Derivation of Geographical Marginalization Index of Bosnia and Herzegovina using GIS Multicriteria Decision Analysis

Ivan Marić[A], Aida Avdić[B*]

[A] *Department of Geography, Center for geospatial technologies, University of Zadar, Trg kneza Višeslava 9, 23000 Zadar, imaric1@unizd.hr*
[B] *Department of Geography, University of Sarajevo, Zmaja od Bosne 33-35, 71000 Sarajevo, aidaavdic@pmf.unsa.ba*

ABSTRACT

Across Europe marginalization has been highlighted as an object of important political concern. In the area of Central Europe and the Balkans, the problem of marginalization has not been sufficiently researched. This particularly applies to the Bosnia and Herzegovina (BiH). Using the GIS multicriteria decision analysis a composite index of geographical marginalization (G_{MAR}) was created. Marginalization is analyzed as a multidimensional concept using the 4 groups with a total of 40 criteria. Spatial patterns were detected from extremely marginalized to extremely non-marginalized regions. The G_{MAR} indicates the existence of regional disparities in BiH. The high degree of marginalization, especially those in the border sector, alerts the implementation of the demarginalization measures.

Introduction and Background

The occurrence of marginalization can be closely related to **socio-spatial polarization** of specific region or country. This is important for those areas that are experiencing or have recently experienced **social**, **economic** or **political** transformation (Madzevic et al., 2013; Mikuš et al., 2016). Bosnia and Herzegovina (BiH) best exemplify this example.

The definitions of **marginality** are numerous, diverse and subject to interpretation (Cullen & Pretes, 2000; Gurung & Kollmair, 2005; Abebaw & Admassie, 2014). However, they have one thing in common. Marginality is regarded as **complex** issue that frequently lies at the root of **poverty** and well-being of people (Graw & Husmann, 2014; Chieffallo & Palermo, 2022) or is closely connected to economic power of regions (Šiljeg et al., 2016).

Since uniform definition of marginality does not exist (Mikuš et al., 2016) in this paper one of the most widely accepted definitions is used where Gatzweiler et al., (2011, 3) are defining marginality *as an involuntary position and condition of an individual or group at the margins of social, political, economic, ecological, and biophysical systems, that prevent them from access to resources, assets, and services, restraining freedom of choice, preventing the development of capabilities, and eventually causing extreme poverty.*

Since the beginning of the introduction of geographers in marginalization research, which put more emphasis on the aspect of space (Déry et al., 2012), most of researchers analyzed economic and social aspects of marginalization.

In this research we analyzed concept of *marginality* as **multidimensional** concept following Gurung & Kollmair, (2005), Von Braun & Gatzweiler (2014); Mikuš et al., (2016), which in simplify way asks *where people are and what they have.* Therefore, marginality is observed through 4 groups of indicators ("sphere of life"):
- physical marginalization,
- demographic marginalization,

- functional marginalization,
- economic marginalization.

Across Europe, marginalization has been highlighted as object of important political concern. However, in the area of Central Europe and the Balkans, the marginalization has not been sufficiently researched. Authors used different methodological patterns in the study of marginalization, most often treating demographic, socio-economic, cultural, ecological, political or physical-geographical dimensions (Nejašmić & Toskić, 2013; Šiljeg et al, 2016; Nejašmić & Toskić, 2016; Anđelković-Stoilković et al, 2018; Mrđen & Marić, 2018; Marić et al, 2020).

In BiH, there are a few authors who have dealt with marginal areas. Most authors considered the issue of spatial disparities in terms of depopulation (Nurković, 2006, Emirhafizović & Zolić, 2017; Gekić et al, 2020, Remenyi et al., 2022). Socio-demographic analysis of the border regions of BiH showed pronounced processes of marginalization and regional differences on the center-periphery line (Avdić et al., 2022), as well as a significant degree of heterogeneity of BiH's municipalities and cities. The limitation of creating more complex marginalization indicies can be attributed to the specific issues regarding statistical data in BiH. In addition to the limited availability of data for the level of local administrative units, a major challenge is long time intervals between censuses.

Measurement of marginalization can be done **qualitatively**, **quantitatively** (Déry et al., 2012; Abebaw & Admassie, 2014, Šiljeg et al., 2016; Mikuš et al., 2016) or combining approach. Since qualitative approach emphasize on the specificity and individuality of a research area, it is more popular in marginalization literature (Martínez-Martínez & Rodríguez-Brito, 2020). The quantitative approach is particularly valuable (Šiljeg et al., 2016). However, the GIS-MCDA has not yet been widely applied in different aspect of human geography.

Therefore, in this paper, the GIS-based multicriteria decision analysis (GIS-MCDA) was used in order to strengthen the methodological aspect of derivation of geographic marginalization model. The objectives of this research were:

- Propose a new methodological framework for quantification of geographical marginalization.
- Define groups of criteria that can be used in deriving a geographic marginalization model (G_{MAR}).
- Derive marginalization model for determined indicators.
- Derive the first geographical marginalization model (G_{MAR}) for BiH.

Materials and Methods

GIS-MCDA

The degree of marginalization is often quantified with a composite index (Luan et al., 2016). In this paper, for the derivation of the G_{MAR} 40 criteria was classified into 4 groups (Figure 1). After a literature, statistical and GIS data analysis, it was concluded that the selected set of criteria (Supporting Table 1) provides a faithful representation of marginalization.

GIS-MCDA analysis was performed using the GAMA extension (Domazetović et al 2019). The GIS-MCDA analysis consisted of six steps: (1) defining the objective; (2) determination of clusters and criteria; (3) standardization; (4) determination of weight coefficients; (5) aggregating the criteria.

The main objective of the GIS-MCDA (1) is derivation of geographical marginalization index (G_{MAR}) of Bosnia and Herzegovina using appropriate criteria which can potentially cause the occurrence marginality. The (2) selected criteria can be regarded as predisposing in their nature regarding the probability of marginalization occurrence. In order to achieve the best reliability of GIS-MCDA model these criteria were selected based on a detailed literature study in which marginalization was analyzed as a multidimensional concept. The selected criteria are different in terms of the unit of expression, which is why their (3) standardization, i. e. transformation to a unique scale (e. g. from 0 - 1 or 1 - 5) was carried out (Malczewski & Rinner, 2015).

Standardization was carried out in two steps: (a) fuzzy membership and (b) reclassification using the Jenks method. The fuzzy membership (FMS) method is common method within GIS that enables the standardization of criteria on a scale from 0 to 1 by applying one of the seven different membership types (MS). Choosing the appropriate MS is an extremely important step because it directly affects the standardization results. The fuzzy linear transformation function was selected. It applies a linear function between the user-specified minimum and maximum values. After the standardization of all criteria on a scale from 0 to 1, these values were reclassified using the Jenks method into 5 classes. This was conducted because the maximum values of all criteria do not necessarily indicate on marginalization occurrence. For example, a higher share of the old population, which has a value of 1 in the fuzzy classification, indicates a marginalized area, while higher value of the total population, which also has a value of 1 in the fuzzy classification, do not indicate marginalization.

Standardization is followed by the (4) determination of the weighting coefficients, which enables grading the in-

fluence of the selected criteria on the final model according to their perceived importance (Veronesi et al., 2017). One of the most popular methods for determining weight coefficients is the analytical hierarchy process (AHP) (Sałabun et al., 2016; Šiljeg et al., 2019), which is integrated within the GAMA tool. The determination of criteria was carried out on two levels:

a) derivation of an individual indicator of marginalization (e. g., physical, demographic, functional and economic);

b) derivation of the final G_{MAR} where each of the four indicators had a selected weighted coefficient.

For the first level, it was decided that due to the lack of literature, almost all criteria within one indicator have an equal impact on the derivation of the selected indicator. Exceptions were the total population and population density within the demographic indicator group. These criteria were collected at the level of settlement, which is a significantly more detailed level compared to the municipalities. Therefore, total population and population density had a higher weight coefficient (0.2) than other criteria (0.075) because they were collected at a detailed administrative level.

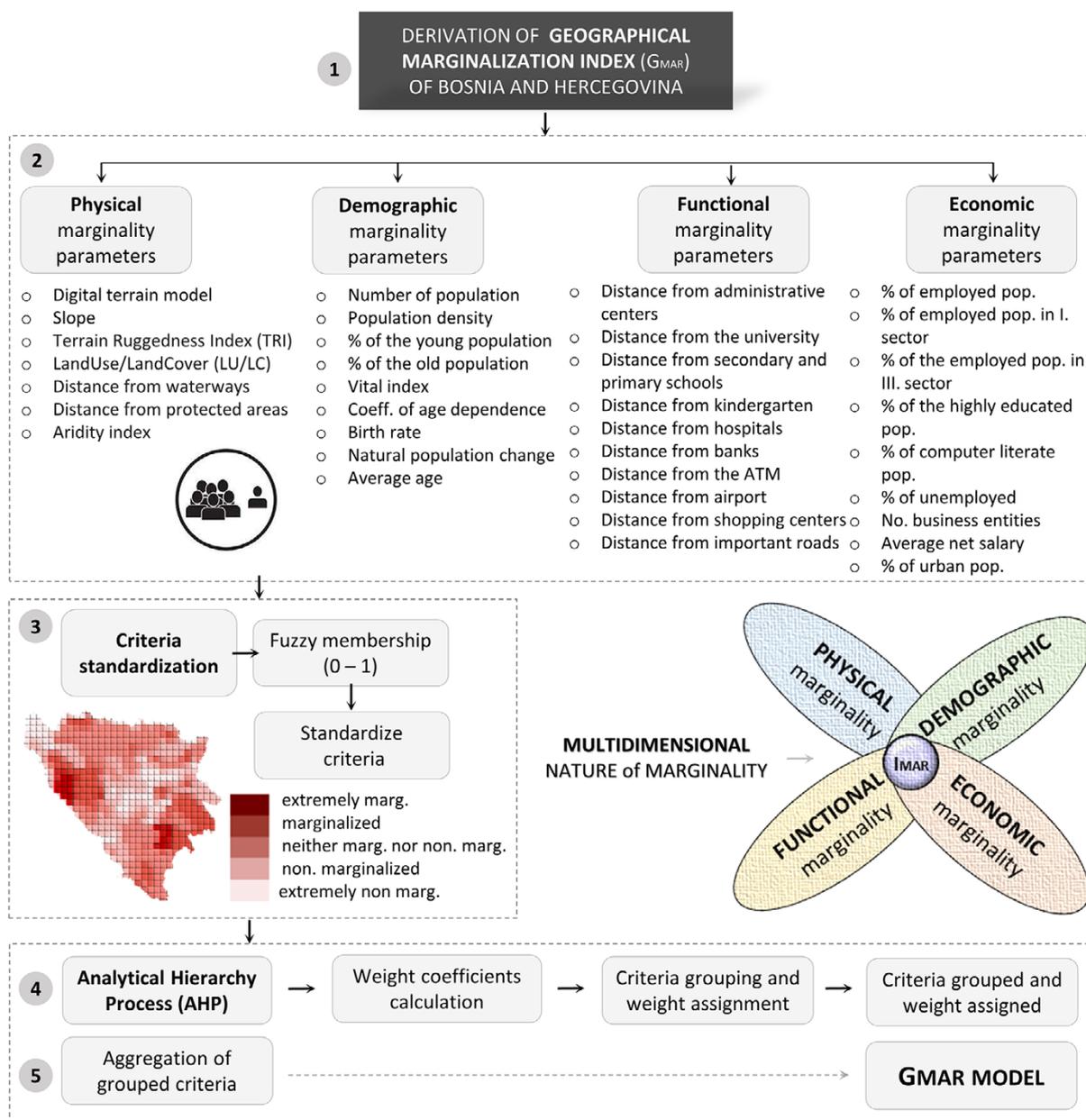For the second level, it was decided that the weighting coefficients of the four indicators are equal (0.25).

Figure 1. GIS-MCDA workflow in derivation of G_{MAR}
Source: modified according to Domazetović et al. (2019)

The last step of GIS-MCDA refers to the aggregation of indicators with the aim of deriving the final G_{MAR} model using the *susceptibility model aggregation* (SMA) tool.

Physical marginalization (P_{MAR})

In the derivation of the P_{MAR} 7 criteria were used (Supporting Table 1): elevation, slope, terrain ruggedness index (TRI); land use/land cover (LU/LC), distance from waterways and protected areas, and aridity index. All criteria had the same weight coefficient of 0.143. For the first three (a, b, and c) and the last criteria (f) the higher value indicates greater marginalization. In most cases, these areas are characterized by limited fertile soil, they have difficult access and harsh climates, making agriculture and infrastructure development challenging. The DTM downloaded from the DIVA GIS[1] (URL 1) was used. The model of slope and TRI was derived in ArcMap 10.8.1.

The LULC model for 2018 was acquired from the Copernicus[2] website. CLC uses a Minimum Mapping Unit (MMU) of 25 hectares (ha) (URL 2). The LU/LC model was reclassified into 5 classes. The reclassification was carried out in way that the thematic meaning of each class was observed regarding the possible effect on marginalization.

Classes such as: *Urban fabric; Industrial, commercial and transport units and Artificial, non-agricultural vegetated areas* received the lowest value of marginalization, while the classes: *Dump sites; Open spaces with little or no vegetation and Wetlands* received the highest marginalization values.

The distance from waterways and the protected areas can influence the marginalization of an area. Distance areas may face water scarcity, making it difficult for communities to engage in agriculture. Also, waterways can provide various economic opportunities. The waterways were acquired from the *Geofabrik[3]*, and the distance model was created in ArcMap (URL 3).

Protected areas are characterized by rich biodiversity and can provide essential ecosystem services. Areas closer to waterways and protected areas often have better access to resources, economic opportunities which can reduce marginalization. Only National Parks and Nature Parks were included in the analysis (URL 4). The aridity index is a measure of the dryness or aridity of a region and is often used to assess the water availability and potential for agriculture. Aridity index model was downloaded from URL 5.

Demographic marginalization (D_{MAR})

In the deriving of D_{MAR} 10 criteria were used (Supporting Table 1). Vital statistics, age structure, total population, and population density were selected to detect demographically marginalized areas. Vital statistics data to the year 2022, and criteria like the birth rate, natural change, and the vital index were used. Higher values indicate more favorable demographic processes. Lower and even negative values (natural change), suggest a certain degree of natural depopulation, which can lead to spatial marginalization.

In the absence of census data, the values used for this group were based on estimates from relevant statistical institutions in BiH for the year 2022 (Federal Institute of Statistics and Institute of Statistics of Republika Srpska). It's important to note that the estimates at the level of one of the entities are based on the concept of a closed population. In this context, areas with higher values of the elderly population share, age dependency ratio, aging coefficient, and average age indicate a higher degree of marginalization compared to areas that experience more favorable conditions.

The estimated population for the year 2022, from which population density is derived, were used to observe the effects of current demographic trends.

Functional marginalization (F_{MAR})

In the derivation of the F_{MAR} 14 criteria were used (Supporting Table 1): real-time distance from capital city, from administrative centers, from universities (URL 6), from secondary schools (URL 7), from primary schools, from larger shops, from pharmacies, from hospital I. rank, from hospital II. rank, from hospital III. rank, from major roads, from airports, distance from banks. All criteria had the same weight coefficient (0.0714).

These criteria are presented with basic accessibility attribute – costs of traveling time (min). The areas with the greatest accessibility were regarded as non-marginalized, while the most remote regions are viewed as marginalized.

The road layer was acquired from *Geofabrik*. Hierarchically most important elements were selected. Attribute of maximum driving speed has been added. The topological check was done and travel cost calculated. A *Network Dataset* was created and real-time distance models derived using *Network Analyst*.

For the distance from administrative centers, the political-administrative structure of BiH has been taken into account. At the first level, the distance from all cantonal centers (Bihać, Orašje, Tuzla, Zenica, Travnik, Goražde, Mostar, Široki Brijeg, Sarajevo, Livno), mesoregional centers of Republika Srpska (Banja Luka, Doboj, Istočno Sarajevo, Bijeljina, Trebinje, and Prijedor), and the Brčko District has been calculated. Also, the distance from the capital city, Sarajevo, has been calculated.

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[1] DIVA-GIS is a free computer program for mapping and geographic data analysis a geographic information system (GIS).
[2] Copernicus is an EU program aimed at developing European information services based on satellite Earth Observation (EO) and in situ data.
[3] Geofabrik is a company for-profit based in Karlsruhe offering OpenStreetMap consulting, training, tile servers, map styling and software development services.

To examine disparities, distances from primary, secondary, and tertiary formal education institutions were calculated. As BiH lacks an official register of public institutions, data from the 'Transparency International' database for the year 2021 were utilized. At the national level, the network of elementary schools comprises 536 public elementary schools, 278 secondary schools, and nine universities was used.

Degree of marginalization is also reflected in accessibility of healthcare infrastructure (Martinez-Martinez & Rodriguez-Brito, 2020). Data were obtained in the same way as for schools. The distance from healthcare centers is presented at three hierarchical levels, considering the organizational structure of the healthcare system (Džubur-Alić, 2018), which includes *clinical centers* (n=5), *hospitals* (n= 31) and *health centers and clinics* (n= 108). The distance from pharmacies, acquired from Geofabrik, was also used.

The greater distance from larger stores (shopping centers, supermarkets) implies greater marginalization and vice versa. The same applies to the banks. Both data were acquired from Geofarbik. For larger stores following attributes were extracted: *mall, convenience, supermarket* and *department store*.

Economic marginalization (E_{MAR})

In the deriving of the E_{MAR} 9 criteria were used (Supporting Table 1). All criteria had the same weight coefficient (0.111). The economic dimension is one of the most important in marginality (Blečić et al., 2023). The previous economic ranking of local government units in BiH was conducted using the Development Index. However, in this analysis it was not considered due to the incompatible calculation methodology. Most of the indicators chosen are based on the 2013 census. This is influenced by the asynchronous publishing of entity statistical offices, as well as the fact that certain indicators are not published at all for local government unit levels.

The selected criteria were: % of employed pop., % of employed pop. in I sector, % of employed pop. in III sector, % of highly educated pop, % of computer literacy, % of unemployed pop., % of urban population (2013 census), while the number of business entities and net wages represent the data from the 2021. An important methodological note concerns newly established local government units, for which data from the municipalities that they were part of until 2013 were used (e. g., Stanari - data from Doboj).

Results

Physical marginality model (P_{MAR})

Using stated physical-geographical criteria expected result have been generated regarding marginalization model (Figure 2). Areas characterized by steep slopes, high elevations, rugged terrain, and arid conditions are more marginalized (W central and SE part of BiH). These areas are characterized by limited agricultural potential, reduced accessibility, and challenges in infrastructure development. On the other hand, regions with gentle slopes, lower elevations, smoother terrain, exhibit lower marginality scores, indicating better suitability for various human activities and development.

Demographic marginality model (D_{MAR})

The marginalized areas in the D_{MAR} can be interpreted along the center-periphery line. The extremely marginalized regions are clearly observed at the western periphery of BiH (Western Bosnia), followed by the eastern areas along the state border (parts of Gornje Podrinje), and fragments of the far southern part of the national territory (Nurković, 2006; Avdić et al., 2022). The marginalization gradually decreases moving towards the interior (Figure 3), which points to what is known as an "extremely non-marginalized" state center. These results align with well-known patterns that are naturally predisposed. For instance, the interior valley-basin regions, such as the Sarajevo-Zenica basin, Tuzla basin, and even the Cazin re-

gion in the far NW, exhibit significantly more favorable demographic conditions compared to the BiH average. On the other hand, regions with higher degree of marginalization are generally economically weakened, post-war devastated areas with weaker physical predispositions for significant developmental.

Functional marginality model (F_{MAR})

Available database and used criteria point to the exceedingly significant importance of transportation infrastructure in revealing marginalization patterns in F_{MAR} (Figure 4).

Similar results were obtained as in the previous model, which indicates the scientifically proven connection between demographic, economic, and functional criteria (Meade et al., 1970; Prskawetz & Lindh, 2007).

It is evident that the highest concentration of various functions is centralized in the interior, around major urban centers such as Sarajevo, Tuzla, Mostar, and Banja Luka (Figure 4), which are relatively well connected both internally and intercity (highways and higher density of major roads). In F_{MAR}, the influence of these urban centers on the surrounding area is notable. Consequently, the degree of marginalization intensifies as one moves away from these centers and transportation hubs.

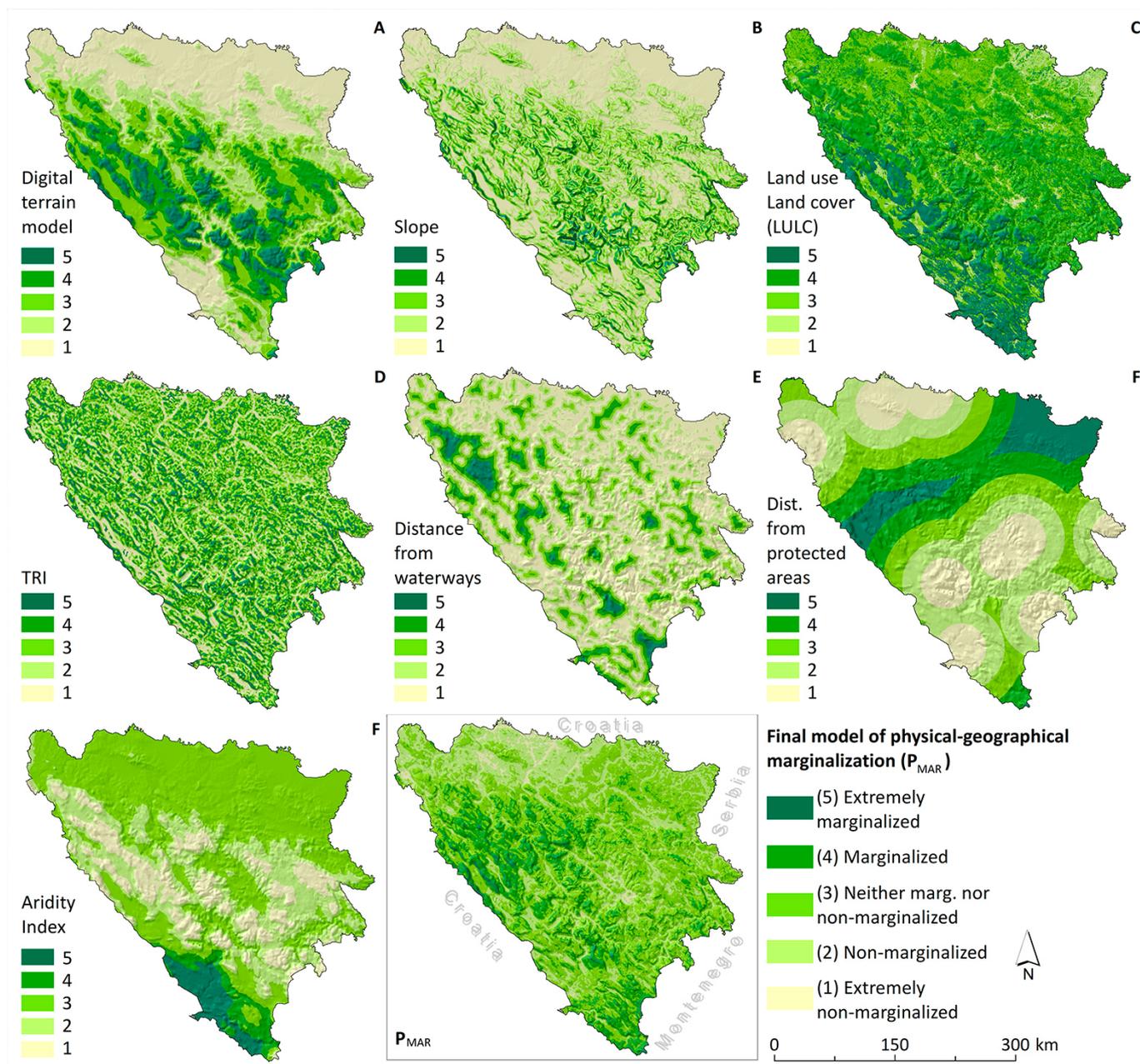The most pronounced marginalization is in the far W and E border regions, which can be linked to intense and

Figure 2. Physical marginalization (P_{MAR})

dynamic emigration processes (direct and indirect impacts of war), which disrupted the educational and healthcare function networks. In the F_{MAR}, it can be observed that a significant part of the national territory is marginalized to a certain degree, while extremely non-marginalized areas stand out only as smaller enclaves within the interior.

Economy marginality model (E_{MAR})

The E_{MAR} is derived from indicators that exhibit slightly different patterns of disparities compared to the other two models. Large urban centers are depicted as non-marginalized areas due to their high share of urban population, economic tertiarization, highly educated and digitally literate population.

Interestingly, a significant part of Herzegovina (urban centers) stands out as a non-marginalized region in economic terms. This is attributed to recent processes of economic revitalization, which are turning this historically significant region increasingly attractive for tourism, into an entrepreneurial area (Socio-economic Indicators by Municipalities of FBiH 2021).

Outside of significant urban regions (regional/cantonal centers), a large portion of the national territory is characterized by a higher degree of economic marginalization (Figure 5), where areas, particularly the northern Posavina
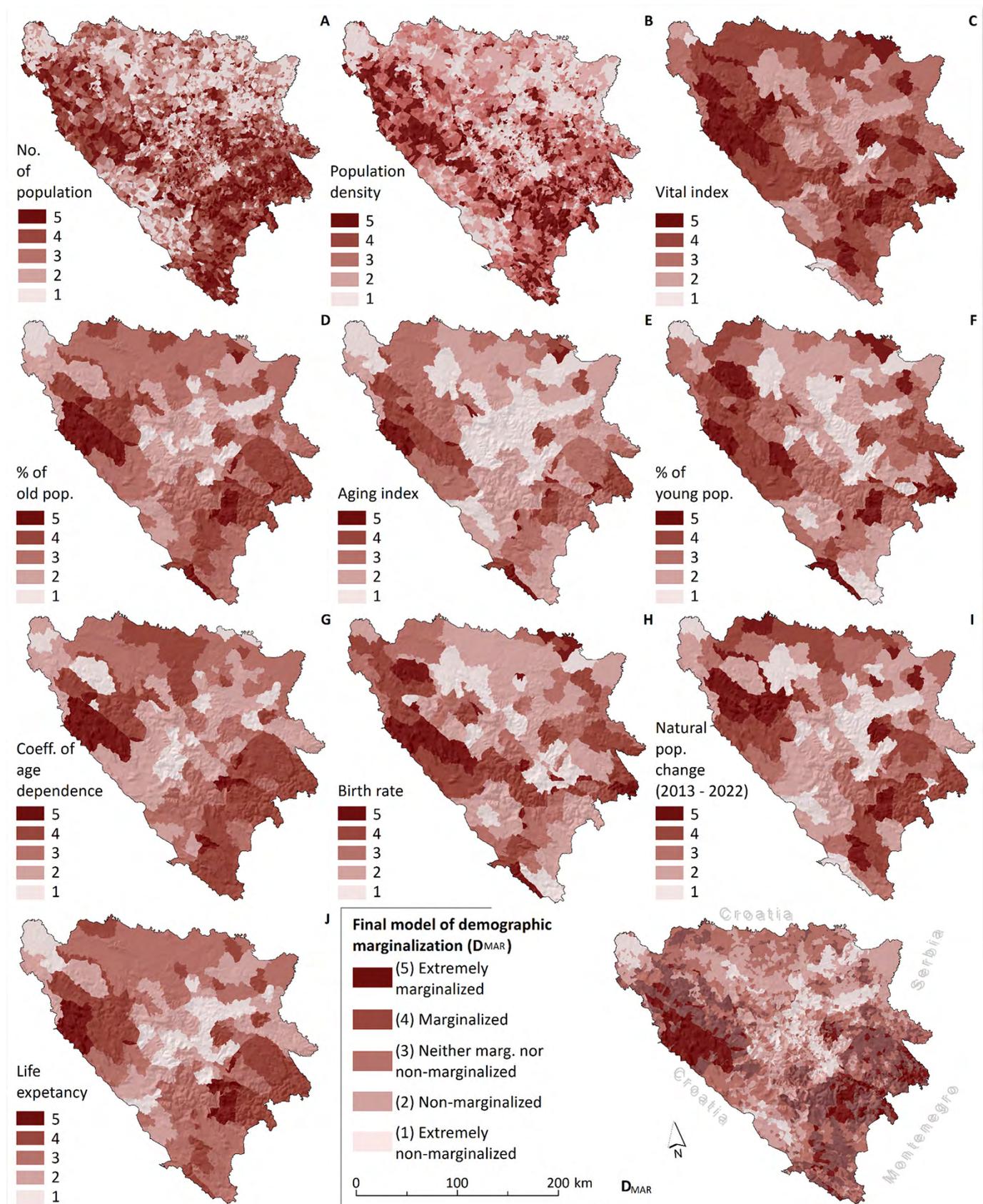
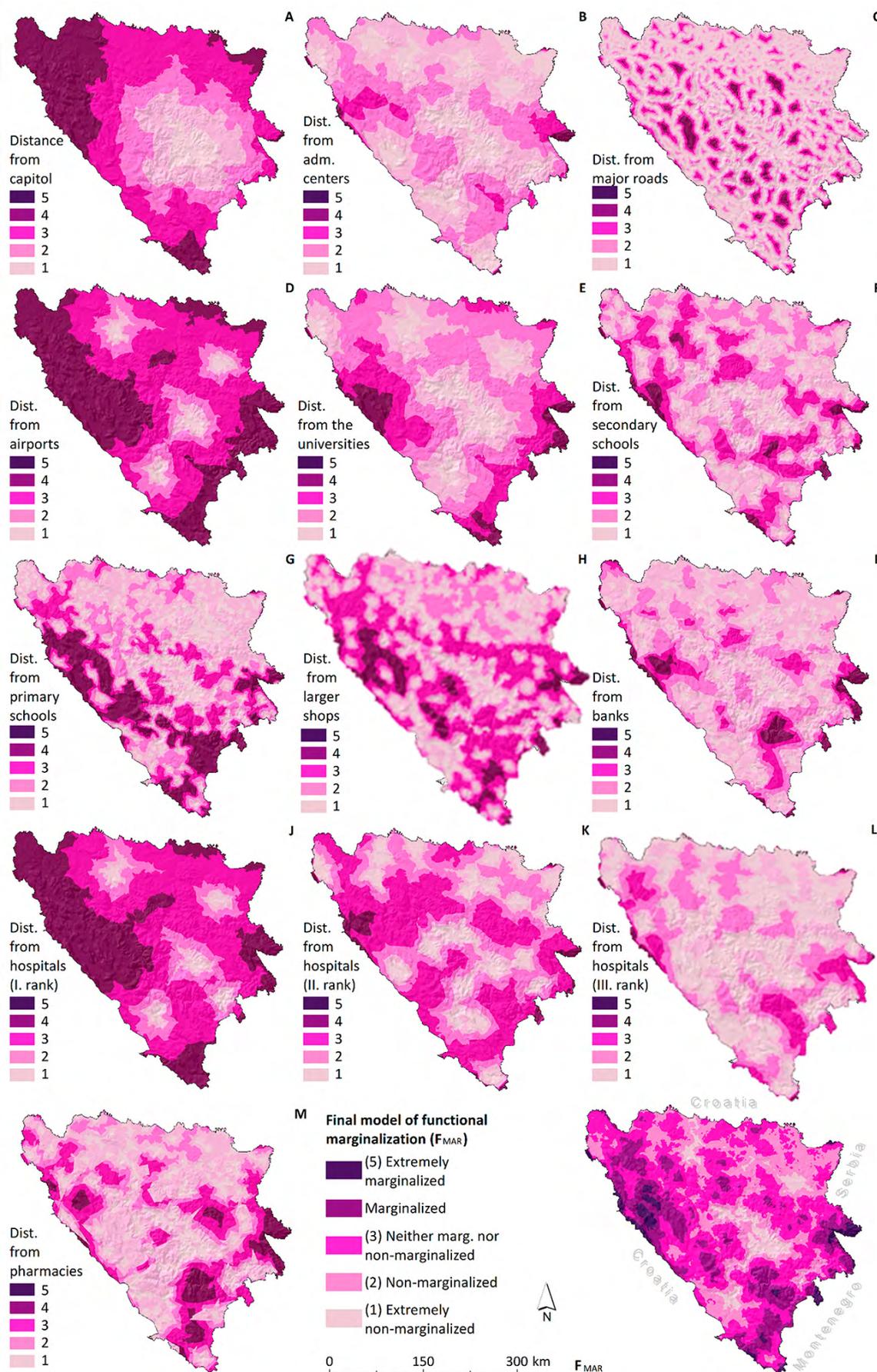**Figure 3.** Demographic marginalization (D$_{MAR}$)

Figure 4. Functional marginalization (F$_{MAR}$)

region, are economically homogeneous with a dominance of agricultural activities.

Extremely marginalized regions are detected in the far W and N border sector, as well as along the Inter-Entity Boundary Line. In future research, greater attention should be devoted to economic marginalization criteria, especially due to the methodological challenges in deriving socio-economic indicators.

Final Geographical Marginalization Model (G_{MAR})

In derivation of G_{MAR} marginalization models P_{MAR}, D_{MAR}, F_{MAR} and E_{MAR} were aggregated (Figure 6). All had the same weight coefficient (0.25).

In the context of BiH this is the first attempt at gaining insight in spatial differentiation of marginality at the sub-municipal level. The results point to regional disparities, as well as local variations within larger regional entities. The spatial distribution of marginality highlights two axes of BiH's overall social development, forming a morphology resembling the letter T (Figure 6). The first axis is naturally predisposed - it encompasses northern Bosnia, where several developmental hotspots of larger urban zones are located (Bihać, Banja Luka-Prijedor, Doboj-Tešanj, Tuzla, and Brčko-Bijeljina). The second perpendicular axis links the valleys of the Bosna and Neretva rivers, through which the Vc corridor is set to pass. This axis primarily includes two developmental focal points: the Sarajevo-Zenica area and the Herzegovina region (with a focus on Mostar). In contrast, large parts of east (Gornje Podrinje and Eastern Herzegovina) and western parts of the country can be considered extremely marginalized, both due to natural predispositions and historical passivity and the consequences of the recent war.

A relatively high degree of marginalization characterizes the hilly and mountainous areas in the central and even northern parts of the country. Interestingly, these maps indicate that the extremely marginalized areas are not located at a great distance from the centers of social development (e.g., Southeastern Bosnia in relation to Sarajevo, Eastern Herzegovina in relation to Mostar, or Western Bosnia in relation to Banja Luka). This could be interpreted as an opportunity for their improved prospects in the future. In this context, it is possible to determine that the administrative-territorial structure has a visible impact on the existing disparities, particularly evident in certain sectors (e.g., around Sarajevo, Mostar, Tuzla, Tešanj, Brčko, etc.), where sharp developmental-marginalization contrasts are noticeable within a small area.

The 5 most marginalized and the 5 most prosperous municipalities were derived. The five most marginalized includes:
- Bosansko Grahovo,
- Drvar,
- Istočni Drvar,
- Glamoč,
- Kupres RS.

Bosansko Grahovo is in local media recognized as "dying city" (URL 8). In it there is a few settlements so excluded and marginalized that it can only be reached from the neighboring country (URL 9). The municipalities of Drvar, Bosansko Grahovo and Glamoč are highlighted as extremely underdeveloped (URL 10 and 11). Namely after Dayton, Drvar was intersected by the Inter-Entity Boundary Line between Federation of BiH and Republika Srpska. In Drvar local residents mentioned distance from bigger settlements, poor traffic connections and lack of interest from Bihać as factors which catalyze marginalization (URL 10). Kupres in the RS is also recognized as one of the most underdeveloped municipalities in BiH (Marković, 2021).

The five most prosperous (non-marginalized) includes:
- Novo Sarajevo,
- Novi Grad Sarajevo,
- Ilidža,
- Centar,
- Vogošća.

The most prosperous municipalities are administratively part of the Sarajevo Canton, three of which (Novo Sarajevo, Novi Grad, and Centar) are integral parts of the City of Sarajevo. Expectedly, these municipalities are the administrative centers, belonging to the first category according to the development index of the Federal Institute for Development Programming (Socio-economic Indicators by Municipalities of FBiH 2021). The most developed municipalities, as per the derived model, are regions with a high concentration of crucial administrative, judicial, healthcare, and educational functions, experiencing a more progressive economic growth rate compared to other regional units in BiH, as well as in relation to demographic development (Sarajevo Canton Development Strategy 2021-2027 – Strategic Platform). The comparative analysis of the ranking list of municipalities according to G_{MAR} with the development index confirms the relevance of the research procedure and points out the greater precision of the G_{MAR}, which takes into account a much larger number of criteria.

Bihać is a city located in the far NW part of the country that, following the derived model, has the greatest differences within its borders regarding marginalized/prosperous areas. Settlements near the city center are economically and demographically more prosperous compared to those situated along the administrative border towards highly marginalized municipalities like Bosanski Petrovac, Istočni Drvar, and Bosansko Grahovo (Bihać Municipality Development Strategy 2014-2023).
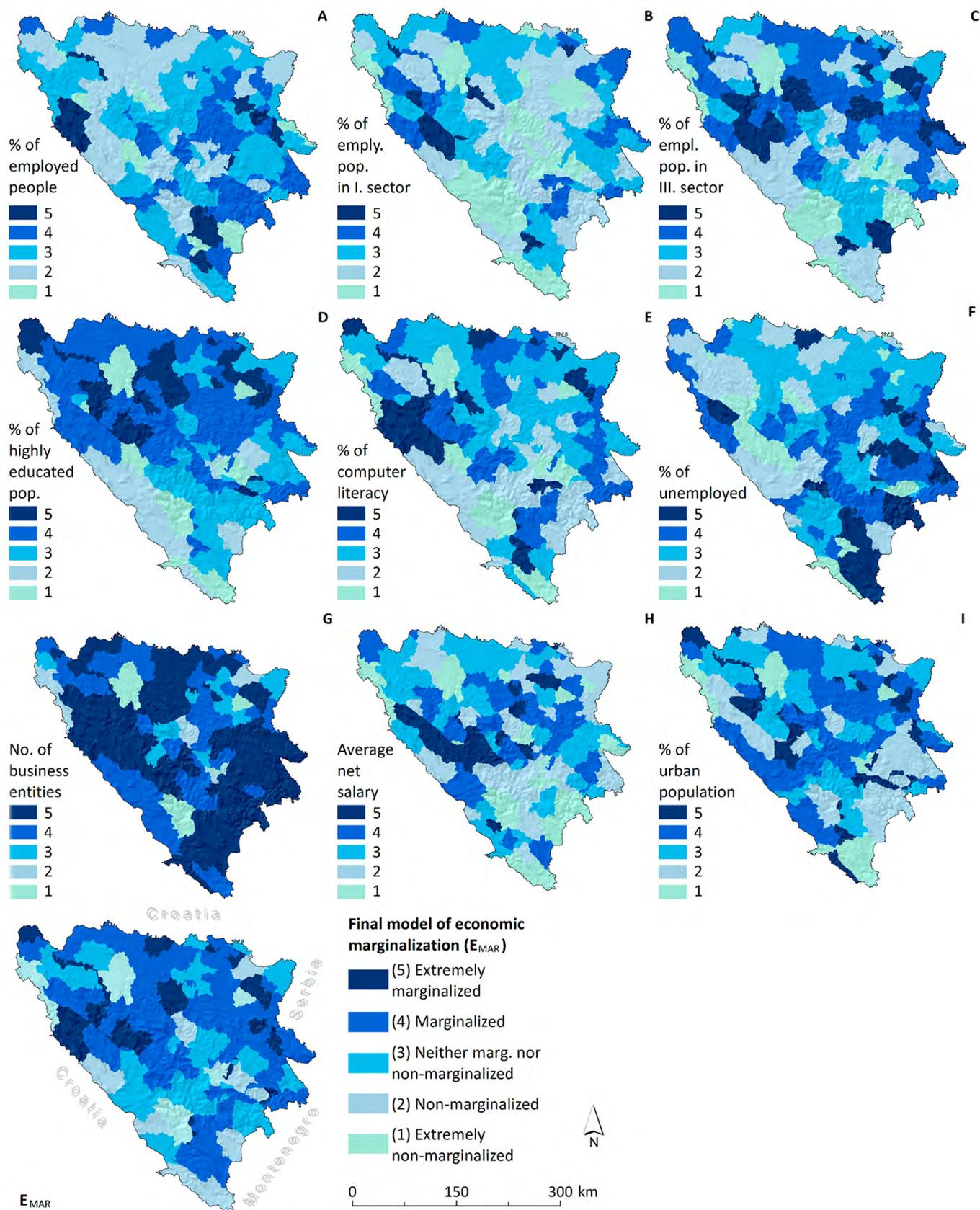
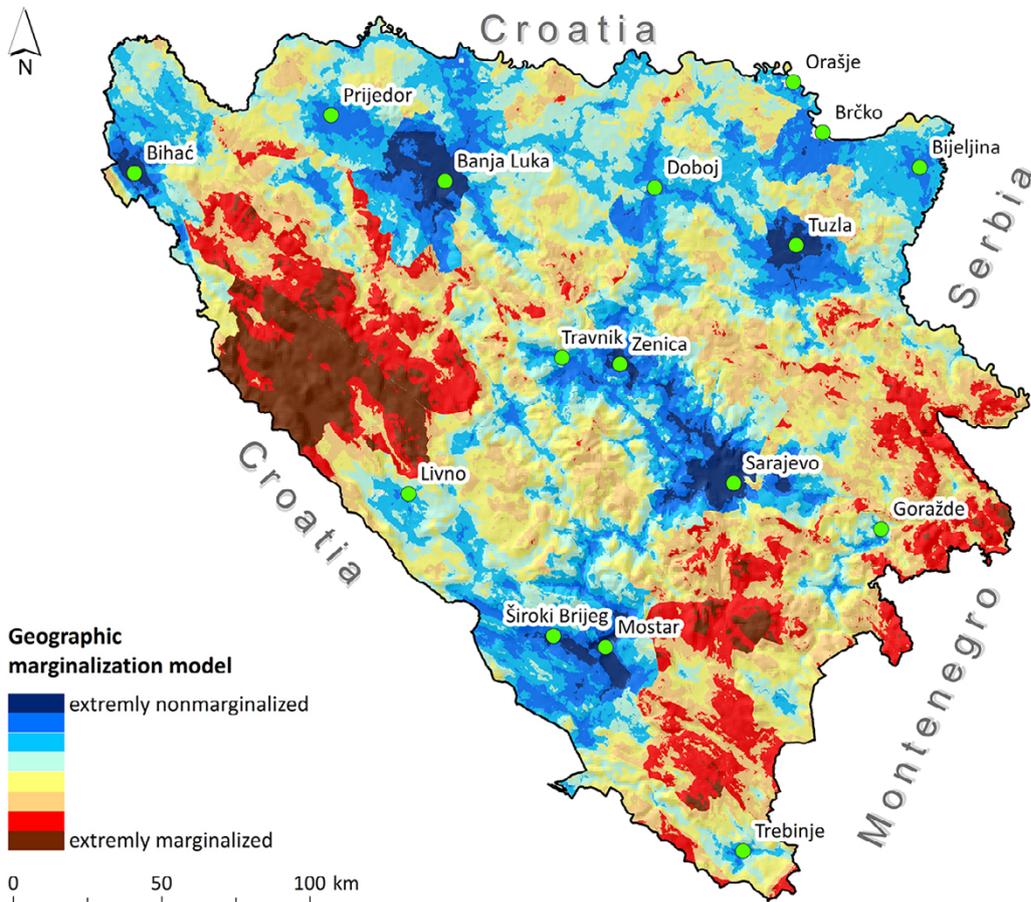**Figure 5.** Economic marginalization (E_MAR)

Figure 6. Final geographical marginalization model (G_{MAR})

Discussion

Methodology aspect

The methodology has proven successful in identifying highly marginalized areas. However, in the classification of non-marginalized zones, it shows a certain degree of generalization (e.g., Sarajevo and Bihać have the same degree of 'non-marginalization'), which could be nuanced in future research and adding more detailed criteria. It's important to note that the rigidity of municipal boundaries has led in some cases to abrupt transitions that do not reflect reality (e.g., the border of Banja Luka with Oštra Luka and Mrkonjić Grad). Such transitions occur due to administrative structure, where units that administratively belong to a larger and more developed urban center are depicted as significantly more developed than they should be.

A more precise picture and smoother transitions between municipalities could be achieved by examining economic, demographic, and functional criteria at the level of smaller spatial units – settlements units, which is a statistically limited procedure. Furthermore, attention should be paid to municipalities that are administratively divided along Inter-Entity Boundary Line (such as Kupres, Drvar, Trnovo, etc.) were data may devalue or overestimate the actual situation. Greater model granularity can be achieved by incorporating a broader set of criteria, such as those related to BiH's ethnic or cultural context, which, according to Grbić (1993), significantly impacts economic and political conditions in society. Degrees of social exclusion and social cohesion are desirable indicators that can further refine the processes of spatial marginalization (Dwivedi et al., 2007).

Validity of results

One of the main shortcomings of the G_{MAR} is the fact that quantification of marginalization is based solely on statistical data might not be entirely consistent or correct with the real situation. Underestimation or overestimation of marginalization can happen (Mikuš et al., 2016). Therefore, it is desirable to include the perceptual marginality of residents (qualitative methodology) in analysis. Furthermore, this data can be used in accuracy assessment of G_{MAR} through one of common validation methods (e.g.,

receiver operating characteristic, success and prediction rate curves, etc.). Considering the nature of marginalization as a complex condition that involves a certain level of vulnerability of social communities or groups due to unequal economic, political, cultural, and social factors, there arises a crucial need for analyzing the attitudes of the population originating from the detected marginal areas. A wide range of qualitative approaches exist, from autoethnographic studies to traditional qualitative methods such as surveys and interviews (Moore, 2018). Such insights can provide valuable inputs for a more detailed understanding of the causes and patterns of marginalization, serving as a valuable tool in formulating place-based policies aimed at demarginalization and the inclusion of problematic areas within regional development strategies.

Conclusion

Derivation of G_{MAR} is the first attempt at gaining insight into spatial differentiation of marginality at the sub-municipal level. The results indicate a deep disparity in BiH regarding marginalized and prosperous areas where two main axes of social development are observed – northern Bosnia with several larger urban zones (Bihać, Banja Luka-Prijedor, Doboj-Tešanj, Tuzla, and Brčko-Bijeljina) and a line connecting the valleys of the Bosna and Neretva rivers with two development zones: Sarajevo-Zenica and the region of Herzegovina with a focus on Mostar.

These zones can be considered, within the context of the mentioned methodology, extremely non-marginalized areas, while regions like Gornje Podrinje, Eastern Herzegovina, and Western Bosnia are extremely marginalized. Bosansko Grahovo stands out as the most extremely marginalized municipality, while Novo Sarajevo emerges as the most developed. Detecting marginalized municipalities can be a crucial step in uncovering patterns of marginalization in BiH, a country that is highly disconnected and lacks a strategic long-term plan for the de-marginalization of economically disadvantaged areas.

Limitations in the research primarily stem from a statistical nature and are tied to the availability and temporal consistency of data. However, a certain degree can be avoided in the future by incorporating a larger number of criteria at the settlement level. This could include factors such as ethnicity, poverty levels, and indicators of social cohesion and inclusion. The presented quantitative approach in future research can be complemented with a qualitative method. These could provide insights into the perspectives of the local population, allowing for a more nuanced understanding of the causes and patterns of marginalization. Such insights could serve as a valuable tool in shaping concrete place-based policies.

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Supporting Table 1. List of criteria used in derivation of G_{MAR} with sources and year of publication/data acquiring

Sphere of life	ID	Criteria	Source	Year
Physical marginality	1.1	Digital terrain model	DIVA GIS	2023
	1.2	Slope	DIVA GIS	2023
	1.3	Terrain ruggedness index	DIVA GIS	2023
	1.4	Land use/Land cover	Copernicus	2023
	1.5	Distance from protected areas	Wikipedia	2023
	1.6	Distance from waterways	Geofabric	2023
	1.7	Aridity index	Figshare	2023
Demographic marginality	2.1	Population number	statistika.ba, URL 11, Popis stanovništva, domaćinstava i stanova u Bosni i Herecgovini, 2013. Rezultati popisa.	2013
	2.2	Population density	statistika.ba, URL 11, Popis stanovništva, domaćinstava i stanova u Bosni i Herecgovini, 2013. Rezultati popisa.	2013
	2.3	% of young population	Socioekonomski pokazatelji po općinama FBiH 2022. Procjene stanovništvo 2013-2022. Procjene stanovništva RS 2013-2022	2022
	2.4	% of old population	Socioekonomski pokazatelji po općinama FBiH 2022. Procjene stanovništvo 2013-2022. Procjene stanovništva RS 2013-2022	2022
	2.5	Vital index	Statistički bilten 343, 360. Rođeni i umrli u Republici Srpskoj 130/23	2022
	2.6	Coeff. of age dependence	Statistički bilten 343, 360. Rođeni i umrli u Republici Srpskoj 130/23	2022
	2.7	Birth rate	Statistički bilten 343, 360. Rođeni i umrli u Republici Srpskoj 130/23	2022
	2.8	Natural population change	Statistički bilten 343, 360. Rođeni i umrli u Republici Srpskoj 130/23	2022
	2.9	Ageing index	Statistički bilten 343, 360. Rođeni i umrli u Republici Srpskoj 130/23	2022
	2.10	Average age	Popis stanovništva, domaćinstava i stanova u Bosni i Herecgovini, 2013. Rezultati popisa.	2013
Functional marginality	3.1	Distance from administrative centres	Geofabric	2023
	3.2	Distance from capital	Geofabric	2023
	3.3	Distance from universities	Database of public institutions in Bosnia and Herzegovina	2021
	3.4	Distance from primary and secondary schools	Database of public institutions in Bosnia and Herzegovina	2021
	3.5	Distance from hospitals (I, II, III)	Database of public institutions in Bosnia and Herzegovina	2021
	3.6	Distance from banks	Geofabric	2023
	3.7	Distance from airports	Geofabric	2023
	3.8	Distance from larger shops	Geofabric	2023
	3.9	Distance from important roads	Geofabric	2023
	3.10	Distance from pharmacies	Geofabric	2023
Economic marginality	4.1	% employed population	Socioekonomski pokazatelji po općinama FBiH 2022.; Gradovi i opštine RS, 2022.	2022
	4.2	% employed population in I sector	Popis stanovništva, domaćinstava i stanova u Bosni i Herecgovini, 2013. Rezultati popisa.	2013
	4.3	% employed population in III sector	Popis stanovništva, domaćinstava i stanova u Bosni i Herecgovini, 2013. Rezultati popisa.	2013
	4.4	% highly educated population	Popis stanovništva, domaćinstava i stanova u Bosni i Herecgovini, 2013. Rezultati popisa.	2013
	4.5	% computer literate population	Popis stanovništva, domaćinstava i stanova u Bosni i Herecgovini, 2013. Rezultati popisa.	2013
	4.6	% of unemployed population	Zaposlenost, nezaposlenost, plaće i troškovi rada,2023; Plaće, zaposlenost i nezaposlenost RS, 2022.	2022
	4.7	Number of business entities	Socioekonomski pokazatelji po općinama FBiH 2022.; Gradovi i opštine RS, 2022.	2022
	4.8	Average net salary	Socioekonomski pokazatelji po općinama FBiH 2022.; Gradovi i opštine RS, 2022.	2022
	4.9	% urban population	Popis stanovništva, domaćinstava i stanova u Bosni i Herecgovini, 2013. Rezultati popisa.	2013