), and combined with isolation that can thus play a contradictory role. The 279 localities included in this class are, for the time being, the only ones spared from the general population decline that characterizes the Romanian Carpathians, visible in the dramatic drop in population after 1990 (from 3,887,440 inhabitants in 1992, when the peak value was recorded, to only 3,054,170 inhabitants in 2021, i.e., a 22% drop in less than three decades).

Class 2, with a similar share (287 localities included), comprises most of the urban centers and many of the localities that have experienced a diversification of economic activities during the communist period (mining, tourism, hydro-energy development, logging, etc.). Their profile is thus marked by significant population growth, particularly in the first part of the communist period (1948–1966). This class, which is mainly located in the Eastern and Southern Carpathians, suffered the greatest shock of the transition, with massive population declines of up to one-third of the population recorded in 1992 (especially in single-industry towns such as Cugir—40% or mining towns such as Bălan—51.4%, Anina—48.3%, Moldova Nouă—44.6%, Ștei—42.2%, most cities in the Jiu Valley). An exceptional decline was also registered by the municipality of Reșița, an important industrial town, residence of Caraş-Severin county (–41.7%).

Class 3 complements the previous two by grouping less accessible, often more recently populated rural areas, primarily focused on exploiting forest resources. Much more common (467 localities), it is distinguished by a profile marked by a substantial increase in population during the communist period but, similar to the previous type, after 1992, it experienced a massive decline attributable primarily to the decline of economic activities that gradually led to an import flow of population, especially young people, in international migration for work, especially in the northern Eastern Carpathians. Further decline in the coming decades, which is to be expected especially in conditions of strong isolation, may make this category of settlements more vulnerable, setting in motion depopulation trends.

Class 4, with a broader dispersion throughout the Carpathian range, with some clustering in the northern Eastern Carpathians, includes 287 localities marked by a relatively early decline, which started after 1948 but has stabilized in recent decades. They are generally older settlements, often more densely populated, usually located close to small and medium-sized urban centers whose demographic balance has thus been disturbed, making them vulnerable to depopulation.

Class 5, much more frequent (757 localities, i.e., more than $\frac{1}{4}$) is distinguished by the early onset of decline, from the beginning of the study period, but at a moderate level. They form compact areas in the depressions of the Eastern Carpathians (Ciuc, Giurgeu, Trei Scaune), in the more accessible areas of the Western or Southern Carpathians (Timis Corridor, Deva-Alba Iulia Corridor). The early decline can be explained by the earlier onset of demographic transition and rural exodus but the relatively favorable position limited its negative effects. Even if the population continues to decline in these areas, especially due to population ageing, the risk of depopulation is lower.

Class 6, comprises most settlements (847), usually small, forming compact areas in the Western Carpathians (central-southern part of the Apuseni Mountains, the Poiana Ruscai Mountains or some areas of the Banat Mountains). It is rare in the Eastern and Southern Carpathians, characterizing the most isolated settlements. Their profile indicates an early onset of decline, at least from the beginning of the period, with an accentuation since the interwar period and a continuous intensification that shows no signs of stagnation. They are the category most vulnerable to depopulation, in some cases completely (45 localities were without inhabitants at the last census) or in an advanced stage (109 localities have fewer than ten inhabitants). Its distribution essentially confirms the general hypothesis. The way these classes are grouped in a spatial profile also derives from changes in urban–rural relations, dominated during the communist period by excessive concentration in urban

centers, and after 1989 by the emergence of the peri-urbanization process and the recurrent decline of massive de-industrialization, especially in the case of single-industry centers or those based on the extractive sector. Rural or urban membership had a stronger influence on population dynamics before 1989, but the situation was more complex afterwards.

3.2. The Typology of Population Dynamics in the Romanian Carpathians (1912–2021) by Geographical Units and Urban–Rural Area

The second AHC analysis summarizes the general description, supported by aggregated information by geographical units and residence environments. The six separate classes show a more attenuated profile than in the previous classification, with the aggregation of the values at a higher scale producing some uniformity (Figure 2). The classes are grouped in threes, with the first group almost exclusively characterizing the urban population. This divergence is consistent with the progressive urbanization that intensified during the communist period, in parallel with the increase in rural exodus.

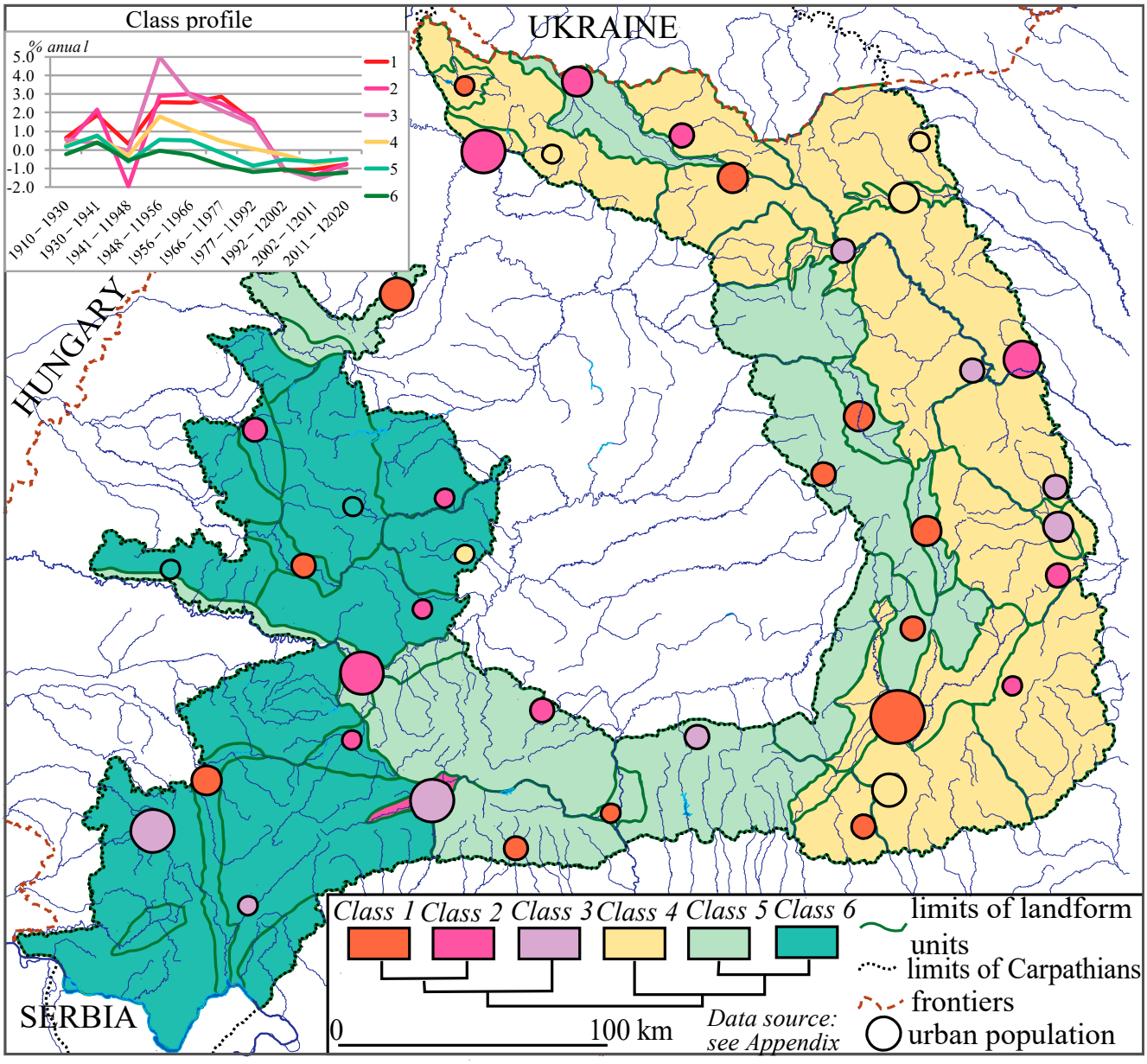

Figure 2. Typology of population dynamics in Romanian Carpathians (1910–2021) by physical-geographical units and urban–rural area.

Consequently, while in 1912 only 21.6% of the population lived in towns, in 1948, a slow growth brought the figure to 25.1%, before rising dramatically to 53.4% in 1992. However, the effects of the transition, which were strongly felt in the Carpathian region, reduced the proportion of the urban population to only 50.1%, which can be explained by the predominance of small and medium-sized towns, often single-industry towns, the only major urban agglomeration being Brasov. The three predominantly urban classes have roughly the same profile, the difference being due to the extent of growth/growth in certain periods. Class 1 groups mainly cities in depressed areas which are distinguished by constant growth throughout the communist period, a sign of increased attractiveness, favored by the position of convergence. Class 2, with a similar profile, is also mainly located in depressed areas and is distinguished by the extent of the population decline between 1941 and 1948, while class 3 is marked by an exponential growth in the first decade of the communist period, including mainly mining towns (Valea Jiului, Banat Mountains, Comănești Depression, etc.) or, in the particular case of the Făgăraș massif, newly created towns immediately after 1948 (Victoria town).

Classes 4–5 characterize rural areas, except for those in the Jiu Valley which, being integrated into a real conurbation have had an evolution close to that of cities. Class 4 is characterized by a more dynamic profile, somewhat intermediate between the typical urban and rural profile, with a significant increase in population between 1948 and 1992 and a much more moderate decrease in the last three decades. Characteristic exclusively of the Eastern Carpathians, except for the Maramureș Depression and the Transylvanian side of the central group, this type of evolution can be explained by the preservation over a more extended period of traditional demographic behavior, specific to the whole northeastern part of the country, but also by the intense exploitation of forestry and agro-pastoral resources, together with the particular morphology expressed by the alternation of vast depressions with relatively accessible mountain massifs. Class 5 characterizes most of the Southern Carpathians, with extensions towards the western side of the Eastern Carpathians or in the extreme north of the Western Carpathians (Meseș-Plopiș Mountains, Vad-Borod Depression). The population decline started here earlier, as early as 1966, the previous growth being rather mediocre, but after 1992 the decline stabilized at moderate values, similar to the previous class. Largely, these rural areas are more polarized by urban centers, with a better-preserved traditional economic system, often oriented towards agro-tourism more recently. Class 6, covering most of the Western Carpathians, has experienced an almost continuous decline in population throughout the period, accentuated after 1948, with no tendency to abate. From the point of view of vulnerability to depopulation, it is the most problematic, with a particular feature being the frequency of small, often isolated villages, even when they are located close to major urban centers (as in the Poiana Ruscăi Mountains, for example). This threefold division of the Carpathians regarding population trends should involve specific sustainable development policies. There is a strong polarization at the regional level, with a fairly clear separation of residence environments (urban—rural). The presence of regional particularities is reinforced and justified by the evidence of coherent areas for the three predominantly rural types, which indicates the differentiated manifestation of factors included in the multivariate analysis.

3.3. Factors Explaining the Differentiated Evolution of the Rural Population in the Romanian Carpathians

Choosing a set of principal component analyses, separating five distinct time sequences, marked by specific political and economic-social developments, as already mentioned in the methodological chapter, is justified because it enables establishing the specific incidence of each factor, the constancy or variability of their action. In addition, explanations that are not supported by strong correlations can be excluded. For each of the five periods, a specific average growth rate was calculated at the level of the 49 major geographical units that make up the Romanian Carpathians. The set of values thus obtained constitutes the dependent variable in the analysis model based on the PLS (Partial

Least Squares Regression) method, with a confidence interval of 95%, the 13 standardized quantitative variables and 17 qualitative variables being tested. The predictive ability of the model is high, as shown by significant r2 values for each of the five periods (Table 4).

Table 4. Correlation between population growth rate and explanatory variables (quantitative components). Values in bold are different from 0 with a significance level alpha = 0.05.

Time		1912–1930	1930–1948	1948–1966	1966–1992	1992–2021
Model quality	r^2	**0.7853**	**0.3410**	**0.6737**	**0.6798**	**0.5859**
Explanatory variable (quantitative components)	IZO	**0.285**	−0.010	**0.343**	**0.526**	0.106
	ALT	**0.491**	0.178	0.112	0.007	0.195
	PAD	0.063	0.152	−0.021	−0.310	−0.002
	PF	−0.074	**−0.283**	0.035	0.105	−0.089
	ARB	−0.147	−0.017	−0.151	**−0.265**	0.123
	DH	**0.267**	−0.022	**0.251**	0.180	**0.378**
	DG	**−0.254**	−0.195	−0.103	**0.428**	0.240
	IV	**0.733**	**0.322**	**0.478**	**0.573**	**0.501**
	URB	**0.558**	0.150	**0.778**	**0.798**	0.031
	RUR	**0.333**	0.190	**0.559**	**0.680**	−0.099
	EMIG	no data	no data	no data	no data	−0.066
	SOM	no data	no data	no data	no data	0.088
	VEN	no data	no data	no data	no data	−0.133

The lower value in the period 1930–1948 can be attributed to the impact of the Second World War, which disrupted previous trends. The attenuation of the value after 1992 may also be an indication of the influence of transition-induced uncertainty with contradictory effects, expressing a different capacity to adapt.

The results (Table 5) show that, overall, the quantitative variables used have a greater predictive capacity than the qualitative variables that can be considered secondary. Each of the five periods is strongly personalized.

Table 5. Correlation between population growth rate and explanatory variables (qualitative component). Values in bold are different from 0 with a significance level alpha = 0.05.

	Time		1912–1930	1930–1948	1948–1966	1966–1992	1992–2021
Explanatory variable (qualitative components)	Geological structure	CRIST	−0.091	−0.010	−0.112	−0.102	0.081
		CRIST-CC	−0.011	**0.212**	−0.190	**−0.346**	**−0.332**
		FLIS	0.127	−0.026	0.140	0.142	**0.221**
		SED	0.027	−0.189	**0.203**	**0.408**	−0.008
		VULC	−0.048	0.050	−0.070	−0.196	0.127
	Economic profile	FOREST	**−0.329**	−0.199	−0.085	−0.114	−0.025
		FORTUR	0.136	0.102	−0.137	0.120	**0.335**
		MINFOR	**0.425**	−0.125	**0.381**	**0.220**	−0.168
		MINTUR	−0.145	−0.030	0.068	−0.152	**−0.328**
		TUR	**0.232**	**0.359**	0.017	0.021	0.018
	Ethnic structure	RO	−0.051	0.131	−0.010	**−0.243**	**−0.384**
		RO-IUG	−0.147	−0.160	0.076	0.023	−0.178
		RO-SLO	0.053	0.000	−0.122	**0.254**	0.020
		RO-UC	**0.237**	**−0.332**	0.084	0.063	**0.278**
		RO-UN	−0.142	0.055	0.052	0.069	0.196
		UN	−0.013	0.052	−0.094	0.194	0.187
		UN-RO	0.160	0.077	−0.072	0.031	0.191

Thus, between 1912 and 1930, there is a strong correlation between the population growth rate and the variables ALT, IZO and DH, but above all, not by chance, there is a very strong dependence on IV, URB and RUR. The decline of the population, which was

already evident in the Western Carpathians during this period, can be explained by the frequency of isolated (usually small) settlements located at high altitudes, a high density of settlements, a high degree of rurality and an earlier onset of the demographic transition, as evidenced by the incipient presence of the demographic ageing process.

The dependence on the URB variable can provide an explanation for this period especially in the Eastern and Southern Carpathians, with more frequent depressions, where the urbanization process was more active. Among the qualitative variables, we note the significant correlation with the mining-forestry or tourism economic profile, in line with the tendencies of the modern economy to exploit mountain resources. The impact of the geological structure was insignificant in this period and from the perspective of the ethnic structure, the presence of Ukrainian communities in the extreme north of the Romanian Carpathians, in conditions of extreme isolation that implied a certain behavioral conservatism, had a relative influence.

In the period 1930–1948, the specific geopolitical context disrupted the incidence of some factors, reducing the predictive quality of the model, a relative dependence being noted in the case of variable IV, a sign that the modification of the population structure through migration or through the deepening of the demographic transition has continued and among the qualitative variables, TUR stands out, which may indicate a diversification of the exploitation of specific mountain resources in the second part of the interwar period when, indeed, many tourist resorts evolve through urbanization and tourism expands in rural areas. This also explains the significant incidence of the CRIST- CC variable, as the massifs with a crystalline-calcareous substratum are by excellence suitable for tourist activities.

The period 1948–1966, overlapping with the first part of the communist period, brings to the forefront quantitative variables consistent with specific economic and social development policies (URB), resurrecting the strong correlation expressed by IZO, DH, IV and RUR. Among the qualitative variables, MINFOR is again significant, in the context of an often wild exploitation of mining and forestry resources (especially under the control of the famous "Sovrom") but SED also makes its presence felt, explicable by the economic value of the sedimentary depression basins, where the main urban centers are located. Broadly speaking, we can say that this period is one of re-establishment of the factor context of the first period.

The period 1966–1992 is interesting both from the perspective of continuity, with an emphasis on the role of isolation and the importance of sedimentary basins, attractive for their character as a bridge between the Carpathian slopes, and by highlighting some previously insignificant factors, primarily ARB and DG of the quantitative ones. It can thus be seen that the delay in population decline in the Eastern Carpathians can also be closely correlated with the presence of larger arable areas, thanks to the frequency of a flat relief, specific to intramontane depressions (13.9% of the total area, compared to only 8.5% in the Southern Carpathians).

As for the overall population density, it seems to be closely related to the previous factor, with the Eastern Carpathians being more densely populated than the Southern Carpathians or, due to the early decline and depopulation process, the Western Carpathians. The latter, having lower altitudes and a higher agricultural use (40% of the total area, mainly in the form of pastures and meadows, compared to 34% in the Eastern Carpathians and 29% in the Southern Carpathians), initially had a much higher overall density due to the frequency of wide corridors and high-altitude plateaus (36 inhabitants/km^2 in 1912, compared to 25 in the Eastern Carpathians and 21 in the Southern Carpathians) but the orientation of the economy towards the exploitation of mining resources led to the early manifestation of rural exodus.

Thus, in 1992, the position of the three mountain ranges was reversed: the Eastern Carpathians, which were mainly oriented towards the exploitation of forestry and tourism resources and intensive use of agricultural land, especially in the depressions, had risen to 33 inhabitants/km^2, while the Southern Carpathians maintained their level

(20 inhabitants/km^2) and the Western Carpathians fell to 25 inhabitants/km^2). If we also take into account the more advanced urbanization of the southern and eastern side of the Romanian Carpathians (62 and 55%, respectively, in 1992 compared to only 41% in the Westerners), the decline in some isolated massifs such as the Apuseni Mountains as a whole or the Poiana Ruscai Mountains, with settlements generally located at altitude and in isolated conditions, becomes explainable.

Among the qualitative variables, the presence of mixed Romanian-Slovak communities, located mainly in the Plopiș Mountains in the north of the Western Carpathians, which, according to the descriptive analysis, is distinguished by a different profile from the rest, is significant. The existence of resources whose exploitation intensified during this period (coal, oil), together with the demographic conservation specific to certain ethnic communities in isolation, may explain this peculiarity.

The latest period is marked by a relative reduction in the degree of significance of the model, which was stable during the communist period. The difficult transition to a market economy generated contradictory developments that often followed one another in quick succession, thus reducing the influence of variables such as IZO, URB, RUR, SED and bringing to the fore variables that were previously less correlated, such as FORTUR or FLIS. The retreat of part of the urban population to rural areas, with the restructuring of many production capacities, the decline of mining activities has in turn reduced the role of altitude and remoteness. The rise of tourism and logging activities explains the stability or positive population dynamics in certain favorably located areas, and habitat density in combination with the process of demographic ageing is becoming the main cause of the accentuation of the depopulation process which, as has been pointed out, affects small settlements in particular.

The strong negative correlation between the qualitative variable RO, which suggests a stronger vulnerability of settlements with a predominantly Romanian population (as in the case of the Apuseni Mountains or the Poiana Ruscai Massif, for example), and areas where the presence of minority communities (Ukrainians in this case) is positively correlated, is striking.

Isolated in the valleys north of the Eastern Carpathians, in Maramures and Bucovina, these remote, conservative communities have so far maintained a demographic vitality that contrasts with the general trends. The fact that the mining or combined mining-tourism economic profile correlates negatively is also illustrative of the massive decline affecting many settlements that had benefited from impetuous development during the communist period. We can thus state that this period, 1992–2020, is certainly a period of transition towards a new equilibrium which will require those factors which will ensure a sustainable adaptation to the new socio-economic context.

These statements were illustrated by mapping the standard residuals of the correlation between population growth rate and the explanatory variables used in the model (Figure 3). It can be seen that, for the most part, the evolution of population growth at the level of the major physico-geographical units conformed to the model analyzed, either with a slight positive deviation, especially in the Eastern Carpathians, or with a slight negative deviation, especially in the Western Carpathians.

It is worth discussing the extreme deviations (outliers), usually present in regions disrupted by massive industrialization during the communist period (the coalfields of Petroșani and Comănești for example) or marked by the presence of important urban centers (Brașov, Baia Mare). The largest positive deviations are mainly in predominantly rural, demographically conservative regions (Bârgăului Mountains, Oaș Depression, etc.) or regions strongly marked by the development of tourism (Rucăr-Bran corridor).

At the opposite pole, extreme negative deviations characterize more isolated mountain areas in the Western Carpathians (Almăj Depression) or in old mining areas that have been in decline for a long time (Metaliferi Mountains, Trascăului Mountains).

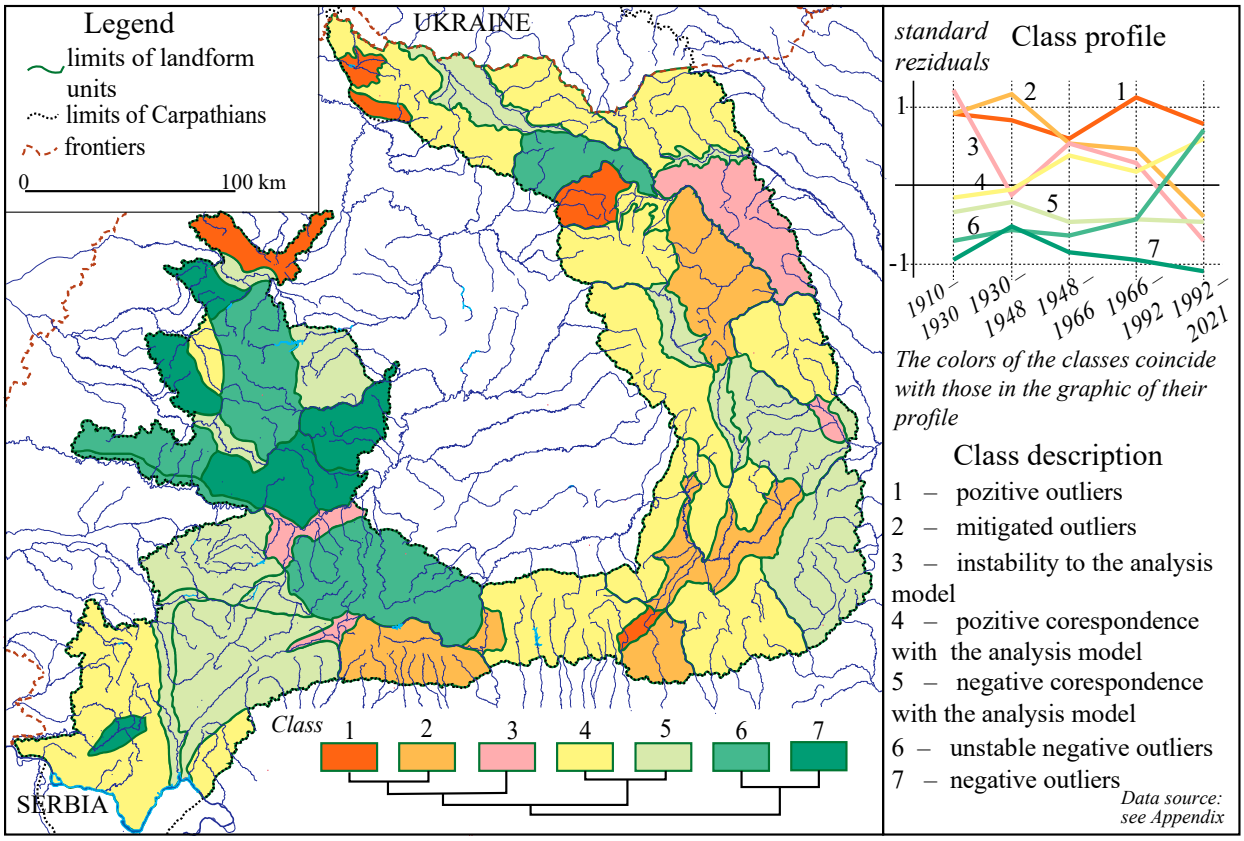

Figure 3. Typology of standard residuals of the correlation between population growth rate and explanatory variables (quantitative and qualitative components) by geographical units.

4. Discussion

The descriptive analysis carried out by means of the two AHCs at micro- and mesoscale broadly confirms the general hypothesis, as there are significant differences between the three Carpathian ranges, especially in terms of the evolution of the rural population. For this reason, further analysis using only rural information was necessary to certify the influence of geographical or economic-social factors on the secular population dynamics, especially in terms of the depopulation process in its different phases of evolution.

The resilience of each physical-geographical unit seems to depend on the extent to which they are able to harness tourism potential in combination with the efficient use of forest resources, with large, favorably positioned settlements having an advantage. From this perspective, the Eastern Carpathians seem to be the best positioned, with the specific qualitative variable FLIS being illustrative. The Romanian Carpathians are thus entering a phase of resizing of the settlement system which, in the areas most affected by the depopulation that has already taken place, translates into a tendency to concentrate the population along the main valleys and in depressions (Table 6). As a result, the population share of settlements located on interfluvial ridges or secondary valleys has decreased in all three major Carpathian regions, especially in the Southern and Western Carpathians. Here, the initial share was also higher, favored by the wide extension of the erosion platforms at altitude, while in the Eastern Carpathians there was even an increase until 1966, with the population of the interfluves being later (14 of the 21 settlements that appeared after 1912 were located here). In the depressions, there was a slight decline in the first part of the study period, the population of secondary valleys and interfluves having its source here.

Table 6. Evolution of population share by relief categories and population density (hab/km^2) in the Romanian Carpathians.

Region	Landform	Share in the Total Population (Rural Areas Only)						Population Density	
		1912	1930	1948	1966	1992	2021	1912	2021
Eastern Carpathians	Interfluves	3.9	4	4.1	4.5	3.7	3.3	10	10
	Depressions	46.6	46.1	45.4	42.4	43	45.6	42	49
	Main valleys	13.1	13.5	13.8	14.6	15.5	15	25	34
	Secondary valleys	36.3	36.4	36.7	38.5	37.8	36.1	18	21
Southern Carpathians	Interfluves	15.6	15.9	15.6	13.3	11.5	9.4	22	11
	Depressions	23	22.7	21.9	21.1	21.2	23.5	33	28
	Main valleys	6.9	7	7.4	9.7	9.5	10	17	19
	Secondary valleys	54.6	54.4	55.1	55.9	57.8	57.1	15	13
Western Carpathians	Interfluves	18.1	18.6	19.2	18.8	15.3	12.5	27	9
	Depressions	30	29.8	29.3	30.3	33.6	37.5	47	30
	Main valleys	5.2	5.3	5.7	6.4	7.4	7.1	36	25
	Secondary valleys	46.8	46.3	45.7	44.6	43.7	42.8	37	17

Data source: see Appendix A.

However, after 1966, better accessibility and more diversified economic opportunities, closely linked to the presence of cities, largely confined to the depressions, led to a new increase in the share, which was very visible in the Western Carpathians. The main valleys have developed favorably, being major routes into the mountain massifs or forming the route of transverse communication routes. The secondary valleys, especially in the Eastern and Southern Carpathians, have also experienced certain favorability, especially linked to the frequency of contact settlements, towards the subcarpathian depressions. In contrast, in the Western Carpathians, where the contact with the lower regions is more abrupt, they have experienced a decrease in weight.

The differences between the three Carpathian ranges are even more accurately captured by the evolution of population density, marked by stability or even increase in the Eastern Carpathians, by relative stability, with the exception of the interfluves in the Southern Carpathians, and by a general decrease, even in depressions in the Western Carpathians, to values that clearly express depopulation trends in the case of the interfluves, with only 9 hab/km^2.

Similar to the whole Romanian territory, the Carpathian mountain area is currently evolving demographically and economically under the impact of two competing processes: rural depopulation and urban (metropolitan) agglomeration. Similar to other mountain regions in Eastern Europe, depopulation seems to become a characteristic feature of the 21st century, inevitable with the transition from a predominantly agrarian to a service-based economy. The structural nature of this transition, dependent on globalization, a phenomenon that even the most isolated settlements in the Romanian Carpathians cannot ignore, implies the presence of disparities generated by the differentiated resilience capacity. This was noticeable during the communist period, when, protected from the effects of collectivization of agrarian structures in hilly or lowland areas, the Carpathian mountain areas preserved their traditional forms of organization of specific activities and links with the local market, benefiting primarily from the expansion of areas occupied by pastures and meadows that allowed livestock farming [41]. Together with the advantages of job creation through the exploitation of subsoil or forest resources, Romania's mountain areas have undergone much more obvious modernization than the lowland regions. Although partially disrupted by the effects of the transition to a market economy, the economic structures of the Carpathian area retain a competitive advantage but have proved fragile in the face of the attraction of emigration for work abroad. The risks and vulnerabilities induced by the depopulation process and the challenges brought by urban agglomeration cannot be ignored. A sustainable alternative for managing the consequences of these

apparently adverse but closely related phenomena is currently lacking, as is the creation of an adapted model of sustainable and innovative population growth that makes the most of existing potential. In order to resist rapid change, isolated communities hit by depopulation should be strongly supported to improve their resilience by adjusting their functionality and internal structure. The issue of depopulation, together with the precariousness of labor utilization and the ageing population, is only with difficulty making its way onto the public agenda of the authorities. Clear strategies aimed at education and vocational training and the sustainable exploitation of resources should be promoted and supported, even if they entail considerable costs. Far from constituting a particular situation, the general decline of the population in the Romanian Carpathians is in line with the trends observed in other mountain regions of Europe [42], from the increasingly frequent abandonment of agriculture [43] to the exploitation of tourism potential within the limits of sustainable development, often by highlighting the cultural-ethnographic specificity [44] or the quality of the environment. The latter is also the foundation of the concept of sustainable mountain development (SMD), already included in Chapter 13 of Agenda 21, which is applicable at various scales in Europe [45].

As far as the sources of information allowed, the results of this study highlight the importance of the determinants of demographic development in the context of completing the demographic transition. Income levels, job stability or the degree of human capital development are variables with long-term effects that can be taken into account for further analysis. The problem of demographic development in mountain areas in Romania is essentially no different from other similar areas in Europe, at least at present. As everywhere else, restructuring inefficient economic systems and sustainable use of local resources can be solutions for maintaining demographic balance and mitigating the depopulation trends already felt in some areas. It is imperative to adopt measures to reduce development disparities, drawing on the experience of Western countries where depopulation of mountain areas is long-standing, with some studies indicating that phenomena such as the precariousness of basic services, exposure to poverty and social exclusion are greater in Eastern Europe, where the situation is more similar to that in Mediterranean countries [46].

5. Conclusions

The results of the analyses show that such studies are necessary to diagnose the current state of the socio-economic system in the mountain regions of Romania. Any territorial development strategy must take into account the trends identified at the local or regional level. Although empirically known, many of the ideas emerging from the analysis show more clearly the interference of some of the factors studied. The experience of advanced countries that have also been affected by the phenomenon of depopulation in the mountain areas shows that there are no generally valid solutions to stop it, some authors are even skeptical about the possibility of reversing negative trends, especially in Eastern Europe [47]. Not even the most radical measures to improve infrastructure or diversify the economy could be implemented without enormous costs, difficult for any state to bear. Integration into the European Union has induced an optimistic view in public perception especially in terms of the use of EU funds. However, the absence of clear objectives and principles, coupled with a lack of theoretical knowledge of the nature of the depopulation process and its regional or local specificities, has so far undermined this optimism [48]. General solutions proposed by studies, such as adapting rural services to specific needs or strengthening the network of small towns, which is deficient at the national level [49], have remained singular, without an echo among public administrations.

As the analyses have shown, in addition to depopulation, there is also a concentration of the population in metropolitan areas, at the expense of rural areas or smaller urban centers. Development policies should therefore be adapted to the local context and focus on what is considered to be the key problem in the depopulation equation: the labor shortage. This study showed the strong explanatory value of the socio-professional structure of the working population, most often the massive population decline being linked to the

predominantly agricultural character and the precariousness of basic services. Reports from international institutions show that policies are needed to retain skilled population, attract temporary labor from non-EU countries and increase labor intensity [50]. The precariousness of the labor market in remote mountain areas, accentuated by the low level of education and poor motivation for agricultural activities, against the backdrop of superior supply in Western states creates massive flows of seasonal or even permanent migration, accentuating depopulation [51]. Associated with the persistence of material deprivation generated by the low level of modernization [52], this phenomenon may explain why the population retention capacity is so low in some areas since before the communist period. Even if, on the whole, the Romanian Carpathians are relatively urbanized if we compare them to the national average, a strong urban–rural dichotomy persists here too, and an urbanization of rural communities is needed in terms of lifestyle, standard of living, as it happens spontaneously around some major cities. Some European reports show that, from the perspective of urban–rural polarization, Romania as a whole is better off than other Eastern countries (Bulgaria or the Baltic States) but the manifestation of strong regional contrasts, as highlighted by our study, is worrying [53]. European policies to integrate isolated rural areas into a dynamic, multifunctional territorial complex through spatial planning and monitoring are becoming a necessity [54] even if it entails costs. Rural development policies should be geared towards ensuring sustainability, otherwise paleo, conjunctural solutions will not be able to reduce the massive depopulation of vast mountain areas. Judicious, integrative land-use planning, closely linked to ecological infrastructure, with the objective of rural renewal, can be a solution for optimizing territorial systems, as has long been practiced in Western countries, and can be an option for saving isolated regions with attractive natural potential [55,56]. Halting the decline is illusory; the objective of these policies should be to slow it down, to achieve a new balance in terms of population structure even by attracting vulnerable groups such as the elderly population to such areas. Some studies show that many mountain areas could be saved by a combination of gentrification and geriatrification [57], promoting the quality of the natural environment. When certain traditions are preserved (handicrafts, woodworking, etc.), the solution of transforming these areas into innovative territories can also be considered. Still, such ideas seem far from the realities of mountain areas in Romania.

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Appendix A

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