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Vojno-geografska obilježja fizičkih čimbenika kopnene granice Republike Hrvatske*

Military-geographical characteristics of the physical factors of the land border of the Republic of Croatia*

Ovim radom prvi je put sustavno kvantificiran odnos fizičko-geografskih obilježja i stabilnosti državnih granica Hrvatske te prikazana važnost fizičko-geografskih barijera na oblikovanje i stabilnost kopnenih granica Republike Hrvatske (RH). Provedena je GIS analiza taktičkoga značaja upotrebom topološki orijentirane metode podudarnosti dvaju entiteta: granične linije te relevantnih fizičko-geografskih i vojno-geografskih čimbenika. Utvrđeno je da markantni fizičko-geografski objekti definiraju 58,6 % granice (45 % rijeke, 14,3 % doline i 7,6 % grebeni). Pomaci riječnih tokova kroz povijest potaknuli su dodatnu analizu i proširenjem zone promatranja duž riječnih tokova za 3 km udio fizičko-geografskih objekata porastao je na 75 %, čime je potvrđena presudna uloga rijeka u formiranju linija razgraničenja. Prirodno determinirane dionice (Sava, Kupa, Drava, Dunav, Sniježnica, Ravna Gora i dr.) potvrdile su se kao čimbenici stabilnosti i sigurnosti kroz povijest, dok su administrativne granice bile podložne promjenama, osobito u Banovini, Kordunu, Istri i zapadnom Srijemu.

Ključne riječi: državne granice, prirodne granice, Republika Hrvatska, stabilnost granica, vojna geografija

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This paper systematically quantifies, for the first time, the relationship between physical-geographical features and the stability of Croatia's state borders, and demonstrates the importance of physical-geographical barriers in shaping and maintaining the stability of the land borders of the Republic of Croatia (RoC). A GIS analysis of tactical significance was conducted using a topologically-oriented method of matching two entities: the border itself, and relevant physical-geographical and military-geographical factors. It was established that prominent physical-geographical features define 58.6% of the border (45% rivers, 14.3% valleys, and 7.6% ridges). Historical shifts in river courses prompted further analysis, and by extending the observation zone along river courses by 3 km, the share of physical-geographical features increased to 75%, thereby confirming the decisive role of rivers in the formation of demarcation lines. Naturally-determined sections (the Sava River, Kupa River, Drava River, Danube River, Sniježnica Mountain, Ravna Gora Mountain, etc.) have proven to be factors of stability and security throughout history, whereas administrative borders were subject to change, particularly in Banovina, Kordun, Istria, and western Srijem.

Key words: state borders, natural borders, Republic of Croatia, border stability, military geography

* The views expressed in this article represent the author's personal opinion; they do not reflect the official position of the institution in which they are employed, nor do they pertain to the situation or relations within the Armed Forces of the Republic of Croatia.

Uvod

U suvremenoj znanstvenoj terminologiji razlikujemo nekoliko pojmova koji se u svakodnevnom govoru često upotrebljavaju sinonimno iako imaju različita značenja. Pojam *border* (granica*) u najširem smislu označava teritorijalnu liniju koja razdvaja jurisdikciju dviju političkih zajednica ili država. On podrazumijeva i funkcionalnu dimenziju jer granica nije tek statična crta na karti, nego i mehanizam kontrole kretanja ljudi, robe i ideja (Anderson i O'Dowd, 1999; Newman, 2006). *Border line* (granična linija) predstavlja precizno određenu i kartografski utvrđenu liniju razgraničenja, definiranu međunarodnim ugovorima ili jednostranim odlukama, koja se u pravilu može geodetski izmjeriti i označiti fizičkim markerima na terenu (Prescott, 2015). Za razliku od toga, pojam *frontier* (međa, pograničje) u povijesnoj i geografskoj literaturi ima šire i dinamičnije značenje: odnosi se na prijelazno područje između dvaju političkih ili kulturnih entiteta, koje nije nužno strogo razgraničeno, već karakterizirano zonom kontakta, sukoba, ali i razmjene (Paasi, 2005; Pounds, 1963).

Povijesni razvoj granica prošao je kroz nekoliko jasno prepoznatljivih faza. U početnoj fazi, poznatoj kao *terrae nullius* ili „ničija zemlja”, granice nisu bile formalno uspostavljene, već su označavale prostore bez čvrste političke kontrole, karakteristične za plemenske, nomadske ili slabo povezane zajednice. Sljedeća prijelazna faza bila je *frontijera*, tj. široki granični pojas u kojem se susreću različite političke sfere utjecaja, često obilježen vojnom prisutnošću, kolonizacijom i sukobima. Tek treća faza, koju Pounds (1963) opisuje kao nastanak linijskih granica (*boundary*), donosi precizno razgraničavanje teritorija na temelju međunarodnih ugovora, kartografskih prikaza i katastarskih izmjera. Upravo u toj fazi granice postaju pravno priznate i čvrsto povezane s pojmom suvereniteta, čime se uspostavlja moderni međunarodni sustav.

Kada se govori o granicama i njihovu postanku i razvoju, one se mogu raščlaniti na prirodne,

* U nastavku teksta neće se posebno naglašavati da je prilikom analize, primjene metodologije ili prikaza rezultata objekt istraživanja bila „kopnena granica”, već će upotrebljavati samo izraz „granica”.

Introduction

In contemporary scientific terminology, we distinguish several concepts that are often used synonymously in everyday speech, although they carry different meanings. The term *border** in its broadest sense refers to a territorial line that separates the jurisdiction of two political communities or states. It also implies a functional dimension, as a border is not merely a static line on a map but also a mechanism for controlling the movement of people, goods, and ideas (Anderson and O'Dowd, 1999; Newman, 2006). The term *border line* denotes a precisely-defined and cartographically-established line of demarcation, determined by international treaties or unilateral decisions, which can, as a rule, be geodetically measured and marked with physical markers in the field (Prescott, 2015). By contrast, the term *frontier* in historical and geographical literature carries a broader and more dynamic meaning: it refers to a transitional area between two political or cultural entities, not necessarily strictly demarcated, but characterised by a zone of contact, conflict, and also exchange (Paasi, 2005; Pounds, 1963).

The historical development of borders has passed through several clearly recognisable stages. The initial stage, known as *terrae nullius* or “no man's land”, lacked formally-established borders, denoting spaces without firm political control, typical of tribal, nomadic, or loosely connected communities. The subsequent transitional stage was the *frontier*, that is, a wide border belt where various political spheres of influence met, often marked by military presence, colonisation, and conflicts. Only the third stage, which Pounds (1963) describes as the emergence of linear borders (*boundary*), brought precise territorial demarcation based on international treaties, cartographic representations, and cadastral surveys. In this stage borders became legally-recognised and firmly tied to the concept of sovereignty, thereby establishing the modern international system.

When discussing borders and their origins and development, they can be classified as nat-

* In the entire paper as it follows, it will not be specifically emphasised that the object of research was the “land border” when conducting the analysis, applying the methodology, or presenting the results; instead, only the term “border” will be used.

etničke i povijesne. Na razvoj društvenih odnosa, odnosno prostorno-funkcionalnih procesa, utjecale su prvobitne prirodne granice, odnosno planinski lanci, rijeke, jezera, mora, močvare, pustinje i neprohodne šume. Politički definirane granice vrlo su često uvjetovane fizičko-geografskim obilježjima. Prirodne granice predstavljaju fizičko-geografske pojave koje svojim značajkama razdvajaju pojedine prostore. Drugim riječima, geografija je u velikoj mjeri definirala obličje životnoga prostora i veze između pojedinih susjednih grupa ljudi na temelju kojih su se razvile razne etničke, vjerske, državne i gospodarske zajednice. Ratzel je (1897) opisao koncept granice i organizacije društva unutar njegovih okvira. Granice nisu statične, već se mogu mijenjati ili zadržati kroz vrijeme. Trećina današnjih svjetskih granica mlađa je od 100 godina (Routley, 2018). Iako procesi, pojave i objekti u stvarnosti rijetko imaju jasno povučene prostorne granice, na kartama su ipak ucrtane umjetno stvorene linije koje označavaju razgraničenja između dvaju suvereniteta – država. U vojnoj geografiji, koja proučava odnos između geografske stvarnosti i vojne djelatnosti, stroge granice doista postoje jer se prostor analizira kroz mogućnosti, slabosti i ograničenja sukobljenih strana. Paasi (2005) i Laine (2015) dali su sustavan pregled teorijskih pristupa i razvoja promišljanja o granicama iz geografske perspektive, polazeći od temeljnih ideja dvaju utemeljitelja modernih koncepata granica – Friedricha Ratzela i Vidala de La Blachea – te prateći njihovu genezu, transformacije i moguća buduća usmjerenja.

S vojnoga stajališta vojna geografija jest primijenjena znanost koja u slučaju granica opisuje njezina obilježja iz aspekta branitelja ili napadača. Vojna je struka prilikom taktičko-operativnih razmatranja granice fokusirana na njezina fizičko-geografska i infrastrukturna (prometnice, mostovi, komunikacije itd.) obilježja prostora jer ona definiraju mogućnosti obrane/napada, dok su društveno-geografska obilježja stavljena u drugi plan. Iz vojne perspektive granice se promatraju kao obrambene linije, odnosno na granice se gleda kao na barijere – pregrade koje odvajaju suverenitete. U oba slučaja (obrani i napadu) analiza

ural, ethnic, and historical. The development of social relations, that is, spatial-functional processes, was influenced by the earliest natural borders such as mountain ranges, passes, rivers, lakes, seas, marshes, deserts, and impenetrable forests. Politically-defined borders are very often conditioned by physical-geographical features. Natural borders represent physical-geographical objects which, by their characteristics, separate specific spaces. In other words, geography has largely defined the form of living space and the links between neighbouring groups of people, upon which various ethnic, religious, state, and economic communities developed. Ratzel (1897) described the concept of the border and the organisation of society within its framework. Borders are not static; they may shift or persist through time. One-third of today's world borders are less than 100 years old (Routley, 2018). Although processes, phenomena, and objects in reality seldom possess clearly-delineated spatial boundaries, maps nonetheless depict artificially-constructed lines that designate the demarcation between two sovereign entities—states. In the case of military geography, which explains the relationship between geographical reality and the military profession, strict borders do indeed exist, as it analyses space within the framework of the opportunities, weaknesses, and limitations of the conflicting parties. Paasi (2005) and Laine (2015) provided a systematic overview of theoretical frameworks and the evolution of geographical mindset about the borders. This analysis is starting from the fundamental ideas of two founders of modern border concepts—Friedrich Ratzel and Vidal de la Blache—and tracing their genesis, transformations, and possible future directions.

From a military standpoint, military geography is an applied science which, in the case of borders, describes features from the perspective of either the defender or the attacker. In tactical-operational considerations, the military profession focuses on the physical-geographical and infrastructural (roads, bridges, communications, etc.) characteristics of the border area, as these define the possibilities for defence or attack, while socio-geographical features are placed in the background. From a military perspective, borders are viewed as defensive lines, i.e. as

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uključuje opće značajke prostora (veličinu, oblik i raspored predmeta promatranja), lokacije (odnos kopna i mora, faktore vremena i udaljenosti itd.), društva (stanovništvo, ekonomija, razvijenost itd.) i razinu ratovanja (taktička, operativna ili strateška) (Galgano i Palka, 2012; Harmon i dr., 2004). Idealne granice prema Holdich (1916) i Kitamura i Lagerlöf (2020) predstavljaju planinski lanci poput Anda, Himalaje ili Pireneja. Holdich (1916) je istaknuo da su granice najučinkovitije, najstabilnije i najdugovječnije ako su definirane grebenima (razvodima – vododijelnicama) planinskih lanaca. Važnost utjecaja geografskih čimbenika na formiranje i stabilnost granica može se pouzdano procijeniti tek kroz analizu konkretnih scenarija i povijesno-geopolitičkih konteksta. Jedan od najočitijih primjera jest kompleksno i trajno sporno pogranično područje Kašmira, gdje se susreću teritorijalne aspiracije Indije, Pakistana i Kine. Ovaj slučaj pokazuje da prirodni elementi, iako često djeluju kao prostorne barijere, ne garantiraju jednoznačno i trajno razgraničenje. Popelka i Smith (2020) upozoravaju da je gotovo četvrtina svjetskih međudržavnih granica utemeljena na riječnim tokovima, što proizlazi iz njihove linearnosti, prostorne urezanosti u krajolik te percepcije prirodne neprohodnosti. Rijeke, međutim, istodobno mogu biti i zone povezivanja i sukoba, što dodatno potvrđuje njihovu ambivalentnu ulogu u oblikovanju političko-teritorijalne kartografije. S druge strane, međunarodne granice u cjelini nisu samo rezultat geografskih datosti, nego prije svega refleksija odnosa moći i sposobnosti država u određenom povijesnom trenutku (Biger, 2021). One, dakle, istodobno izražavaju prirodnu logiku prostora i političko-stratešku dinamiku, što ih čini ključnim predmetom interdisciplinarnih analize u geografiji i sigurnosnim studijama.

Vojna geografija primijenjena je znanost usmjerena na rješavanje vojnih problema geografskim metodama i alatima (Galgano i Palka, 2012). S gledišta vojne geografije nije dostatno analizirati samo graničnu liniju, već i prostor prema dubini teritorija susjedne i vlastite države. Taj prostor ili operativna dubina potrebna za angažman snaga

barriers separating sovereignties. In both cases (defence and attack), the analysis includes the general characteristics of space (size, shape, and distribution of the area under observation), location (relationship between land and sea, factors of time and distance, etc.), society (population, economy, level of development, etc.), and the level of warfare (tactical, operational, or strategic) (Galgano and Palka, 2012; Harmon et al., 2004). According to Holdich (1916) and Kitamura and Lagerlöf (2020), ideal borders are mountain ranges such as the Andes, Himalayas, or Pyrenees. Holdich (1916) emphasised that borders are most effective, stable, and enduring when defined by mountain ridge watersheds. The significance of geographical factors for the formation and stability of borders can only be reliably assessed via the analysis of specific scenarios and historical-geopolitical contexts. One of the clearest examples is the complex and persistently disputed border region of Kashmir, where the territorial aspirations of India, Pakistan, and China converge. This case illustrates how natural elements, although often acting as spatial barriers, do not guarantee unequivocal and lasting demarcation. Popelka and Smith (2020) point out that nearly one-quarter of the world's interstate borders are based on river courses, owing to their linearity, spatial incision into the landscape, and the perception of natural impassability. Rivers, however, can simultaneously serve as zones of connection and conflict, further confirming their ambivalent role in shaping political-territorial cartography. Conversely, international borders as a whole are not merely the outcome of geographical conditions, but above all a reflection of the balance of power and the capabilities of states at a given historical moment (Biger, 2021). Thus, they simultaneously express the natural logic of space and the political-strategic dynamic, making them a crucial object of interdisciplinary analysis in geography and security studies.

Military geography is an applied science directed at solving military problems using geographical methods and tools (Galgano and Palka, 2012). From the perspective of military geography, it is not sufficient to analyse only the borderline, but also the area extending into the depth of the territory of both the neighbouring and the home state. This space, or op-

ovisi o snazi i veličini vojne postrojbe¹, pri čemu dubina i veličina može varirati s obzirom na morfometrijska i fizičko-geografska obilježja graničnoga pojasa. Istodobno geografija pruža vojnoj struci analitički okvir i bitno pridonosi procesu donošenja odluka u planiranju i vođenju operacija. Unatoč tomu do danas nije razvijen univerzalno prihvaćen model vojno-geografske analize prostora, ponajprije zbog izrazite složenosti čimbenika koji na nju utječu. Riječ je o širokom rasponu fizičkih i društvenih elemenata – od oceanografije, klime i reljefa do demografskih kretanja i prometno-komunikacijskih mreža – čija važnost varira ovisno o konkretnim okolnostima i vrsti vojnoga djelovanja (Collins, 1998).

Cilj je rada utvrđivanje fizičko-geografskih čimbenika na kopnenim granicama RH i analiza njihovih vojno-geografskih obilježja. Dok se većina dosadašnjih istraživanja zadržavala na povijesno-geografskim ili pravnim aspektima granica, ovaj rad ih razmatra i kroz vojno-geografski pristup, s naglaskom na kvantitativnu procjenu fizičko-geografskih čimbenika u oblikovanju i stabilnosti granica RH. Istraživanje je potaknuto neobičnim oblikom teritorija RH, odnosno postavljeno je pitanje kako je moguće da takav oblik teritorija okružen brojnim susjedima uopće egzistira na relativno ograničenu prostoru površine 56542 km². Iz toga istraživačkog pitanja formirana je i temeljna hipoteza istraživanja prema kojoj markantni elementi fizičko-geografske osnove predstavljaju ključne preduvjete za uspostavu i dugoročnu održivost stabilnih međudržavnih odnosa. Rad time doprinosi razvoju vojno-geografske metodologije u hrvatskoj znanosti te donosi prvu sustavnu kvantitativnu analizu fizičko-geografskih obilježja granica taktičke važnosti na cjelokupnom teritoriju RH.

erational depth required for the engagement of forces¹, depends on the strength and size of the military unit, with its depth and extent varying according to the morphometric and physical-geographical features of the border zone. At the same time, geography provides the military profession an analytical framework and makes a significant contribution to the decision-making process in planning and conducting operations. Nevertheless, to this day, no universally accepted model of military-geographical spatial analysis has been developed, primarily due to the marked complexity of the factors affecting it. These include a wide range of physical and social elements—from oceanography, climate, and relief to demographic trends and transport-communication networks—whose significance varies depending on the specific circumstances and the type of military activity (Collins, 1998).

The aim of this paper is to identify the physical-geographical factors along the land borders of the RoC and to analyse their military-geographical characteristics. Whereas most previous research has focused on the historical-geographical or legal aspects of borders, this paper also considers them from a military-geographical perspective, emphasising the quantitative assessment of physical-geographical factors in shaping and stabilising Croatia's borders. The research was prompted by the unusual shape of Croatia's territory, raising the question of how such a form, surrounded by numerous neighbours, can exist at all within a relatively small area (56,542 km²). From this research question, the central hypothesis was formulated: that prominent elements of the physical-geographical framework represent key prerequisites for the establishment and long-term sustainability of stable interstate relations. The paper thus contributes to the development of military-geographical methodology in Croatian science and provides the first systematic quantitative analysis of the physical-geographical features of borders of tactical significance across the entire territory of the RoC.

1 Područje operacije (dubina) od granice prema unutrašnjosti ovisi o vrsti operacije, veličini i rasporedu snaga, logistici, sustavima nadzora, protuzračnoj obrani, vatrenoj moći i dometu ubojitih sredstava (topništva, raketnih sustava, dronova itd.). U *Department of the Army* (2022) sekcija 6, 8 6-1, opisana je doktrina upotrebe vojnih kopnenih snaga u odnosu na veličinu i dubinu područja te veličinu postrojbi.

1 The area of operations (depth) extending from the border towards the interior depends on the type of operation, the size and deployment of forces, logistics, surveillance systems, air defence, firepower, and the range of weapon systems (artillery, missile systems, drones, etc.). In the *Department of the Army* (2022), Section 6, Figure 6-1, the doctrine of employing land forces is described in relation to the size and depth of the area, as well as the size of the units.

Kratak povijesni pregled formiranja kopnene granice Republike Hrvatske i njezinih vojno-geografskih istraživanja

Granice sa svim susjednim državama (2361,7 km): Bosnom i Hercegovinom (BiH), Crnom Gorom, Mađarskom, Slovenijom i Srbijom ugrubo su definirane, odnosno njihovo stanje datira nakon Drugoga svjetskog rata 1945. godine, pri čemu treba istaknuti da „osnovicu” za formiranje velikoga dijela granice s BiH i Mađarskom čine prijašnji ugovori/dogovori kroz povijest (sl. 1). Darques (2017, 108) je izložio detaljni pregled starosti granica Hrvatske i izmjene njezinih položaja u zadnjih 200 godina. Osim granice s Mađarskom, pretežitom ostatku granica koje su formirane za Socijalističke Federativne Republike Jugoslavije zajednički je genetski postanak utemeljen tadašnjim uređenjem katastarskih općina. One predstavljaju lokalne administrativno-funkcionalne cjeline, pri čemu su granice katastarskih općina posljedično postale i granice država. Razumljivo je da je na nekim područjima definiranje opsega katastarskih općina uvjetovano prirodnim barijerama kao što su velike rijeke (Dunav, Drava, Kupa ili Sava) i planinski sustavi. Uzročno-posljedično, a s ciljem kvalitetnijega i funkcionalnijega životnog okruženja, na nekim područjima granica općina „prekrojena” je i temeljem etničkoga sastava stanovništva. Raspored naselja i njihova etnička homogenost i/ili heterogenost uvelike su uvjetovani ekonomskim vezama – u prvom redu prometnom povezanošću koja je također predisponirana fizičko-geografskim značajkama prostora.

Najdužu granicu od 1001,4 km Hrvatska dijeli s BiH. Posavski dio utvrđen je 1918. godine, dok je najveći dio granice određen 1699. godine mirom u Srijemskim Karlovcima. Povijesni razvoj granice uz Pounje opisali su Kozličić i dr. (2011). Ličko-dalmatinski dio granice doživio je brojne promjene, odnosno možemo reći da je definiran povijesnim načelom (Pavličević, 1993). Položaj granice formirali su brojni sukobi između Mletačke Republike i Turaka krajem 17. st. i početkom 18. st. Godine 1718. Dubrovačka Republika ustupila je dio teritorija Osmanlijama, čime je

A brief historical overview of the formation and military-geographical research of the land border of the Republic of Croatia

The borders with all neighbouring states (2361.7 km)—Bosnia and Herzegovina (BiH), Montenegro, Hungary, Slovenia, and Serbia—are roughly defined, with their current status dating from after the Second World War in 1945. It should be emphasised, however, that the “foundation” for much of the border with BiH and Hungary was established by earlier treaties/agreements throughout history (Fig. 1). Darques (2017, p. 108) provided a detailed overview of the age of Croatia’s borders and the changes in their positions over the past 200 years. Apart from the Hungarian border, the majority of the other borders formed during the Socialist Federal Republic of Yugoslavia share a common genesis rooted in the cadastral municipality system of that period. These municipalities represented local administrative–functional units, and their boundaries consequently became state borders. It is understandable that in some areas the delimitation of cadastral municipalities was influenced by natural barriers such as major rivers (the Danube, Drava, Kupa, or Sava) and mountain ranges. Consequently, and with the aim of creating a more functional living environment, in certain areas municipal borders were also “redrawn” on the basis of the ethnic composition of the population. The distribution of settlements and their ethnic homogeneity and/or heterogeneity were largely conditioned by economic ties—primarily transport connectivity, which itself was predisposed by the physical-geographical characteristics of the area.

Croatia shares longest border with BiH, measuring 1,001.4 km. The Posavina section was established in 1918, while the greater part of the border was determined in 1699 by the Treaty of Karlowitz. The historical development of the border along the Pounje region was described by Kozličić et al. (2011). The Lika-Dalmatian section of the border underwent numerous changes and can be said to have been shaped according to historical principles (Pavličević, 1993). The position of the border was influenced by a series of conflicts between the

Hrvatska presječena i omogućeno im je izravno izlazno područje kod Neuma i Sutorine u Boki kotorskoj. Zanimljivo je da je na izgled granice s BiH uz Plješevicu i na dijelu Korduna najviše utjecao gospodarski faktor, pri čemu su aspiracije za eksploatacijom drvene mase definirale graničnu liniju tadašnjih kotara (Bihaća, Bosanski Novi, Bosanskog Petrovca i Drvara).

Za definiranje granice s Crnom Gorom ključan je Berlinski kongres 1878. godine i rad mješovitih povjerenstava 1879. – 1881. godine, koji su precizirali austro-ugarsko-crnogorsku razdjelnicu. Nakon 1918. godine ona postaje unutarnja, a 1945. godine fiksira se kao republička granica SR Hrvatske i SR Crne Gore (Jelavich, 1983). Načelom *uti possidetis juris* 1991. – 1992. godine ista je crta internacionalizirana te zadržana i nakon crnogorske neovisnosti 2006. godine, pri čemu je dugoročnu predispoziciju granice stvarala dubrovačka tampon-politika prema Osmanlijama (Neum, Sutorina) (Pavličević, 2007).

Granica s Mađarskom (355,3 km) uglavnom je prirodna (Mura i Drava) te jednim dijelom i etnička (južna Baranja). Mirovni ugovor s Mađarskom potpisan 4. lipnja 1920. godine u Trianonu odredio je sadašnje granice. Ugovor se odnosio na Međimurje (od 1848. godine dio Hrvatske, zatim ponovno od 1861. godine pod Ugarskom te od 1918. godine dio Kraljevine Srba, Hrvata i Slovenaca), gdje je u trenutku potpisivanja gotovo u cijelosti živjelo hrvatsko stanovništvo. Ugovorom je definiran i status Prekodravlja, odnosno triju naselja s isključivo hrvatskim stanovništvom: Gola, Ždala i Repaš, koja su pripala Hrvatskoj. Povijesnogeografski pregled postanka, starosti i promjena na granici s RH izložio je Klemenčić (1991). Južni dio Baranje od 1945. godine postao je dio Hrvatske na temelju etničkoga ključa iako nikada prije nije bio dio Hrvatske (Boban, 1995). Ulogu Drave kao prirodne i državne granice opisao je Hajdú (2011), a prema Čelanu (2014) ona je jedna od najstabilnijih i najstarijih u Europi.

Granica sa Slovenijom naslijeđena je iz doba habsburške vladavine, a uspostavljena je nakon 1945. godine. Administrativni ustroj i etnički sastav stanovništva oblikovali su njezin položaj. Bognar (2001) je u svoj analizi (provedenoj na

Venetian Republic and the Ottoman Empire at the end of the 17th and the beginning of the 18th century. In 1718, the Republic of Ragusa ceded part of its territory to the Ottomans, which cut across Croatia and enabled them to secure direct access to the Adriatic Sea at Neum and Sutorina in the Bay of Kotor. Interestingly, the configuration of the border with BiH along Plješevica and in parts of Kordun was predominantly shaped by economic factors, e.g. aspirations for timber exploitation determined the borderline of the districts (Bihać, Bosanski Novi, Bosanski Petrovac, and Drvar).

The border with Montenegro was defined by the Congress of Berlin in 1878 and the work of mixed commissions between 1879 and 1881, which specified the Austro-Hungarian—Montenegrin demarcation line. After 1918, it became an internal border, and in 1945 it was fixed as the republican boundary between the Socialist Republic of Croatia and the Socialist Republic of Montenegro (Jelavich, 1983). By the principle of *uti possidetis juris* in 1991–1992, the same line was internationalised and retained after Montenegro's independence in 2006, with the long-term predisposition of the border shaped by Dubrovnik's buffer policy towards the Ottomans (Neum, Sutorina) (Pavličević, 2007).

The border with Hungary (355.3 km) is predominantly natural (the Mura and Drava rivers) and, in part, ethnic (southern Baranja). The Peace Treaty with Hungary, signed on 4 June 1920 in Trianon, established the present borders. The treaty concerned Međimurje (part of Croatia from 1848, then again under Hungary from 1861, and from 1918 part of the Kingdom of Serbs, Croats, and Slovenes) where, at the time of signing, the population was almost entirely Croatian. The treaty also defined the status of Prekodravlje, namely the three settlements of Gola, Ždala, and Repaš, all with exclusively Croatian populations, which were assigned to Croatia. A historical-geographical overview of the origin, age, and changes to the border with Croatia was presented by Klemenčić (1991). The southern part of Baranja became part of Croatia in 1945 on the basis of the ethnic principle, even though it had never previously been part of Croatia (Boban, 1995). The role of the Dra-

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Sl. 1. Ukupna duljina državne granice RH* i njezin osnovni vremenski okvir uspostavljanja (prema Boban, 1995)
Fig. 1 Total length of the state border of the RoC* and its timeframe of establishment (according to Boban, 1995).

Izvor: Državna geodetska uprava (DGU) (stanje 6. svibnja 2020. godine)
Source: State Geodetic Directorate (DGU) (status 6th May 2020)

topografskoj karti mjerila 1 : 100 000) istaknuo da se u slučaju granice RH sa Slovenijom preko 75 % granične linije veže za markantne elemente prirodne osnove, i to prvenstveno za vodene tokove i grebene gorskih uzvišenja ili pak za vršne padine viših gora i planina. Povijesni pregled razvoja granične linije i političko geografska obilježja dijela granice sa Slovenijom koja obuhvaća Žumberački kraj i Kupsko-čabarsku dolinu proveli su Bognar i Bognar (2010). Metodom

va as both a natural and state border was described by Hajdú (2011), and according to Čelan (2014) it is among the most stable and oldest in Europe.

The border with Slovenia was inherited from the period of Habsburg rule and was established after 1945. Its position was shaped by the administrative organisation and the ethnic composition of the population. Bognar (2001) in his analysis (carried out on a topographic map at a scale

deskripcije zaključili su da je pri razgraničenju korištena prirodna osnova, odnosno rijeke i vršni grebeni gorskoga masiva. Važnost graničnih rijeka Kupe, Sutle i Mure opisao je u svojim radovima Zajc (2012; 2017; 2022). Perko i dr. (2019) proveli su detalju GIS analizu promjene riječnih tokova i posljedičnu problematiku definiranja granične linije.

Današnja granica sa Srbijom (326,3 km) uz Dunav određena je katastarskim izmjerama prema granicama tadašnjih katastarskih općina Belog Manastira i Sombora. Povijesno-geografski osvrt razvoja granice u Podunavlju izložili su Pavličević (1993) te Vukosav i Matijević (2020). Srijemski dio granice redefiniran je nekoliko puta, pri čemu je etnički sastav stanovništva na graničnom području zaključno s 1948. godinom formirao izgled granice (Jelić, 1993; Klemenčić, 1993).

Etnički ključ kao glavni faktor razgraničenja bio je presudan na područjima zapadnoga Srijema, gornjega Međimurja, Baranje i u Istri. Granice su većinom definirane na osnovi granica između tadašnjih kotara, a središtima kotara gravitirala su naselja koja su prometno i ekonomski ovisila o njima. Bilo je nekoliko iznimaka i upitnih linija razdvajanja između federativnih republika. One se uglavnom odnose na etničke „otoke” uz granicu, pri čemu su dodatnim aktima dopušteni prelasci naselja iz jedne u drugu državu (npr. područja oko Štrigove i Raskrižja u zapadnom Međimurju, sela u zapadnom Srijemu, sela oko Donjeg Lapca ili Buja).

of 1:100,000), emphasised that more than 75% of Croatia's border with Slovenia is aligned with prominent elements of the natural framework, primarily watercourses and mountain ridges, or the upper slopes of higher hills and mountains. A historical overview of the development of the borderline and the political-geographical features of the section of the border with Slovenia encompassing the Žumberak region and the Kupa-Čabar valley was provided by Bognar and Bognar (2010). Using the descriptive method, they concluded that the delimitation was based on natural features, namely rivers and mountain ridgelines. The significance of the Kupa, Sutla, and Mura border rivers was described in the works of Zajc (2012; 2017; 2022). Perko et al. (2019) conducted a detailed GIS analysis of changes in river courses and the resulting challenges in defining the borderline.

The present-day border with Serbia (326.3 km) along the Danube River was defined by cadastral surveys, according to the boundaries of the (then) cadastral municipalities of Beli Manastir and Sombor. A historical-geographical review of the development of the border in the Danube region was provided by Pavličević (1993) and Vukosav and Matijević (2020). The Srijem section of the border was redefined several times, with the ethnic composition of the population in the border area ultimately shaping the border's configuration by 1948 (Jelić, 1993; Klemenčić, 1993).

The ethnic principle, as the main factor of delimitation, was decisive in the areas of western Srijem, upper Međimurje, Baranja, and Istria. Borders were mostly defined on the basis of the boundaries between the districts of the time, with settlements gravitating towards district centres on which they depended economically and in terms of transport links. There were, however, several exceptions and disputed demarcation lines between the federal states. These mostly concerned ethnic “islands” along the border, where additional acts allowed the transfer of settlements from one state to another (e.g. the areas around Štrigova and Raskrižje in western Međimurje, villages in western Srijem, and villages around Donji Lapac or Buje).

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Predmet, metode i izvori podataka istraživanja

Rad analizira markantne elemente fizičko-geografske osnove prisutne na granicama RH. Njihova su obilježja istražena i interpretirana s vojno-geografskoga te manjim dijelom s povijesno-geografskoga i sigurnosnoga aspekta. Analiza je provedena isključivo po graničnoj liniji², dok je pogranični pojas uključen posljedično.

Primijenjena je svojevrсна mikroanaliza granice, tj. topološki orijentirana analiza podudarnosti dvaju entiteta. Osnovni entitet činila je granična linija, a promatrane entitete predstavljali su fizičko-geografski čimbenici i vojno-geografska obilježja. Promatranje granice kao linije omogućilo je primjenu GIS alata (ArcGIS Pro 2.9.1, vizualni programski jezik *Model builder*). Svojstva zemljišta pridružena su graničnoj liniji korištenjem alata *Intersect*. S vojno geografskog aspekta postoje ograničenja prilikom promatranja granice kao linijskoga objekta, ali u velikoj mjeri odražava stvarne terenske uvjete i omogućuje jasnu interpretaciju rezultata na taktičkoj razini. Takvim pristupom zanemaruje se njezina stvarna prostorna širina i funkcionalna složenost. Gubi se mogućnost cjelovita sagledavanja taktički relevantnih obilježja graničnoga prostora, uključujući mikroreljef, pristupačnost, nadzor i operativni kapacitet terena. Darques (2017, 5–19) detaljno opisuje problematiku analize graničnih linija, graničnoga područja i graničnog pojasa.

Podatci o izvorišnom obličju i vremenima definiranja granice na slici 1 prikupljeni su iz Boban (1995) i Klemenčić (1993). Zbog mikropromjena kroz vrijeme prikaz ima shematsko-informativni karakter. U ovom su radu istraženi prisutni fizičko-geografski čimbenici na granici koji uključuju: nadmorsku visinu, vertikalnu raščlanjenost reljefa, nagibe padina, grebene, doline, rijeke, klimatska obilježja, pokrov i upotrebu zemljišta te svojstva tla koja definiraju vojno-geografska obilježja terena. Fizička osnova formira pozitivne ili negativne čimbenike koji utječu na planiranje i

² Granična linija RH korištena u analizi preuzeta je od strane DGU-a sa stanjem dana 6. svibnja 2020. godine.

Subject, methods, and data sources of the research

The paper analyses the prominent elements of the physical-geographical framework present along the borders of the RoC. Their features have been investigated and interpreted from a military-geographical perspective, and in the narrow sense from historical-geographical and security standpoints. The analysis was conducted exclusively along the borderline², with the border zone being included consequentially.

A form of microanalysis of the border was applied, namely a topologically-oriented analysis of the correspondence between two entities. The primary entity was the borderline, while the observed entities were the physical-geographical factors and military-geographical characteristics. Considering the border as a line enabled the use of GIS tools (ArcGIS Pro 2.9.1, *Model Builder* visual programming language). Terrain properties were associated to the borderline using the *Intersect* tool. From a military-geographical perspective, there are inherent limitations in viewing the border as a linear object; however, this approach still largely reflects actual terrain conditions and enables a clear interpretation of results at the tactical level. Such a perspective, nevertheless, overlooks the border's actual spatial extent and functional complexity, thereby diminishing the ability to comprehensively assess tactically relevant characteristics of the border zone, including microrelief, accessibility, surveillance potential, and the operational capacity of the terrain. Darques (2017, pp. 5–19) provided a detailed account of the issues relating to the analysis of borderlines, border areas, and border zones.

Data on the origin and the periods of border definition in Figure 1 were collected from Boban (1995) and Klemenčić (1993). Due to micro-changes over time, the representation has a schematic and informative character. In this paper, the physical-geographical factors present along the border were examined, including: altitude, vertical dissection of the relief, slope gradients, ridges, valleys, rivers, climatic features, land cover and land

² The borderline of the RoC used in the analysis was obtained from the DGU, with the status as of 6th May, 2020.

provedbu vojnih aktivnosti u prostoru. U svrhu pružanja informacije o mogućnostima nadzora, kontrole, opremanja, organiziranja obrane i napada i dr. na graničnoj liniji i u području granične linije istražena su svojstva vizualnoga nadzora, zaštićenosti pješačkih snaga od otkrivanja iz zraka, prikrivenoga kretanja, mobilnosti snaga i tenkoprohodnosti terena. S obzirom na razinu ratovanja utjecaj geografije varira i može se promatrati s triju razina ratovanja, odnosno na strateškoj, operativnoj i taktičkoj razini (Harmon i dr., 2004). Predmetna analiza provedena je s taktičke razine (vertikalna raščlanjenost reljefa, pokrov i upotreba zemljišta, prikrivenost, maskiranje, tenkoprohodnost i mogućnost vizualnoga nadzora) i dijelom s operativne razine (klima, tenkoprohodnost i nadmorska visina terena) vojnoga djelovanja, dok konačni zaključci i rezultati mogu biti upotrijebljeni za donošenje odluka na taktičkoj, operativnoj i strateškoj razini. Istraživanjem nije obuhvaćena analiza prisutne infrastrukture, stanovništva, udaljenosti između objekata, brojnost te dometa i polja vatri naoružanja.

Kao podloga za geomorfometrijska istraživanja (nadmorsku visinu, vertikalnu raščlanjenost reljefa, izdvajanje grebena i dolina) korišten je javno dostupan Digitalni model visina (DMV) Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global (USGS, n. d.). Prilikom klasifikacije terena sukladno Weiss (2001) statistički prostorni obuhvat za definiranje grebena postavljen je na 2000 metara, a za doline na 300 metara. Strojno dobiveni reljefni oblici validirani su na topografskoj karti RH mjerila 1 : 25 000 (TK25 DGU). Izdvojeni grebeni sistematizirani su prema geomorfološkoj mikroregionalnoj raspodjeli sukladno Bognar (1999).

Podaci o vodotocima i prometnicama vektORIZIRANI su s TK25 DGU. Klimatska obilježja preuzeta su iz Klimatskoga atlasa (Zaninović i dr., 2008). Kao izvor podataka za pokrov i upotrebu zemljišta korišten je set podataka Corine Land Cover (CLC) iz perioda od 2012. do 2018. (*Corina Land cover*, n. d.).

Analiza vidljivosti i mogućnosti nadzora zemljišta provedena je alatom *Viewshed*. Tijekom postupka granična linija definirana je kao mnoš-

use, as well as soil properties that define the military-geographical characteristics of the terrain. The physical framework constitutes either positive or negative factors influencing the planning and execution of military activities in the area. For the purpose of providing information on the possibilities of surveillance, control, equipping, organising defence and attack, etc. along and in the vicinity of the borderline, the following properties were analysed: visual surveillance; protection of infantry forces from aerial detection; concealed movement; force mobility; and terrain trafficability for tanks. Depending on the level of warfare, the influence of geography varies and may be considered for the three levels of warfare: strategic; operational; and tactical (Harmon et al., 2004). This analysis was conducted at the tactical level (vertical dissection of the relief, land cover and land use, concealment, camouflage, tank mobility, and possibilities of visual surveillance) and partly at the operational level (climate, tank mobility, and terrain altitude) of military activity, while the final conclusions and results may be used for decision-making at the tactical, operational, and strategic levels. The research did not include an analysis of existing infrastructure, population, distances between objects, manpower, or the range and fields of fire of weaponry.

As a basis for geomorphometric research (altitude, vertical dissection of the relief, identification of ridges and valleys), the publicly-available Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global was used (USGS, n.d.). In the terrain classification, following Weiss (2001), the statistical spatial scope was set at 2,000m for defining ridges and 300m for valleys. The machine-generated relief forms were validated at the Topographic map of the RoC at a scale of 1:25,000 (TK25 DGU). The extracted ridges were systematised according to the geomorphological microregional distribution, in line with Bognar (1999).

Data on watercourses and roads were vectorised from TK25 DGU. Climatic characteristics were taken from the *Climate Atlas* (Zaninović et al., 2008). As the data source for land cover and land use, the *Corine Land Cover (CLC)* dataset for the period 2012-2018 was used (Corine Land Cover, n.d.).

tvo stajnih točaka koje su segmentirane u kontinuiranim razmacima od 50 m na temelju kojih je računata vidljivost (promatrač i promatrana lokacija podignuti za 2 m) do udaljenosti 6 km od granice³. Analiza je provedena na podlozi DMV SRTM i CLC. Stajne točke-lokacije unutar grmlja i šumskog pokrova⁴ izuzete su iz analize jer visoka vegetacija onemogućava promatranje. Dodatni problem predstavljala je i struktura DMV, jer on u sebi sadrži visinu vegetacije, pa samim time analiza vidljivosti s tih ili na te točke ne bi bila točna. U završnom koraku analize dobiveni rezultati vidljivosti sa svih (28337) pojedinačnih točaka spojeni su u jedinstveni sloj (alat *Count overlapping features*) temeljem kojega je izračunata ukupna površina zemljišta s koje se segment granice može vidjeti s teritorija RH.

Utvrđivanje mogućnosti nadzora zemljišta iz zraka provedeno je na podacima CLC-a, koji su raspodijeljeni u tri kategorije: dobra, srednja i loša prikrivenost od promatranja (drona, aviona, satelita i sl.) iz zraka (tab. 1). Na temelju toga izdvojeni su potencijalni koridori za prikriveno kretanje izvidnika, krijumčara ili nezakonitih migranata. Analiza je rađena za vršno vegetacijsko razdoblje, pri čemu npr. listopadna šuma tijekom zimskih mjeseci nije pogodna za prikriveni pokret. Poljoprivredne površine kategorizirane su kao „loše” zbog nedostatka podataka o kulturama (za predmetnu CLC klasu ne postoje informacije o zasađenoj kulturi) i plodoređu iako u praksi (npr. kukuruz ljeti) mogu privremeno služiti kao zaklon.

Koristeći se načelima neizravne logike, provedena je analiza tenkoprohodnosti granice za tenk M-84 prema Heštera (2021). Upotrijebljen je raspon koeficijentata usporenja vozila od 0 do 1, pri čemu 0 predstavlja nemogućnost kretanja, a 1 nesmetan pokret vozila. Analize nagiba zemljišta provedene su na DMV SRTM, vodotoci i cestovna mreža preuzeti su s TK25 DGU, pokrov i način korištenja zemljišta klasificiran je na osnovi CLC modela podataka (tab. 2). Pedološ-

3 Do udaljenosti od 6 km moguće je dalekozorom (povećanja 7 do 8 puta) osmotriti vozilo (Department of the Army, 2019, B-8).

4 Isključeni CLC slojevi pod ID kodom: 311, 312, 313, 323, 324, 411 i 141.

The visibility and land surveillance analysis was carried out using the *Viewshed* tool. In the process, the borderline was defined as a set of observation points segmented at continuous intervals of 50m, from which visibility (observer and observed location raised by 2m) was calculated up to a distance of 6km from the border³. The analysis was performed using the SRTM DEM and CLC as the base layers. Observation point locations within shrub and forest cover⁴ were excluded from the analysis, as tall vegetation prevents observation. An additional issue was posed by the DEM structure itself, since it incorporates vegetation height, meaning that visibility analyses from or towards such points would not be accurate. In the final step of the analysis, the visibility results from all 28,337 individual points were merged into a single layer (using the *Count Overlapping Features* tool), which was then used to calculate the total land area from which a segment of the border can be seen from the territory of the RoC.

The assessment of land surveillance vulnerability from the air was carried out using CLC data, which were classified into three categories: good; moderate; and poor concealment from aerial observation (drones, aircraft, satellites, etc.) (Tab. 1). Based on this, potential corridors for concealed movement of scouts, smugglers, or irregular migrants were identified. The analysis was conducted for the peak vegetation period, because deciduous forest is unsuitable for concealed movement during the winter months. Agricultural areas were categorised as “poor” due to the lack of data on crops (the relevant CLC class does not contain information on the planted crop) and crop rotation, although in practice (e.g. maize in summer) they may temporarily serve as cover.

Using the principles of fuzzy logic, an analysis of the terrain trafficability at the border was carried out for the M-84 tank, according to Heštera (2021). A range of vehicle deceleration coefficients from 0 to 1 was applied, where 0 represents an inability to move and 1 indicates unrestricted movement. Slope analyses were conducted on the SRTM DEM, watercourses and the road network were taken from TK25

3 A vehicle can be observed with binoculars (7–8× magnification) at a distance of up to 6km (Department of the Army, 2019, B-8).

4 Excluded CLC layers (ID codes): 311, 312, 313, 323, 324, 411 and 141.

Tab. 1. Koeficijenti za reklasifikaciju mogućnosti prikrivanja i prikrivenoga kretanja pješništva
Tab. 1 Coefficients for the reclassification of concealment and concealed movement possibilities of infantry

Mogućnost prikrivanja / Concealment potential	Težišni koeficijent / Weighting coefficient	Prohodnost zemljišta za pješaka (nagib°) / Terrain trafficability for infantry (slope°)	Težišni koeficijent / Weighting coefficient	Mogućnost prikrivenoga kretanja / Concealment potential	Rezultat umnoška prohodnosti i mogućnosti prikrivanja / Product of trafficability and concealment potential
Izvrсна* / Excellent*	1	Prohodno (<10°) / Go (<10°)	1	Odlično / Excellent	1
Dobra** / Good**	0,5	Umjerenoprohodno (10°–20°) / Slow Go (10°–20°)	0,8	Dobro / Good	0,51 – 0,99
Loša*** / Poor***	0,25	Teško prohodno (20°–30°) / Very slow go (20°–30°)	0,4	Loše/ Poor	0,01 – 0,5
		Neprohodno (>30°) / No Go (>30°)	0	Nepogodno / Not suitable	0

*CLC kod/CLC code: 311, 312,313, 323, 324, 411.

**CLC kod/CLC code: 111, 141, 221, 222, 223, 242, 243, 333, 334.

***CLC kod/CLC code: 112, 121, 122, 123, 124, 131, 211, 212, 231, 321, 332, 422, 511, 512

ka osnova preuzeta je s Osnovne pedološke karte (OPK) RH mjerila 1 : 50 000 (Heštera i dr., 2019). Dodatno na metodologiju Heštera (2021) uključena je stjenovitost podloge kao faktor usporenja (vidi tab. 3). Stjenovitost se referira na udio stijenskih izdanaka koji se nalaze na površini⁵, odnosno na hrapavost terena. Stanje/scenarij prohodnosti tla postavljeno je u ljetni period godine, odnosno fizikalna svojstva prohodnosti tla nisu razmatrana u analizi.

Analiza mogućnosti prikrivenoga pokreta snaga provedena je kombiniranjem setova podataka o prohodnosti terena i mogućnosti otkrivanja pokreta iz zraka.

DGU, while land cover and land use were classified based on the CLC dataset (Tab. 2). The pedological basis was obtained from the Basic Pedological Map (BPM) of the RoC at a scale of 1:50,000 (Heštera et al., 2019). In addition to the methodology of Heštera (2021), ground rockiness was considered as a deceleration factor (see Tab. 3). Rockiness refers to the proportion of rock outcrops on the surface, i.e. the roughness of the terrain⁵. The soil trafficability state/scenario was set for the summer period of the year, meaning that the physical properties of soil trafficability were not considered in the analysis.

The analysis of the possibilities for concealed movement of forces was carried out by combining datasets on terrain trafficability and the likelihood of movement detection from the air.

5 Kartiranje stjenovitosti OPK-a izrađene prema kategorijama i metodologiji USDA, (1951).

5 Rockiness of BMP was mapped according to categories and methodology of USDA (1951).

Tab. 2. Tenkoprohodnost (M-84) – koeficijenti usporenja prema pripadajućem pokrovu i načinu korištenja zemljišta
Tab. 2 Tank M-84 trafficability – deceleration coefficients of related land cover and land use type

Koeficijent usporenja / Coefficient of deceleration	TK25* ili CLC kod s opisom pokrova ili načina korištenja / TK25* or CLC code with land coverage and land use type
0	TK25 – Vodotok / Stream (111) – Gusto urbano područje / Continuous urban fabric (311, 312, 313) – Šume / Forests (221) – Vinogradi / Vineyards (411) – Močvara / Swamp (512) – Jezera / Lakes
0,1	(131) – Otvoreni kop / Mine extraction sites (324) – Prijelazno područje šuma i grmlja / Transitional woodland shrub
0,2	(112) – Otvoreno urbano područje / Discontinuous urban fabric (141) – Zelena urbana područja / Green urban areas (242) – Miješano kultivirano zemljište / Complex cultivated patterns (323) – Makija / Sclerophyllous vegetation
0,3	(121) – Industrijsko ili komercijalno područje / Industrial or commercial units (222) – Voćnjaci / Orchards (223) – Maslinici / Olive groves
0,5	(243) – Pretežno poljoprivredno zemljište / Land principally occupied by agriculture (334) – Požarišta / Burnt areas (422) – Solane / Salines
1	TK25 – Ceste / Roads (123) – Luke / Port areas (124) – Aerodromi / Airports (211, 212) – Oranica / Non irrigated and irrigated arable land (231) – Pašnjaci / Pastures (321) – Livade / Natural grassland (332) – Gola stijena / Bare rock (333) – Rijetka vegetacija / Areas of sparse vegetation

*Izvor podataka: DGU (<https://geoportal.dgu.hr/services/tk/wms>, 20. 8. 2023.)

*Data source: DGU (<https://geoportal.dgu.hr/services/tk/wms>, 20. 8. 2023.)

Tab. 3. Tenkoprohodnost (M-84) – koeficijenti usporenja uslijed stjenovitosti površine
Tab. 3. Tank M-84 trafficability – deceleration coefficients regarding terrain rockiness

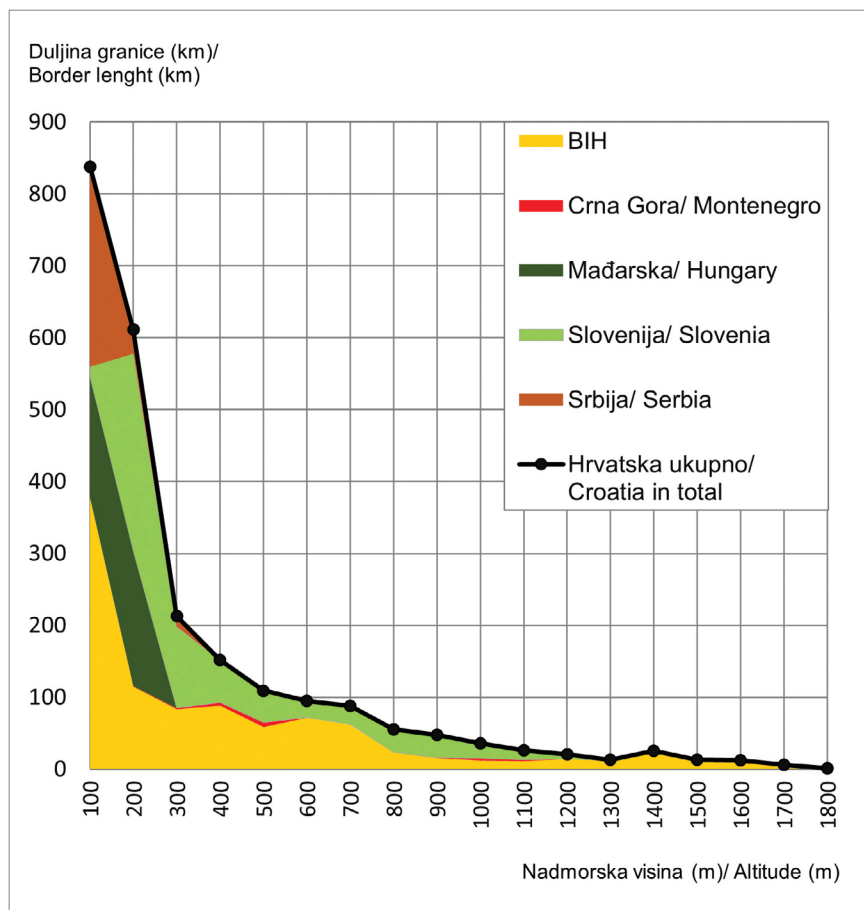
Koeficijent usporenja / Deceleration coefficient	Stjenovitost (pokrivenost površine u %) / Rockiness (coverage of surface %)	Razmak (m) između stijenskih izdanaka ili slobodnih stijena / Space (m) between stone outcrops or loose rocks
0	90+	Puna pokrivenost / Full coverage
0,1	50–90	>= 3
0,2	25–50	3–10
0,35	10–25	10–30
1	0–10	30+

Rezultati istraživanja

Prema razdiobi prikazanoj na slici 2, najveći dio državne granice RH nalazi se u nizinskim područjima. Na visinama do 200 m/nm smješteno je 61,4 % ukupne duljine granice (1.449 km), što se ponajprije odnosi na riječne dionice uz Dravu, Dunav i Savu. Oko trećine granice, odnosno 33,7 % (795 km), proteže se na visinama između 200 i 1000 m/nm, dok se preostalih 4,9 % (117 km) nalazi na nadmorskim visinama iznad 1000 m/nm. Aritmetička sredina nadmorske visine državne granice iznosi 421 m, dok je medijalna vrijednost 300 m.

Research results

According to the distribution shown in Figure 2, the majority of Croatia's border lies in lowland areas. At altitudes of up to 200m a.s.l., 61.4% of the total border length (1,449 km) consists of river sections of the Drava, Danube, and Sava rivers. About one third of the border, i.e. 33.7% (795 km), extends at altitudes between 200 and 1,000m a.s.l., while the remaining 4.9% (117 km) lies at elevations above 1,000m a.s.l. The arithmetic mean altitude of the state border is 421 m, while the median value is 300 m.

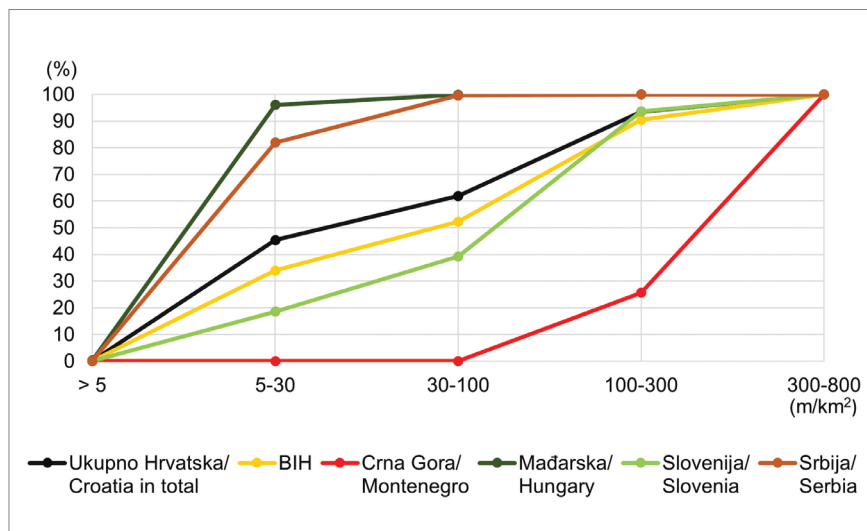


Sl. 2. Duljina granice RH sukladno pripadajućoj nadmorskoj visini i susjednoj državi

Fig. 2 The length of the border of the RoC according to the corresponding altitude and neighboring country.

Prema Koppenovoj klasifikaciji na granici RH najzastupljenija je Cfb umjereno topla vlažna klima s toplim ljetom s 92,6 % ili na 2186 km, Cfa umjereno topla vlažna klima s vrućim ljetom 7,2 % ili 169 km obuhvaća krajnji jug, dok Csa sredoze-

According to Köppen's classification, the most prevalent climate along Croatia's border is Cfb—a temperate warm humid climate with warm summers—covering 92.6% or 2,186 km. The Cfa type—a temperate warm humid climate with hot summers—



Sl. 3. Vertikalna raščlanjenost reljefa na granici RH
Fig. 3 Vertical dissection of the terrain along the border of the RoC.

mna klima sa suhim vrućim ljetom obuhvaća samo 0,2 % ili 5 km duljine granice.

Na slici 3 prikazana je vertikalna raščlanjenost područja uz granice RH. Slabo raščlanjene ravnice čine (< 30 m/km²) 45,4 % ili 1071 km, odnosno gotovo čitavu duljinu granice s Mađarskom (96,2 % ili 341 km) i Srbijom (88 % ili 267 km). Slabo i umjereno raščlanjen reljef (30 – 300 m/km²) obuhvaća 48,1 % ili 1460 km, od čega se 93 % odnosi na granicu s BiH (565 km) i Slovenijom (494 km). Izrazito raščlanjen reljef (300 – 800 m/km²) ima najmanji udio (6,5% ili 153 km) i pripada granicama BiH, Slovenije i Crne Gore.

Analiza je pokazala da je 58,6 % odnosno 1385 km od ukupno 2360 km državne granice RH determinirano markantnim fizičko-geografskim obilježjem (vidi sl. 4 i tab. 4), odnosno da na toj duljini granica prelazi preko vodotoka, doline ili grebena. Tu rijeke (među kojima se ističu Sava, Kupa, Dunav, Una, Drava i Sutla) dominiraju kao granični element s ukupno 1063 km ili 45 % ukupne duljine granice, pri čemu njih 14,3 % prolazi unutar jasno formiranih riječnih dolina. Iako su takvi podatci neizostavni u svakoj vojno-geografskoj analizi, rezultati dobiveni primijenjenom metodologijom ne obuhvaćaju informacije o pogodnim mjestima prelaska rijeka niti o visini obala, širini, dubini i brzini vodotoka (Rybansky i dr., 2024; Sedláček i Dohnal, 2025). Grebenima je određeno 7,6 % ili 179 km granice, pri čemu valja istaknuti brdsko-udo-

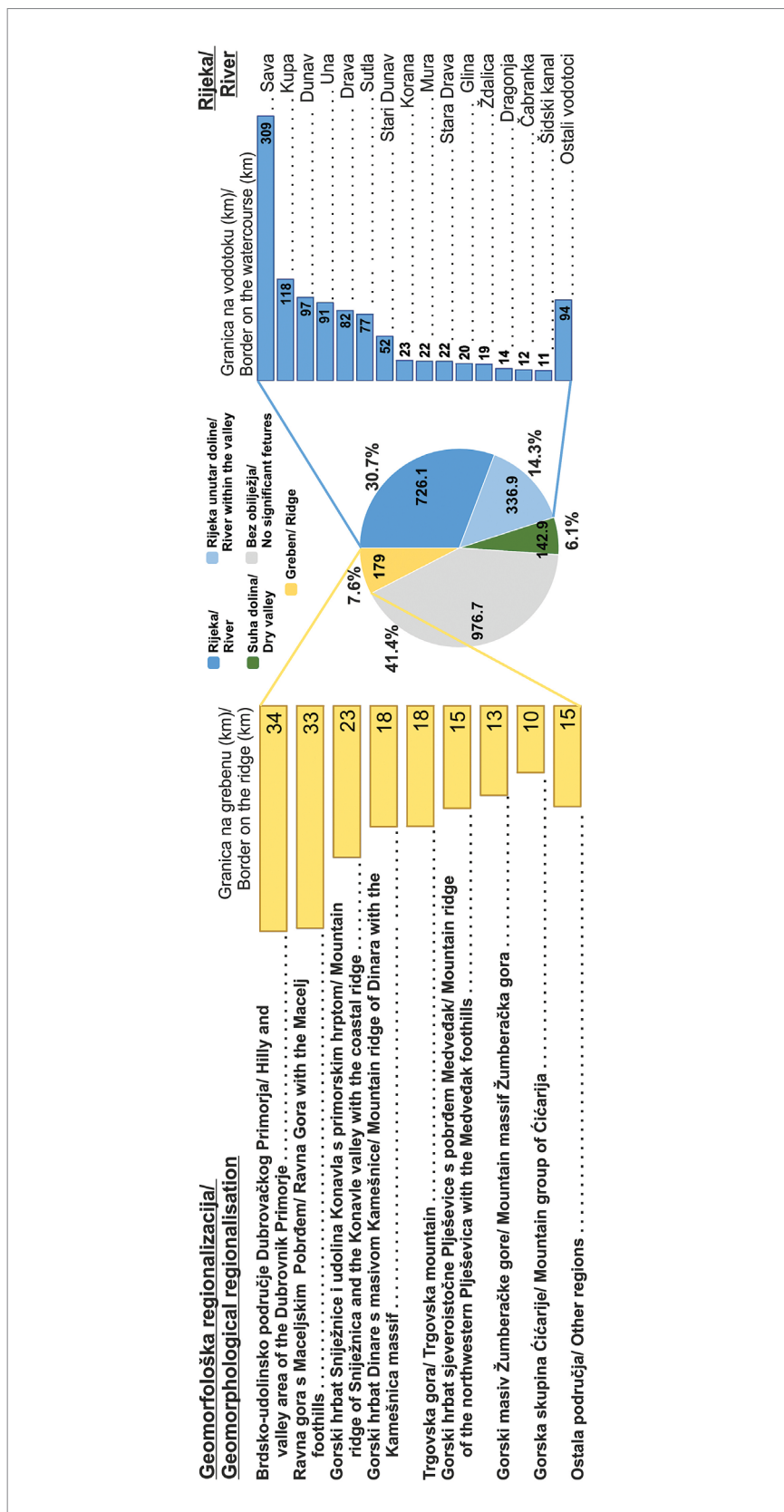
accounts for 7.2% or 169km, encompassing the far south, while the Csa Mediterranean climate with dry hot summers covers only 0.2% or 5km of the border length.

Figure 3 shows the vertical dissection of the areas along Croatia's borders. Slightly dissected plains (<30m/km²) account for 45.4% or 1,071 km, representing almost the entire length of the border with Hungary (96.2% or 341km) and Serbia (88% or 267km). Slightly to moderately dissected relief (30–300m/km²) covers 48.1% or 1,460km, of which 93% corresponds to the borders with BiH (565km) and Slovenia (494km). Highly-dissected relief (300–800m/km²) has the smallest share (6.5% or 153km) and occurs along sections of the borders with BiH, Slovenia, and Montenegro.

The analysis showed that 58.6%, or 1,385km of the total 2,360km of Croatia's border, is determined with prominent physical-geographical features (see Fig. 4 and Tab. 4), meaning that the border follows watercourses, valleys, or ridges for this length. Within this, rivers (notably the Sava, Kupa, Danube, Una, Drava, and Sutla) dominate as border elements, with a total of 1,063km or 45% of the total border length, of which 14.3% run within clearly formed river valleys. Although such data are indispensable in any military-geographical analysis, the results obtained through the applied methodology do not include information on suitable river crossing points, nor on bank height, width, depth, or flow rate (Rybansky et

Sl. 4. Udio i duljine (km) markantnih fizičko-geografskih objekata na granici RH s istaknutim najdužim rijekama i grebenima

Fig. 4 Proportion of prominent physical-geographical features along the border of RoC, with the longest rivers and ridges.



Tab. 4. Udjeli i ukupne duljine (km) izdvojenih markantnih fizičko-geografskih čimbenika prema susjednim državama
Tab. 4 Proportions and total lengths (km) of selected prominent physical-geographical factors along the borders with neighboring countries

Država / Country	Duljina granice / Border line length	Vodotok / Stream	Greben / Ridge	Suha dolina / Dry valley	Udio fizičko- geografskog čimbenika u ukupnoj duljini / Share of the physical- geographical factor in the total length
BiH	1001,4	475,1	100,9	48,9	62,4 %
Crna Gora / Montenegro	19,5	0,0	15,9	0,8	85,5 %
Mađarska / Hungary	355,3	154,5	0,0	0,0	43,5 %
Slovenija / Slovenia	659,1	259,6	62,1	93,2	62,9 %
Srbija / Serbia	326,3	173,7	0,0	0,0	53,2 %
Ukupno / Total	2361,7	1062,9	179,0	142,9	58,6 %

linsko područje Dubrovnika (1,4 % ili 34 km), Ravnu goru s Maceljskim pobrdem (1,4 % ili 33 km) te područje Sniježnice (1 % ili 23 km). Doline bez vodotoka i grebeni koji su ujedno i državna granica nisu prisutni na granicama s Mađarskom i Srbijom zbog dominantnoga fluvijalnog, fluvijalno-akumulacijskoga i sufozijskoga tipa reljefa (lesnih zaravni). Granice prema svim državama fizički su determinirane prema primijenjenom kriteriju, pri čemu se posebno ističe granica s Crnom Gorom (85 %) te granice prema BiH i Sloveniji, gdje gotovo 2/3 duljine granice predstavlja neko markantno fizičko-geografsko obilježje.

Rezultati analize prikazani u tablici 5 otkrivaju da su najveće promjene evidentirane u 1945. godini, dok su rijeke kroz povijest (vidi sl. 1) imale ključnu ulogu u definiranju znatnoga dijela granice. Linearost i paralelnost rijeka na sjeveru (Drave, Mure i dijelom Dunava) i jugu (Une i Save) te središnjega položaja slavonskoga gorja kao svojevrsna utvrđenja predstavljaju izvrstan okvir za organizaciju obrane ako dođe do napada iz bilo kojeg smjera, a poglavito iz smjerova sjevera ili juga. Predmetna situacija doprinijela je stabilnosti i dugovječnosti granica unutar hrvatskoga dijela panonskoga bazena, koji dodatno naglašava ulogu rijeka Save, Drave, Mure i Une kao granica. Budući da naše rijeke koje ujedno predstavljaju granicu nemaju istaknutu gospodarsku funkciju

al., 2024; Sedláček and Dohnal, 2025). Ridges account for 7.6% or 179km of the border. Particularly notable are the hill-valley area of Dubrovnik (1.4% or 34 km), Ravna Gora with the Macelj hills (1.4% or 33km), and the Sniježnica area (1% or 23km). Valleys without watercourses and ridges that simultaneously form state borders are absent along the borders with Hungary and Serbia, due to the predominance of fluvial, fluvio-accumulative, and suffosional relief types (loess plateaus). The borders with all neighbouring states are physically determined according to the applied criterion, with the border along the Montenegro standing out in particular (85%), as well as those with BiH and Slovenia, where almost two-thirds of the border length follows a distinct physical-geographical feature.

The results of the analysis presented in Table 5 reveal that the greatest changes were recorded in 1945, while rivers have historically played a key role in defining significant sections of the border (see Fig. 1). The linearity and parallelism of rivers in the north (the Drava, Mura, and partly the Danube) and the south (the Una and Sava), together with the central position of the Slavonian highlands as a kind of natural stronghold, provide an excellent framework for organising defence in the event of an attack from any direction, particularly from the north or south. This situation contributed to the stability and longevity of the borders within the Croatian part of the Pannonian Basin, further emphasising the role of the Sava,

Tab. 5. Duljina granice (km) prema godini uspostavljanja u odnosu na fizičko-geografsko obilježje (vidi sl. 1)
Tab. 5. Length of border (km) by year of establishment with reference to physical-geographical feature (see Fig. 1)

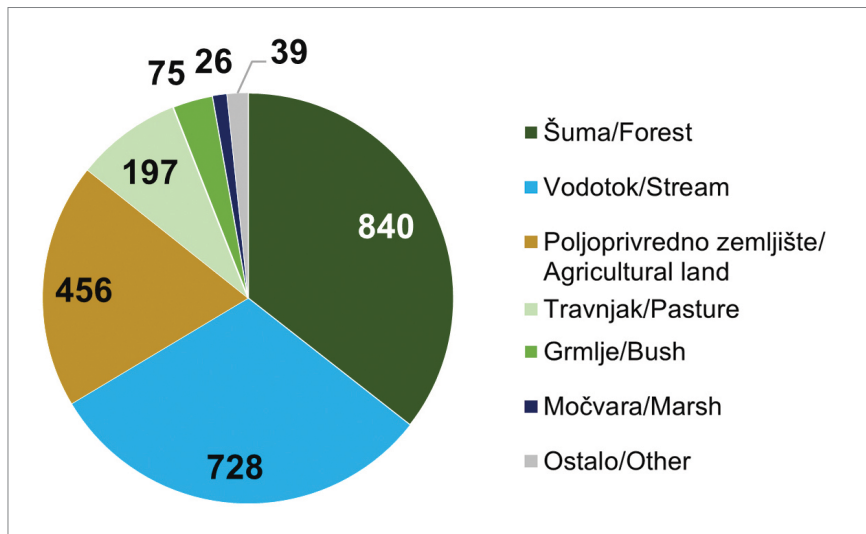
Godina / Year	Granica na rijeci / Border on a river	Granica na grebenu / Border on a ridge	Granica po dolini / Border in a valley	Preostali dio granice / Remaining part of the border	Ukupna duljina granice / Total length of the border
1699	361,2	0,0	7,6	14,2	382,9
1718	0,0	40,3	0,0	58,1	98,4
1878	98,3	36,1	35,1	280,9	450,5
1920	136,7	0,0	0,0	130,2	266,9
1922	0,0	15,9	0,8	2,8	19,5
1945	450,6	84,9	94,3	465,0	1094,9
1946	7,1	0,6	1,4	14,0	23,2
1948	8,9	0,0	0,0	0,0	8,9
1956	0,0	1,0	3,6	11,7	16,4
Ukupno / Total	1062,9	179,0	142,8	976,9	2361,7

u smislu plovnosti (osim Dunava i dijela Save) ili iskorištavanja hidroenergije (osim hidroelektrane Varaždin), može se reći da one ponajprije djeluju kao prirodne razdjelnice prostora. Rijeke osiguravaju preduvjet stvaranja ozračja sigurnosti i sužuju prostor za moguća „otvorena pitanja” i pokretanje ratnih sukoba jer nije moguća laka komunikacija i razmjena dobara i ideja, što posljedično dovodi do stvaranja jezičnih, etničkih i drugih socijalnih grupiranja stanovništva. Međutim, jednako je upečatljivo da je gotovo jednak iznos (oko 977 km) oblikovan mimo prirodnih objekata. Ova činjenica upućuje na to da su administrativne i političke odluke imale barem jednako veliku, a u određenim razdobljima i prevladavajuću ulogu u formiranju granica. Slijedom navedenoga možemo reći da su granice i obilježja RH izrazito fizičko-geografski determinirane u kontinentalnom dijelu, dok južni dio predstavlja kombinaciju fizičkih i socijalnih čimbenika. Rezultati su sukladni Darquesu (2017, 115) prema kojemu su hrvatske granice druge po starosti unutar političkoga okružja Balkanskog poluotoka (nakon BiH) što implicira stabilnost granice.

Prema CLC-u (sl. 5) 2/3 granice nalazi se u šumama i vodotocima (rezultat prema TK25 DGU na sl. 4), a na poljoprivrednom zemljištu 19,3 %. Ostali tipovi pokrova i korištenja zemljišta pokrivaju 14,3% ili 373 km.

Drava, Mura, and Una rivers as borders. Since Croatian rivers that also form borders have no significant economic function in terms of navigability (with the exception of the Danube and part of the Sava) or hydroenergy use (apart from the Varaždin hydroelectric power plant), they may be regarded primarily as lines of separation. Rivers create preconditions for a climate of security and reduce the space for potential “open questions” and the outbreak of armed conflict, as easy communication and the exchange of goods and ideas are not possible. This, in turn, leads to the formation of linguistic, ethnic, and other social groupings of the population. However, it is equally striking that an almost identical length (around 977km) was shaped independently of natural features. This indicates that administrative and political decisions played at least an equally significant, and at certain times even a prevailing, role in border formation. Consequently, it can be said that Croatia’s borders and territorial shape are strongly determined by physical-geographical factors in the continental part, while the southern part represents a combination of physical and social factors. The results are consistent with Darques (2017, p. 115), according to whom Croatia’s borders are the second oldest within the political context of the Balkan Peninsula (after BiH), which implies border stability.

According to the CLC (Fig. 5), two-thirds of the border lies within forests and watercourses (corresponding to the TK25 DGU results in Fig. 4), while

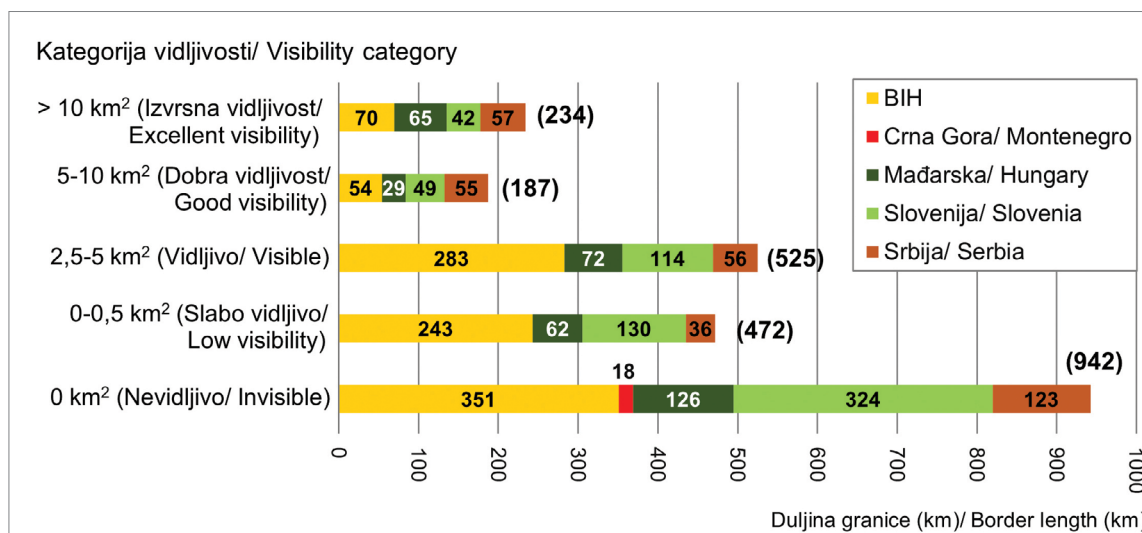


Sl. 5. Pokrov i način korištenja zemljišta na granici RH (km)
Fig. 5 Land cover and land use type on the border of the RoC (km)

Na slici 6 prikazana je mogućnost vizualnoga nadzora granice RH s teritorija RH. Kategorije vidljivosti oblikovane su u skladu sa statističkom distribucijom podataka temeljenoj na standardnoj devijaciji premda ne korespondiraju strogo s razredima standardne devijacije. Potrebno je napomenuti da su predmetni rezultati izrazito varijabilni i nije ih moguće jednodimenzionalno definirati. Uzrok varijabilnosti rezultata jest nesavršenost same granične linije, stoga u stvarnosti površina s koje se neki segment može nadzirati varira između 0 i 113 km² (površina dobivena temeljem maksimalnoga dometa vizualnog nadzora, odnosno prema formuli za površinu kruga koja glasi: $P = r^2\pi \times 6 \text{ km}$). Sukladno navedenom, vizualni nadzor granice nije moguć na 39,9 % ili 942 km granice, dok je vrlo ograničena i slaba vidljivost moguća na 20 % ili 472 km granice. Nevidljivi prostor pretežito obuhvaća visoko gorske dijelove Gorskoga kotara, Žumberka, Like te južnu Dalmaciju i Baniju. Nevidljivost je uzrokovana šumskim pokrovom. Izvrsna vidljivost moguća je na prostoru Baranje, donjega dijela toke Sutle, na Dinari, u Dubrovačkom zaleđu i Prekodravlju. Nužno je istaknuti da predmetna analiza i ostale analize u nastavku rada koje podrazumijevaju upotrebu klasičnih optičkih instrumenata prikazuju rezultate tijekom idealnoga stanja atmosfere, odnosno kada vidljivost ne narušavaju magla, kiša, snijeg, naoblaka i dr.

19.3% runs across agricultural land. Other land cover and land use types account for 14.3% or 373 km.

Figure 6 shows the possibility of visual surveillance of Croatia's border from its own territory. Visibility categories were defined according to the statistical distribution of the data based on standard deviation, although they do not correspond strictly to standard deviation classes. It should be noted that these results are highly variable and cannot be unambiguously defined. The cause of variability lies in the irregular form of the borderline, which is not a perfect line; therefore, in reality, the area from which a segment can be observed varies between 0 and 113km² (the obtained area based on the maximum possible range of visual surveillance, that is, according to the formula for the area of a circle, which is: $A = r^2\pi \times 6 \text{ km}$). Accordingly, visual surveillance of the border is not possible along 39.9% or 942km of the border, while very limited or poor visibility is possible along 20% or 472km. The invisible space predominantly includes the high mountain areas of Gorski Kotar, Žumberak, Lika, as well as southern Dalmatia and Banija. The invisibility is primarily caused by forest cover. Excellent visibility is possible in Baranja, the lower section of the Sutla Valley, on Dinara Mountain, in the Dubrovnik hinterland, and in Prekodravlje. It is essential to emphasise that this analysis, as well as the other analyses presented later in the paper involving the use of classical optical instruments, depicts results under ideal atmospheric conditions, that is, when visibility is not impaired by fog, rain, snow, cloudiness, or similar factors.



Sl. 6. Mogućnost vizualnog nadzora granice s teritorija RH prema pripadajućim državama
Fig. 6 Possibility of visual surveillance of the border towards neighboring countries from the territory of the RoC.

Izvršnu zaštićenost pokreta pješačkih snaga (sl. 7) pruža 36 % ili 851 km granice, što je u izravnoj korelaciji sa šumskim pokrovom (sl. 5). Ta područja poglavito se odnose na granice s BiH (Banija, Plješevica i Kamešnica) i Slovenijom (Čičarija, Gorski kotar, Maceljsko gorje i Žumberak). Otvoreni visokogorski predjeli obrasli niskim raslinjem (južni dio granice s BiH) te velike rijeke predstavljaju prostorne cjeline s niskim stupnjem prikrivenosti pješništva za nadzor iz zraka, a obuhvaćaju 51,7 % ili 1221 km ukupne granice.

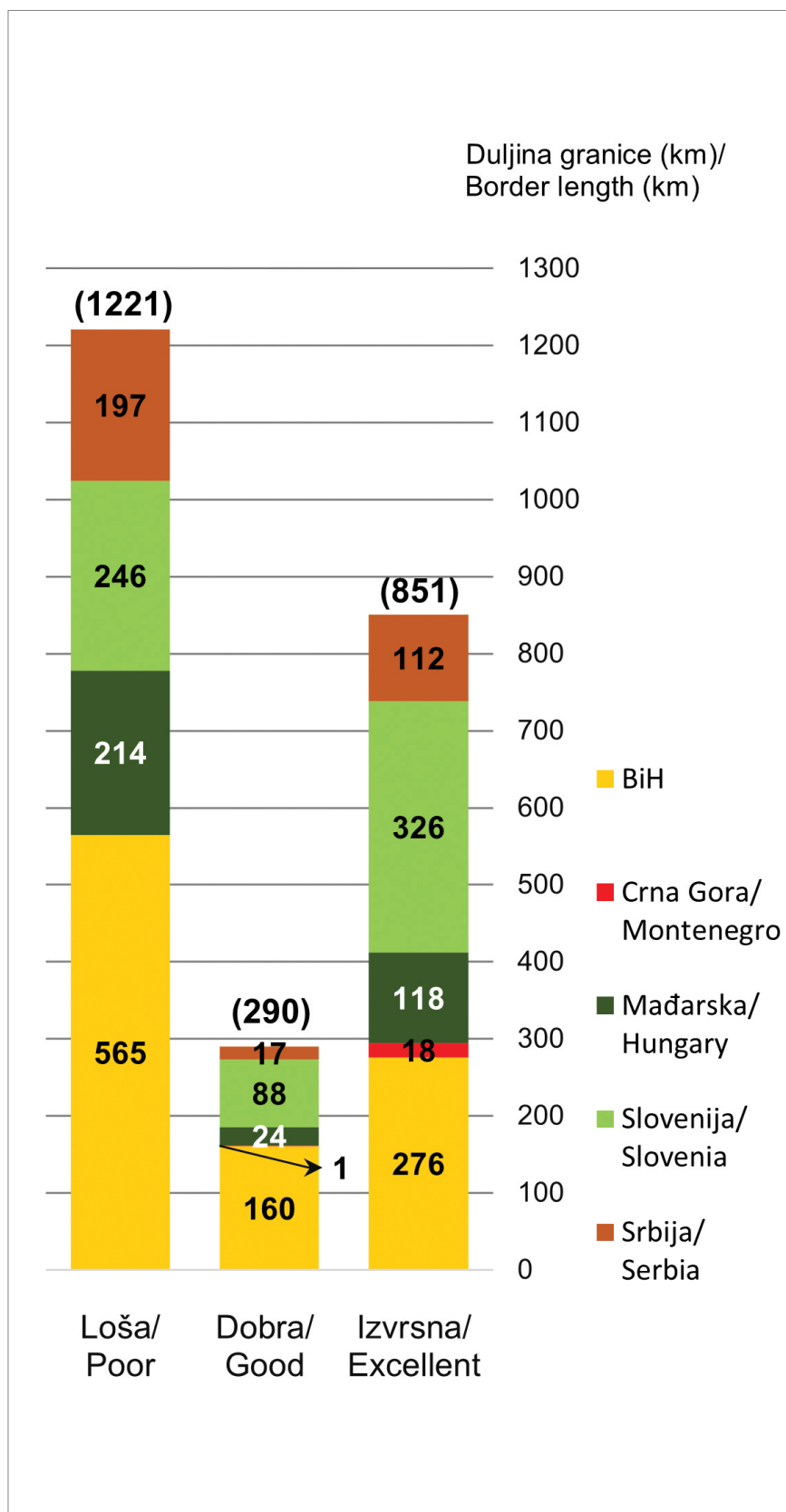
Granična linija RH je na 71,5 % ili 1689 km duljine neprohodna za tenk M-84 (sl. 8). Razlog tomu su vodotoci, šume i stjenovitost planina krškoga područja. Najznačajniji udio unutar 14,3 % ili 337 km prohodnoga područja odnosi se na Baranju i dio zapadnoga Srijema te jugozapadnu Banovinu i područje oko grada Imotskog. Valja istaknuti da se predmetna analiza odnosi na meteorološke uvjete obilježene niskim količinama padalina i visokim temperaturama zraka, pri čemu suho stanje tla omogućava neometanu pokretljivost vozila, dok bi se u kišnim razdobljima udio neprohodnih površina znatno povećao.

Značajan udio od 63,5 % odnosno 1501 km državne granice (sl. 9) obilježuju uvjeti koji one-

Excellent concealment for the movement of infantry forces (Fig. 7) is provided along 36% or 851km of the border, which directly correlates with forest cover (Fig. 5). These areas primarily include the borders with BiH (Banija, Plješevica, and Kamešnica) and Slovenia (Čičarija, Gorski Kotar, the Macelj hills, and Žumberak). Open highland areas covered with low vegetation (the southern section of the border with BiH) and major rivers represent spatial units with a low degree of infantry concealment from aerial surveillance, encompassing 51.7% or 1,221km of the total border length.

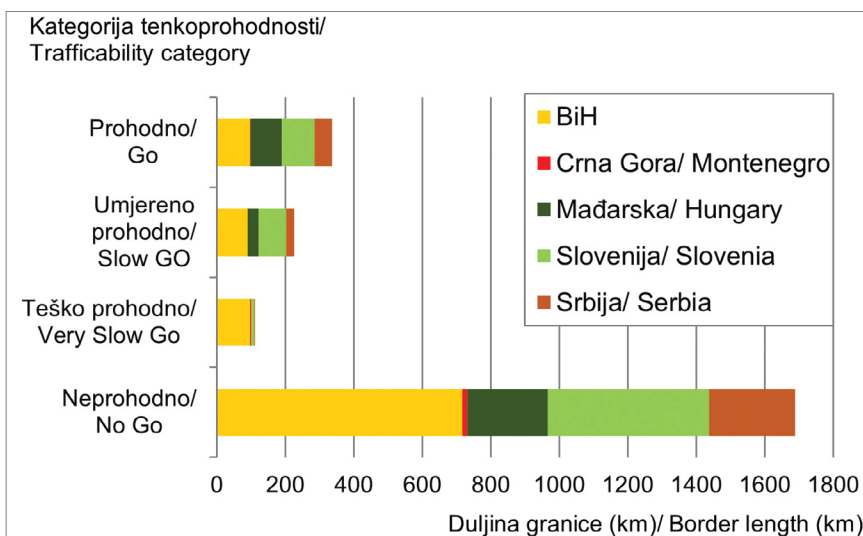
Along 71.5% or 1,689km of its length, Croatia's borderline is impassable for the M-84 tank (Fig. 8). The main reasons for this are watercourses, forests, and the rocky terrain of the karst mountain areas. The most significant share within the 14.3% or 337km of passable areas relates to Baranja and part of western Srijem, as well as southwestern Banovina and the area around the town of Imotski. It should be noted that this analysis refers to meteorological conditions characterised by low precipitation and high air temperatures, where dry soil conditions allow for unrestricted vehicle mobility. In rainy periods, however, the proportion of impassable terrain would increase significantly.

A significant share of the state border, 63.5% or 1,501km (Fig. 9), is characterised by condi-



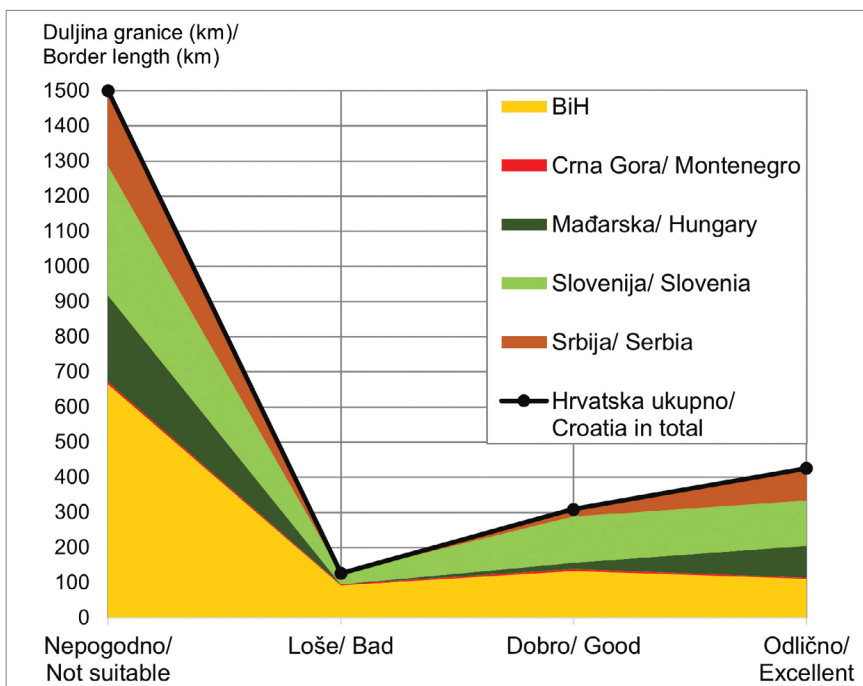
Sl. 7. Zaštićenost pješačkih snaga od otkrivanja iz zraka na graničnoj crti RH prema pripadajućim državama

Fig. 7. Protection of infantry forces from aerial detection along the border line of the RoC towards neighboring countries



Sl. 8. Tenkoprohodnost (za tenk M-84) granice RH prema pripadajućim državama

Fig. 8 Trafficability of border (for an M-84 Tank) of the RoC towards neighboring countries



Sl. 9. Mogućnost prikrivenog kretanja pješništva na granici RH

Fig. 9 The possibility of covert movement of infantry along the border of the RoC

moćuju prikriveno kretanje pješačkih snaga, ponajprije zbog prisutnosti vodotoka, strmih planinskih padina te otvorenih travnatih i poljoprivrednih površina. Nasuprot tomu, šumski kompleksi na zaravnjenim predjelima Banovine, Korduna, zapadnoga Srijema i Gorskog Kotara predstavljaju najpogodnije prostorne cjeline za nesmetan pokret pješništva, a obuhvaćaju 18 % ukupne duljine granice.

tions that prevent the concealed movement of infantry forces, primarily due to the presence of watercourses, steep mountain slopes, and open grassland and agricultural areas. In contrast, forest complexes on the flat areas of Banovina, Kordun, western Srijem, and Gorski Kotar represent the most suitable spatial units for unobstructed infantry movement, covering 18% of the total border length.

Rasprava

U jednom segmentu istraživanja ova je analiza dovela do određene diskrepancije između očekivanih rezultata i stvarnosti na terenu. To se poglavito odnosi na dio granice s Mađarskom uz rijeke Mura i Dravu. Granica je ondje prvotno uspostavljena Prvom katastarskom izmjerom (Jozefinski premjer, 1781. – 1785.), a njezino je stanje potvrđeno Trianonskim sporazumom (Feletar i Glamuzina, 2001). Trenutačno se inicijalna granična linija ne poklapa sa središtima riječnih tokova. Budući da su Mura i Drava u ovom dijelu toka tipične nizinske rijeke čije je meandriranje i premještanje sedimenata vrlo intenzivno, fizionomija vodotoka stalno se mijenja. Slična situacija, iako manje izražena, zabilježena je i na Dragonji, Dunavu, Sutli i Uni. Tamo su nastali brojni izolirani „otoci” koji, iako nemaju presudnu ulogu u ratnim sukobima, mogu određeni prostor izdvojiti iz nodalno-funkcionalne cjeline te izazvati administrativno-pravne sporove među državama. Kao što rijeka Sava svojom punom dužinom čini granicu na dijelu s BiH, očekivani rezultat pretpostavljao je da i rijeka Drava cijelom dužinom gotovo u potpunosti čini granicu s Mađarskom. Međutim, granična linija u mnogim dijelovima ne korespondira s koritom rijeke Drave. Sličnu problematiku opisali su na konkretnim primjerima Abad i dr. (2014), Donaldson (2009) i Plachta i Sthapit (2025). Primjeri meandriranja riječnih tokova koji su izmijenili prvotno uspostavljene granice zabilježeni su i drugdje u svijetu, primjerice na: Rio Grandeu (Sjedinjene Američke Države-Meksiko), Gangesu i Brahmaputri (Indija-Bangladeš), Parani (Brazil-Paragvaj) ili Maas (Njemačka-Nizozemska). Najčešće se ovi problemi uzrokovani prirodnim procesima rješavaju diplomatskim sporazumima (spor između SAD-a i Meksika razriješen ugovorom Boundary Treaty 1970.) i rjeđe dovode do ozbiljnijih sukoba.

Slijedom dobivenih rezultata načinjena je dodatna analiza koja je promatrala rijeke kao granične barijere unutar zone od 3 km. Usporedbom podataka sa sl. 4 i tab. 6 razvidna je bitna promjena u duljini granice koju predstavlja rijeka. Proširenjem zone promatranja granična linija s rijekom kao markantnim obilježjem dodatno je povećana za gotovo 400 km. Prema tome možemo reći da je 61,4 % ili 1450 km granice RH definirano vodotokom.

Discussion

In one segment of the research, this type of analysis led to sort off discrepancy between the anticipated results and the reality on the ground. This relates primarily to the section of the border with Hungary along the Mura and Drava rivers. The border there was originally established during the First Cadastral Survey (Josephinian Survey, 1781–1785), and its status was confirmed by the Treaty of Trianon (Feletar and Glamuzina, 2001). At present, however, the initial borderline does not coincide with the central river channel. Since the Mura and Drava in this part of their courses are typical lowland rivers, with highly dynamic meandering and sediment displacement, the morphology of the watercourses is constantly changing. A similar, though less-pronounced, situation has been recorded along the Dragonja, Danube, Sutla, and Una. Numerous isolated “islands” have formed therein which, although not of decisive importance in wartime, can detach specific areas from their nodal-functional unit and provoke administrative-legal disputes between states. As has been observed in the case of the Sava river; although the expected result was assumed, for example, that the Drava would also almost entirely form the border along its full length. Comparable issues have been described in concrete case studies by Abad et al. (2014), Donaldson (2009), and Plachta and Sthapit (2025). Examples of river meander altering originally-established borders have also been documented elsewhere in the world, such as on the Rio Grande (United States-Mexico), the Ganges and Brahmaputra (India-Bangladesh), the Paraná (Brazil-Paraguay), and the Meuse (Germany-Netherlands). In most cases, such problems caused by natural processes are resolved through diplomatic agreements (for instance, the US-Mexico dispute was settled by the 1970 Boundary Treaty) and only rarely escalate into more serious conflicts.

Based on the obtained results, an additional analysis was carried out that considered rivers as border barriers within a 3km zone. A comparison of the data with Fig. 4 and Tab. 6 reveals a significant change in the length of the border represented by rivers. By expanding the observation zone, the borderline characterised by a river as a prominent feature increased by almost 400km. Accordingly, it

Tab. 6. Usporedba duljine granične linije na rijekama i rijeke kao granične prepreke u operativnom smislu
Tab. 6. Comparison of the length of the boundary line along rivers and rivers as boundary obstacles in the operational context

Rijeka / River	Rijeka kao granica (km) / River as border (km)	Rijeka kao operativna prepreka na granici / River as an operational obstacle on the border	Postotak promjene / Percentage of change
Sava	308,7	312,2	1,1
Dunav**	148,4	227,7	53,4
Drava***	122,7	239,7	95,4
Kupa	118,1	118,8	0,6
Una	90,9	147,0	61,7
Sutla	77,3	117,0	51,4
Korana	23,3	27,2	16,8
Mura	22,2	96,2	332,5
Glina	19,6	22,3	13,7
Dragonja	13,8	22,7	64,5
Čabranka	12,4	14,2	14,5
Ostale rijeke* / Other rivers	105,5	105,5	0,0
Ukupno / Sum	1063,0	1450,5	36,5
Udio (%) u ukupnoj duljini granice / Percentage of total border length	45,0	61,4	

*isključeno iz analize zbog male duljine vodotoka / Excluded from the analysis due to the short length of the watercourse

**zajedno sa Starim Dunavom / In conjunction with the Old Danube

***zajedno sa Starom Dravom i Ždalicom / In conjunction with the Old Drava and the Ždolica

Nadalje, iako dobiveni rezultati pružaju jasne indikacije o njihovoj primjenjivosti na taktičkoj, a djelomično i na operativnoj razini, u kontekstu mogućega oružanog sukoba ili kontrole migracijskih tokova, postavlja se pitanje njihove interpretacije u širem, holističkom okviru strateških i geopolitičkih razmatranja. Suština problema proizlazi iz same prirode rezultata, temeljenih ponajprije na analizi granične linije. Takav linijski, jednodimenzionalni pristup promatranju granice ne odražava u potpunosti kompleksne prostorne odnose i procese između dvaju entiteta jer na njih presudno utječe širi granični prostor, odnosno zona uz granicu⁶.

Ključno analitičko pitanje stoga glasi: *Koliko široka i duboka treba biti zona obuhvaćena analizom?* Odgovor je kontekstualan i u značaj-

can be stated that 61.4% or 1,450km of Croatia's border is defined by a watercourse.

Furthermore, although the results obtained provide clear indications of their applicability at the tactical level—and partly at the operational level—in the context of a possible armed conflict or the control of migration flows, the question arises of how they should be interpreted within the broader, holistic framework of strategic and geopolitical considerations. The essence of the problem lies in the very nature of the results, which are based primarily on the analysis of the borderline. Such a linear, one-dimensional approach to observing the border does not fully reflect the complex spatial relations and processes between two entities, as these are decisively influenced by the wider border area, i.e. the zone adjacent to the border⁶.

6 U hrvatskom je jeziku riječ granica istoznačnica za graničnu liniju i prostor koji ju okružuje do same granične linije. U engleskom pak jeziku postoje dva termina: boundary (linija razdvajanja) i border (prostor do granične linije).

6 In Croatian, the word *granica* is synonymous with both the borderline itself and the surrounding area up to the borderline. In English, however, two distinct terms exist: *boundary* (the line of separation) and *border* (the area adjacent to the boundary).

noj mjeri ovisi o zahtjevima zapovjednika, koji, na temelju dodijeljene zadaće, mora angažirati odgovarajuću veličinu snaga, sredstava i opreme (Department of the Army, 2022). Darques (2017) pokušava elaborirati to pitanje, no otvorenim ostaje problem modeliranja i valorizacije čimbenika koji oblikuju vojno-geografski prostor. Koristeći GIS model, Starr i Thomas (2005) uspjeli su kvantificirati karakteristike svih kopnenih granica u svijetu na način da su testirali njihov utjecaj u sukobima promatrajući lakoću interakcije, važnost i vitalnost granice. Međutim, složenost i problematika strukturiranja modela osobito se očituju na taktičkoj i operativnoj razini. Primjerice, na taktičkoj razini teško je pronaći odgovarajuću metodu valorizacije zemljišnoga pokriva unutar modela podataka. Ako se određeno područje klasificira kao travnjak, logično je pretpostaviti njegovu pogodnost za vizualni nadzor. Međutim, dovoljan je uzak šumski koridor ili promjena stajališne točke da se taj nadzor u potpunosti onemogući. Na operativnoj razini problem se dodatno produbljuje: pojam operativne dubine ne podrazumijeva statičnu prostornu kategoriju, već obuhvaća područja u kojima se mogu izmjenjivati dva ili tri planinska grebena i/ili više riječnih barijera koje djelomično prate graničnu liniju. Takva prostorna kompleksnost otežava kvantitativno definiranje stupnja zaštićenosti granice ili identifikaciju operativnih prepreka u dubini vlastitoga ili protivničkoga teritorija. Iz navedenoga proizlazi da su pokušaji kvantitativnoga modeliranja prostora opterećeni značajnim metodološkim ograničenjima. To je ujedno i razlog zbog kojega ne postoji cjelovit vojno-geografski model sposoban sustavno valorizirati fizičko-geografske čimbenike u graničnom području. Pritom se postavlja i pitanje treba li rješenje nužno tražiti u formaliziranim modelima. Primjer afganistansko-pakistanske granice ilustrira taj problem. Gouge (2016) je razvio metodološki okvir za procjenu propusnosti granica i identifikaciju koridora pogodnih za prijelaze pobunjeničkih skupina. Ipak, takav pristup pruža uvid u samo jedan od brojnih elemenata nužnih za razumijevanje terenskih uvjeta u graničnim područjima. Naime, za sveobuhvatnu analizu vojno-geografskih obilježja granice potrebno je

The key analytical question therefore is: *How wide and how deep should the zone covered by the analysis be?* The answer is contextual and largely depends on the commander's requirements who, on the basis of the assigned task, must engage the appropriate size of forces, assets, and equipment (Department of the Army, 2022). Darques (2017) attempted to elaborate on this issue, but the problem of modelling and evaluating the factors shaping the military-geographical space remains unresolved. Using a GIS model, Starr and Thomas (2005) managed to quantify the characteristics of all land borders worldwide by testing their impact in conflicts, considering ease of interaction, significance, and vitality of the border. However, the complexity and challenges of structuring such a model are particularly evident at the tactical and operational levels. For instance, at the tactical level it is difficult to find an adequate method of evaluating land cover within a data model. If a particular area is classified as grassland, it is logical to assume its suitability for visual surveillance. In contrast, a narrow forest corridor or a change in observation point may completely prevent such surveillance. At the operational level, the problem becomes even more pronounced: the concept of operational depth does not imply a static spatial category but encompasses areas where two or three mountain ridges and/or multiple river barriers may alternate, some of which partly follow the borderline. Such spatial complexity makes it difficult to quantitatively define the degree of border protection or to identify operational obstacles in the depth of one's own or the adversary's territory. From this it follows that attempts at quantitative modelling of space are burdened with significant methodological limitations. This is also the reason why no comprehensive military-geographical model exists that is capable of systematically evaluating physical-geographical factors in border areas. At the same time, the question arises whether the solution should necessarily be sought in formalised models. The example of the Afghanistan-Pakistan border illustrates this problem well. Gouge (2016) developed a methodological framework for assessing border permeability and identifying corridors suitable for insurgent group crossings. However, such an approach provides insight into only one of the many elements necessary for understanding terrain conditions in border areas. In other words, a comprehensive analysis of the military-geographical

uključiti i opće te društvene čimbenike, koji nisu u potpunosti obuhvatljivi numeričkim metodama. Drugim riječima, vojno-geografska analiza granica ne može počivati isključivo na kvantitativnim tehnikama i statističkim pokazateljima, već zahtijeva i metodološke pristupe karakteristične za humanističke i društvene znanosti.

Sukladno dobivenim rezultatima polazišnu hipotezu možemo prihvatiti. Upravo su granični odnosno pogranični dijelovi na kojima nisu prisutni markantni fizičko-geografski objekti bili prostori gdje se odvijalo najviše vojnih sukoba. Među ostalim, tijekom Domovinskoga rata, Drugoga svjetskog rata ili turskih (osmanlijskih) pohoda kao poprišta sukoba mogu se izdvojiti dijelovi granice na područjima zapadnoga Srijema, Banije, Korduna i Like. Suprotno tomu, panskne rijeke (Sava, Drava, Dunav, Kupa, Mura i Sutla) i gorski hrptovi sjevernoga dijela Hrvatske predstavljaju stabilne granice na kojima nisu vođeni sukobi i nije dolazilo do pomicanja granice tijekom dugih perioda u povijesti. Njihova linearost, jasna prepoznatljivost u prostoru i obrambena funkcija davali su im prednost pred drugim prirodnim objektima poput grebena ili dolina, koji su korišteni u znatno manjoj mjeri. Starr i Thomas (2005) također su došli do zaključka da vrlo visoka i vrlo niska razina interakcije društvenih zajednica i prirodnih prepreka smanjuju mogućnost sukoba. Valja pritom naglasiti da se pojava sukoba ili njihovo izostajanje ne može uvijek tumačiti samo fizičko-geografskim obilježjima.

Granice Hrvatske formirane su međudjelovanjem fizičko-geografskih struktura i političko-povijesnih procesa, pri čemu se najviši stupanj ranjivosti očituje na dionicama koje ne slijede markantne prirodne objekte. Paradigmatičan slučaj predstavlja konfiguracija linije razdvajanja 1991. – 1995. godine, kada je granica tzv. Republike Srpske Krajine u znatnoj mjeri slijedila povijesno uvjetovane administrativne granice te glavne prometne osi (riječne doline, krške zaravnine, niže prijevoje), dok je tek u ograničenoj mjeri bila vezana uz morfološke barijere poput rijeka ili planinskih grebena. Takav reljefni diskontinuitet rezultirao je povećanom operativnom propusnošću prostora i olakšanim taktičko-operativnim

characteristics of borders requires the inclusion of general and social factors that cannot be fully captured by numerical methods. Military-geographical analysis of borders, therefore, cannot rely solely on quantitative techniques and statistical indicators but also demands methodological approaches characteristic of the humanities and social sciences.

Based on the results obtained, the initial hypothesis can be accepted. The very sections of the border or borderland areas where no prominent physical-geographical features are present, were the locations where the greatest number of military conflicts took place. Among others, and during the Croatian War of Independence (locally known as the Homeland War), the Second World War, or the Turkish and Ottoman campaigns, the conflict zones included parts of the border in western Srijem, Banija, Kordun, and Lika. Conversely, Pannonian rivers (Sava, Drava, Danube, Kupa, Mura, and Sutla) and the mountain ridges of northern Croatia represent stable borders where no conflicts were fought and no border shifts occurred over long historical periods. Their linearity, clear recognisability in space, and defensive function gave them an advantage over other natural features such as ridges or valleys, which were used to a far lesser extent. Starr and Thomas (2005) likewise concluded that both very high and very low levels of interaction between social communities and natural obstacles reduce the likelihood of conflict. It should be emphasised, however, that the occurrence or absence of conflict cannot always be explained solely by physical-geographical features.

Croatia's borders were formed via the interplay of physical-geographical structures and political-historical processes, with the highest degree of vulnerability evident along sections that do not follow prominent natural features. A paradigmatic case is the configuration of the line of separation in 1991–1995, when the border of the so-called Republic of Serbian Krajina largely followed historically conditioned administrative boundaries and major transport axes (river valleys, karst plateaus, lower passes), while only to a limited extent did it align with morphological barriers such as rivers or mountain ridges. Such relief discontinuity resulted in increased operational permeability of the area and facilitated tactical-operational shifts of the front line. A concrete example is provided by

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D. Gernhardt
T. Guštin

**Vojno-geografska
obilježja fizičkih
čimbenika kopnene
granice Republike
Hrvatske**

**Military-
geographical
characteristics of
the physical factors
of the land border
of the Republic of
Croatia**

pomacima crte bojišta. Konkretni primjer pruža slučaj iz Domovinskoga rata gdje sektor Kor-dun-Banovina: linija od Turnja (južno predgrađe Karlovca) preko Vojnića i Gline do Dvora nije imala orografski ili hidrogrfski oslonac, već je bila oblikovana prema kotarskim međama i cestovnim pravcima (državne ceste D1/D6). Linija razdvajanja pritom je prelazila krške zaravni i niske prijevoje (npr. između Slunja i Rakovice te dalje prema Plitvicama, Korenici i Udbini). Stoga je i završna operativna akcija Hrvatske vojske 1995. godine (vojno-redarstvena operacija Oluja) zbog brojnih avenija prilaza bila usmjerena prema pravcu Karlovac – Slunj – Plitvice – Korenica – Udbina – Gračac – Knin, čime je potvrđena presudna uloga fizičko-geografske podloge u određivanju dinamike ratnih djelovanja.

Sljedeći je primjer nestabilnosti granica Vojne krajine na području Banije i Srijema tijekom 18. i 19. st. Ti su prostori bili pojas ili kontakt zona tijekom sukoba Habsburške Monarhije i Osman-skog Carstva. Uzroci stalne ranjivosti određeni su izrazito pogodnim manevarskim zemljištem koje nije pružalo čvrstu osnovicu za uspostavljanje jasne obrambene linije. Time su nastali specifični etnički i religijski obrasci, koji su stoljećima kasnije utjecali na dinamiku međudržavnih odnosa i stabilnost granica.

Istria i riječko područje posebni su slučajevi višekratnih rezova suvereniteta i administrativnih preustroja. To je osobito vidljivo na sjeveroistoku Istre gdje lokalna orijentacija reljefa stvara heterogenu propusnost: primjerice, pružanje Čičarije mjestimice je okomito na pružanje državne crte, pa jedan te isti masiv nudi i bočne barijere i „prijevoje” pogodne za pokret snaga.

U vojnoj terminologiji granica se često određuje kao „dobra” ili „loša”. Međutim, to se obilježje može promijeniti ovisno o scenariju ratovanja. Bognar i Bognar (2010) ističu da je prirodno determinirana granica uzrok stabilnosti i izostanka bilateralnih sporova. Kitamura i Lagerlöf (2020) dokazali su da je geografija (planine, klima, rijeke i vertikalna raščlanjenost) jedan od razloga zbog kojih je europski kontinent fragmentiran na velik broj država.

the Croatian War of Independence, where the Kor-dun-Banja sector—the line from Turnje (southern suburb of Karlovac) through Vojnić and Glina to Dvor—lacked orographic or hydrographic support, instead it was shaped by district boundaries and road routes (state roads D1/D6). The line of separation, in this case, crossed karst plateaus and low passes (e.g. between Slunj and Rakovica, and further towards Plitvice, Korenica, and Udbina). Accordingly, the final operational action of the Croatian Army in 1995 (Operation Storm) was directed along the axis of Karlovac–Slunj–Plitvice–Korenica–Udbina–Gračac–Knin, owing to the numerous avenues of approach, thereby confirming the decisive role of the physical-geographical elements in determining the dynamics of military operations.

Another example of instability is the border of the Military Frontier in the Banija and Srijem regions during the 18th and 19th centuries. These areas represented a belt or contact zone during the conflicts between the Habsburg Monarchy and the Ottoman Empire. The causes of persistent vulnerability were rooted in the highly favourable manoeuvre terrain, which did not provide a solid basis for establishing a clear defensive line. This gave rise to specific ethnic and religious patterns that, centuries later, influenced the dynamics of interstate relations and the stability of borders.

Istria and the Rijeka area represent special cases of repeated shifts in sovereignty and administrative restructuring. This is particularly evident in northeastern Istria, where the local orientation of the relief creates heterogeneous permeability; for example, the alignment of the Čičarija range is in places perpendicular to the course of the state line, so that the same massif simultaneously provides lateral barriers and “passes” suitable for the movement of (military) forces.

In military terminology, a border is often described as “good” or “bad”. However, this characteristic may change depending on the warfare scenario. Bognar and Bognar (2010) emphasised that a naturally determined border is a source of stability and the absence of bilateral disputes. Kitamura and Lagerlöf (2020) demonstrated that geography (mountains, climate, rivers, and vertical dissection) is one of the reasons why the European continent is fragmented into such a large number of states.

Zaključak

Zaključno, granice Hrvatske, prema Hartshorne (1935), možemo definirati kao kombinaciju: (1) subsekventnih – oblikovanih u skladu s etničkim, povijesnim i političkim razvojem: granica prema Sloveniji i Mađarskoj, (2) superimponiranih (nametnutih): granica uz Hercegovinu, okolicu Neuma i uz Crnu Goru te (3) reliktnih: Dunav i Sava. Granice RH oblikovane su u interakciji prirodne osnove i političko-administrativnih odluka, pri čemu rijeke predstavljaju stabilan i dugotrajan okvir, dok su presudne promjene i konačan oblik granice ipak određivani geopolitičkim i administrativnim intervencijama.

Utvrđeno je da markantni fizičko-geografski objekti definiraju 58,6 % granice, pri čemu rijeke (45 %) čine najvažniji granični element, na doline otpada 14,3 %, a 7,6 % granice na grebenima predstavlja značajan obrambeni potencijal. Granice RH izrazito su fizičko-geografski determinirane u kontinentalnom dijelu, dok južni dio predstavlja kombinaciju fizičkih i socijalnih čimbenika.

Proširenjem zone promatranja duž riječnih tokova za 3 km povećan je ukupni udio fizičko-geografskih objekata te raste na 75 %, čime je potvrđena presudna uloga rijeka u formiranju linija razgraničenja. Pritom je utvrđeno da je nedosljednost između granične linije i središta riječnih tokova posljedica prirodnih procesa i promjene dinamike vodnoga toka (na rijekama Muri, Dravi, Dunavu, Dragonji, Sutli i dr.) tijekom dugih vremenskih perioda.

Markantna fizičko-geografska obilježja utrla su temelje uspostave stabilnih odnosa prema susjednim državama. Stabilnu granicu s BiH nalazimo u Posavini, Drava je osigurala višestoljetni mir sa Mađarskom, a 2/3 granice sa Slovenijom čine markantna fizičko-geografska obilježja; grebeni (9,4 %), doline (14,1 %) i rijeke (39,4 %). Administrativno ustrojen dio granice bez jasnih fizičko-geografskih objekata (25 %), odnosno manevarsko zemljište, bilo je poprište sukoba u različitim povijesnim razdobljima (Banija, Kordun i zapadni Srijem – Domovinski rat i turbulentna Vojna krajina).

Conclusion

In conclusion, Croatia's borders can, according to Hartshorne (1935), be defined as a combination of: (1) subsequent—shaped in accordance with ethnic, historical, and political development: the borders with Slovenia and Hungary; (2) superimposed (imposed): the borders with Herzegovina, the area around Neum, and with Montenegro; and (3) relict: the Danube and Sava rivers. The borders of the RoC were shaped through the interaction of the natural framework and political-administrative decisions. While rivers represent a stable and long-lasting framework, decisive changes and the final configuration of the border were nonetheless determined by geopolitical and administrative interventions.

It was established that prominent physical-geographical features define 58.6% of the border, with rivers (45%) constituting the most important border element, valleys accounting for 14.3%, and 7.6% of the border lying along ridges, which represent significant defensive potential. Croatia's borders are strongly determined by physical-geographical factors in the continental part, while the southern part represents a combination of physical and social factors.

By extending the observation zone along river courses by 3 km, the overall share of physical-geographical features increased to 75%, thereby confirming the decisive role of rivers in the formation of demarcation lines. At the same time, it was established that the inconsistency between the borderline and the central courses of rivers is the result of natural processes and changes in river dynamics (on the Mura, Drava, Danube, Dragonja, Sutla, and others) over long periods of time.

Prominent physical-geographical features have laid the foundations for the establishment of stable relations with neighboring states. A stable border with Bosnia and Herzegovina is found in Posavina, the Drava River has ensured centuries-long peace with Hungary, and two-thirds of the border with Slovenia consists of prominent physical-geographical features: ridges (9.4%); valleys (14.1%); and rivers (39.4%). The administratively defined sections of the border lacking

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Vojno-geografski gledano granice definirane rijekama na kontinentalnom dijelu RH čine najpogodnije uvjete za jednostavniju kontrolu i nadzor granice. Granica s BiH na krškom/južnom dijelu RH čini pogodno okruženje za obranu i nadzor. Prolazi višim nadmorskim visinama prekrivenima šumskom vegetacijom i za vozila neprohodnim krševitom terenom te stoga nije pogodna za manevar i pokret vojnih snaga većega opsega. Brežuljkasti predjeli sjeverozapadnih dijelova kontinentalne RH, sjever hrvatskoga dijela Baranje, istočni dio zapadnoga Srijema i područja oko Korduna i Banovine najmanje su fizičko-geografski determinirani, pa na njima treba mnogo više materijalno-tehničkih resursa kojima bi se mogla provoditi obrana, nadzor i kontrola. Rezultati mogućnosti vizualnoga nadzora pokazuju da gotovo 40 % granice nije moguće osmatrati s hrvatskoga teritorija (područja oko Žumberka, zapadnoga Srijema, Banovine, Korduna i Gorskog kotara). Navedena područja treba posebno vrednovati i iz perspektive nadzora stabilnosti granice u mirnodopskom okruženju, odnosno propusnosti i „ranjivosti” granice na nezakonite prelaske migranata. Dodatno, ulaskom RH u Schengenski prostor te su granice postale i granice Europske unije.

Topološki orijentirana GIS metoda analize granice pokazala se korisnom za kvantitativno vrednovanje fizičko-geografskih čimbenika, no i dalje ostaje ograničena u taktičkom smislu jer ne daje informacije o širini, dubini i brzini rijeka, broju paralelnih grebena niti o mikro-terenskim varijacijama. Rezultati su iskoristivi kao osnovno polazište za pripremu i planiranje operacija na operativnoj razini, ali za pružanje cjelokupne operativne slike nužna je provedba vojno-geografske analize koja treba uključivati i kvalitativne pristupe te interdisciplinarnu interpretaciju.

clear physical-geographical features (25%), i.e. manoeuvre terrain, have been the sites of conflict in various historical periods (Banija, Kordun, and western Srijem—the Croatian War of Independence and the turbulent Military Frontier).

From a military-geographical perspective, river-defined borders in the continental part of Croatia provide the most favourable conditions for simpler control and surveillance of the boundary. The border with BiH in the karstic/southern part of Croatia offers a suitable environment for defence and monitoring. It runs across higher elevations covered with forest vegetation and through rocky terrain impassable for vehicles, making it unsuitable for manoeuvre and large-scale movement of military forces. The hilly areas of north-western continental Croatia, the northern part of Croatian Baranja, the eastern part of western Srijem, and the areas around Kordun and Banija are the least physically-geographically determined, requiring substantially more material and technical resources to enable defence, surveillance, and control. The results of the visibility analysis show that almost 40% of the border cannot be observed from Croatian territory (areas around Žumberak, western Srijem, Banovina, Kordun, and Gorski Kotar). These areas in particular should be evaluated from the perspective of monitoring border stability in peacetime, i.e. the permeability and “vulnerability” of the border to irregular migrant crossings. Additionally, with Croatia’s accession to the Schengen Area, these borders have also become the borders of the European Union.

The topologically oriented GIS method of border analysis proved useful for the quantitative evaluation of physical-geographical factors, but it remains tactically limited, as it does not provide information on river width, depth, or flow rate, the number of parallel ridges, or micro-terrain variations. At the same time, the results are applicable as a basic starting point for operational-level preparation and planning, but to provide a comprehensive operational scene it is necessary to carry out a military-geographical analysis that also incorporates qualitative approaches and interdisciplinary interpretation.

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