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CHARACTERISTICS OF THE URBAN ENVIRONMENT IN AND ISSUES IN THE CREATION OF A GREEN SHIELD AROUND THE CITY OF MAKHACHKALA, DAGESTAN, RUSSIA

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Abstract. This paper addresses issues of beautifying the capital of Dagestan, Makhachkala, and boosting nature conservation in that city. An insight is provided into the following characteristics of the city's socio-economic and environmental development: the prevalence of haphazard rather than consistent patterns in the development of the living environment of Makhachkala residents and an extreme lack of funding for nature conservation activities. The four key sites within Makhachkala's potential "green shield" are (1) Eltav Forest in the northwest; (2) the Caspian Sea with its sandy beaches in the northeast; (3) Lake Ak-Gel in the southeast; (4) Tarki-Tau Mountain in the southwest. The need is stressed for creative management decisions that will take full account of the ethnocultural and ethnopsychological characteristics of the city's urban environment.

Keywords: Dagestan, Makhachkala, sustainable development, nature conservation, green shield, city's geo-environmental landmarks

Introduction

While many large cities are places with serious social, economic, and environmental issues, many of them are also generators of innovation and

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drivers for achievement of the Sustainable Development Goals (SDGs), a program of action for the period 2016–2030 adopted by the United Nations General Assembly to help tackle critical global challenges and improve the economic and social well-being of people around the world. In the context of this program, on January 1, 2017, the Russian government brought into force a special law covering the creation around cities of forest-and-park green belts, areas with limited natural resource use, popularly known as the "green shield law" (Federal Law No. 353-FZ On Forest-and-Park Green Zones of July 3, 2016). A green shield is an environmentally effective area that can be developed through the establishment of special nature conservation regimes and the creation of a forest-and-park belt on areas occupied by forests, waterbodies, and other natural sites that perform environment-forming, nature conservation, ecological, sanitary-hygienic, and recreational functions[2].

So far, relevant ordinances on the creation of forest-and-park green belts around large cities have been adopted in 63 of Russia's constituent regions. This includes the Republic of Dagestan, whose capital, Makhachkala, has been ahead in population increase of many of its counterparts in Russia[3] (Bagomedov, 2013; Chernyshov, 2012). Specifically, whereas in the period 1979–1989 its population rose from 251,000 to 315,000, i.e. around 26%, in the intercensal periods 1989–2002 and 2002–2010 it rose from 337,000 to 378,000 (12%) and from 378,000 to 697,000 (84%), respectively[4,5] (Ionov, 2020).

Factors such as the extensive natural reproduction of its population and a massive migration from the countryside to Makhachkala, coupled with extensive residential construction, have led to the capital virtually swallowing up Kaspiysk, its satellite city, and many of the nearby townships. This has led to the emergence of the Makhachkala agglomeration – one of the largest in the south of Russia and the largest in the North Caucasian Federal District (Zubarevich, Safronov 2019). Based on estimates from Moscow-based geographers E.V. Antonov and A.G. Makhrova, the metropolis had a population of 1.2 million as early as 2018, with the figure growing by 94,000 in the period 2010–2018 alone (Antonov, Makhrova, 2019).

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[2] Gosduma prinyala vo vtorom i tret'yem chtenii zakonoproyekt ONF o «zelonom shchite» [Elektronnyy resurs] // Obshcherossiyskiy narodnyy front. 17.06.2016. URL: https://onf.ru/2016/06/17/gosduma-prinyala-vo-vtorom-i-tretem-chtenii-zakonoproekt-onf-o-zelenom-shchite/ (data obrashcheniya 20.08.2021).

[3] Sovremennyye ekologicheskiye problemy Dagestana. Makhachkala: DGPU, 1994. 198 s.

[4] Demograficheskiy yezhegodnik. 2002 god. Stat. sbornik. Makhachkala: Goskomstat RD, 2003. 192 s.

[5] Naseleniye SSSR: Po dannym Vsesoyuznoy perepisi naseleniya 1989 g. / Gos. komitet SSSR po statistike. Informatsionno-izdatel'skiy otdel. M.: Finansy i statistika, 1990. 45 s.

Judging by Makhachkala's medical-environmental and sanitary-hygienic performance, which has been covered openly starting somewhere in the late 1980's, there are reasonable grounds to state that the capital of Dagestan has virtually the entire spectrum of environment pollutants, with the concentration thereof on particular components at times reaching record levels[6,7,8]. Based on the latest environmental research, the last 10 years have witnessed a fivefold increase in cancer cases among Makhachkala residents, with a high risk of infectious diseases observed[9,10]. There is an obvious need to boost urban greening in the capital. Based on the standards of the World Health Organization, a metropolis such as Makhachkala ought to have no less than 50 square meters of forest and approximately 300 square meters of suburban forest per resident (Eldarov, 2020). In Makhachkala, these figures are currently much lower, and over the last three decades the city has posted a catastrophic decrease in them (Kotilko *et al.*, 2019).

The above indicates the relevance and vital importance for Makhachkala of the objective of building a healthy living environment for its residents, including via the creation of a "green shield" around the city.

Social-environmental characteristics of Makhachkala's urban environment

As is the case with most other large cities, the environmental situation in Makhachkala tends to be influenced by the following four major groups of factors (which differ in genetic attributes): natural, urban planning, technical-economic, and sociocultural (Kirilovab and Makhrova, 2020; Sluka, Tikunov and Chereshnia, 2019).

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6 Gosudarstvennyy doklad «O sanitarno-epidemiologicheskoy obstanovke v RD v 1995 godu» / Otv. red. E. YA. Omariyeva. Makhachkala, 1995. 114 s.

7 Gosudarstvennyy doklad «O sanitarno-epidemiologicheskoy obstanovke v RD v 2018 godu» / Otv. red. E. YA. Omariyeva. Makhachkala, 2019. 135 s.

8 Doklad o sostoyanii okruzhayushchey prirodnoy sredy Respubliki Dagestan v 2001 godu. Makhachkala: Izd-vo «Yupiter», 2002. 224 s.

9 Mediko-gigiyenicheskiy atlas Respubliki Dagestan / otv. red. E.YA. Omariyeva, E. M. El'darov. Makhachkala: Poligraf-servis, 2002. 132 s.

10 Pokazateli sostoyaniya zdorov'ya naseleniya RD v 2015 godu. Makhachkala: Minzdrav RD, 2016. 317 s. 33. Rybina YU. Gradonachal'nik popalsya na auktsione [Elektronnyy resurs] // Kommersant». 07.11.2018. URL: https://www.kommersant.ru/doc/3793286 (data obrashcheniya 20.08.2021).

Natural and urban planning factors tend to have minimal change over time. Their conservative nature somewhat simplifies the development, organization, and implementation of nature conservation programs. However, underestimating their effect on the environmental situation may have far-reaching negative consequences. The essential natural and urban planning factors shaping Makhachkala's natural environment include the following:

- quite pronounced arid climatic conditions, with the rebuilding of disrupted biological communities, therefore, taking a long time;
- meagerness and overall poor condition of the city's greenery – its "lungs";
- the city being situated on a tract of open sand and an area of dry steppe that is worked for agricultural purposes, which, combined with frequent wind, is conducive to increased levels of suspended particulates in the air, as well as fraught with powerful dust storms;
- unstable level of the Caspian Sea, which requires that building in the littoral area be done having consideration for the natural phenomenon of seawater encroaching now and then onto the coast and resulting groundwater surges across much of the city;
- Makhachkala being situated on a narrow littoral plain, with Tarki-Tau Mountain on one side and the Caspian Sea on the other; as a result, the city is crossed by a significant portion of through transportation, numerous inter-district pipelines, and multiple power transmission lines;
- orographic and maritime barriers in the territorial development of the capital determining the city's elongated built-up area and the active degradation of the northern and southern green belts, which play a crucial role in protecting Makhachkala from dust storms;
- heavy short rains typical of the submontane areas, Tarki-Tau Mountain being a large water-collecting area, the city being situated on a narrow littoral lowland strip, and the city's poor storm drainage system as key factors contributing to occasional floods in it and its streets being polluted by effluents from sewage;
- in the area of urban development, a major issue being difficulty in forestalling landslides on the sides of Tarki-Tau Mountain;

- concern increasingly growing over the seismic danger posed by the erection of buildings and constructions, including multistoried ones, in the area as a result of multiple violations of aseismic construction regulations.

The need for nature conservation activity on the capital's periphery is dictated by a somewhat different set of issues. These areas have large tracts of land that are affected by irrational economic activity (e.g., impromptu landfills for municipal and construction solid waste, operation of sand pits, oil and gas production, etc.). What adds relevance to the objective of recultivating them is the rapid growth of Makhachkala's demoeconomic potential. A highly important issue is industrial solid waste disposal and the organization of areas for storage of toxic chemicals and burial of toxic industrial and medical waste.

A special group of issues is unwarranted land grabs and housing development in highly protected areas near the October Revolution Canal and the lakes Vuzovskoe, Ak-Gel, Makhachkalinskoe, Bolshoe Turali, and Maloe Turali. For many years, the capital's authorities have, in flagrant violation of urban land use legislation, granted entrepreneurs and commercial enterprises plots in school and kindergarten areas and areas housing healthcare facilities, just a stone's throw from busy highways or right under high-voltage power line cables.

Another issue of concern for the city is the poor environmental condition of most of the small watercourses within it. These watercourses currently act mainly as stormwater collectors; they are used for the disposal of industrial and municipal wastewater as well. The following streams have turned into this kind of collector in Makhachkala over time: a rivulet that used to run from the township of Tarki into Lake Ak-Gel; a rivulet named Talginka, which originates in a resort area of the same name; a rivulet named Ternair, which begins in the vicinity of the Separatorny Poselok microdistrict and ends at the beach in the Makhachkala-1 microdistrict.

When contrasted with the alarming condition of the city's water resources, some of its other environmental problems appear to remain somewhat under the radar. This in part is associated with the territorial-differentiated nature of their manifestation. For instance, residents of Makhachkala's central districts, especially those situated along the major throughways converging here, are faced, along with significant noise

pollution, with an environmental issue such as smothering smog in windless weather (Kotilko *et al.*, 2019).

The negative effect of the above-mentioned and some other natural-geographic and urban planning factors on the living environment of Makhachkala residents is augmented to a significant degree by the impact of technical-economic and sociocultural factors. In addition to impacting on the urban environment with a special force, these factors tend to be characterized by great diversity, relatively high mobility in time and space, and being amenable to regulatory control by humans.

Among the *technical-economic factors* influencing the current environmental situation in the capital of Dagestan, the most prominent are the following:

- overall poor condition of the city's material-technical base, testimony to which is its extremely low capital-to-labor ratio and power supply per person vis-à-vis other large cities in the Russian Federation; low level of mechanization and automation of production processes in the city;
- the city's flawed functional-sectoral structure, which is expressed in the significant imbalance across fields of specialization, production operations, and sectors (most importantly, manufacturing and services), which is affecting the city's entire economy;
- the city's industry, widely represented by environmentally unfavorable production operations, having a sectoral structure that is irrational in terms of natural resource use;
- many of the city's enterprises having outmoded plant and equipment;
- low share of highly skilled workers among the city's employed population; slow process of implementing innovative solutions, including effective nature conservation technologies.

No less diverse are the *sociocultural factors*, both internal and external.

Dagestan occupies a peripheral position in relation to Russia's center. Consequently, its capital may not expect to be given priority attention by the country's central government (Borodina, 2017). There is also the ethnopolitical factor – Makhachkala cannot compare to predominantly Slavic cities in the North Caucasus such as Rostov, Krasnodar, Novorossiysk, or Stavropol,

which, on average, have been 1.5–2 times ahead of Dagestan's capital in key economic and social indicators[11] (Gadzhiyev, Rabadanov, Eldarov, 2017).

Poverty in Makhachkala is mainly due to rampant corruption among the city's officials. To be specific, over the last seven years, criminal prosecutions have been brought against as many as four top officials in the capital, with the mafia nicknames of the first two of them known widely among Makhachkala residents (Aliyev, 2018; Akhmedov, 2016; Kots, 2013; Sarkarov, 2017).

The fact that there have been a series of headline-making arrests of top officials in the capital stands as testimony to not only the success of the federal government's efforts to combat corruption but also to cruel interclan wars being waged in the republic. Among the most remarkable aspects of the political behavior of those in charge of major financial-political clans in Makhachkala and all of Dagestan is their ability to demonstrate in a most vivid manner their loyalty to the federal center, win the support of powerful protectors in Moscow, and engage in active interaction with the security apparatus – above all, the Federal Security Service.

Mistrust of corrupt officials has largely distanced the city's general public from a focus on resolving issues of organizing and beautifying the urban environment. No less pronounced has been the distancing of the city's public authorities from a focus on acting in the best interests of its residents.

The current state of the capital of Russia's southernmost polyethnic settlement is being reflected in all aspects of the life of its residents. At present, the development of its urban environment is characterized by a natural erosion of traditional rural culture among new settlers and at the same time a failure of typical templates of urban culture to be firmly adopted by them. Consequently, low levels of environmental culture and environmental literacy have become the city's calling card.

The above-mentioned issues in the governance of the city of Makhachkala provide an explanation for why some of its districts still have no piped water and gas, central heating, sewers, and stormwater diversion. A good example is Semender, a large housing development that has seen flagrant violations of basic construction and sanitary-hygienic standards and rules (e.g., garbage going uncollected for weeks, many stray dogs, cows

[11] Doklad o sostoyanii okruzhayushchey prirodnoy sredy Respubliki Dagestan v 2001 godu. Makhachkala: Izd-vo «Yupiter», 2002. 224 s.

feeding on garbage, etc.). A combination of the above social-environmental factors is pretty much what has been behind the overall unsatisfactory condition of the capital's environment (Eldarov, 2020).

Problems with key sites within the city's "green shield"

The monitoring of the city's park areas has helped identify plots that will be included in the forest-and-park green belt around the city of Makhachkala – a total of 32 areas, with 15 of these having established boundaries and being cadastrally registered.

The combined area of the 15 cadastrally registered forest-and-park areas (inclusive of suburban plantings) is 4,899 hectares. The combined area of the city's internal plantings, which include greenery in parks, public gardens, alleys, stadiums, and streets, is around 380–390 hectares, i.e. around 5 square meters of greenery per resident (against a recommended standard of 20–30 square meters).

The boundaries have yet to be established for Lenin Komsomol Park, Fiftieth Anniversary of the October Revolution Park, a public garden on Gamidov Avenue, a public garden on Peter I Avenue across from Lake Ak-Gel, City of Craftsmen Park, Suleiman Stalsky Boulevard, Khappalaev Alley in New Kyakhulai, Rodopa Boulevard, Friendship and Deputies Public Garden, Fazu Alieva Public Garden, Entrepreneurs Alley, and other areas.

According to a member of the Makhachkala City Council, a working committee on green plantings was recently established comprising some of the republic's top researchers and foresters. The committee has allegedly suggested cutting down 70% of the trees in Lenin Komsomol Park. The above-mentioned member of the City Council is of the view that greenification work in the city is not always conducted in an effective manner, a good example being the case of Akushinsky Avenue, where practically all of the greenery planted over the last 2–3 years is now gone. According to the official, while many of the recommendations proposed may be good, there is a need for a sound legal-and-regulatory framework for maintaining the city's green shield. Having one in place should help prevent inconsistent decision-making on such issues[12].

Based on the results of a round-table discussion held by the Dagestan

[12] Dagestan v autsayderakh po sozdaniyu zelonogo shchita [Elektronnyy resurs] // Gazeta «Chernovik». 02.06.2019. URL: https://chernovik.net/content/lenta-novostey/dagestan-v-autsayderah-po-sozdaniyu-zelenogo-shchita (data obrashcheniya 20.08.2021)

All-Russia People's Front, it has been recommended to devote more attention to the issue of slowness in surveying the city's forest-and-park areas and explore the possibility of including Eltav Forest in the list of public areas to be beautified as part of the municipal program 'Building a Modern Urban Environment'[13].

The city of Makhachkala stretches from the northwest to the southeast along the coast of the Caspian Sea. The city is planned in such a way that there are four major geographic reference points to focus on – northwestern, northeastern, southeastern, and southwestern. Accordingly, the major sites within the "green shield" tied to the geo-environmental landmarks in the capital of Dagestan are as follows: (1) Eltav Forest and the road to the township of Sulak – northwest; (2) the Caspian Sea with Makhachkala beaches – northeast; (3) Lake Ak-Gel and the road to the city of Derbent – southeast; (4) Tarki-Tau Mountain – southwest. These are the principal natural sites among the 33 elements in the green belt around the capital of Dagestan.

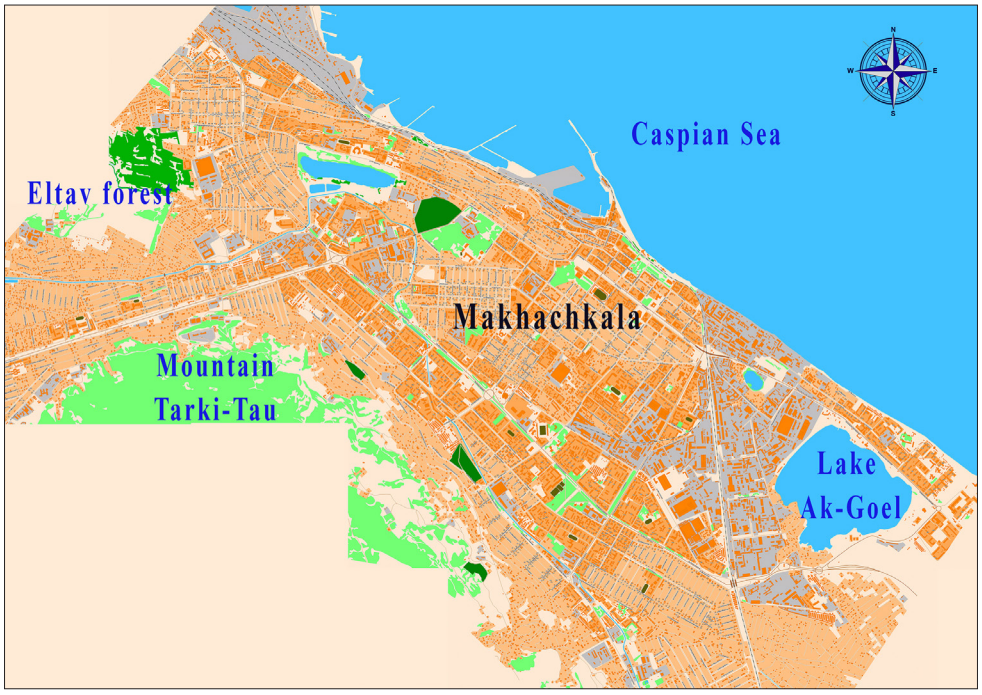

Figure 1. Key sites within the "green shield" around Makhachkala

[13] Aktivisty ONF prizvali uskorit' protsess sozdaniya «zelonogo shchita» Makhachkaly [Elektronnyy resurs] // Obshcherossiyskiy narodnyy front. Novosti regionov. 18.01.2019. URL:https://onf.ru/2019/01/18/aktivisty-onf-prizvali-uskorit-process-sozdaniya-zelenogo-shchita-mahachkaly/ (data obrashcheniya 20.08.2021).

Northwest (Eltav Forest and dune sands). The condition of Eltav Forest, a key site within the Makhachkala "green shield", is currently an area of concern for many residents of the capital. Specialists from the Mountain Botanical Garden of the Dagestan Federal Research Center of the Russian Academy of Sciences have warned that the forest may be doomed. However, they have also expressed the hope of a park area being established within its grounds (Asadulayev, 2019).

Several years ago, the ecosystem under examination was dealt a most powerful blow. To be specific, in 2014, construction work began on the outskirts of Eltav Forest to erect a multistoried house for rehoused tenants of derelict properties. This is quite a vivid example of how a noble cause can be adroitly used for nefarious purposes. Using forged documents, the crooks got hold of a large patch of land within the nature conservation area. Journalists later found out that in some cases the actions of the city's government and nature conservation authorities aimed allegedly at conserving Eltav Forest were in actuality nothing but a sham. While claims for ownership of the forest plots were legally filed, members of the city's administration were almost never present at the proceedings. Consequently, the lawsuits would end in favor of the crooks, who would just proceed with their "squatter" construction, showing hardly any remorse about the deforestation in the area.

It stands to reason that without addressing this kind of elaborate fraudulent land use schemes at a public level it will be difficult to create an ecologically sound urban environment in the city. At the same time, it must be remembered that Eltav Forest has been declared a protected natural area for the first time in the history of the capital, which has been accomplished thanks to the dedicated efforts of the current Mayor's Office. Despite the need for tight protection of the forest having been voiced by former government officials at all levels for many years, little headway had been made in resolving the issue, with the total area of plantings in Eltav Forest eventually shrinking over the last few decades by as much as 3 times, i.e. by 48 hectares of land.

What makes it doubly sad is the fact that in the 1930s immense work was carried out in the city to expand the natural area of this forest with the aim of protecting the capital from dust and sand storms from the north and northwest. Numerous windbreaks were created north of Makhachkala along the dune ridges on the coast of the Caspian Sea. Unfortunately, these dunes have been virtually razed to the ground over the last few decades.

The republic's nature conservation authorities keep turning a blind eye to the rampant extraction of sand for construction on the coast of the Caspian Sea both north of Makhachkala and on all of the republics seashores. The scale of this activity has been immense. Furthermore, it has been proven that the mining of redeposited sand formed by secondary wind deposition in maritime Dagestan is what is behind the process of progressive intensification of wind erosion (deflation) in the area, which in the end may lead to a worsening of the environmental and recreational situations along the foreshore (Aliyev, Sluka, Eldarov, 1993; Ignatov *et al.*, 1995).

Given the above, there is a need to introduce, in a gradual manner, restrictions on the mining of dune and beach sand while searching for and using alternative sources of this material beyond the coastal area of the Caspian Sea. The potential for this is there. There are several proven quartz sand fields in the submontane area, and they are quite large. If need be, it may be possible to develop new fields in promising areas of alluvial sand along the Kizlyar to Karlanyurt rail line. As regards sea sand, it may be a good idea to reserve it for the purpose of conserving and improving the natural landscape in the recreational zone.

Northeast (Caspian Sea and Makhachkala beaches). The current projects on constructing centralized water disposal systems along the coast in the capital envisage the creation of four district water-treatment systems. Currently, just one such system is in operation (System 1); it handles the treatment of almost a third of the sewage produced in Makhachkala and Kaspiysk. The rest of the sewage is dumped into the sea without making it to the treatment facilities. The area where this kind of dumping mainly occurs is the northern part of the water area of a former out-of-town beach, where there is a deep-water collector for emergency discharge of the city's sewage water. The poorly built collector, which is located in the breaker zone, has incurred some serious damage over the years. As a result, highly concentrated sewage has for years spread along Makhachkala's entire coastal area over a large distance, all the way to the city's central beach[14].

In the mid-1980s, the authorities developed a detailed plan for the second phase of construction of the sewerage network in the Makhachkala agglomeration. The project was launched on the eve of Perestroika (1989). It resulted in the construction of a 9.7 km long sewage collector (65.5% of what was originally planned). That said, only 5 billion rubles worth of work was completed against a target of 9.6 billion. An analysis of the underground

[14] Vodnyye resursy Dagestana: sostoyaniye i problemy. Makhachkala: ZK BVU, 1996. 180 s.

collector's condition conducted five years ago revealed a very poor quality of the work done, with flagrant violations of concrete pouring standards. Russia's Ministry of Construction, for reasons unknown, failed to provide the funding required to continue the construction of a tunnel to treatment facilities (2 billion rubles worth of work planned for 2016) (Abdulgamidov, 2016).

At the time the above scheme was being established, the nearshore areas of the capital of Dagestan and its satellite, the city of Kaspiysk, were receiving 350,000 cubic meters of sewage per day, with 200,000 cubic meters (70–75 million cubic meters per year) of this being untreated sewage. If expressed in terms of the prices of that period, the cost of the work left to complete was over 100 billion rubles. Taking into account the real growth of the actual agglomeration, expenditure on completing the construction of the city's entire drainage system was to be no less than 0.5 trillion rubles. Currently, the government is considering only a minimum funding threshold of 100 billion rubles.

The centralized water supply and sewage networks in Makhachkala's coastal area must serve not only the actual city but also the numerous recreational facilities along the coast of the Caspian Sea. The northern section stretches from the city of Makhachkala to the River Krivaya Balka, and the southern one – from the capital to the city of Izberbash. It appears to be advisable for the owners of these resorts to pool resources to fund the construction of water systems that will be in shared use among them (Borodina, 2017; Eldarov, Sluka, 1994).

The wellbeing of this maritime city is largely dependent on the level of development of its port complex. In just about any civilized country, the seaport is associated with the fish market. For instance, in Istanbul the fish market is located right on the seafront. Fish can be purchased there from mobile stands; you can have it fried and enjoy it at a table on site. Most maritime cities live the sea, tourism, fisheries, tankers, dry-cargo vessels, container ships liners, cruisers, ferries, large and small yachts, sailboarding, kitesurfing, paddleboarding, wakeboarding, small boats, barks, karbasses, motorboats, berths, piers, wharves, etc. and that is natural (Babchenko, 2013).

By contrast, right now the Makhachkala port is an empty, lifeless place. As is currently the case with the majority of Russia's port cities, nobody rents a berth and there are no yachts laying off here. You will not hear music playing on cruise liners here; nor will you come here across much buzzing activity in the form of passengers embarking into little recreation boats or

the morning's catch being unloaded. You will not find here anything but the military, the Customs, and the maritime police (Babchenko, 2013).

Southeast (Lake Ak-Gel). Lake Ak-Gel, situated on the southeastern outskirts of the capital of Dagestan, is quite a deep freshwater body of lagoonal origin, with an area of over 1 square kilometers. The lake lies virtually in the heart of the developing Makhachkala agglomeration. Surrounded by numerous residential and industrial properties, it is exposed to high levels of human-induced impact. The industrial and transportation complex enterprises operating in the lake's vicinity often dump toxic wastewater into it. As a result, most of its once abundant ichthyofauna is now gone. The lake has long been ignored by birds of passage, let alone resident fowl.

As a result of uncontrolled construction activity in the area, the lake's littoral and water conservation zones are pretty much gone now. Today's Lake Ak-Gel is a waterbody left without natural self-reproduction and self-cleansing mechanisms. A rivulet that once ran into it from the township of Tarki has been used as a sewage collector for a long time now (Tsapiyeva, Denevizyuk, 2013).

The city's former leadership desired to backfill Lake Ak-Gel, Makhachkala's largest natural waterbody, with the aim of selling a set of pricey plots of land in the area. Luckily, thanks to vehement protesting on the part of the city's general public, the project was scrubbed. Having said that, the littoral zone continues to be a place where multistoried buildings and constructions of varying function are built. There is a need to work on the issue of integrated development of Lake Ak-Gel and areas around it in a most dedicated manner.

Restoring the lake environmentally will require artificial water supply, removing all sources of polluting runoff into it, fish propagation programs, developing children's yachting, and developing other eco-friendly types of water recreation. Of importance is the creation of a sound legal framework that will counteract illegal seizure of protected lakeside land. Every effort must be made to bring to justice dishonest officials and entrepreneurs who, under the specious pretense of beautifying an area of public use, seek to carry out their own business projects without much regard for the environmental and aesthetic effect that kind of activity can have on the site. In other words, when it comes to resolving nature conservation issues affecting Ak-Gel, it is important to try and see the "hidden hazards" that the municipal government is unable to tackle on its own without the help of the general public.

With that said, the actions of those in charge of the municipal government must be coordinated as much as possible with the interests and initiatives of representatives of the city's nongovernmental environmental organizations.

The above idea is clearly illustrated by the story of a project aimed to build a church on the shore of this lake, which was being persistently pushed through by a group of officials and entrepreneurs. The effort was soon exposed as a fraud by residents of Makhachkala, with the fraudulent plan found to be as follows: build an Orthodox Christian temple in order to morally justify the construction activity in the lake's water conservation and protected shoreline areas, which was being carried out in flagrant violation of Russia's Water Code. A community of caring individuals quickly emerged in the capital to defend the lake. Of note is the fact that the majority of this group were ethnic Russians permanently residing in Makhachkala (Makhmudova, 2018).

The current plan for integrated beautification of the park around Ak-Gel is being considered in conjunction with creating a large environmental site not far from it – a public area starting near the Prophet Isa Ecclesiastical-and-Educational Center and ending on the coast of the sea. However, in implementing the project, the authorities have been faced with the issue of having to regain hold of certain plots previously purchased by private individuals for construction purposes, a problem that requires looking for ways to prevent potential conflicts in the area of urban land use (Ionov, 2020; Eldarov, 2020).

Southwest (Tarki-Tau Mountain). Discussions around issues of ecological development of the capital's suburban zone tend to begin in recent years with the topic of acute conflicts in the area of land use around Tarki-Tau Mountain. The key cause behind them is that the government has long paid little attention to issues of building in and making recreational use of these areas, which has led to the local community addressing them in a resolute, and at times even aggressive, manner. Over the last 15 years, activists representing the townships Tarki, Kyakhulai, and Alburikent have mounted a loud protest against the freewheeling recreational use of the mountain by Makhachkala residents. In particular, they have spoken out against bonfires on the slopes of Tarki-Tau Mountain, pits used as improvised braziers, crowded outdoor parties, etc., arguing that activities of this kind should be held only with permission from the council of elders in the settlements (Sluka, Tikunov, Chereshnia, 2019).

There are many areas on the slope of Tarki-Tau Mountain that back in the Soviet era were designated for afforestation. Today, most of them are treeless plots that are rented out to anyone willing to use them. However, profit from renting these plots out can never justify the damage their use is causing to the area's environment. The issue worthy of special consideration is construction activity in landslide hazard areas on the mountain's piedmont slopes.

The aggressive behavior displayed by residents of Tarki, Kyakhulai, and Alburikent is a sign of frustration boiling over in the region, as their appeals have been left unanswered by the authorities. Therefore, it is important that Makhachkala residents know the real cause behind the exacerbation of both nature conservation and ethnopolitical issues in the area, which is the failure of the authorities to provide a constructive response to the fair and lawful demands of the Tarki council of elders.

There have been numerous cases of construction activity being carried out on the landslide hazard slopes of Tarki-Tau Mountain. Future climatic changes in the Caspian Sea region that are expected to result in colder and more humid weather may naturally galvanize landslide processes, which, in turn, may lead to the destruction of homes in the place's piedmont areas and endanger the lives of their residents.

Thus, one can only rejoice in the robust nature conservation efforts by the councils of elders in settlements near Tarki-Tau Mountain. The residents are perfectly aware of the fact that their natural environment is something they inherited from past generations, so they must treat the cause of conserving and protecting it as a sacred one.

Conclusion

Rectifying the critical condition of the environment in the capital of Dagestan, Makhachkala, will require a raft of urgent measures to be taken based on creative decisions made taking into account the city's distinctive geographic-environmental and socio-economic characteristics. Furthermore, given Dagestan's multiethnic makeup, it will be important to take into account the diversity of its ethnocultural traditions of natural resource use. In particular, it will help to launch at a legislative level the process of reviving the centuries-old laws and norms on natural resource use that are well adapted to the mentality, traditions, and customs of Dagestan's mountainous peoples. However, for now Dagestanis will have to be guided exclusively by common federal laws, most of which do not take account of

local characteristics. The current legal situation may be fraught with serious implications for the environment of the Country of Mountains.

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GEOGRAPHICAL IMAGE OF THE WORLD IN THE LONDON PSALTER MAPS FROM THE 13TH CENTURY

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Abstract: The subjects of this paper are two maps from the 13th century Psalter, found in London. These are the Psalter World Map and the Psalter List Map. Both maps are designed in the shape of a circular disk, modeled on medieval *mappae mundi T-O type*. The first is a pictorial map, the second is descriptive. The primary goal of these maps was not to objectively present geographical reality, but to express biblical symbolism and medieval Christian cosmology and thus serve as a reminder in devotional practice. By their deconstruction, we discover not only the religious Christian view of the world, but also the historical and cultural representations of medieval people projected on a geographical basis. Maps from the London Psalter have so far been viewed more as a "religious document" than as an objective "geographical image" and a "historical document". Therefore, they were rarely used as a historical-geographical source. The aim of this paper is to deconstruct the text and context of the mentioned two maps and thus interpret their imaginative geography and geographical representations, the meaning of symbols and toponyms, which may be of interest to researchers dealing not only with historical cartography but also with historical and human geography.

Keywords: Psalter World Map, Psalter List Map, Medieval *mappae mundi*, T-O maps, geography, Medieval cartography, toponyms.

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Introduction

In the London Psalter, or book of psalms from the 13th century, there are two unusual maps of the Old World on the obverse and reverse of the same paper. They are called the Psalter World Map and the Psalter List Map. Both maps are designed in the shape of a circular disk, modeled on medieval *mappae mundi*. This type of map was made mainly by monks in the monasteries of Western Christianity between the 5th and 15th century, called "monastery maps", "monastic maps" or "radkarte" in German. They had a round or oval shape in the form of the letter O inscribed with T (T-O type maps), in different variants (Uhden, 1931; Destombes, 1964). T-O maps originate from the ancient conception of the Earth's sphericity and zonal belts - climates (Talbert and Unger, 2008). The prototype of this type of map is the Picture of the World from the "Etymology" of St. Isidore of Seville from 623. Related to this is the Salusta map model. O - represents the world's ocean that surrounds the land, and T - the inland waters that divide the land circle in three continents of the Old World - Asia, Europe and Africa - one for each of the three sons of Noah. Such maps did not have a grid, scale, and conventional legend (Woodward, 1987; Pajт, 1988; Орачев, 2005; Rana, 2008; Burke, 2016).

Woodward noted that maps of the *mappae mundi* type represent "history projected on a geographical basis" (Woodward, 1987). However, the geographical image of the world on medieval monastery maps had a multifaceted polyvalent context - cognitive, ideological, religious. The geographical representations of Europeans about distant oriental countries whose protagonists were crusaders are far more polyvalent than those usually created in Arabic or Chinese cartography. They speak the language of symbols not only about the real features of geographical space, but also about historical and imaginary events and characters, cultural phenomena, mythical legends and biblical stories, so it can be said that these maps represent a "projection of culture on a geographical basis" (Šakaja, 2015). To this we can add a projection of mythological and religious representations, since such maps usually served the needs of pilgrimages or as a reminder in devotional practice.

For world maps of this type, narrative is key. Their primary goal was not to accurately portray geographical reality, but to spatially express biblical symbolism. They are more a narrative than a mirror of reality, more a cartographic illusion than an objective perception of geographical space. Medieval cartographers used imaginative picture drawings to depict distant worlds surrounding European Christian civilization from the North, South

and East, even more stranger and unnatural than they actually were (Klein, 2016; Foys and Heather, 2018).

The Psalter World Map is a kind of pictorial *mappae mundi* of the Ebstorf-Hereford type. It was named after the Psalter of London (a book of prayers with psalms) in which it was found as an illustration (Morgan, 1988). On the reverse is the Psalter List Map. In the calendar of the Psalter, April 3rd is marked as a holiday in honor of St. Richard of Chichester (died 1253), who was canonized in 1262, which means that the Psalter was created after that date. It is kept in the British Library in London (British Library Add. MS. 28681, fol. 9r and fol. 9v).

The dimensions of the Psalter are 17x12.5 cm, the paintings on parchment 10x15 cm, and the diameter of the circle with the world map is about 8.5 cm. The Psalter World Map, although small in size, contains an unusually large number of details and 91 geographical names of places. The map was probably created on the basis of a larger map, which was given to King Henry III around 1230 and placed in the painted hall of the Palace of Westminster, which burned down in a fire in 1263 (Barber, 2013). However, the description of Matthew Paris's Westminster map (Matthew Paris's, c. 1200-1259) suggests that this map was based on the Macrobius map model. The visual emphasis on France and Paris on the Psalter World Map indicates that its model was a French map (Van Duzer, 2019).

Based on Ven's comparative diagrams showing the overlap of toponyms between the Psalter World Map and the work "*Descriptio mappe mundi*" by Hugh of St. Victor (Hugh of St. Victor, c. 1096-1141), it was determined that there is a 69% overlap, while there is a 76% overlap between the Psalter List Map and the mentioned work "*Descriptio*" (Wacha and Levernier, 2019). On the Psalter List Map, the distribution of cities by provinces is completely different, and there is no support in the part "*Descriptio*", although there is a high degree of overlap of toponyms. Based on that "it seems that the Psalter List Map on the reverse is a copy of an older map" (Schöller, 2014). The Psalter also contains other illustrations, including enlarged pictorial initials denoting the main parts of the text (Büttner, 2004; Brot, 2018).

The Psalter World Map is rarely used as a historical source, because its perception of objective geographical space is small compared to academic cartography. Harley believes that maps of the *mappae mundi* type could play a greater role in the practice of historical geography, if they were treated as text. Their "deconstruction paves the way for the reintegration of cartography as a work of historical and human geography" (Harley, 1989).

Iconography and symbolism of the Psalter World Map

Regarding the Psalter World Map the Psalter List Map, Brot asked some important questions: What is the function of these maps in the Psalter? Why are these maps included in the book of Psalms? What are the possible connections between the maps and the text in the Psalter? (Brott, 2018).

The main function of the mentioned maps in the London Psalter is to use the cartographic image of the world and the illustration of biblical representations to serve for the interaction between the object and the observer during devotional practice (La Porte, 2012). The Psalter World Map presents medieval semi-mythical geography, which places the real world in the context of faith in salvation (Reudenbach, 1998). Long before the modern concept of the East, shadows of Christian notions emerged on the eastern horizon, woven into the early medieval imagination. It is not only a geographical but also a spiritual map, designed to help the observer during prayer as a reminder and alternative guide to an alternative pilgrimage. It intertwines notions of the material world with theological notions of the spiritual world (Wacha & Brott, 2020).

The Psalter World Map is actually a three-part image, which shows the whole universe in the spirit of Christian cosmology and eschatology - the kingdom of heaven and the kingdom of Earth, a universe in which divine apparition, nature, man and his creations, mythical and real, superhuman and human. In the upper part is an illustration of Christ's presence in the cosmos, in accordance with the Christian prayer recorded in the Bible: "Our Father, who art in heaven, Hallowed be thy name; Thy kingdom come, Thy will be done in earth, as it is in heaven" (Matthew 6: 9-13; Luke 11: 2-4). God the Savior Jesus Christ appears on the starry sky as a judge, with the cross sign on the halo of holiness, in a robe in the royal burgundy color with a white hem and in a shirt of precious lapis lazuli color. With his right hand raised with two outstretched fingers, he seems to be blessing, which symbolizes salvation. Two winged angels swinging a thurible, for the purpose of cleansing the sacred space, which symbolizes the kingdom of heaven. With his left hand, Jesus holds a small T-O globe as a Pantocrator (Almighty). The image of Christ Pantocrator was popular in Byzantine art. In Western Christianity, it is mostly associated with the scene of the Last Judgment (Woodward, 1987; Barber, 2013).

The middle part of the painting on the body of Christ is dominated by a round map of the earthly sphere which "transforms a schematic circular

disk into a visual encyclopedia" (Barber, 1989). The places of Christ's earthly mission are marked on the map, which will later become the focal points of the pilgrimage. Jerusalem in the center of the earthly disk and the small solar disk east of paradise, suggest a geocentric view of the world, as well as many words and sentences in the Psalms. The words Earth (terra) and World (orbis terra) are repeated in the Psalter 168 times (Brott, 2018). The round map model centered in Jerusalem is an illustration of the divine plan for the creation of the world (Bagrow, 1966). Jerusalem as the geographical and spiritual center of the world, in accordance with the Holy Scriptures, creates the so-called "omphalos syndrome" (Gr. omphalos - navel, center) and suggests where the creation of the world began (Whittington, 2014). "Positioning Jerusalem at the center of the map becomes a feature of world maps after 1120 as a consequence of the crusader mentality" (Barber, 2013). Around it is the Holy Land with places related to the life and suffering of Jesus Christ. The Holy Land is hypertrophied in relation to other regions, in accordance with its importance in Christianity. In the Far East is the Garden of Eden, with Adam, Eve and the tree. In the northeast, there is a fenced and isolated landscape of evil Gogs and Magogs. In the unknown peripheral areas in the south, mythical visions of grotesque and monstrous characters of evil people and animals are distorted, which instilled fear of the uncivilized and non-Christian world. These scenes represent segments of complex Christian mythology (Strickland, 2003; Van Duzer, 2013).

The map is dominated by circular shapes (a disk-shaped Earth with the center in Jerusalem, a circular world ocean, an atmospheric envelope with wind figures, semicircular directions of mountain ranges and rivers), which indicate the circular organization of geographical space, the perfection of God's creation. Medieval people knew that the Earth had the shape of a sphere, but they still represented it as a disk. It is interesting that on the eastern edge (above) of the Psalter Map is the text *Col[um]ne [H]erculis*, and on the western edge (below) is a drawing of the Pillars of Hercules, which means that they knew that the Earth was round, but they mistakenly believed that East and West meet on the world's oceans behind the Pillars of Hercules (today's Gibraltar).

On the outer edge of the map, the figures of 12 windmills with the names of the winds are presented:

Subsolanus - eastern; *Ve[n]tus Eurus* - east-southeast; *Ventus Euronothus* - south-southeast; *Anster vel Nothus* - southern; *Libonothus* - south-southwest; *Ve[n]t[us] Aufricin[us]* - west-southwest; *Ventus Zaphirus* - western; *Vent[us]*

Corus - northwest; *Ve[n]t[us] Circi[us]* - north-northwest; *Ve[n]tus Septe[n] trion[alis]* - northern; *Aquilo* - northeast; *Ve[n]t[us] Wultur[us]* - east-northeast wind (Millller, 1895; Whittington, 2004).

The ocean as a water zone surrounds the terrestrial world. The ocean and the Mediterranean Sea are colored green, the Red Sea red, and the rivers blue. On the Red Sea, the passage of Moses is marked, through which, according to the biblical legend, the Israelites came out of Egypt.

Some important imperial cities are marked with a symbol in the form of a crown - Rome, Constantinople, Alexandria, Carthage. The golden-yellow triangular symbols represent cities and places that are relevant for that time, such as the birthplace of Alexander the Great in Macedonia. Some places related to Christ's life on Earth are also marked in Galilee: Bethlehem - Christ's birthplace, Nazareth - where he grew up, Jericho and the Knights or Bethsaida - where he healed blind people, Capernaum and the Sea of Galilee - where he performed miracles, Jerusalem - where he was crucified and resurrected.

A larger number of places on the Psalter World Map and Psalter List Map are directly related to the texts of the Bible than to the psalms themselves, although both are intended to illustrate and clarify the texts of the psalms. Of the 36 geographical names listed or repeated in the text of the psalm, seven are located on the Psalter World Map: Jerusalem, Babylon, Mount Zion, Egypt, and Ethiopia. Lebanon is mentioned six times in the Psalms and marked on the map as a mountain. The Jordan River is mentioned three times. Egypt is shown along the Red Sea, including the narrow passage of Moses (Brott, 2018).

The lower part of the painting presents an underground world dominated by two conflicting two-legged feathered dragons, as symbols of trickery and hatred. They are the antipodes of the two angels in heaven.

On the Psalter World Map, there is a three-part structure of geospace in terms of civilization. Similar to ancient Greece and Rome, there are areas where "we, the civilized" Christian people live, centered in Jerusalem, "barbarians" in the enclosure of Gog and Magog in the northeast, and "monsters" living in a distant unknown country in the south of ecumene. According to one hypothesis, the monsters represent the unknown inhabitants of central Africa in the legendary (fictional) Christian kingdom of Presbyterian John. According to the second hypothesis, these are different creations of God, which have been moved here from God's world. "This realm is of great

interest to the monastic public, where creatures represent the sinful nature of man and act as material visualizations or manifestations of deviant behavior" (Strickland, 2003). According to the third hypothesis, it is a cartographic representation of the "anti-ecumenical" or "southern continent". The Roman Neoplatonist from the 5th century, Ambrose Theodosius Macrobia, in his work "Comments on Scipio's Dream" (Comentarii in somnium Scipionis 2, 9), believes that the ecumenism is separated by an ocean from the unknown anti-ecumenism where the "Antipodes" live. It is the notions of monster races, as the Antipodes of "normal", "superior" people of the Christian world, that are "embedded in the geographical imaginations of medieval *mappae mundi*" and placed on the margins of maps (Šakaja, 2015, 279-280).

Thus, the Psalter World Map symbolically accumulates and merges religious, mythical, historical and geographical contents. At the same time, the contents are asynchronous, often over a long period of time, ranging from biblical and ancient times to the middle of the 13th century, when this map was created. The real spatial proportions are disturbed on it, the contours of the land and the sea are completely deformed due to the adjustment of the drawings. The Psalter map shows a synchronic-diachronic and real-imaginative mosaic in which there are places that evoke narratives from the Bible (Noah's Ark on Mount Ararat, Garden of Eden in the East, Paradise Rivers), from Greek mythology (Pillars of Hercules, Amazons, Troy), New Testament (places of Christ's earthly mission) and from European cultural and political history (Rome, Constantinople). In that way, time and space are relativized and merged into one imaginary asynchronous-holistic picture of the world.

Analysis of geographical contents of the Psalter World Map

Geographical contents in Asia

The geographical horizon of Europeans in the Middle Ages did not reach far beyond the former empire of Alexander the Great. The attitude of Europeans towards the Asian geographical area was complex and complicated. He was both familiar and unknown to them, friendly and hostile, astonishing but also exotic and mysterious. Thus, in the representations of Asia, fear and curiosity that spring from the Christian mythological representations are displayed on the medieval monastery maps at the same time. The European perception of

the Holy Land surrounded by a non-Christian, uncivilized and barbaric world was present on the maps until the Great Geographical Discoveries. Among the vast geodiversity of various distant and exotic countries of the Old World, the attitude of Europeans towards the Orient, which was constantly in sight - was especially complex - they turned their gaze to it in prayers and crises, believing that there is a mythical paradise, the center of the world (Jerusalem) and the Holy Land (Palestine) and places related to the mission of Jesus Christ. Crusades and new geographical discoveries in the Middle Ages showed that the Orient was not a distant country, on the contrary, that it was close (Middle East), and moreover, that parts of this territory were once European. There is a legendary mountain (Ararat) at the top of which is a boat with the inscription Arca Noah - Noah's Ark, and to the east is the river *Fl. Contolis* (Arax). There are the historical *Troy* (Troy), *Capadocia* (Cappadocia), *Caladoni* (Chalcedonia), *Antochia* (Antioch), and above all the Holy Land in which Jerusalem is the spiritual and geographical center of the world. Around it are the biblical places of *Belehem* (Bethlehem), *Jericho* (Jericho), *Cesarea Palestine* (Caesarea Palestine), *Mare mortuum* (Dead Sea), rivers *fl. Jor* and *Dan* (forming the Jordan River), *Thorens Cedron* (Kidron Valley), *Stannum Geneser* (Sea of Galilee, with fish), *M. Syon* (Mount Zion), *M. Liban(n)s* (Lebanese mount.), *Bethsaida* (Betsaida), *Thiberiadis* (Tiberias), *Niniue* (Nineveh), *Lachis* (Lochis), *Acaron*, *Puteus Josep* ("Joseph's pit" in Galilee, where according to biblical legend the brothers sold the prophet Joseph into slavery). Thus, the usual dichotomy of Christians against unbelievers, the righteous against sinners, could only be partially applied in Asia.

The East is at the top of the map and there is also a mythical paradise. According to the book of Genesis: "And the Lord God planted a garden in Eden to the east; and there set up the man whom he had created" (Genesis 2: 8). Between them is the tree of life in the midst of the garden, and the tree of the knowledge of good and evil" (Genesis 2: 9), with the cunning serpent (Genesis 3: 1). Five holy rivers of paradise spring from the fountain of paradise. These are: *Tigris* - Tigris, *Euphrates* - Euphrates, *Geon* - Nile, *Phison* (Pishon) - maybe Indus and *Ganges* - Gang. Only four rivers of paradise are mentioned in the Bible: Pishon, Gihon, Hiddekel (Tigris) and Evfrat (Euphrates) (Genesis: 2: 10-14). Paradise as the source of heavenly rivers symbolically represents the source of good (Delumeau, 2000).

The theological question of where world evil comes from is geographically localized on the map in Northeast Asia (top left). It shows an area surrounded by two mountain walls, between which is the Caspian iron gate of Derbent, built by Alexander the Great. This area signifies the

biblical land of Gog and Magog, which the prophet Ezekiel cursed as the personification of evil (Ezekiel, 39). This myth of the "empire of evil" was identified as Scythia, later as the Mongol Empire, and can be recognized in some recent global geopolitical models, for example in Mackinder's theory of world "Heartland" as the "pivot of history" (Mackinder, 1904), and in phrases about the "axis of evil" (Muir, 2011).

Toponyms in Asia

[Paradisus] - Paradise (drawing of a fenced paradise garden, figures of Adam and Eve separated by a tree).

Arbor Solis - Tree of the Sun. According to the novel "Alexandrida", two sacred trees of the Sun and the Moon in the east, have prophesied to Alexander the Great that he would conquer the world but not return home, he will die of poisoning in Babylon.

Arbor Lun[e] - Tree of the Moon (Moon Tree).

C[iuitac] Iazaro[n] - On the Psalter List - Thazaron. The name originating from the toponym Lazorum gens, which appears on the Ebstorf map (Miller, 1896), or from "gens optimam Chathmorum" ("the people living in India"), mentioned by Hugh of Saint-Victor in his work "Descriptio mappe mundi" (Gautier Dalche, 1988). Thazaron may refer to the Khazars or Khaaria (*Gazar*), (Chekin, 2006), or Ariana (persian Aryanem - "the land of the Aryans", sanskrit Āryāvarta - "abode of the Aryas").

C[iuitas] Nisapi – The city of Nisibi in the East is mentioned by Hugo of St. Victor in the 12th century and Aethicus Ister in the 16th century.

Are liberi [et] colu[m]ne erculis - Arcades of Freedom and Pillars of Hercules.

C[iuitas] Pabibotra - City of Polybot (mythical giant).

Phison - Pishon, one of the five rivers of paradise.

Geon - Gihon, one of the rivers of paradise.

Tigris - Tigris, one of the rivers of paradise.

Eufrates - The Euphrates, one of the rivers of paradise, flows from the East to the Armenian Mountains and from there again it springs and flows under the name *Euph[er]ates* towards the Persian Gulf.

Ganges fl[uuius] - Ganges, one of the rivers of paradise.

Mare Rubrum et Sinus Persicus (*no inscription*) - Red Sea and Persian Gulf.

[*Transitus Hebreorum*] (*drawing without inscription*) - The Passage of the Jews (Moses' Passage in Red sea, through which the Jews left Egypt).

Regio Coro - Karakorum area, the historical area around the Aral Sea. The city of Karakorum was the seat of Genghis Khan.

Satima - a place mentioned in the Fourth Book of Moses: "And Israel at that time abode in Settim" (4 M, 25: 1), and "Ablesatim in the plains of Moab" (4 M, 33: 49)

Turr[is] - from tauris - a tower, perhaps the tower of Babel in Babylon.

P[er]sida - Persia.

Niniue - Nineveh, the ancient city and capital of Assyria, on the East bank of the Tigris River. It is mentioned in several places in the Bible, as an enemy city of the Jews and Israel (Genesis; The Gospel of Matthew, the Gospel of Luke).

C[iuitas] Theodosopolis - Theodosiopolis, a city in eastern Anatolia, today's Erzerum. It was the seat of the episcopate in the late Roman province of Armenia Tertia.

C[iuitas] Elam - Elam, one of the oldest civilizations, the historical core of Iran (provinces Ilam and Khuzistan). The capital of Elam was Suza (founded around 4000 BC).

C[iuitas] Peliopolis - Heliopolis ("city of the sun"), the former capital of ancient Egypt state, near present-day Cairo. According to Egyptian mythology, this is the birthplace of the god Amon-Ra. In Christian mythology, it is known for the tree of the Virgin Mary, the resting place of the Blessed Virgin Mary, on the way from Israel to Egypt.

C[iuitas] Pesiopolis - Persepolis, located northeast of the present-day city of Shiraz in Iran. It was the capital of the Achaemenid Empire.

Asya Minor - Asia Minor.

M[ons] Orcatoten - Solinus mentions Mount Catoten near Scythia (Collectanea Rerum Memorabilium, 37.1), probably the Armenian Mountains. Atropatene is the old name of Azerbaijan.

Fl[uuius] Ci[n]til[is] - The Contolis River, probably present-day Araks. Herodotus, Virgil (Vergilius) and Strabo mention this river. According to

some, it is the biblical river Gihon (1 Book of Kings, 1: 33, 38). Pliny (6.10) mentions Cyrus river, in the Caucasus. It springs near Erzerum in Turkey and flows into the Kura River in Azerbaijan. Further east stretches Upper Albania.

M[ons] Libani - The mountains of Lebanon, like the cedar of Lebanon, are mentioned in many places in the Bible.

Troia - Troy, the legendary city and scene of the Troyan War described in Homer's epic Iliad in the 9th or 8th century BC.

Jerusalem - Jerusalem, as the geographical and spiritual center of the world. In the biblical book of the prophets Ezekiel writes, "Thus says the Lord God: This is Jerusalem. I have set her in the center of the nations, with countries all around her" (Ezek. 5: 5). According to the New Testament, Jerusalem and the Holy Land are the spiritual center of Christianity. This idea came to the fore especially during the Crusades in the 13th - 14th century (Woodward, 1985, 1987).

Belehem - Bethlehem, about 10 km south of Jerusalem, the center of pilgrimage as the birthplace of Jesus Christ (according to the New Testament).

Torrens Cedron - Qidron Stream. According to the New Testament, Jesus Christ crossed this valley many times on his way to the Garden of Gethsemane.

M[ons] Syon - Mount Zion, the hill on which, according to the New Testament, Jesus Christ held a secret supper with the apostles. There is the Church of the Assumption of the Blessed Virgin Mary and the tomb of David.

Stannun Genesar - Lake of Gennesaret (also called Galilee, Lake Tiberias, Kinneret Lake or sea). The drawing of the two fish is reminiscent of the Gospel legend of fishing with the help of Jesus (Luke 5: 1-11; John 21: 1-14).

Thiberiadis - The city of Tiberias, on the shores of the Galilee lake, the center of the region of Galilee. Herod, king of Judea, founded it in the year 20 AD and named it Tiberias, in honour of Roman Emperor Tiberius.

Mare Mortuum - Dead Sea, actually a salt lake into which the Jordan River flows. It is related to the biblical legend of Sodom (Gen. 13:13, 18:16, Ezek. 16:49; Luke 17:29) and Gomorrah (Gen. 14: 9; 2 Mk. 16:23; 4 M. 11:32, etc.).

Ierico - Jericho. Archaeological remains of the city, about 9000 years old, are located on the west coast of the Jordan River, 15 km upstream from the

confluence with the Dead Sea. It is mentioned in the Bible as "a city of palms" which the Jews conquered from Canaan. The Romans demolished it in 68 AD. It is mentioned in several places in the Old Testament (4. Moses 22: 1; 26: 3; 31:12; 33:50; 34:15; 35:1, etc.) and in the New Testament (Hebrews, 11:30; Luke 10:30; 18:35; 19:1).

M[ons] excelsus ubi deabolus statuit d[omi]n[u]m - High mountain where the devil tempted the Lord (according to the Gospel of Matthew, 4:8-10, without the drawing of the mountain).

Betheida - Bethsaida. The New Testament mentions two cities under that name - Bethsaida Julia, where Jesus fed 5000 people with five loaves of bread and two fish (Matt. 14: 19-21; 15: 34-38) and Bethsaida of Galilee, the birthplace of the apostles Andrew, Peter and Philip.

Corozaim - biblical Chorazin, today Korazim, north of the Galilee lake (Matthew, 11:21).

Azot[us] - Ashdod (a city in Israel).

Cesarea Palestine - Caesarea Palestine, a city between Tel Aviv and Haifa. It was built by Herod the Great and dedicated to Octavian Augustus Caesar, hence his name. It was the administrative center of the Roman province of Judea, the early Christian center and the capital of the Byzantine province of Palestine Prima.

Acaron - The city of Ako or Accra in Israel, located on the shores of the Mediterranean Sea. After the crusade conquest of Jerusalem in 1187, Accra became the capital of the Crusader kingdom of Jerusalem, which existed until 1291. The Order of the Teutonic Knights was founded in Accra.

Ior - Jor, the Jordan River, in which John the Baptist baptized Jesus (Matthew 3:13).

Dan - the Dan River, in Arabic *Leddan*, a left tributary of the Jordan River in Israel. It springs from Tel Dan (Tell al-Qāḍī), near the biblical city of Dan, formerly called Laish (Judges, 18:29), in the far north of Israel (Judges, 20:1).

C[iuitas] Lachis - Lachish (Tel-Lachish), a city in the kingdom of Judah. The siege of the Assyrians and the fall of Lachish is mentioned in the Bible (Jeremiah, 34:7; Isaiah, 36:2; 37:8; Nehemiah, 11:30; diary, 32:9).

Arca Noe - Noah's Ark (with a drawing of an ark on top of Ararat).

Armenia - Armenia.

Calcidonia - Chalcedon, today part of Istanbul, called Kadıköy. In the temple The Fourth Ecumenical Council was held in Chalcedon by the Great Martyr Jefimija in 451.

Albania Superior - Upper Albania

Albania Inferior - Lower Albania (in Azerbaijan)

C[iuitas] Spartan - The city of Pertan or Parthan, in ancient Caucasian Albania. On some others medieval *mappaemundi*, Parthan is situated in the province of Armenia or Parthia. Parthan in Albania can only be seen on the Psalter Map, which is the result of the wrong localization of the city of Parthan in Armenia.

C[iuitas] Parthia - Parthia (area in northeastern Iran).

Amazones hic manent - "Amazon women live here". In Greek mythology, the Amazon women are women warriors. According to Herodotus, their existence can be compared to that of the Scythians and Sarmatians.

Are Alexandri - Alexander's sacrifice (Altar). Altars as sacrifices can serve as markers for the four sides of the inhabited world (oecumene): Pillars of Bakh (Bakhus) in the East, Hercules' Pillars in the West, the Altars of the Philaeni (Arae Philaeno'rum) in the South, near the bottom of the Great Syrtis, and Alexander's Altars in the North (Джаксон, Коновалова, Подостинов, Фролов, 2017). Alexander the Great erected sacrifices as altars in several places. For example, when he decided to stop the campaign in India, he built 12 altars to the gods on the banks of the river Hyphasis and a pillar with the inscription: "Alexander the Great stopped here".

Fl[uuius] H[er]mes - The river of Hermus, flowed from central Phrygia through Lydia into the Aegean Sea. In Greek mythology, Hermus is the god of river from Lydia in Anatolia.

C[ivitas] Antiochia - Antioch, today's city of Antakya in Turkey, near the border with Syria. It is mentioned in the New Testament (Acts, 6). The Church of Antioch is one of the oldest, founded in 37. The famous Council of Antioch was held there in 341. The Crusaders conquered Antioch in 1098, which they held until 1268.

C[iuitas] Capadocia - City of Cappadocia.

Arumphei - Arumphei (island in the north).

Abatiam - Albatia island north of Scythia, mentioned by Solinus (19: 6).

Murus Alexandri - Alexander's wall with a gate is considered to represent the Great Gorgan Wall (Gorgan is the ancient Greek name for Hyrcania). It's a brick wall in between the Caspian Sea and Mount Elbrus, 195 km long and 6-10 m wide. Archaeological research has established that the wall was erected before Alexander, during the Sassanid dynasty, as a defense against nomadic tribes from Central Asia. The wall is an association with the biblical legend of Gog and Magog (Genesis, 10: 2; Ezekiel, 38 and 39; Apocalypse, 20:7-9). It is also mentioned in the Qur'an (18, 93 and 21, 96), on the Hereford and Ebstorf maps. According to the legend of Alexander, the purpose of the wall was to keep the evil Gog, whose hordes from the kingdom of Magog were to flood the world on Judgment Day. Some authors mistakenly identify it as the Great Wall of China (Anderson, 1932; Woodward, 1987), and some as the Caspian Iron Gate of Derbent (in the Republic of Dagestan), built by Alexander the Great.

Pr[ouincia] Hircania - Province of Hyrcania. Hyrcania was an area in Persia along southeastern rim of the Caspian Sea.

C[iuitas] Licia - City of Lycia.

Octogora - with a pyramidal sign as a city. The city is marked on the Hereford map as Octoricirus, and on the Ebstorf map of as Ottorogorra. According to Orosius, this is the name of the river (1.2.13).

C[iuitas] Saphiri - Safris city (Nukusafris). Nukus in Uzbekistan on the Amu Darya River.

C[iuitas] Carnis - Orosius mentions two cities of similar name: Carras (Orosius, 1.2.41) and Carris (1.2.42).

C[iuitas] Ciropolis - Kiropolis, founded by Cyrus the Great 544 BC on the North of the Achaemenid Empire.

Geographical contents in Europe

It could be expected that the geographical area of Europe is presented with the least errors. But it is not so. The aim of the author was primarily to show the places of worship and centers important for Western Christianity. Psalm 38 mentions Jerusalem, Rome, Santiago de Campostela as pilgrimage destinations. The Psalter World Map shows several pilgrimage centers established in the 12th and 13th centuries and several cities selected as landmarks for pilgrims: Constantinople, Cluni in the region of Burgundy, Paris, Aquitania, Lyon, Rome and Canterbury, Colonia (Cologne), Barcelona, London.

Toponyms in Europe

Sclaueni Occidentalis - Western Slavs.

Ruscita - Ruthenia or Little Russia? K. Miller read it as *Irii Scite*. That's why it is not clear whether the cartographer had in mind the Russians or the Scythians (Chekin, 2006). Ruscita is further West than western Sclavinia, and may mean Ruthenia or Galicia-Volyn Russia (the term Little Russia here means the medieval state of Ukraine).

Olcus - Olta, a left tributary of the Danube in Romania. Miller thinks it's the Volga or Volkhov, but they are not tributaries of the Danube.

Danubius - the river Danube.

Sarmatica - Sarmatia. The Sarmatians are a people whose tribes inhabited in ancient times areas East and West of the River Don (Tanais).

Citia - Scythia. Scythian tribes inhabited southern Russia and central Asia. On this map Citia is positioned west of Sarmatia.

Citha - Little Scythia, an ancient region south of the lower Danube, in present-day Dobrogea (Miller, 1896). The letter r is similar to t, and the letter h is like b, so this name could mean Cirba (Serbia). That would be the first cartographic appearance of the name Serbia. On Pietro Vesconte's map from 1320, Se[r]uia or Se[r]via is marked. On the map of A. Dalorto from 1325 we find the name Seruia. On the map of Angelino Dulcert from 1339, Seruia and the city of Scopi (Skopje) are marked with the flag of a red double-headed eagle on a golden yellow background, which is the first artistic representation of the Serbian state flag (Соловјев, 1936). In 1448, Andreas Walsperger wrote the name Serfia on her map of the planisphere, similar to the Arabic Sirfia. On Fra Mauro's map from 1459, Servia is marked.

Hu[n]garia - Hungaria, Hungary. The name Hūgaria (Hungary) may be interprets as Bu [r] garia (Bulgaria) (Орачев, 2005). By analogy, the neighboring name Citha would mean Cirba (Serbia).

Dalmatia - a Roman province along the eastern coast of the Adriatic Sea, separated from Liburnia by the river Titius (Krka river) and from the Greek Illyria in the south by the River Drilo (Drin). It was the homeland of St. Jerome.

Co[n]stantinopolis - Constantinople, today Istanbul.

Grecia - Greece, the cradle of ancient Greek civilization.

Larissa - Larissa, a city in Thessaly.

Archaia - Arcadia (or Achaia?).

Macedonia - Macedonia, a country in the north of ancient Greece. It was originally called Emathia, and was significantly expanded by the conquests of Philip, the father of Alexander the Great. He annexed to his kingdom: Paeonia in the north; part of Thrace in the east to the River Nestos, as a district which the Thracians commonly called Macedonia Adiecta; the Halkidiki peninsula in the south; and in the west part of Illyria to Lake Lychnitis (Thurston, 1898).

Roma - Rome, the capital of the Roman Empire and the seat of the Roman Catholic Pope.

Cisilia - Sicily, an island.

Creta - Crete, an island.

Calipso - Calypso. Mythical island according to Homer's Odyssey.

Mare - Sea (unknown).

Saxonia - Saxony, part of Germany.

Ala - Halle, Saale in Germany.

Coloni[a] - Cologne, an ancient Roman city on the Rhine. The relics of the Holy Three Wise Men are kept in the famous Cologne Cathedral, which were brought to Cologne in 1164 as great shrines. According to the New Testament, sages from the East first came to worship the newborn Jesus and to present him as a king with gold, as a god with incense, and as a man with a noble myrrh (Matthew 2: 1-2, 11).

Bri[tannia] - Britain.

Walni - Wales.

Scocia - Scotland.

Ibernia - Hibernia, Ireland.

Cornu[bia] - Cornwall.

Bolonia - Boulogne-sur-Mer.

Burgu[n]dia - Former Duchy of Burgundy, today mainly the region of Burgundy.

Parisius - Paris (the icon is shown on the island of Île de la Citè).

Bel[gis] - City of Belgis (?). According to Isidore (14.4.26): *Belgis autem civitas est Galliae, a quo Belgica provincia dicta est.* [The city of Belgis is Gaelic, after which the province of *Belgica* is named].

Normannia - Normandy.

Equitania - Aquitaine. Normandy and Aquitaine were part of the Angevin Empire (Fr. - L'Empire Plantagenêt), which existed between 1154 and 1242. King Henry III of England considered them his hereditary lands. Because of that, they were probably marked on the map, while the other provinces of France were left out.

Lugdune[n]sis - Roman Province *Gallia Lugdunensis*. Its capital was Lugdunum (the current site of Lyon).

Barcinona - Barcelona.

Hispania - Spain.

Galicia – Galicia. Area in the northwest of the Iberian Peninsula. The capital city Santiago de Compostela has been one of the most important places of pilgrimage in Catholicism since the Middle Ages (the Camino de Santiago route), because relics of St. James the Great lay there (hence the name of the city of Santiago).

[Colum[p]ne Herculis] - Pillars of Hercules (drawing next to Gibraltar).

[Mons Pireneus] - Pyrenees mountains (drawing without inscription).

[Alpes] - Alpine mountains (drawing without inscription).

M[ons] Riphei - Riphean mountains, north of the Pontus, probably the Urals. A nameless river springs there, probably Tanais (Don), or perhaps Borysthenes (Dnieper), although none of them in reality spring from high mountains.

Ip[er]bor[e]a - Hyperborea. Hyperboreans are the mythical northernmost people. Solinus (16.1) mentions the Hyperboreans as blessed people. Maybe Lapps?

Mons Sueuus - Swabian mountains from the term Svevi - Schwabe. That term may also mean the Swedish mountains (Chekin, 2006). Further west is Saxony, which stretches, according to maps, on the shores of the North Ocean.

Norwegi[a] - Norway (shown as an island).

Rivers without names are: Rhône and Saône, Rhine with two tributaries, Tiber and Arno.

Geographical contents in Africa

The name Africa is not written on this map. The ancient Greeks called the African continent Libya. The Romans meant only the northern, Mediterranean part of the continent, which they divided into provinces. The border between Asia and Africa was not clearly defined. According to Orosius (1.2.8), Africa begins in Alexandria. On the Psalter World Map, *Egyptus* (Egypt) and *Athiopia* (Ethiopia) are marked, which were considered part of Asia, and to the west, the Nile Delta, North Africa and the Atlas Mountains area are exaggerated.

Sub-Saharan Africa is shown only as a zone with fourteen mythical monstrous half-human races. Pliny the Elder in his work "Naturalis historia" (The Natural History), around 77 AD, described a series of monstrous races in "India" (which was the collective name for the entire Far East) and in "Ethiopia" (or Africa), and they were adapted by Julius Solinus in the 3rd century. For example, on the southern margin of the Psalter Map we find drawings of the following fourteen monstrous races, which were identified by Conrad Miller (Miller, 1895), based on the description of Pliny and Solinus:

1. *[Phanesii]* - Panotti, a people with huge ears with which they can cover themselves;
2. *[Sine naribus]* - People without noses, whose faces are weakly expressed;
3. *[Gens ora concreta]* - People with other mouths, who feed themselves by drinking through a reed tube;
4. *[Gentes carent lingua]* - People without tongues, use nodding and gestures to talk;
5. *[Psambari]* - People without ears;
6. *[Marmini Ethiopes]* - Mauritanians or maritime Ethiopians - people with four eyes, and therefore very accurate in archery;
7. *[Sciapod / Monoculi]* - People with one very large foot and one eye, lying on their back and use their foot as an umbrella;
8. *[Amyctreae] (Gens labro prominente)* - People with oversized lower lips used for face protection from solar heat;

9. *[Blemmye]* - People who have eyes and mouths on their chests;
10. *[Oculis in humeris]* - Epiphagi, people without a head with eyes on their shoulders;
11. *[Trocodites]* - Troglodytes, inhabitants of caves who eat wild animals and snakes;
12. *[Artobatitis]* - People who walks on all four legs;
13. *[Anthropophagi]* - Cannibals;
14. *[Antropophagic Cynocephales]* – Cannibals with dog heads.

Toponyms in Africa

Ethiopia - Ethiopia, a country south of Egypt, which embraced Christianity very early.

Nilus fl[uuius] – The River Nile, with seven tributaries in the Delta.

Stannum - Mountain lake, source of the River Nile.

Montes Nubie - Nubian Mountains.

Egyptus - Egypt (biblical Miṣr).

Memphis - Memphis, the first imperial city in history. Founded around 3500 BC as an administrative the center of Upper and Lower Egypt, 25 km south of present-day Cairo.

Alexandria - Alexandria.

Babilonia - the city of Cairo in Egypt. It should not be confused with Babilonia Magna in Mesopotamia (Савић, 2015).

C[iuitas] Saltabri - City of Saltabri (unidentified).

Damiete - Damietta, Tamiatis, a city in the Nile Delta. In the 12th and 13th centuries, it was targeted on several occasions by crusaders as a strategically important point for the conquest of Egypt and Palestine.

Tapnis - Daphnae, today's al-Dafna, an ancient city in Egypt, on the road from Pelusium to Memphis. Many Jews settled here after the destruction of Jerusalem. It is mentioned in the Bible as Tahpanhes (Jeremiah, 43: 7,8; 44: 1; 46:14) or Tehaphnehes (Ezekiel, 30:18).

Pelusium - Pelusium, Pelusion, a city in Sinai, today's Tell el-Farama. It is mentioned in the book the prophet Ezekiel (30:15).

Beronice - Berenice, today's city of Benghazi in Libya. Ancient Greek colony Hesperides (Eusperides), later renamed Berenice (probably after Berenice, an Egyptian princess, daughter of King Ptolemy II and the Seleucid queen). The city was one of the five cities of Pentapolis, Cyrenaica, an ancient Christian episcopate.

P[rouincia] Lexa[n]dria - Province of Alexandria. Instead of the initial letter A is a hyphen.

Terra arenos et sterilis - Sandy and barren land (Sahara desert).

Are Philenor[um] - The Altars of the Philaeni, on the border between Carthage and Cyrene. Two landmarks on the place where the two Philaeni brothers from Carthage agreed to be buried alive in order to mark the border and establish peace. They are mentioned by Strabo (III, 171; XVII, 836), Polybius (II. Cc .; III. 39); Salust South. (19, 79); Pliny (V. 4); Mela (I. 7: 6); Skilax (p. 47).

Cartago - Carthage, a city and state in today's Tunisia.

Zeugis r[egio] - Zeugitāna Regio, northern part of Tunisia, former northern region of Africa Propria in Carthage Empire, which surrounded Carthage. The area of Byzacium or Byzacena stretched to the south.

Mauritania - Roman Mauretania stretched between the Atlantic in the West, the Mediterranean in the North, Numidia to the East, and Getulia to the South. The Romans came to this land during the war against Jugurtha 106 BC. In the time of Caligula in 40 AD, it became a de facto Roman province, and was formally constituted as such by Claudius, a large part of Numidia was added to it and divided along the river Malva into a western part, called Tingitana after the capital Tingis (Tangier), and an eastern part called Caesarea, after the capital of Julius Caesar (Zershell). In the later division of the empire under Diocletian and Constantine, the eastern part of Mauritania Cesariensis, from Saldae to Ampsaga, was proclaimed a new province and named Mauritania Sitifensis after the city of Setifs. Under the later Roman emperors, Mauritania had a large number of episcopal chairs (Thurston, 1898).

M[ons] Atlans - Atlas Mountains.

C[iuitas] Oliopolim - Heliopolis.

Monasterium S[ancti] Pet[ri] - Monastery of St. Peter (marked with a triangle with a cross on top). It is about the Orthodox Coptic monastery of St. Anthony in the oasis of the Eastern desert in Egypt, which has an ancient church dedicated to St. Peter and Paul.

Orrea Iosep - Joseph's barn. They are mentioned in the Old Testament (Genesis: 40). They were marked with three pyramidal signs, because the pyramids were considered to be barns.

Presuli duo manent - Two bishops stayed here. Regarding Orrea Joseph, this suggests that two bishops always resided at the pyramids.

C[iuitas] Garema - Germa in Libya. The ancient name of Garama. It was the capital of Garamantide - the land of the Garamantes, from the 11th century BC to 669 AD.

Getulia - Gaetulia (Orosius, 1.2.90) and Gaetulos (Isidore, 14.5.6), an area in north-west

Africa inhabited by Gaetuli (Romanized name for Berbers).

P[rouincia] Mathabres - Province of Natabres. It is also mentioned on the Hereford map.

Gorgade[s] - Cape Verde (?)

Tacona - Tarragona (?), as an island. Orosius (1.2.104) mentions the city of Tarragona on the island of Mallorca.

Figure 1. The London Psalter Map, BL Add. MS 28681, f.9r
(red letter inscription by M. Grčić)

Figure 2. Psalter List Map, 13th century, British Library Additional MS 28681, f. 9 v

Iconography and symbolism of the map of the Psalter List

The Psalter List Map is a schematic T-O type world map that contains a list of areas and cities classified by continents of the Old World. This map is significantly different from the previous map on the obverse. The textual content in a circle with a diameter of 17 cm, "provides the observer with the opportunity to participate in a dynamic devotional form that has its roots in the geography of humanity and the earthly kingdom." Christ as the creator presides over the macrocosm in the act of creation" (Brott, 2018).

The Psalter List Map shows the figure of Jesus Christ standing and hugging the Earth's disk divided into three parts, which represent the continents of Asia, Europe and Africa. In that illustration, the Earth's circle covers almost the entire body of Jesus. His head is above the world, which he hugs with open arms, while standing barefoot on the heads of two feathered dragons, under the Earth's disk. The fact that the head of Jesus is above the world, the Earth's disk on the body of Jesus and the dragons under the feet, symbolizes that God controls the heavenly, earthly and underground world. Two-legged dragons with a snake-like tail are depicted as trickery and evil. The serpent is the only living thing that God has cursed (Genesis 3:15) and punished as the embodiment of evil (Romans 16:20; Hebrews 2:14; 1 John 3: 8; Revelation, 12: 7, 17). In the upper left and right corners of the heavenly vault are four winged angels who gesture with their hands towards the central figure, as if presenting Christ the Savior to the world. Alternatively, they may be helping Christ in the Last Judgment. The circular disk, which represents the world, covers the whole body of Christ, so that only his head, hands embracing the world and feet can be seen. There are opinions that this figure represents Adam, who shows the four corners of the world with his body, but the presence of four angels indicates that it is still Jesus Christ, who is here in the role of another Adam.

Analysis of geographical contents of the Psalter List Maps

The Psalter List Map contains the names of 75 areas and 77 cities in Asia, Africa, and Europe (Brott, 2018). In addition, 39 initials identify areas (provinces). The map shows twelve places from the text of the Psalter: Egypt, Tarshish, Arabia, Saba, Judea, Jerusalem, Babylon, the Jordan River, Mesopotamia, Syria, Ethiopia and Assyria. Egypt is listed in the Asia area, while Saba is listed in the Africa area, in the province of Ethiopia. Some of the geographical names on the Psalter List Map are not marked on the

previous Psalter World Map, for example: Wasconia (Gascony), Pictavia, Neustria, France, Alemannia, Saxonia, Gothia, Wadelia, Bulgaria. Some names exist on both maps, but with different spellings, for example Jazar appears on the map and Tazar appears on the Psalter List. The order of the names of places may correspond to their place on the map, but they could also be arranged according to the route of travel starting from the southeast to the northwest. Their appearance is organized by landmarks more than by longitude and latitude, with the indication of places, in order for travelers to prepare for the cities they will meet in each region while traveling a certain route. The European area on the Psalter List Map may have been influenced by pilgrimage routes and itineraries but the cities listed do not form a clear travel route nor do they appear to coincide with any known pilgrimage route. Perhaps this Psalter List highlights some of the historically and religiously significant cities on the continent. Each city could serve to remind the observer to recall some information related to that location. The following is a list of toponyms by continent, in the order shown on the original.

Geographical list of areas and cities in Asia

- *Aſia maior h[abe]t pr[o]uinciaſ· xviii·ciuitateſ p[ri]ncipaleſ· xxxi[a]· - Greater Asia has 18 provinces [i] 31 capitals.*
- *In India: eſt·c(iuitates)·[illegible] Thazaron·Sagaſta ·* - In India, the cities of Thazaron [and] Sagasta. Thazaron (Jazaron on the Psalter World Map). Related to the name Lazorum gens, which appears on the Ebstorf map (Miller, 1896), or "gens optimam Cathmorum" (people who reside in India) which appears in the work of Hugh of St. Victor under the title "Descriptio mappae mundi". Sagasta has not been identified, perhaps Sagadan mentioned by Hugh of St. Victor (Gautier Dalché, 1988).
- *In Parthia: Aracuſa·(et) [*ctisfon] ·* - In Parthia: Cities Arachosia and Ktesiphon. Parthia is a historical area in northeastern Iran, which encompassed the western half of Greater Khorasan and was the political and cultural core of the Parthian Empire. Arachosia is an ancient territory in Afghanistan and Pakistan, with the capital Alexandria (today's Kandahar). Ktesiphon was the capital of the Parthian and Sasanian empires in Mesopotamia.
- *In Media: Meda (et) Elam ·* - In Media: Meda and Elam. Media was the first Iranian empire, from the end of the 8th to the middle of the 6th centry BC.

Elam is an ancient civilization (2700 - 539 BC) in the west and southwest of present-day Iran (Ilam province, lowland Khuzestan) and parts of Iraq.

- *In Affrica: Theſia·(et) archademo(n) ·Thesia (?)* - In Africa (Africa is incorrect name for Assyria): Thesia (perhaps Theodosiopolis, Erzurum) and Archademon (perhaps Archimedon, mentioned by Hugh of St. Victor in connection with Assyria) (Wacha and Lewrnier, 2019).
- *In P(er)ſida: P(er)ſepol(is) (et)duſiſ* - In Persia: Persepolis and Dusis. Persia is today's Iran. Persepolis, the ancient Persian name of Parsa, was the capital of the Achaemenid Empire (550 - 330 BC). It was built by Darius I, about 70 km northeast of the present-day city of Shiraz in the Iranian province of Fars. Dusis, more precisely Susis is Susa, one of the residences of Darius I.
- *In Meſopota(m)ia: Edeſſa (et) niniue(m)* · - In Mesopotamia: Edessa and Nineveh. *Edesa* is the predecessor of today's city of Urfa, in the province of Shanliurfa in upper Mesopotamia. It is important in Christianity as the birthplace of the apostle Thaddeus and the place where the Holy Mandylion was located (the miraculous icon of Jesus Christ on canvas). During the First Crusade, the Crusaders founded the county of Edessa in 1099. *Niniva* - the biblical "great city" (Jonah 3:2, 4:1), on the east bank of the Tigris, in present-day Mosul in northern Iraq.
- *In Caldea: Carra (et) Babilo(n)ia magna* - In Chaldea: Carra and Babylon (Babilonia Magna). Chaldea is the ancient name for Mesopotamia. It is known that the biblical Babylon was in Chaldea. According to Strabo, "New Babylon is a fortress, built by Babylonian exiles near Memphis in the time of the Persian kings ... From there you can clearly see the pyramids on the opposite bank of the river near Memphis, which is nearby" (Strabo, XVII, I, 30). In one document from the first half of the 12th century, it is said that Caesarea Palestine under the Saracens flourished between Babylon and Babylonia, that is, between Baldach (Baghdad) in Persia and Memphis in Egypt" (Савић, 2015). Ludolf von Sucheim says that "New Babylon and Cairo (Carra / Alcayre) are two extremely large cities, not far from each other, located on the Nile, a paradise river." It then goes on to call the city, which was once called Carra (Cairo) now Alcayre. Ludolf goes on to talk about "Old Babylon" which is located northeast, about thirty days away from the Nile Delta (Deycks, ed. 1851; Ludolphus, digital 2013). "Pilgrims and travelers used the name Babylon for both cities - Chaldean and Egyptian" (Laurent, 1873).

- *In Arabia: Philadelphia(i)* - In Arabia: Philadelphia. This is Amman, which is referred to in the Bible as "Rabbath Ammon". Egyptian King Ptolemy II Philadelphus ruled the city from 285 to 246 BC and renamed it after his name in Philadelphia (meaning "brotherly love").
- *In ſyria: A(n)tyochia·i(n) q(ua) (et) Damaſcuſ ·* - In Syria: where Antioch and Damascus are. Antioch (present-day Antakya in Turkey) is mentioned in the New Testament (Acts 6: 5; 11:21, 27; 13: 1; 15:23, 30). The Church of Antioch is one of the oldest Christian communities, founded in 37. Its first bishop was the Holy Apostle Peter. The Church Council of Antioch was held in 341. Damascus is also mentioned in the New Testament (Acts 9: 2, 3, 8, 10, 19, 27).
- *In Iudea: I(e)r(usa)l(e)m i(n) q(ua) (et) Bethleem* - In Judea: in which are Jerusalem and Bethlehem. Judea is a geographical area and a former Roman province. According to the New Testament, Jesus Christ was born in Bethlehem, and he was crucified in Jerusalem.
- *In Galilea: Nazaret Caphernau(m)* - In Galilee, Nazareth and Capernaum. Galilee is a predominantly mountainous region in northern Israel. Nazareth is mentioned in the New Testament as the place where Jesus Christ spent his childhood. In the First Crusade, the Crusaders conquered Galilee and proclaimed Nazareth as its capital (1099). Capernaum - a city in the north of the Sea of Galilee. It is mentioned in the New Testament as a place of preaching Jesus Christ and miraculous healing of people.
- *In samaria sebaſte q(ue) olim dicebat(ur) ſamaria* - In Samaria, Sebaste[a] which was once called Samaria. A mountainous area and city (Hebrew - Shomron) in the northwestern part of Eretz Yisrael ("Land of Israel").
- *In Paleſti(n)a Ascalo(n) (et) Azot(us)* - In Palestine, Ashkelon and Azotus. Ashkelon, the birthplace of King Herod. It is mentioned in the Bible (Joshua 13: 3; 1 Samuel 6:17; 2 Samuel 1:20; Judges 1:18; Jeremiah 25:20; 47: 5, 7). The Crusaders conquered it in 1153. Azotus (Ashdod, now Esdud). It is mentioned in the Bible (Joshua, 1:22; 13: 3; 15:46, 47; 1 Samuel 5: 1,2; 1 Isaiah 20: 1; Jeremiah 25:20; Zechariah 9: 6; 2 Chronicles , 26: 6).
- *In egipto: Alexa(n)dria (et) c(iuitates) glath (et) Me(m)phiſ ·* - In Egypt: Alexandria and the cities of Glath and Memphis. Glath has not been identified. Memphis - the ancient capital of Egypt, south of modern Cairo.
- *In Etheopia: Nadaber* - In Ethiopia: Nadabah.

- *In Cilicia·Tharſiſ* - Tarsus city in Cilicia (Cilicia was located on the border of Asia Minor with Syria), which is mentioned in the Bible (Jonah, 1: 3; 4: 2). Today's Tarsus in Turkey.
- *In frigia: yliu(m)·(et)·t(ro)ia·* - In Phrygia: Ilium and Troy (mentioned in the Iliad).
- *In Nichomedia: Bithi(ni)a·* - In Nicomedia: Bithynia. In fact, it's the other way around. Bithynia is a province on the northern coast of Asia Minor. It is mentioned in the New Testament (Acts 16:7; Peter, 1:1). One of its cities was Chalcedon. Nicomedia or Nicomidia is an ancient city on the site of today's Izmit in Bithynia. It was founded and named after the Bithynian king Nicomedes I of Bithynia.
- *Aſia minor h(abe)t p(ro)ui(n)cia(s)·xi·c(iuitates)·principaleſ·xiii·In illa eſt Epheſiſs* -Asia Minor has eleven provinces, thirteen capitals. In it is Ephesus. Ephesus is one of the two most important ancient cities in Asia Minor (the other is Smyrna). It is mentioned in several places in the Acts of the Apostles and the Epistles of St. Paul in the New Testament.
- *In Cypro inſula · c(iuitas) · Paphuſ·* - On the island of Cyprus the city of Paphos (birthplace of Aphrodite. Visited by St. Paul).
- *In armenia·c(iuitas)·Calcedonia·* - In Armenia Halkidon. In the ancient Greek city of Chalcedon, the Fourth Ecumenical Council was held in 451. Today, the city is part of Istanbul called Kadikoy (Turkish: Kadiköy - Judge's Village).
- *In Creta inſu[la]·ciuitaſ Centapoliſ* - On the island of Crete, the city of Centapolis. Maybe Pentapolis. Crete and Cyrenaica formed a Roman province in 27 BC. Cyrenaica was called Pentapolis.
- *In licaonia·ciuitaſ Niacetum·* - In Lycaonia, the city of Nicaea. Lycaonia is an area in the interior of Asia Minor. Nicaea or Iznik is an ancient city in Anatolia. It is known in church history as the venue of the First and Second Ecumenical Councils of Nicaea).
- *In Sicilia·Ciuitaſ·Siracuſana· Cathinia·* - In Sicily the city of Syracuse [and] Catania. Syracuse is known as the place where Archimedes lived, and for the Christian catacombs from early Christianity (Acts 28:12). The Kingdom of Sicily was founded by the Normans in 1130. Catania is the second largest city in Sicily, close to Mount Etna.
- *[I]n Capadocia·Ciuitaſ eiuſdem nominiſ·(et)(·)abduſ* - In Cappadocia the city of the same name and Abdus. Cappadocia is a vast province in eastern Asia Minor. It is mentioned in the New Testament (Acts 2: 9; 1 Peter, 1: 1).

- *In Sithia ſuperiore: Ciuitaſ·Gangaria* - In Upper Scythia the city of Gangaria (unidentified).
- *In ſithia i(n)feriore·...* - In Lower Scythia ...
- *In hyrca(n)ia·deſ(er)ta m(u)lta ·(et)·c(iuitas)·Padau(m)·* - In Hyrcania many deserts and the city of Padaum. Hyrcania is a historical-geographical region southeast of the Caspian Sea, in today's Iran and Turkmenistan. Padaum has not been identified.
- *In alba(n)ia·c(iuitas)·ſpartu(n)* - In Albania, the city of Spartun. It means Caucasian Albania. The city of Spartun or Partan on other medieval *mappae mundi* is situated within the province of Armenia or Parthia.

Geographical list of areas and cities in Europe

- *Europa h(abe)t p(ro)ui(n)ciaſ·xxxiiii·c(iuitates)·p(rin)c(ipales) p(ro)ui(n) cial(es)·xxv·* - Europe has 34 provinces, [and] 25 main provincial cities.
- *p(ro)ui(n)c(ie)·Tracia* - province of Thrace. Historical-geographical area in the southeast of the Balkan Peninsula, divided between Bulgaria, Greece and Turkey.
- *Grecia. - Greece.*
- *Achaia. - Achaia.*
- *Boetia· - Boeotia.*
- *Dalmatia· - Dalmatia.*
- *Dardania ·* - Dardania. A Roman province formed by Emperor Diocletian in 284, in the southern part of Upper Moesia, with the capital Naissus.
- *Theſſalia ·* - Thessaly.
- *Lacedemonia ·* - Lacedaemon, the ancient name for Sparta.
- *Theſſalia minor ·* - Little Thessaly.
- *Apulia ·* - Apulia.
- *Ytalia i(n) q(ua)roma ·* - Italy where Rome is.
- *Ca(m)pania ·* - Campania
- *Hyſpania ·* - Spain.
- Galecia · - Galicia, an area in the northwest of the Iberian Peninsula, in Spain.

- *Wafco (n)ia i(n) q(ua) b(or)deleſ* · - Gascony, in which Bordeaux is.
- *Pictavia* - Poitiers, a city in France. In the battle of Poitiers in 732, the French stopped the Moorish invasion of Central Europe.
- *Aq(ui)ta(n)ia*· - Aquitaine, region of France.
- *Neuſtria*· - Neustria means "western kingdom" in the northwest of the Frankish state during the Merovingian dynasty, from the 6th to the 8th century, as opposed to Austrasia or the "eastern kingdom" or Austria.
- *Franc(n)cia* - France.
- *Allemannia*· - Germany.
- *Dacia*· - Dacia (lat. Dacia), a state created by the Dacians in the first century, in much of present-day Romania. On the Ebsdorf map from 1234, it is marked: *Dacia regio et Gotia orientalis*.
- *ſaxonia*· - Saxony.
- *Gocia*· - Gothia, a Christian principality on the Crimean peninsula, from the 13th to the 15th century. It was also called the principality of Theodore and was one of the hereditary states of the Byzantine Empire after the crusade in 1204.
- *Scicia* - Scythia.
- *Wa(n)dalia* · - Vandalia. Many researchers, on the basis of ancient sources, equate the Wends (Slavs) with the Vandals, who were divided into tribes and founded kingdoms throughout the Slavic area. The Germans called the Lusatian Sorbs Wendels (Vandals).
- *Bulgaria*· - Bulgaria
- *G(er)ma(n)ia*· - Germania (Roman name for territories inhabited by Germanic tribes).
- *Meſſia* - Moesia, a Roman province in parts of present-day Serbia and Bulgaria. It was divided in the time of Domitian, 85 or 86, into Upper and Lower Moesia.
- *Pa(n)no(n)ia* · - Pannonia, a Roman province. At the beginning of the 2nd century, it was administratively divided into Upper Pannonia (Pannonia Superior) in the West and Lower Pannonia (Pannonia Inferior) in the East.
- *Gallia bellica*· - Gallia Belgica, a former Roman province in present-day Belgium, Luxembourg and neighboring parts of France, Germany and the Netherlands. The indigenous population was Belgians, a mixture of Celts and Germans.

- *c(iuitas)·Belgiſ·* - City of Belgis (in the Roman province Gallia Belgica).
- *B(ri)ta(n)nia maior c(iuitates)·lo(n)do(n)ia· Ca(n)tuar(ia)·* - United Kingdom, cities London [and] Canterbury. Canterbury is the center of Christianity in England, known for the Canterbury Cathedral from 597. It was the seat of the first Archbishop Augustine of Canterbury, who is considered the Apostle of England and the founder of the Church in England. Archbishop Thomas Beckett (1170) was killed and buried in the cathedral, which made the cathedral a place of pilgrimage for members of the Catholic Church and the Anglican community.
- *Hyb(er)nia· c(iuitates)·Dublinia·Armachuſ·* - Ireland, the cities of Dublin and Armagh (an important religious center of Ireland since Celtic times).
- *Scocia ciuitaſ ſ(an)c(t)i Andree·* - Scotland, the city of St. Andrews (St. Andrew, the ecclesiastical capital of Scotland).
- *NorWegia·* - Norway.

Geographical list of areas and cities in Africa

- *Termini affrice ·Ex parte orientis · Nilus A meridie zona torrida · A septe(n)t(ri) one ma[re] medit(er)raneu(m)· Ab occide(n)te medit(er)ranei m[are] refluxio· H(ec) h(abe)t p(ro)vi(n)cias s(u)bscriptas·* - Borders of Africa: East, Nile; in the south the tropic zone; in the north, the Mediterranean Sea; to the west, the Mediterranean Sea (Gibraltar Pass). It has the provinces listed below:
- *In libia: C[iuitas] · Cirene ·* - In Libya the city of Cyrene. Cyrene was originally a Greek colony, known as the home of the poet Callimachus, the founder of the New Academy in Athens, Carneacles, the mathematician and geographer Eratosthenes, and the ancient writer Synesius, who associated Neoplatonic conceptions with Christian teaching. Cyrene is mentioned in the Bible in connection with the Jewish diaspora and in the New Testament in connection with Simon of Cyrene who carried the cross for Jesus (Matthew 27:32; Mark 15:21; Luke 23:26) and other preachers (Acts, 2:10, 6: 9; 11:19, 20).
- *In zeugi q(ue) (est) [uera] affrica: C(iuitas) Kartago ·* - In the region of Zeugis which is [real] Africa: the city of Carthage, on the site of today's city of Tunisia.
- *In Getulia: ...*– In Getulia [illegible]. Getulia (Gaetulia) is an ancient area in north-west Africa, south of Mount Atlas, in the vicinity of the Roman province of Mauritania.

- *In Numidia: C(iuitas)· Ippone·* - In Numidia: the city of [H]ippone, today's port city of Annaba in Algeria. Numidia is a Roman province in North Africa, and the city of Hippone is the birthplace of Saint Augustine.
- *In Maur[ita]nia: C(iuitas)·Ceſarea·* - In Mauritania: City of Caesarea. The eastern part of the Roman province of Mauritania was named Caesarea, after the capital of Julius Caesar, near the present-day city of Cherchell in Algeria.
- *In Tingitan[ea?] [:?] [C(iuitas)·?] Tingiſ ·* - In Tingitana (in the Maghreb area), the city of Tingis (today's Tangier in Morocco).
- *In Ethiopia orienta[lis·] [C(iuitas)·?] Saba·* - In Eastern Ethiopia, the city of Saba.
- *In Ethiopia occide(n)t[alis·] Gades·Iux(ta) q(uam) mo(ns) Athl[as]* - In Western Ethiopia, Cadiz, near the Atlas Mountains. Here, the term Western Ethiopia refers to northwestern Africa.
- *In Ethiopia ult(er)i[ore :] monſtra ſu[illegible]* - In external Ethiopia: creatures [further illegible].

Conclusion

Medieval maps or *mappae mundi*, were used not only to present a geographical image of nature and people, but also to show the biblical world after God's act of Creation. A map of the real geographical world, and complementary images, illustrate medieval semi-mythical geography. The real geographical world is placed in the context of the belief in salvation and in the moral framework of the Christian imagination, emphasizing, for example, in the two maps of the world in the London Psalter, that the world is not only created but protected by God and perhaps even the body of God. Such maps had a primary function in devotional practice, but could also serve as an itinerary on pilgrimages and as an educational tool in religious studies and theology, aiding in memory and providing guidance on information on a variety of topics that could never be fully written on such a small paper.

The Psalter World Map and the Psalter List Map have textual and pictorial content, which allows them to have multiple functions, as works of art and as a reference guide for religious and secular texts. Text, image, and map function in such a way that they manage to convey information and yet remain ambiguous enough to allow for different interpretations. Succeeding in combining so many different areas of study on such a small

paper, the psalter maps aimed to attract readers, inviting them to return to the geographical map again and again to reflect on the diversity and greatness of the world as God's creation. Today, the Psalter World Map attracts the attention of researchers who deal with the history of the expansion of the geographical horizon of man, or the history of the geographical knowledge of medieval people.

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APPLICATION OF GIS IN SELECTION OF LOCATION FOR CONSTRUCTION OF NUCLEAR POWER PLANTS IN SERBIA

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Abstract: The use of nuclear energy in the world represents one of the main alternatives to fossil fuels. Significant greenhouse gas emissions from fossil fuel combustion could be replaced by cleaner energy such as nuclear. In this paper, by using Geographic Information Systems (GIS), available databases and Analytic hierarchy process (AHP), the results in the selection of the location for the construction of nuclear power plants (NPP) in Serbia were obtained. The research area includes zones between large rivers (Danube, Sava, Tisa, Velika Morava) with an area of 8757.45 km². An analysis of natural (seismicity, geological background, hypsometry, slope of the terrain, distance from faults, ground cover, land use method) and anthropogenic conditions (distance from the state border, settlements, roads and railways) was carried out, with the elimination of protected areas from further research due to of its ecological significance. After multi-criteria analysis, weighting coefficients were assigned for each criterion using the AHP method. The results showed that 0.02% of the area is suitable, and 8.68% partially suitable for the construction of nuclear power plants. This paper provides an adequate overview of the most suitable locations for the use of nuclear energy, so that the obtained results can be applied in further research by national services in charge of nuclear sciences.

Key words: nuclear power plants, GIS, Serbia, AHP

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Introduction

Not so long ago, solutions to many problems of human society were expected from mastering of nuclear energy. The first nuclear power plant was put into operation in the 1950s. Today, nuclear energy provides about 10% of the world's electricity from about 450 nuclear reactors (World Nuclear Association, 2021). Nuclear technology uses energy released by the splitting of atoms of certain elements.

Global energy demand is projected to grow significantly over the next 50 years. Much of that demand will come from parts of the world where energy consumption is relatively low compared to developed countries and which will be increasingly included in the global economy (Kristiansen, 2017; Cvetković et al., 2021). As demand grows, the world community will face a serious challenge - producing enough energy to meet economic growth and improve social development while, on the other hand, the environment needs to be protected and improved. There is no doubt that it is a great responsibility of decision-makers to establish appropriate policies that would adequately address this challenge. Among the various energy sources that contribute to the world's reserves, nuclear energy ranks first in terms of complexity in decision-making. The economic, technological and social consequences of nuclear energy make every decision far more demanding and difficult. Serious questions that our society raises about nuclear energy include the safety of installations, the disposal of radioactive waste, the ability of nuclear energy to reduce greenhouse gas emissions, and a handful of questions about nuclear weapons (Nuclear Energy Agency, 2003). From the environmental aspect, the impact of nuclear energy exploitation on population and biodiversity is studied, but also on air, soil and water quality (Langović et al., 2017; Doderović et al., 2020; Durlević, 2020).

Electricity obtained in reactors through a controlled process of nuclear fission has great advantages over fossil fuels, from significantly lower fuel consumption (1 g of uranium replaces 2.5 tons of high quality coal), minimal CO_2 emissions into the atmosphere, lower prices of 1 kWh of produced electricity (Хајдин & Поломчић, 2016).

The biggest shortcomings refer to nuclear safety, which is associated with catastrophic and long-lasting consequences in case of accidents, then the problems of storing of used-up nuclear fuel that remains radioactive for thousands of years, then declining uranium reserves in the world,

and very expensive and long construction of nuclear power plants (NPP). Endangering the environment with the use of fossil fuels in recent years has strengthened the position of supporters of the use of nuclear energy, but it was enough that one accident, such as the last one in the Fukushima Daiichi NPP in Japan, to question all its benefits, and in many countries even to ban the use of this type of energy (Preston et al., 2007; Visschers & Siegrist, 2013; Neumann & Hopf, 2013; Park & Ohm, 2014; Rhodes, 2014; Ercan et al., 2015; Fukunaga, 2021). Since the Chernobyl disaster in 1986 (Borzilov & Klepikova, 1993; Makhonko et al., 1996; Bennett et al., 2006; Saenko et al., 2011) in European countries, a moratorium on the construction of NPP is still in force (Хајдин & Поломчић, 2016). Public concern is growing when it comes to the application of nuclear energy, especially after major nuclear disasters (Peters & Slovic, 1996; Sjöberg, 2000; Viklund, 2004; Smith, 2013; Sundström & McCright, 2016; Filipović & Kešetović, 2017). With the approval of the Law on the Prohibition of the Construction of Nuclear Power Plants in the Federal Republic of Yugoslavia, a moratorium was introduced in Serbia, which prohibits not only the construction of nuclear power plants but also their development. The ban also applies to investment decisions, implementation of investment plans and technical documentation for the construction of nuclear power plants, nuclear fuel production plants and used-up nuclear fuel reprocessing plants. Due to this ban, the study of nuclear energy and technology in higher education institutions has been reduced to a minimum (Cvetković et al., 2021).

Serbia, which has no NPP, is surrounded by nuclear reactors, most of which are on the Danube, a transit river. In the vicinity of Serbia, in the diameter of 600 kilometers, there are nuclear power plants "Krsko" in Slovenia, "Kozloduy" in Bulgaria, "Paks" in Hungary and "Cherna Voda" in Romania (Стојсављевић, 2008).

Using Geographic Information Systems (GIS), the paper will present potential locations for the construction of nuclear power plants in the territory of the Republic of Serbia through various criteria and analyzes. The research area covers a zone of 5 kilometers on both sides of the riverbed: Danube, Sava, Tisa and Velika Morava. This is one of the first papers in Serbia in which a modern methodology has been developed for the identification of the most suitable surfaces for the application of nuclear energy using software packages, databases and Analytic hierarchy process (AHP).

Materials and methods

Study area

The study area covers a zone of five kilometers on both sides of the bed of four large rivers in the territory of the Republic of Serbia: the Danube, Sava, Tisa and Velika Morava. Due to their hydro potential, these river flows were taken into account for the needs of the analysis of the mentioned area. As the minimum flow for the smooth operation of a nuclear power plant is in the range from 130 to 150 m^3/s, the investigated watercourses meet this criterion and their coastline may represent potential locations for the construction of nuclear power plants. The research area covers an area of 8757.45 km^2.

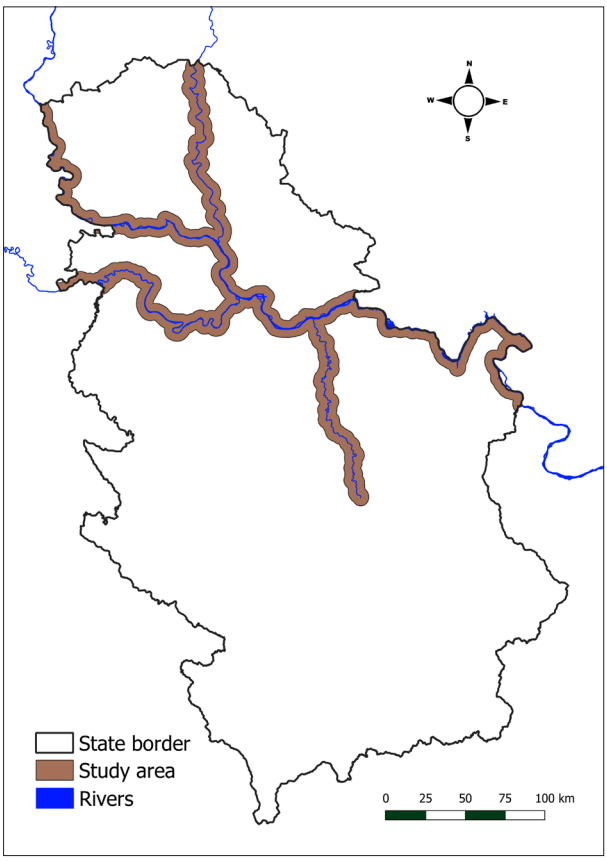

Figure 1. Geographical position

Depending on the type of cooling system to be applied in a nuclear power plant, large amounts of water are required. It is an essential part and is used daily, but is most necessary in the event of an accident when used to cool the core. In addition to the proximity of the river flow, important natural factors that were analyzed are: geological base, hypsometry, terrain slope, seismic hazard, faults and landslides, land use and pedological cover.

Methodology

Analytic hierarchy process (AHP) is a method of support in the decision-making process based on the formation of a hierarchy of problems and the original procedure for evaluating the elements by levels of the hierarchy until the final synthesis determines the weight of all elements at the lowest/highest level. Based on mathematics and human psychology, it was developed by Saaty (Saaty, 1980; Saaty 1990) and has been widely used worldwide ever since.

The AHP method is very flexible because it allows you to easily find connections between criteria and alternatives. This method approaches the relevance of real-world criteria and determines the interaction between the criteria, in the case of complex problems with many criteria and a relatively large number of alternatives. By applying this method, complex problems can be explained by a specific hierarchy, so that the analysis includes quantitative and qualitative aspects of the problem. AHP connects all levels of the hierarchy, which allows recognizing how a change in one criterion affects other criteria and alternatives (Forman & Selly, 2001; Atanasova-Pachemska et al. 2014). For the needs of analysis and interpretation of data and results, the software package QGIS 3.10 was used.

To obtain potential areas for the construction of nuclear power plants in the research area, the comparison of criteria in 3 groups was performed, and then the final comparison of the results obtained from each of the 3 groups separately. The criteria were placed in relation to each other, in order to then obtain matrices in order to further obtain the weighting coefficient for each criterion.

The first group that was analyzed were natural factors, the evaluation of seismic hazard was carried out, as well as geological base, hypsometry, slope of the terrain, ground cover and distance of the area from faults.

Table 1. Evaluation of natural factors

Seismic Hazard (MCS)	Grade	**Hypsometry (m)**	Grade
VI-VII	4	0-200	5
VII	3	200-400	4
VII-VIII	2	400-600	3
VIII	1	600-800	2
		>800	1
Rock type	Grade	**Terrain slope (°)**	Grade
Alluvial sediments	3	0-5	5
River-swamp sediments	3	5-10	4
Facies of the bed	2	10-15	3
Facies of the flood period	3	15-20	2
Facies of the abandoned riverbed	3	>20	1
River terrace sediments	3	**Distance from fault (km)**	Grade
River lake terrace	3	0-5	1
Deluvium-prolovium	3	5-10	2
Aeolian sediments	4	10-15	3
Tertiary clastic sediments	1	15-20	4
Tertiary clastic and carbonate sediments	1	>20	5
Flysch	1	**Ground cover**	Grade
Mesozoic clastic sediments + volcanoclastic rocks	1	Artificial surfaces	1
		Bare land	5
Mesozoic clastic and carbonate sediments	2	Agricultural land	3
Mesozoic clastic and carbonate sediments + volcanoclastic rocks	2	Grassy areas	4
Mesozoic carbonate sediments	3	Shrubs	4
Igneous rocks	5	Deciduous forests	3
Diabase-corneal formation	3	Mixed forests	3
Ultramafits	3	Evergreen forests	3
Paleozoic clastic sediments	2	Wet soils	2
Metamorphic rocks	3	Water surfaces	1

Seismic hazard is an extremely important factor in determining the locations for the application of nuclear energy and the aim is to keep the area where NPP would be planned, as seismically active as possible. A return period of 475 years was used for this research, and the data were taken from the Republic Seismological Institute. An indispensable factor in

the study of an area is the geological basis. When locating NPP one should be especially careful because on the composition of the rocks it depends whether a terrain is more or less prone to earthquakes, as well as landfalls and landslides. Tertiary clastic and carbonate sediments in which landslides are highly probable, but also flysch and Mesozoic clastic and carbonate sediments with volcanoclastic rocks do not represent adequate surfaces for NPP construction. On the other hand, magmatic rocks represent an ideal base for the construction of NPPs. Data on the geological base were obtained by analyzing the contents of the geological map of the SFRY.

Altitude is one of the important factors in locating nuclear power plants. Terrains up to 200 meters are suitable for construction, while with the increase in height, the possibility of proper construction decreases. The slope of the terrain represents a significant topographic parameter. The monitoring of hydrological phenomena, as well as the speed of surface water runoff, and the intensity of geomorphological processes, depend on the slope of the terrain. The most suitable terrains are those with a slope of 0° to 5° and occupy a significant part of the research area (more than 83%). Data on altitude and slope of the terrain were obtained through a Digital Elevation Model (DEM) with a spatial resolution of 25 meters. We used the EU-DEM issued by the European Agency for Environmental Protection. Faults are the basic structural units in the lithosphere that are formed by moving parts of the rock mass along a crack called a paraclase or fault surface. According to the paraclase, parts of the rock mass can be raised, lowered and moved longitudinally under the influence of vertical and horizontal pressures (Шестановић, 1997). As such, they represent a very unfavorable part of the terrain and care should be taken that certain facilities, especially nuclear power plants, are not built in their immediate vicinity, but as far away from faults as possible.

The way of land use in the research area is extremely heterogeneous. There are as many as 27 classes, and the landscape is predominantly covered by agricultural areas with a share of 41.26%, a significant area is occupied by deciduous forests with an area of 1405 km² of the observed territory. The most favourable locations for the construction of nuclear power plants - areas with sparse vegetation, have a spread of about 1.24 km². A geospatial database (Corine Land Cover, 2018) issued by the European Environment Agency was used to obtain data on land use.

By digitizing the areas from the GeoSrbija portal, a map of the basic ground cover was made, which more precisely shows the method of land use

in 10 classes. A significant share of 49.14% is occupied by agricultural land, while deciduous forests are second in share, with 20.76% of the surveyed territory. Bare lands that would be most suitable for the potential location of a nuclear power plant according to this class, have a share of 0.29%.

Protected natural assets are an elimination factor in finding a potential location for nuclear power plants in a specific research area. They occupy a total area of 1099.42 km², which is 12.55% of the total research area. During the analysis, protected goods located outside the territory of the research area were taken into consideration, because the impact of nuclear power plants would very much apply to them as well. Thanks to a joint project of UNEP and IUCN, the World Database on Protected Areas (WDPA) was obtained and used in the paper.

Table 2. Evaluation of land use

Land use	Grade	**Land use**	Grade
Settlements	1	Meadows	5
Larger settlements	1	Complex of agricultural plots	4
Industrial and commercial zones	1	Agricultural areas with natural vegetation	3
Traffic infrastructure facilities	1	Deciduous forests	2
Ports	1	Coniferous forests	2
Airports	1	Mixed forests	2
Exploitation of mineral resources	3	Pastures	4
Landfills	3	Woody and shrubby vegetation	5
Construction sites	2	Beaches, sand and dunes	3
Parks	3	Areas with sparse vegetation	5
Sports and recreational facilities	2	Swamps	3
Agricultural land	4	Larger rivers	3
Vineyards	4	Water surfaces	3
Orchards	4		

The proximity of the nuclear power plant to the state border is one of the most important safety criteria in the event of an accident. The Republic of Serbia borders eight countries, and if an emergency situation occurs, the impact would spread to surrounding countries, such as the 1986 Chernobyl accident. The most suitable areas with a distance of over 20 kilometers are represented with a share of 63.66%.

Table 3. Evaluation of anthropogenic factors

Distance from the state border (km)	Grade	**Distance from state roads (km)**	Grade
< 5	1	< 3	5
5-10	2	3-6	4
10-15	3	6-9	3
15-20	4	9-12	2
>20	5	>12	1
Distance from railways (km)	Grade	**Distance from the settlement (km)**	Grade
< 3	5	< 2.5	1
3-6	4	2.5-5	2
6-9	3	5-10	3
9-12	2		
>12	1		

Access to the main state roads and railways is an unavoidable factor in locating a nuclear power plant due to easier access to the power plant itself, but also the transport of radioactive waste to the disposal site. The content analysis concludes that the traffic infrastructure is at a satisfactory level because the areas of less than 3 km in the territory of the research area are most represented with a share of 72.03%. Nuclear power plants as an anthropogenic creation have a great negative impact if an accident situation occurs. For this reason, it is important that settlements be as far away as possible from a potential nuclear power plant.

In order to obtain potential areas for the construction of nuclear power plants in the research area, a comparison of criteria in 3 groups was performed, and then a final comparison of the results obtained from each of the 3 groups separately. The criteria from the tables are placed in relation to each other, in order to then obtain matrices in order to further proceed towards obtaining the weighting coefficient for each criterion.

Table 4. Assignment of values and comparison between parameters

Group 1	Geology	Seismic hazard	Slope	Faults
Geology	1	0.5	2	1.5
Seismicism	2	1	2.5	2.5
Slope	0.5	0.4	1	1
Faults	0.667	0.4	1	1
Group 2	Settlements	Roads	Railways	Border
Settlements	1	2.5	4	5
Roads	0.4	1	2.5	3
Railways	0.25	0.4	1	2
Border	0.2	0.333	0.5	1
Group 3	Land use	Pedological cover	Protected areas	
Land use	1	1	1.5	
Pedological cover	1	1	1.5	
Protected areas	0.667	0.667	1	
Groups	**Group 1**	**Group 2**	**Group 3**	
Group 1	1	3	4	
Group 2	0.333	1	2	
Group 3	0.25	0.5	1	

The mathematical operation of squaring the matrix gives a new one, in which by summing the values for each row of the matrix (criterion) and dividing each sum of the row by the total sum, we obtain a coefficient, i.e. significance for each criterion.

Table 5. Coefficients of each parameter

Criterion	**Coefficient**	**Criterion**	**Coefficient**
Geology	0.158807	Railways	0.031155
Seismicism	0.269522	Border	0.01983
Slope	0.09553	Land use	0.050887
Faults	0.102447	Pedological cover	0.050887
Settlements	0.124876	Protected areas	0.033925
Roads	0.062134		

The final coefficient of each parameter was obtained by multiplying the weight coefficient within the group to which it belongs and the weight coefficient of the group when compared with other groups. Furthermore, with the help of GIS, by multiplying each parameter with its final coefficients and mutual summation of parameters, the final map was obtained.

Results and discussion

By processing and analyzing the available data in geographic information systems and AHP, a synthesis map of the benefits of building nuclear power plants on the territory of the Republic of Serbia was obtained.

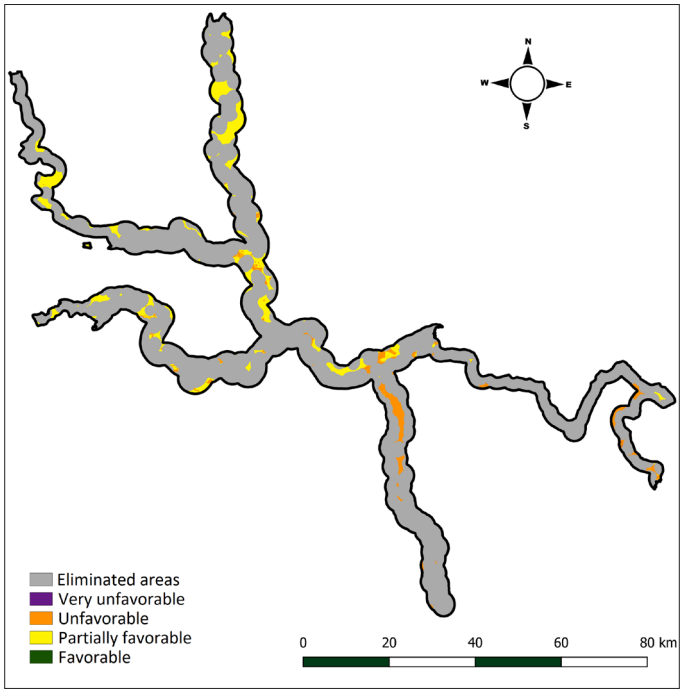

Figure 2. Synthesis map of suitability

Classified values are: eliminated areas, very unfavourable, unfavourable, partially favourable and favourable areas.

Eliminated areas include all protected natural assets located in or near the research area itself, as well as the distance from the settlement because it is impossible from several aspects to build a nuclear power plant on such

areas. The most ideal areas are not even a few kilometers along the border, but if the two countries cooperate on the joint use of energy (such as Croatia and Slovenia), it is possible to find an adequate location.

Using the Analytic Hierarchy Process, a map of potential locations for the construction of nuclear power plants was obtained, where 88.15% of the research area was eliminated, 0.01% were extremely unfavourable areas for construction, 3.15% were unfavourable areas, 8.68% were partially favourable, and 0.002% of the territory was favourable for construction.

The most suitable locations are characterized by the presence of magmatic rocks, flat terrain at lower altitudes. These are areas with sparse vegetation that are far enough away from the faults and have the lowest seismic activity compared to other parts of the study area. The most suitable areas are far enough from the settlement and the state border, and are located near roads and railways, which would facilitate the transport of materials, both for the construction and during the operation of the nuclear power plant. It can be concluded from the map that in the village of Martonoš, which belongs to the municipality of Kanjiža, there are suitable and partially suitable areas for the construction of nuclear power plants. It is also interesting to note that in the zone of 5 kilometers from the river Velika Morava, only in the settlements of Mala Krsna, Skobalj and Osipaonica (which belong to the municipality of Smederevo) and in Pozarevac, there are partially suitable locations for the construction of nuclear power plants. The municipality of Negotin, with the settlements of Mihajlovac, Jabukovac and Mala Krsna, has extremely unsuitable areas for potential NPP locations.

In the areas around the Danube, partially suitable areas are in the municipalities of Apatin, Odžaci, Bač, Bačka Palanka, Šid, Novi Sad, Palilula, Pančevo, Kovin, Veliko Gradište and Kladovo. The Sava River in its zone also has partially suitable areas in certain municipalities. Sremska Mitrovica stands out especially because it offers the most such areas.

Conclusion

Geographic information systems allow users to visualize, research, analyze, and interpret the vast majority of data in order to gain a better understanding of the problem (Damoom et al., 2019). By analyzing natural and anthropogenic factors and using GIS technology, relevant results were obtained for potential locations for the construction of nuclear power plants

in an area of 8757.45 km², which is about 10% of the entire territory of the Republic of Serbia.

Based on the obtained results, it can be concluded that 8.682% (760.3 km²) of the investigated territory is suitable or partially suitable for the construction of nuclear power plants. These are the areas that received the highest grades in the evaluation of natural and anthropogenic factors. Making a decision on the construction of a nuclear power plant is neither an easy nor a naive task because in addition to considering all natural and anthropogenic factors, the state should have a stable system and established laws so that work of NPP go smoothly and to react properly in any unfavorable situation.

In addition to cabinet work, it is necessary to validate the results in the field, as well as to assess the susceptibility of the most suitable areas to natural disasters: torrential floods, landslides, forest fires, soil erosion, etc. (Dragićević et al., 2011; Ristić et al., 2012; Novković et al., 2018; Blöschl et al., 2019; Durlević et al., 2019). For now, the main obstacle in Serbia regarding the issue of nuclear power plants is the moratorium that occurred after the Chernobyl accident. Lifting the moratorium in the future would enable more detailed research and possible construction of nuclear power plants, because the Republic of Serbia strives for European Union (EU) standards in reducing the use of fossil fuels for energy needs, so that nuclear energy with renewable energy sources in the coming decades would be a suitable support for production of zero-emission greenhouse gas electricity.

Nuclear power plants are extremely complex facilities and the radioactive waste that would be produced in them would be specially treated in order to minimize the risk to the environment. A large number of countries in the world and the region exploit nuclear energy because nuclear power plants continue to be one of the cleanest ways to obtain energy.

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WRITTEN WORD OF PAVLE M. VUJEVIĆ

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Abstract: After completing Serbian Orthodox Gimnasium in 1889, in Novi Sad, Pavle M. Vujević, he has been studied geography in Vienna, where in 1904 he defended doctoral disertation. He improved his knowledge in climarology and meteorology in Berlin and Postdam. For full professor of University of Belgrade he was scelected in 1921. He has written more than 150 scientific articles from climatology, meteorology, hydrology and geography.

Key words: Pavle M. Vujević, geography, climatology, meteorology, potamology, variation climate, bioclimatic elements, climatological statistics.

A student of famous professors from Vienna

Among our famous geographers of the past, Pavle M. Vujević, one of the closest and most loyal associates of Jovan Cvijić, a corresponding and regular member of the Serbian Academy of Sciences and Arts, recognizable in international scientific institutions as a climatologist and meteorologist of world importance, author of extensive scientific studies and university textbooks.

Pavle M. Vujević was born in Ruma on August 22, 1881. After graduating from the Serbian Orthodox Gimnasium in Novi Sad, he went to Vienna where he completed his studies studying geography, geology, physics, climatology, and meteorology and hung out with Milutin Milanković (1879–1958), then a student and doctoral student in technical sciences.

In Vienna, under the mentorship of renowned scholars Albrecht Penck (1858–1945), Eduard Suiss (1831–1914), Julius von Hann (1839–1921)

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and Wilhelm Tomaschek, 1841–1901), in 1904 he defended his doctoral dissertation entitled Tisa, a potamological study, which was published in Leipzig in 1906, when the author was 23 years old. In the doctoral dissertation of Pavle M. Vujević analyzed the flows of the Tisza River in different seasons from the most upstream part of the river to its confluence with the Danube. By constructing an isohiet map of the basin, according to data from 244 rain gauge stations and flow data, he determined the water balance of the basin (for the period 1891–1900), an equation that is often attributed to his mentor in the professional literature. With four new equations, Vujević determines the flows on the Tisza as a function of precipitation, which practically means that with each annual amount of precipitation, the runoff, ie the flow, can be determined. Vujević explains the frequent coincidence of high waters and the formation of flood waves on the Tisza by the regime and intensity of precipitation, the topography of the terrain and the shape of the upper and middle course basins. The chapter in which the erosive and accumulative processes in the riverbed and the meander's bed are discussed is especially important, the evolution of which is explained on a mathematically based theory (Rakićević, 1998). To determine the flow of the Tisza River, he used four mathematical equations and precipitation data in a basin with 244 rain gauge stations. This book is considered a classic work in the domain of potamology – the science of rivers and is therefore often cited in hydrological studies and textbooks. It was the first permanently significant scientific contribution of Vujević to modern science. He determined the relations between precipitation, runoff and evaporation, which is of special importance for knowing the water balance and the possibility of rational use of water of a large plain river, known for its fairly large basin. He treated the flow of the Tisza through four equations as a function of precipitation, which is important for knowing erosion, accumulation of materials and conditions for the formation of flood waves. After defending his dissertation and publishing a book about the Tisza, Pavle M. Vujević was very interested in hydrology, and over time, in the field of this science, he published several articles (Hydrography of the Kingdom of Yugoslavia, Hydrography of Yugoslavia, Hydrography and Climate of Vojvodina, Danube, Rivers and Lakes of Yugoslavia, Hydrological characteristics of rivers in Serbia, Climate and hydrography of Yugoslavia, Hydrographic conditions of Yugoslav waters). In addition to hydrology, he was even more successful in climatology and meteorology and went deep into the domain of mathematical geography and climatological statistics. Scientific articles, extensive monographs and university textbooks from the mentioned disciplines are still cited today.

Scientific training in Berlin and Potsdam

After defending his doctoral dissertation, in 1904 and 1905, Vujević continued his professional development at the Prussian Meteorological Institute in Berlin, as well as at the Meteorological Observatory in Pastdam. There he met and collaborated with the famous German meteorologists Wilhelm von Becold and Gustav Hellmann, under the supervision of Jovan Cvijić, when, starting in 1902, he regularly informed about his work. He returned to Novi Sad from Germany. As one of the Serbs, educated in Vienna, he felt a moral obligation to give his knowledge to his home country - Serbia. At the urging of Cvijić, on the recommendation of Albrecht Penck, in March 1907 he was elected assistant professor of climatology and meteorology, the University of Belgrade was founded in 1905 and was very useful in building the Department of Geography, headed by Cvijić, as well as in preparatory actions for the establishment of the Serbian Geographical Society. To the students of geography of the then Faculty of Philosophy, University of Belgrade, Vujević taught mathematical geography, general climatology, dynamic meteorology. In addition, he held special courses on weather and weather forecasting, the climate of the Balkan Peninsula, climate and man, dynamic meteorology and water circulation in nature. From the election for assistant professor (1907), associate professor (1919) and full professor (1921), until 1941, he was the only university professor of climatology and meteorology in Belgrade and Serbia.

Geographical Society and its Glasnik

In 1910, Pavle M. Vujević participated in the founding of the Serbian Geographical Society, where he was elected its secretary and together with Jovan Cvijić (1865–1927), edited I, III-IV, V, VI, VII-VIII volumes of the Glasnik of the Serbian Geographical Society, which was printed at the suggestion of Jovan Cvijić from 1928 to 1948 as the Glasnik of the Geographical Society. The original name was returned to him in 1948, and as such it remains.

Glasnik Srpskog geografskog drustva, po reci profesora Borivoja Z. Milojević, the bed of the late Jovan Cvijic is especially close to his heart: his famous studies give great value to every issue of Glasnik; there is not a single issue of Glasnik, and there is not a single, almost not the smallest work, published in Glasnik, on which Cvijić's clever gaze did not stay, he was seriously ill, he took care of Glasnik, which was being reprinted.

Continuing the work of Cvijić, Pavle M. Vujević approached Glasnik with utmost sincerity and demanded from his associates to check once and again everything they wrote, especially the tables of statistical data, which are the basis for analyzes and conclusions. Loyal to the Serbian Geographical Society and its Glasnik, Pavle M. Vujević published several different works, reviews, notes on the pages of the periodical geographical publication on the Balkan Peninsula, analyzed statistical data and wrote obituaries in memory of his predecessors. From Glasnik, we especially single out an extensive study on the climate of the island of Hvar, which brought him the title of honorary citizen of the town of Hvar, Vujević was the president of the Serbian Geographical Society in three election terms: 1931-1933, 1947–1955 and 1956–1959.

He was especially engaged in organizing the Third Congress of Slavic Geographers and Ethnographers, which was held in 1930 in Belgrade. He edited the publications from the mentioned congress: Kingdom of Yugoslavia, geographical and ethnographic review, page 167, editions in Serbian and French and Description of the path of Slavic geographers and ethnographers, first and second part, a total of 371 pages. In addition, he is known as a long-term editor of the Report of the Meteorological Observatory in Belgrade, that is, the Proceedings of the Geographical Institute Jovan Cvijić of the Serbian Academy of Sciences and Arts and its Special Editions. In 1954, he was proclaimed the lifelong, and to this day the only, honorary president of the Serbian Geographical Society.

Unrepeatable war sufferings

Pavle M. Vujević was a quiet, honest and overworked man and scientist, who enjoyed great respect from his students and associates in the country and abroad. The second decade of the 19th century, when Serbia was affected by great war events, fell hard on him, because it separated him from everyday teaching and research work. He took part in the Balkan wars and the First World War. As a soldier, he crossed the Albanian mountains and arrived in Corfu, severely physically and mentally ill. Although the General Department of the Supreme Command approved his departure for treatment in San Giovanni, he did not board the ship, probably because there were more serious patients. After the end of the Great War, he was sent to London, where he worked on collecting aid within the Red Cross. Upon his return to Belgrade, on June 21, 1919, he determined that the manuscripts he

had been working on for years had disappeared in the bombing and looting. In two letters to Jovan Cvijić, who was still in Paris, he informed that he had visited his house and wrote the following: The library is in good condition, but it seems that something has been reduced. They didn't leave me a single letter. They tore out my atlases. The mass of the houses remained the same as after the bombing. The world will not repair houses; the government is requiring private apartments. My apartment was requisitioned by the Ministry of Food. They barely allowed me to bring out at least my books. I couldn't take anything from things. Among the books I found all my lectures. At least that saved my 15-year work. The temperature tables of the Kingdom of Serbia and the manuscript were taken to me. I worked on that for two full years in the basement of the Observatory, and all that work failed. I have nothing left of the manuscript. Most of the books I procured after the Bulgarian war were taken away. I lost all the dictionaries, all the atlases, all the maps, except for a few 1: 75,000. He was engaged in the renewal of the Geographical Institute and the University, of which he was rector 1919–1920.

Jovan Cvijić and the establishment of meteorological stations in Serbia, Macedonia and Montenegro. During 1919, he helped Jovan Cvijić at the Peace Conference in Paris. He spent some time at the head of the Meteorological Observatory in Belgrade, lectured at the Faculty of Agriculture in Zemun, the Faculty of Agriculture in Novi Sad, and lectured in Cambridge and Aberdeen. He could do all that because he was a modernly educated scientist, who studied not only geography, but also geology, physics, meteorology and climatology, and was in contact with Albrecht Penck, as well as with Jovan Cvijić and Milutin Milanković (1879–1958).

Hanging out with Milutin Milanković

Pavle Vujević was friends with Milutin Milanković, who at that time was intensively dealing with the theoretical foundations of climate. It can be assumed that there was Milanković's influence on Vujević: Vujević tried to look at the climate of the Balkans for a longer period (Opra, 1997). In that sense, the year 1931 is significant, when Vujević in Paris, published the work Historical documents on climate variations in the territory of the Kingdom of Yugoslavia and surrounding areas. The work has 55 pages with 300 records on time and climate between 1358 and 1864. He made records based on insights into the books of Orthodox monasteries and churches, but also from books in Turkish and Latin. Vujević organized teaching courses in

which he interpreted the overall knowledge about the circular movement of water in nature, dynamic meteorology, climate and man, weather, weather forecast and the climate of the Balkan Peninsula. From 1947 to 1955 he was the head of the Department of Meteorology at the Faculty of Natural Sciences and Mathematics in Belgrade, and from 1957 to 1961 the head of the Geographical Institute Jovan Cvijić of the Serbian Academy of Sciences and Arts. For several years, he was elected Director of the Meteorological and Climatological Institute of Serbia. He was the representative of Yugoslavia in the European section of the World Meteorological Organization and the president of the National Commission for the International Geophysical Union at the Academic Council of Yugoslavia (1955).

Recognitions and work in international organizations

Over time, Pavle Vujević was elected a corresponding member of the Czechoslovak Geographical Society of Prague in 1926 (Ceskoslovenská Spolecnost Zemlepisná), the Geographical Society of Berlin in 1928 (Gesellschaft für Ergkunde zu Berlin), an honorary member of the Czechoslovak Geographical Society of Prague in 1931 (Ceskoslovenskén), a corresponding member of the Bulgarian Geographical Society from Sofia in 1935 (Bulgarian Geographical Society), the Hungarian Meteorological Society in 1940 (Magyar Meteorolgiai Tarsaság), the Geographical Society of Croatia (1961). He was elected an honorary doctor of the University of Vienna in 1954, the Meteorological Society of Serbia and the Geographical Society of Berlin. In 1960, he received the Lifetime Achievement Award given by the Commission of the Council for Scientific Work of the Socialist Republic of Serbia, for special achievements in the field of science, as well as the Jovan Cvijić Medal. He is the holder of the Albanian Monument, the Order of Saint Sava, the Order of Labor of the First Order, and the Seventh of July Award of the Government of Serbia. Due to the high scientific reach, the Senate of the University of Vienna in 1954, the doctoral dissertation of Pavle M. Vujević, included in the category of golden doctorates. Vujević participated in the work of the International Commission for the Study of Climate Change, for which he used the terms climate variation, climate variation. He collaborated on projects of the World Meteorological Service. For the corresponding member of the Serbian Academy of Sciences and Arts, Vujevic was elected on November 14, 1950, and a regular on January 30, 1958. In 1961, he was a member of the Presidency of the Academy of Sciences. He was declared an honorary citizen of the town of Hvar for his extensive work on the climate

of the island of Hvar (243 pages), for which he used data from 60 years of observations of climatic elements.

Writer of university textbooks

The university textbooks Mathematical Geography (XVIII + 815 pages) and Meteorology (476 pages) are among the most important editions of the University of Belgrade in the first half of the 20th century. The work Climatologically Statistics (310 pages) is unique in our country. For an extensive and very comprehensive university textbook Fundamentals of Mathematical and Physical Geography, which in the first part deals with the problems of mathematical geography and geophysics, and in the second atmosphere and oceans, it was stated that it was printed among the first at the University of Belgrade after the First World War. Kingdoms of Serbs, Croats and Slovenes was written on the basis of a good knowledge of world-proven original literature and in its own way it contributed to the high level of teaching and, in its time, to the true aspirations of students and teachers of the University of Belgrade.

The textbook was an irreplaceable reading for students of many professions whose interest was not only in physical geography, in the broadest sense of the word, but also in meteorology, climatology, oceanography, cosmography and the Earth as a planet – a member of the solar system, orientation, determination of geographical coordinates, calculation of time) and its physical properties: mass, density, structure, magnetism, electricity (Rakićević, 1998). The university textbook Meteorology, published by Prosveta from Belgrade, appeared in print in 1948 on 476 pages. It was the only one of its kind in Serbia and Yugoslavia at the time, and it is still quoted today. He contributed many times to the general introduction to the peculiarities of the atmosphere and pointed out the applicative importance of climatology and meteorology in a number of vital human activities (agriculture, traffic). Due to its lessons, messages and significance, in 1949 he received the First Prize of the then Government of Yugoslavia. Climatologically statistics is possibly one of the most unusual, but very important, university textbooks (Naučna knjiga, 1956). These are instructions for collecting and processing meteorological data and their numerical, graphical and cartographic representation. It abounds in the interpretation of standard methods of mathematical statistics, established probability theories, aspects of control, elements of periodicity of phenomena and processes, computer procedures,

which... often from a very extensive material of meteorological observations can obtain a simple overview of climate change from which certain laws can be derived, to determine the connections and the influence of certain meteorological elements on a specific climatic phenomenon. This textbook is the result of a conscientious and dedicated effort of a teacher's nature, the will to instruct people who want to teach them in climatological work, and it has an exceptional necessity and practical significance. The concept of the textbook is based mainly on the author's many years of experience, and largely presents his original work (Rakićević, 1998). Pavle M. Vujević published scientific and professional articles in domestic and foreign journals in Serbian, German, French and English. Due to the inalienable scientific significance, lessons and messages, many views of Pavle M. Vujević, exhibited in numerous works and extensive books, are still quoted today, especially knowledge about bioclimate.

Climate as the morphology of the atmosphere

Pavle M. Vujevic was a man with many humane and hard-working human qualities, because of which he enjoyed great respect from students and associates, both in Serbia and abroad. He emphasized the importance of science and taught respect, respect, diligence, modesty, and perseverance. He emphasized the fact that almost everything on the planet Earth is based on numerous mutual relations, mergers and permeations, direct, indirect and feedback, evolution. He interpreted climate as the morphology of the atmosphere (Dukić, 1981) in great dependence on the circulation of the atmosphere, changes in the intensity of solar radiation, the distribution of the sea and land, i.e. degree of maritimeity and continentality. It has been noted in the literature that he was, and remains, a pioneer of microclimatology and an immortal researcher of prismatic air layers. In addition, he was the first to start measuring soil temperature at certain depths, which is extremely important for agro climatology. Respecting the climatic conditions, respecting the dialectical-materialist scientific method, he brought them into connection with geomorphology, that is. Relief features. He defined climate as the morphology of the atmosphere, in which the most important are various air masses, quickly changing and easily moving, where the existing relations between the sea and the land are of interest, which maintains the degree of continentality, that is, the degree of maritimeness. With the textbooks Meteorology and Climatologically Statistics, he contributed to the scientific and applied knowledge of the relevant sciences, important for agriculture,

construction, traffic, weather forecast, i.e. the overall life of man and human society. Of special importance is the contribution he gave to the research of microclimatology, ie, research of ground layers of air and thermal regime of the soil at certain depths.

Professor of encyclopedia

Academician and university professor, one of the pillars of our science, Pavle M. Vujević reaches the national, European and world level. His basic scientific preoccupations concerned climatology, meteorology, mathematical geography, astronomy and hydrology. He was a climatologist who, from a pronounced physical-geographical, spatial, aspect, perceived and interpreted the peculiarities of time and climate. Significant journalistic activity of Pavle Vujević is also reflected in his work on Stanojević's National Encyclopedia (Book I–IV, Zagreb, 1928–1929), for which he wrote over 1200 determinants in the field of physical geography and geophysics. In addition, with his professionally popular works, he also greatly contributed to the affirmation of geography as a current, especially its share in the general educational and cultural enlightenment of the people. All the more so because there was something enlightening in his nature. A lot could be learned from him, as a scientist, professor, leader (Rakićević, 1998). In the eighth book of the Encyclopedia of Yugoslavia, published by the Yugoslav Lexicographic Institute in Zagreb, in 1957, on page 549, about Vujević, the text of his doctoral student, later professor of the Faculty of Geography and longtime president of the Serbian Geographical Society, Dušan Dukić (1923-2013), reads: Vujević, Pavle, geographer climatologist (Ruma, August 22, 1881 – Belgrade, November 17, 1966). He finished high school in Novi Sad, and studied at the University of Vienna, where he received his doctorate in 1904.

In March 1907, Vujević became an assistant professor of climatology and meteorology at the Faculty of Philosophy in Belgrade, and since then his intensive teaching and scientific work has begun. He participated in the Balkan Wars and the First World War, in 1919 he became an associate professor, in 1921 a full professor at the University of Belgrade, where he taught physical and mathematical geography, meteorology and climatology. For the climate monograph on the climate of Hvar (Belgrade, 1927–1932), in which he proved that the climate of Hvar is more suitable for treatment and rest than many famous Mediterranean beaches, he received a kind of recognition - he was elected honorary citizen of Hvar in 1931. In 1924–1948,

Vujević was the director of the Meteorological Observatory in Belgrade, the organizer of the network of meteorological stations in Serbia, Macedonia and Montenegro, the head of the meteorology department at the Faculty of Science in Belgrade (1947–1955), the director of the Geographical Institute (1957). He was a corresponding member of many foreign geographical societies, a lifelong honorary president of the Serbian Geographical Society (1954), Vujević received multiple awards for his long-term teaching, scientific-organizational and scientific work (over 150 scientific articles). Many of his works have become classic works in river hydrology and microclimatology. Academician Pavle Vujević died in Belgrade on November 17, 1966.

In 1967, the Serbian Academy of Sciences and Arts printed the Monument (Special Editions, Book CDXII, page 24), dedicated to the late academician Pavle M. Vujević. The speeches of academician Miodrag Tomić, academician Milisav Lutovac, professor of meteorology Marjan Čadež, professor of hydrology Dušan Dukić and president of the Serbian Meteorological Society, Milutin Radošević, were published at the commemorative gathering, which was held on March 25, 1967.

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Conclusion

Pavle M. Vujević belongs to the generation of scientists, university professors and academics who are among the founders of scientific and teaching work in Belgrade, in the first years after the founding of his university. He was educated and trained abroad, but he remained faithful to Serbia and in his own way contributed to the development of hydrology, climatology and meteorology as subjects and operational disciplines in the field. He published short notes, chronicles, statistics, obituaries, reviews of foreign literature, scientific articles, scientific monographs and university textbooks in domestic and foreign journals in Belgrade, Zemun, Zagreb, Novi Sad, Cetinje, Skopje, Sarajevo, Leipzig, Vienna, Paris, Prague, Warsaw, and Sofia. His works have been published in Serbian, German, French, English and Czech. The weather and events in Serbia, on the Balkan Peninsula and in Europe were not in his favor. He often created radio under very unfavorable conditions. In 85 years of his life, among other things, he had the First Balkan War, the Second Balkan War, the First World War, the Second World War, Serbia under the occupation of foreign powers, the formation of the Kingdom of Serbs, Croats and Slovenes and several changes of name, borders and political and social order. For more intensive scientific studies, he lacked data from specific meteorological observations, from a large number of stations in Serbia and on the Balkan Peninsula. It is known that in 1904 there were 83, and in 1914 only 11 meteorological stations in Serbia. Climate studies by Vujević were not an end in itself. He brought the climate into direct and indirect connection with man and human activity. When he defined the basic bioclimatic elements, drying power and cooling power, ie determined the elements of equivalent and equivalent-effective climate and their effect on the human body, he pointed out the importance of climatotherapy. When it comes to the influence of climate on the general life of man, the following sentences are often quoted today: Sunny days have a completely different influence on mood than cloudy and gloomy days. When the sky is clear, a person is not only happier, but also more enterprising and willing to work. In addition, there are significant differences in the nature of the talkative and enthusiastic Spaniards and Italians and the measured and cold-blooded British and Scandinavians. This is felt in literature, music, and folk art. Folk songs are ballads for northerners, and romances for southerners.

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ANALYSIS OF THE SPATIAL DISTRIBUTION OF THE DROUGHT IN THE LIM VALLEY AND ON THE UPPER COURSE OF THE RIVER IBAR IN MONTENEGRO

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Abstract: This paper analyzed the spatial distribution of drought at meteorological stations on the Lim valley (Plav, Andrijevica, Berane and Bijelo Polje) and on the upper course of the river Ibar (Rožaje). The goal of this research is to point out the modern climatic characteristics in relation to the current state of aridization, which is a limiting factor for economy of the population in many areas throughout the world. The method used for such purposes is the De Marton drought index. Results of the research indicated a decrease in the annual drought index through the Lim valley, with the highest values for Plav (IDM=61,9), and the lowest for the lowest downstream station Bijelo Polje (IDM=41,3). The values of this climate index indicate the conditions of very humid (Berane, Bijelo Polje and Rožaje) and extremely humid climates (Plav and Andrijevica), with huge drainage and forest vegetation. By applying the De Marton index on a seasonal and monthly level, the highest values of this indicator were established in the winter season.

Keywords: De Marton drought index, seasonal drought index, monthly drought index, interpolation, aridization.

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Introduction

During the last decade, issues related to climate change are being researched by numerous scientific studies (Bačević et al., 2017; Gavrilov et al., 2019). Temperature and rainfall are the most important climate elements. Popović, Radulović and Jovanović (2020) established that the average temperature of the planet Earth is around 15°C. The merit for such result belongs to the greenhouse effect. Number of international agreements exists in the field of environment that contain different types of goals and principles relevant to the field of climate change. Atmospheric protection includes: the Convention on Long-range Transboundary Air Pollution (1979) with its 8 protocols and 4 amendments, the Vienna Convention for the Protection of the Ozone Layer (1985) and the Montreal Protocol on Substances that Deplete the Ozone Layer with its 4 amendments, UNFCCC (1992) with the Kyoto Protocol (1997), the Amendment to Annex B of the Kyoto Protocol (2006) and the Doha Protocol (2012), which is yet to be enforces (Todić, 2016).

Numerous studies have concluded that the process of aridization is included at the regional and global level (Ahmed et al., 2019). Drought related research are intensified in scientific circles for the last two decades (Tadić, Dadić, & Bosak, 2015). Drought is a natural disaster which characterized by the length of the dry period that is significantly above normal. In other words, the deficit of precipitation is significantly below normal (Dragićević and Filipović, 2009). Unlike natural disasters in which the effect is manifested immediately after its occurrence (floods, eruptions, earthquakes), droughts are a natural phenomenon that is characterized by slow development and can last a long time. Its influence is manifested for months and even years after its appearance (Dragićević and Filipović, 2009; Spinoni, Naumann, & Vogt, 2017). Aridity is a critical factor in determining the evolution of natural vegetation, taking into account the water stress that can occur with the reduction of vegetation cover (Kosmas et al., 1999).

The effects of drought on the environment can be direct (biophysical: changes in site conditions, decrease of water level) and indirect (such as reduced income from agricultural production, increasing food prices). The increase in droughts can negatively affect water resources, agricultural production and activities that rely on surface water and groundwater (Dragicevic and Filipovic, 2009; Gebremedhin, Kahsay & Fanta, 2018; Paltineanu et al., 2007). The impact of the drought on the environment is reflected in land degradation, which affects the reduction of natural resources areas (Rajic, 2014). Monitoring the situation of drought is especially important

in areas where agriculture is the dominant activity of the economy, as well as for management of degraded land and desertification processes (Barzani-Marani et al., 2017;Pelliconi, Caloiero, & Guagliardi, 2019).

Numerous experts study the intensity and spatial distribution of drought in the world: in Ethiopia, Iran, Pakistan, India (Ahmed et al., 2019; Dabbaghi and Manjari, 2017; Gebremedhin, Kahsay & Fanta, 2018; Piri et al., 2017;Rakhecha & Dhar, 1975). The differences are attending due to the geographical position, relief (direction of the mountains) and distance from the sea. In Europe, drought is mostly affecting the southern and southeastern part of the continent (Tadić, Dadić & Bosak, 2015). De Marton droughtindex method used for analysis of drought on the Danube Delta between 1965 and 2005 revealed values below IDM= 20 for the most part (Lungu, Panaitescu & Plesoianu, 2012). In Greece, between 1965 and 1995, the differences in the value of the De Marton drought index were found between Larissa (IDM=16,28) in the east and Ioannina in the west (IDM=43,01), due to the meridian extension of Mount Pind (Balzas, 2007). In the period from 1965-1999, the growth of this index from Pristina and East (IDM=30) to the south (up to IDM=45) was established on the territory of Kosovo and Metohija, which is influenced by the growth of precipitation and high mountains on the edge (Bačević et al., 2017). In the period from 1981-2010, the annual value of the De Marton index of IDM=29,6 was established on the territory of the Leskovac valley (Milentijević et al., 2018).

Research area

Data were analyzed at meteorological stations in the valley of Lim (Plav, Andrijevica, Berane and Bijelo Polje) including a meteorological station Rožaje, on Ibar valley in the eastern part of Montenegro. The research area includes the mountain part of Montenegro - Montenegrin mountains and surfaces (Marković, 1966). Mountains have a large impact on the climate, because the changes of altitude change the climate elements in the form of reducing temperature and increasing precipitation (Rakićević, 1971; Vujević, 1948).

Rozaje is on the eastern part of Montenegro in the upper Ibar. It borders the municipality of Berane and the municipality of Petnjica, while the rest of its border is also the state border of Montenegro between Serbia (Radojičić, 2015). Municipality Rožaje, by geographical location and altitude, belongs to moderate-continental zone where predominates climate with cold winters and cool summers. The average number of days in a year with a temperature

below 0°C is 166, and with a temperature above 30°C is 4 days (Radojičić, 2008). Insolation is about 1500 hours a year (around 4 hours a day), which is a significant value for mountainous areas (Ministry of Agriculture and Rural Development of Montenegro, 2020).

The municipality of Plav is located in the southeastern part of Montenegro, near Lake Plav. It borders the municipalities of Andrijevica and Berane. A significant feature in the relief is Prokletije. At the time of the last glacial (Würm), the ice on Prokletije covered an area of 250 km2 (Cvijić, 1921). The climate of the Plav-Gusinje region is mountain-valley, and at altitudes above 1300 m it is distinctly mountainous (Radojičić, 2005). Because of its natural characteristics, Plav represents a mountainous place and climatic spa (Marković, 1966).

The meteorological station in the municipality of Andrijevica is located at the altitude of 772 m. Between sea and municipality, there is around 88km of air line. It is located in the valley extension of the river Lim. The municipality is developed on fluvio-glacijal terrace, on the left side of the river Lim, between Zlorečica and Krasta. It is located at the crossroads of roads to Berane, Podgorica, Plav and Peja (Bakić, 2005; Marković, 1966).

Berane, with the meteorological station at the altitude of 690m, is the center surrounded by Andrijevica, Petnjica and Plav. Municipality has been developed on northern-east part of Berane valley. Berane valley has continental climate. Because of the differences in climatic elements, climatic regionalization in the Lim valley has been done on Berane variety (higher average and maximum temperatures) and on Plav-Gusinje climate variety region (Joksimović, 2016).

Municipality of Bijelo Polje is the fifth largest municipality in Montenegro by area and third by population. It borders Berane on south-east, on west it borders Mojkovac, and on the north-west it borders Pljevlja. The climate of Bijelo Polje is moderate continental (Radojičić, 2002).

Table 1. Meteorological stations

Meteorological stations	Latitude (φ)	Longitude (λ)	Altitude (m)
Rožaje	42°51′	20°10′	1007 m
Plav	42°36′	19°56′	910m
Andrijevica	42°44′	19°47′	772m
Berane	42°50′	19°52′	690m
Bijelo Polje	43°02′	19°45′	606m

Source: Department of Hydrometeorology and Seismology of Montenegro, 2008-2018

Data and research methodology

The research is limited to the period between 2009 and 2018. Analysis of climate parameters has been conducted at the period of one decade because of the lack of data for longer period of time. Data were taken for each year individually from the website of the Institute of Hydrometeorology of Montenegro. In order to obtain values of the annual, seasonal and monthly De Marthon drought index, we needed to take the monthly and annual values for the temperature and precipitation. The initial hypothesis of this research is that the process of aridization is still not expressed in the mountain areas.

While forming the database, data for specific montly values of temperature and precipitation were missing. Such case was with the meteorological stations in Rozaje, Bijelo Polje and Andrijevica, while data were complete at the stations in Plav, Berane and Kolasin. Lack of some values were resolved using the interpolation procedure.

With the help of available data on other stations, the prediction of unknown geographical data on stations for which they are missing is performed (Gebremedhin, Kahsay & Fanta, 2018). Interpolation of mean monthly and mean annual temperature values was performed by applying the method of differentiation with the help of the two nearest stations for the same length of the data series. The missing monthly temperature values from Rozaje and Andrijevica were interpolated with the help of the meteorological stations at Berane and Plav. Monthly temperature values at Bijelo Polje were interpolated with the help of the temperature values at the stations at Berane and Kolasin (φ=42°50′ andλ=19°31′, altitude of 944m). The method of this differentiation was conducted according to the following pattern (Ducić and Anđelković, 2009):

$$Tam = \frac{[(\mathrm{Tbm} + \mathrm{Dab}) + (\mathrm{Tcm} + \mathrm{Dac})]}{2}$$

Tbm and Tcm represents mean montly values of temperature on the stations that are being used to compare temperature values, for the month that is lacking values. Dab and Dac expresses mean differences between temperatures from the stations for which the interpolation is performed with the stations on which the comparison is made.

Interpolation of monthly and annual amounts of precipitation was performed by applying the quotient method, because this method is suitable for interpolation of those climatic elements whose values are expressed

in sum. Interpolation of monthly precipitation amounts at meteorological stations Bijelo Polje, Rožaje and Andrijevica was performed with the same stations, as in the case of temperature interpolation. The results were obtained according to the following formula (Ducić and Anđelković, 2009):

$$Pam = \frac{[(\mathrm{Pbm} * \mathrm{Qab}) + (\mathrm{Pcm} * \mathrm{Qac})]}{2}$$

Pbm and Pcm represent values of monthly sum of precipitation at the stations with which the interpolation is performed, with the month that is lacking data. Qab and Qac represents quotients between the station for which the data is lacking with the similar stations on which the data for specific month exists.

Climate indexes represents significant indicators of climate changes (Gebremedhin, Kahsay, & Fanta, 2018). Drought indexes are climate indexes that are being used for following and prediction of the droughts (Piri et al., 2017). Drought indexes are most simplified tool for analyzing this phenomenon (Zemunac, Rajić & Bezdan, 2018). It is really hard to find universal index, due to differences in the drought definition itself (Rajić and Zemunac, 2017). For the better part, they are based on hydrological parameters, such as flow and water level, and meteorological parameters: precipitation and air temperature (Tadić, Dadić& Bosak, 2018). Drought indexes represents numerical indicators of the degree of dryness of the climate at particular location and provide base for classification of climate types, while depending on the availability of the water resources (Pellicone, Caloiero & Guagliardi, 2019). There are numerous indexes that are being used to analize drought of specific area: De Marton's drought index, Gracanin's rain factor, Johanson's continental index, Seljanin's hydrothermal coefficient, Lang's rain factor, standardized climate water balance index, Palmer's index of drought, Palfaiev's index of drought, UNESCO drought index (Balzas, 2007; Barzani-Marani et al., 2017; Gebremedhin, Kahsay, & Fanta, 2018; Lungu, Panaitescu & Plesoianu, 2012;Milentijević et al., 2018; Paltineanu et al., 2007; Rajić, 2017;Tadić, Dadić& Bosak, 2015; Zemunac, Rajić &Bezdan, 2018).

De Marton's drought index represents significant climate index which performs a detailed characterization of the climate in certain area (Ducić and Anđelković, 2009). This index can be used for calculation of the different periods of time, such as months, seasons and years (Gavrilov et al., 2019). The increase of value on the De Marton's drought index suggests that climate is more humid, while the decrease of the value indicates an aridization of the

climate of the studied region (Dabbaghi and Manjari, 2017; Lungu, Panaitescu & Plesoianu, 2012). Annual values of De Marton's index were calculated in order to represent characteristics of humidity, while the seasonal and monthly values were calculated to analyze the variability of such parameter during the year (Milentijević et al., 2018). De Marton's index is considered as one of the conventional methods in the climate classifications and it is often used in climate research projects, especially in development of water-gate and in agricultural area (Piri et al., 2017).

De Marton's drought index determines the characteristics of the climate, but also the characteristics of landscape, such as drainage and runoff (table 2). E. De Marton found out that the value of drought index IDM=20 represents the limit of dryness and that this number might be handy for determining dry months during the year (Dukić, 1976). Index values are an indication of the type of drainage territory, so it can be areic, endoreic, exorheic and an area of abundant exorheic drainage. Desert and semi-desert areas correspond to index values below IDM<10. Areas with a De Marton index between 10 and 30 are steppe and wooded steppe areas, while areas with an index over 30 are forest areas.

Table 2. Characteristics of the area depending of the value of De Marton's drought index

Index values	Climate types	Index values	Drainage	Area
IDM<10	Dry	IDM<5	Areic areas	Desert
10≤ IDM<20	Mildly dry	5<IDM<10	Endorheic area	Border desert
20≤ IDM<24	Mediterranean	10<IDM<20	Exo/endorheic area	Steppes
24≤IDM<28	Mildly wet	20<IDM<30	Exorheic area	Forrest steppes
28≤ IDM<35	Wet	30<IDM<40	Periferic	Forrest
35≤ IDM≤55	Very wet	IDM>40	Abundantly	Forest
IDM>55	Extremely wet			

Source:Ducić and Anđelković, 2009; Gebremedhin, Kahsay, & Fanta, 2018.

In order to calculate the annual drought index at selected meteorological stations, data about mean annual precipitation amounts (P) and mean annual temperatures (T) for the defined period (2009-2018) were necessary. Number 10 is included to avoid negative index values, due to mean annual temperatures below 0°C that are typical for highland areas, assuming that the mean annual temperature will not be below -10°C (Lungu, Panaitescu& Plesoianu, 2012; Rajić and Zemunac, 2017). The annual drought index is calculated according to the pattern (Ducić and Anđelković, 2009):

$$IDM = \frac{\mathrm{P}}{(\mathrm{T} + 10)}$$

Seasonal index of drought is analyzed in order to detect the differentiation in the values of this climate index during the year. It is being calculated individually for each station for the period between 2009 and 2018. They are analyzed individually for each of the four seasons, by calculating the mean seasonal values of precipitation (Ps) and the mean seasonal values of temperature (Ts). For winter, the required data is taken for the December of last year, January and February. Spring season includes the data from March, April and May, summer season for June, July and August, while for the autumn season, the required data is from September, October and November. The seasonal drought index is calculated according to the following pattern (Gebremedhin, Kahsay, & Fanta, 2018):

$$IsDM = \frac{4\mathrm{Ps}}{(Ts + 10)}$$

The results of monthly drought index indicates the differentiation of this climate indicator during the both year and the season. Monthly values of De Marton's drought index indicates that these values has a significant influence on the climate characteristics of research area. The monthly drought index is calculated according to the following pattern (Milentijević et al., 2018):

$$ImDM = \frac{12\mathrm{Pm}}{(\mathrm{Tm} + 10)}$$

Research results

Annual drought indices differ at meteorological stations in this part of Montenegro (Table 3). Highest value of the annual drought index has the meteorological station Plav (IDM=61,9), while the lowest value has Bijelo Polje (IDM=41,3). The values of the De Marton's index IDM>55 in Plav and Andrijevica, indicate extremely humid climate conditions in the period between 2009 and 2018. At other meteorological stations (Rožaje, Berane and Bijelo Polje), the values of the De Marton's index range from IDM=41,3-52,3 which indicates very humid climate conditions during the same period. The values of the De Marton's index are higher than IDM>40 at all meteorological

stations, which is an indicator of abundant drainage and coverage of the entire territory under forests.

While analyzing the value differences of De Marton's drought index, it can be noticed that it is decreasing through Lim valley. The amount of precipitation is also decreasing in that direction. Andrijevica receives most precipitation (1113,83mm), while meteorological station at Bijelo Polje is station with the smallest amount of precipitation in the Lim valley (876,9mm). The average annual temperature for the period between 2009 and 2018 is increasing down the Lim valley. Plav has the lowest average annual temperature (9,8°C), while the meteorological station at Bijelo Polje shows biggest annual temperature (11,2°C). Such distribution of these climate elements is affected by altitude, where increase of the altitude means that the average temperature decreases while the precipitation increases. This is directly reflected on changes on values of De Marton's drought index,which increase is proportional to the altitude and the sum of annual amount of precipitation, but inversely proportional to the average annual air temperature.

Table 3. Annual drought index

Meteorological station	Mean annual temperature (°C)	Mean annual precipitation (mm)	Annual drought (IDM)
Rožaje	8,6°C	972 mm	52,3
Plav	9,8°C	1224,3 mm	61,9
Andrijevica	9,9°C	1113,83 mm	56
Berane	10,7°C	904,2 mm	43,6
Bijelo Polje	11,2°C	876,9 mm	41,3

Source: Department of Hydrometeorology and Seismology of Montenegro, 2008-2018

The seasonal values of the De Marton's drought index differ at these meteorological stations depending on the season (Table 4). The highest values of this climate index are during the winter months due to low seasonal temperatures. The average value of the winter drought index is IsDM=117,8, which corresponds to the conditions of extremely humid climate. Plav has the highest average value of the winter drought index (IsDM=162,3), while Bijelo Polje has the lowest value (IsDM=77,9). The differences of the drought index during the winter between the places in the Lim valley are proportional to the differences in the annual values, so that the values decrease throughout the Lim valley.

The spring and autumn values of the De Marton index are approximate. The average spring values are slightly higher compared to the autumn values at these meteorological stations. The values of the average spring index of IsDM=32,1 correspond to the conditions of a humid climate. Plav has by far the highest value of the spring drought index (IsDM=52,4), compared to other meteorological stations. Bijelo Polje has the lowest value of the spring drought index (IsDM=21,4) due to less precipitation and higher spring temperatures. The declining trend in the value of the De Marton drought index through the Lim valley is also present during the spring season. Rozaje has a lower value (IsDM=31,4) in relation to Plav and Andrijevica, but higher than Berane and Bijelo Polje.

Observing the average seasonal values of the De Marton drought index, it can be noticed that they are the lowest during the summer. The average value of the drought index during the summer months at these 5 meteorological stations is IsDM=11,2. It refers to the Mediterranean characteristics of the climate during the summer and according to that value it is close to the conditions of a moderately arid climate. The highest value of the summer drought index during the period 2009-2018 was recorded in Rožaje (IsDM=16,9), due to the higher amount of precipitation during the summer months compared to the other stations, which are covered by this research. Berane has the lowest value (IsDM=8,8) due to less precipitation during the summer months (June, July and August) compared to other meteorological stations.

Average values of the autumn drought index between the period of 2009 and 2018 are IsDM=27,3, which indicates moderately humid climates in that part of the year. Plav has the highest value of the autumn drought index (IsDM=33,1), while Bijelo Polje has the lowest value (IsDM=20,5). These values are decreasing through the Lim valley. Rozaje has lower values in relation to Plav and Andrijevica, but higher than Berane and Bijelo Polje.

Plav, Rožaje and Bijelo Polje have higher spring values compared to autumn, while the situation is reversed at the meteorological stations Andrijevica and Berane. Highest values of the winter, spring and autumn drought index were recorded at the meteorological station Plav, while the lowest in Bijelo Polje. During the summer season, there are deviations, so Rozaje has the highest value, and Berane has the lowest. The obtained results of seasonal drought index indicates that the differences between the examined meteorological stations are proportional to the differences in annual values during the winter, spring and autumn seasons. The exceptions are the ratios of these values during the summer season.

Table 4. Seasonal drought index

Meteorological station	Seasonal drought index (IsDM)			
	Winter	Spring	Summer	Autumn
Rožaje	115,7	31,4	16,9	26,7
Plav	162,3	52,4	10,1	33,1
Andrijevica	137,5	31,6	9,9	32
Berane	95.7	23.8	8.8	24.3
Bijelo Polje	77,9	21,4	10,1	20,5
Average	117,8	32,1	11,2	27,3

Source: Department of Hydrometeorology and Seismology of Montenegro, 2008-2018

Monthly drought indexes vary by months at the examined meteorological stations (Table 5). The highest average monthly values of the De Marton's drought index, for these 5 stations, were recorded for the winter months: January (ImDM=110,38), December (ImDM=103,18) and February (ImDM=93,22). Plav and Andrijevica have the highest values of monthly drought index during the winter months, whose index values exceed ImDM>100. Rožaje has the lowest values of the drought index for the months of December (ImDM=75,6) and February (ImDM=70,6), while Bijelo Polje has the lowest January values (ImDM=83,2). The monthly values for December and January decrease in proportion to the annual values down the Lim valley.

The values of the monthly indexes for the spring months are lower compared to the winter months, but higher compared to the months during the summer season. At the meteorological stations on the Lim Valley, the March values are lower than in February, but almost twice as high as in April. Rozaje is an exception with a higher index for March (ImDM=81,4) compared to February (ImDM=70,6). At all meteorological stations, there is an increase in the index during May compared to April. The highest values of monthly indexes for March (ImDM=104,3) and April (ImDM=53,4) were recorded in Plav, while Andrijevica has the highest monthly index for May (ImDM=61). In Bijelo Polje, the lowest monthly values of the De Marton's index for March (ImDM=55,3) and April (ImDM=32,8) were recorded, while Berane has the lowest May value (ImDM=44,8) of this climate indicator.

De Marton's values of drought index for summer months are significantly lower. June, compared to May, has lower values on all of the examined stations, while July values are higher than in August. August is a month that has least values of De Marton's index of drought throughout the

year (ImDM=17,36). Rozaje has the highest values for each of the summer months. Berane has smallest values for June (ImDM=30,9) and August (ImDM=13,1), while lowest value at July was recorded at Andrijevica (ImDM=18,4).

Monthly values for autumn months are being increased as the season passes. Average values at these five stations are changing as follows: September values (ImDM=34,48) are higher than in August (ImDM=17,36), but lower compared to October (ImDM=57,74), while October's values are lower in relation to the November ones (ImDM=85,04). Meteorological station at Rozaje has biggest values for September (ImDM=40,4), while Plav has biggest values for October and November (ImDM=69,3; ImDM=110,3 - accordingly). Bijelo Polje has the lowest values of monthly indexes for all months during the autumn.The legality of the values of the monthly drought indices falling down the Lim valley is represented in all months during the autumn.

Table 5. Monthly drought indexes(ImDM)

Month	Rožaje	Plav	Andrijevica	Berane	Bijelo Polje	Average (ImDM)
I	97,6	155,2	123,3	92,6	83,2	110,38
II	70,6	132,5	112,3	72,1	78,6	93,22
III	81,4	104,3	87,6	67,6	55,3	79,24
IV	42,6	53,4	45,9	37,9	32,8	42,52
V	59,4	60,2	61	44,8	45,4	54,16
VI	54,7	31	36,6	30,9	31,4	36,92
VII	34,1	23	18,4	18,9	25,4	23,96
VIII	27,7	16,5	14,6	13,1	14,9	17,36
IX	40,4	37,6	36,1	30,6	27,7	34,48
X	53,6	69,3	66,2	54,6	45	57,74
XI	69,4	110,3	106,9	75	63,6	85,04
XII	75,6	147,1	118,8	90,8	83,6	103,18

Source: Department of Hydrometeorology and Seismology of Montenegro, 2008-2018

In order to analyze variation of drought during the year in more detail, it is necessary to point out single months that has higher amount of drought, in which the value of De Marton's index is ImDM<20. Months that are characterized by drought are only present during the summer season, while, out of the all examined stations, only Rozaje doesn't have single dry month during this research period. August is the only dry month (except for the Rozaje), because all the values are lower than ImDM=20 on De Marton's drought index: Plav (ImDM=16,5), Bijelo Polje (ImDM=14,9), Andrijevica

(ImDM=14,6) and Berane (ImDM=13,1). July, during this examined period, is a dry month on the following meteorological stations: Andrijevica (ImDM=18,4) and Berane (ImDM=18,9).

The dry months are ocurr due to the higher average temperature in the summer months. The difference in mean summer temperatures is present between Berane and Bijelo Polje with average summer temperatures above 20°C, while average summer temperatures below 20°C can be found at Plav (18,8°C) and Andrijevica (19°C). At the meteorological station Rozaje, dry months are not present even during the summer due to a slightly lower average summer temperature (17,6°C), which is a consequence of higher altitude.The amount and regime of precipitation during the summer is a significant factor of dry months. The amount of precipitation in the summer season is significantly lower compared to other seasons. The average amount of precipitation at all meteorological stations during this period of research is 62,3 mm. The average amount of precipitation for all meteorological stations is 84,56mm for June, 59,5mm for July and42,98mm for August. Rožaje has the highest average amount of precipitation during the summer (88,31 mm) due to the higher altitude. At other meteorological stations, the average amount of precipitation during the summer ranges from 52-60 mm.

Conclusion

Climate change exacerbates soil degradation processes, mainly through changes in precipitation and evapotranspiration regimes that are further exacerbated by the occurrence of extreme meteorological events (Soils, Society and Global Change, 2007). Understanding the climatic conditions of a particular area is an essential step for studying different human activities (Piri et al., 2017). Aridity is characterized by rare and highly variable precipitation that is usually associated with a high degree of evaporation (Rakhecha and Dhar, 1975). Drought analysis and quantification in a particular area is important for all those who are working in the field of climate change, environmental protection, improving the management strategy of agriculture and water management (Rajić and Zemunac, 2017; Zemunac, Rajic, & Bezdan, 2018). One of the most dangerous and harmful effects of drought is the pressure on natural resources (water, land, air), habitats and ecosystems, and in addition it has an impact on numerous other processes and phenomenons (Maticić, 2002).

Considering the importance of climatic features and modern changes on the transformation of the natural environment and the impact on economic activities, this research paper gives an overview of annual, seasonal and monthly values of drought index at meteorological stations Rozaje (Ibar valley), Plav, Andrijevica, Berane and Bijelo Polje (Lim valley). Annual drought index with IDM values greated than 40 indicates that the climate of this area is humid and that the aridization process in this area is still not represented. The annual values of the De Marton's drought index are proportional to the increase in altitude and the amount of precipitation, and inversely proportional to the annual temperature. The values of the annual drought index using the De Marton's model are IDM=61,9 for Plav, IDM=56 for Andrijevica, IDM=52,3 for Rožaje, IDM=43,6 for Berane and IDM=41,3 for Bijelo Polje.

Regardless of the high annual values of the drought index, based on the analysis of seasonal and monthly values of the drought index, oscillations of this parameter were established during the year. The highest seasonal values of the drought index are during the winter (IsDM=117,8), while they are lowest during the summer (IsDM=11,2) on average for all analyzed meteorological stations. The months with the highest values of the drought index are January (ImDM=110,38) and December (ImDM=103,18). August is the month in which the average value of the drought index is ImDM=17,36 and based on the individual values for each meteorological station, it is the dry month at all meteorological stations in the Lim valley.

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WATER QUALITY ASSESSMENT OF THE MONTENEGRIN PART OF THE LIM RIVER USING THE SERBIAN WATER QUALITY INDEX (SWQI)

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Abstract: The paper analyzes the water quality of the Montenegrin part of the Lim River using the Serbian Water Quality Index (SWQI) method. This method uses ten physical, chemical, and microbiological parameters (temperature, pH value, electrical conductivity, oxygen saturation, BOD_5, suspended solids, total nitrogen oxides, orthophosphates, ammonium, coliform bacteria) and summarizes them in a water quality index number. Data from the Institute of Hydrometeorology and Seismology of Montenegro (IHMS) from the Annual Reports on Water Quality from 2010 to 2018 were used to assess water quality. The results of this research, according to SWQI, show that in the upper course of the Montenegrin part of the Lim, at the control stations Plav and Andrijevica, water has excellent quality. Downstream, passing through the urban areas of Berane and BijeloPolje at the control stations Skakavac, Zaton, BijeloPolje, Dobrakovo, the water quality enters the class of very good and good quality. The results of average SWQI values at all control stations for the research period of eight years indicate that the quality in the Montenegrin part of the Lim River can be classified as very good (87). The paper confirms the importance of the SWQI as a useful method for presenting water quality data despite its many advantages and disadvantages. In order to achieve relevant results and the actual ecological status of the river, it is necessary to apply the Water Quality Index (WQI), which includes inorganic parameters.

Keywords: SWQI, water quality, Montenegro, WQI, Lim

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Introduction

Water quality has recently become a significant issue in managing international river basins, especially in Europe. The issue of river water quality is reflected in environmental, economic, technological, and demographic changes (Shmueli, 1999; Kowalkowskiet al., 2006; O'Connell, 2017; Babić et al., 2019).

Water quality plays a vital role in all aspects of human and ecosystem survival. All living and industrial activities are controlled by physical, chemical, biological, and microbiological conditions in rivers and underground aquifers (Jakovljević, 2012).

In recent years, river water quality analysis based on mathematical indices that include physical, chemical, biological, and microbiological parameters has become increasingly common. Authors from around the world use different Water Quality Indices (WQI) as indicators of river pollution (Bordalo et al., 2006; Lumb et al., 2006; Bharti & Katyal, 2011;Jakovljević, 2012; Singh et al., 2013; Tyagi et al. et al., 2013; Ismail &Robescu, 2017; Babić et al., 2019;Durlević, 2020;Doderović et al., 2020).

Various environmental departments or agencies develop many WQI methods: National Sanitary Foundation, British Columbia Water Quality Index, Oregon Water Quality Index, Malaysian Water Quality Index, Florida Water Quality Index, Columbia Water Quality Index, Canadian Water Quality Index, Taiwan Water Quality Index, Washington State Water Quality Index, French Water Quality Index, Serbian Water Quality Index (Jakovljević, 2012).

Serbian Water Quality Index (SWQI) is based on the basic method of the Water Quality Index. It was developed by the Serbian Environmental Protection Agency (SEPA). This method uses ten physical, chemical, and microbiological parameters (temperature, pH value, electrical conductivity, oxygen saturation, BOD_5, suspended solids, total nitrogen oxides, orthophosphates, ammonium, coliform bacteria) and summarizes them in a water quality index number (SEPA; Jakovljević, 2012; Durlević, 2020).

The same indicator and classification for WQI developed by the Serbian Environmental Protection Agency (SEPA) were used and developed by the Agency for Nature and Environment Protection of Montenegro (ANEPM). In addition to the Agency for Nature and Environment Protection of Montenegro (ANEPM) in the territory of Montenegro, the SWQI method, which is based on the basic WQI method in the Adriatic Sea Basin, was applied by Doderović et al. (2021) to assess water quality in the Morača River basin.

Research Area

The research area of our paper is the Montenegrin part of the Lim River (Figure 1). Lim belongs to the Danube basin and is the most important river in the hydrological sense in Montenegro. The river source is Lake Plav, although its headwaters include rivers Vruja and Grnčar, which form the Ljuča, the river that flows into Lake Plav. The Lim flows through Montenegro, Serbia, and Bosnia and Herzegovina. It is the largest tributary of Drina, both in terms of the amount of water and the area of the basin, and it flows into it at a somewhat lower place than Medjedja. Before Andrijevica, the Murinska River and Zlorečica flow into Lim on the left side and Djurička, Rženička, Velička, and Komaračarivers on the right. From Andrijevica to Berane, Kraštica, Trebička, Ševarinska and Bistrica flow into Lim on the left and Šekularska and Kaludjerskarivers on the right. From Berane to BijeloPolje, Brzava and Ljubovidja flow into Lim on the left and Dapsićka and Lješnica on the right. From BijeloPolje to Dobrakovo, BjelopoljskaLješnica flows on the left side and BjelopoljskaBistrica on the right. The total length of the stream is 219 km, 87 km of which flows through the territory of Montenegro. The area of the Lim River basin in Montenegro is 2,280 km^2. The total area of the Lim River basin is 6,016 km^2 (Institute for Hydrometeorology and Seismology of Montenegro (IHMS); Hrvačević, 2004; Burić, 2010; Radojičić, 2005, 2008, 2015).

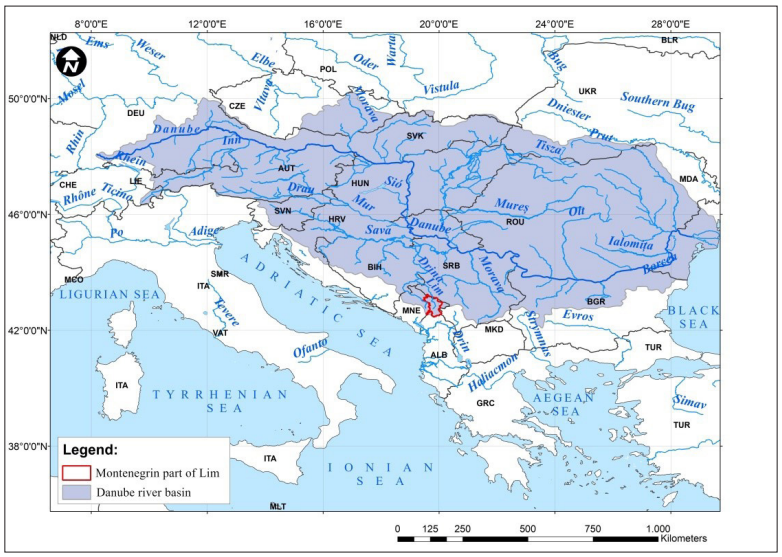

Figure 1. Position of the Montenegrin part of the Lim River

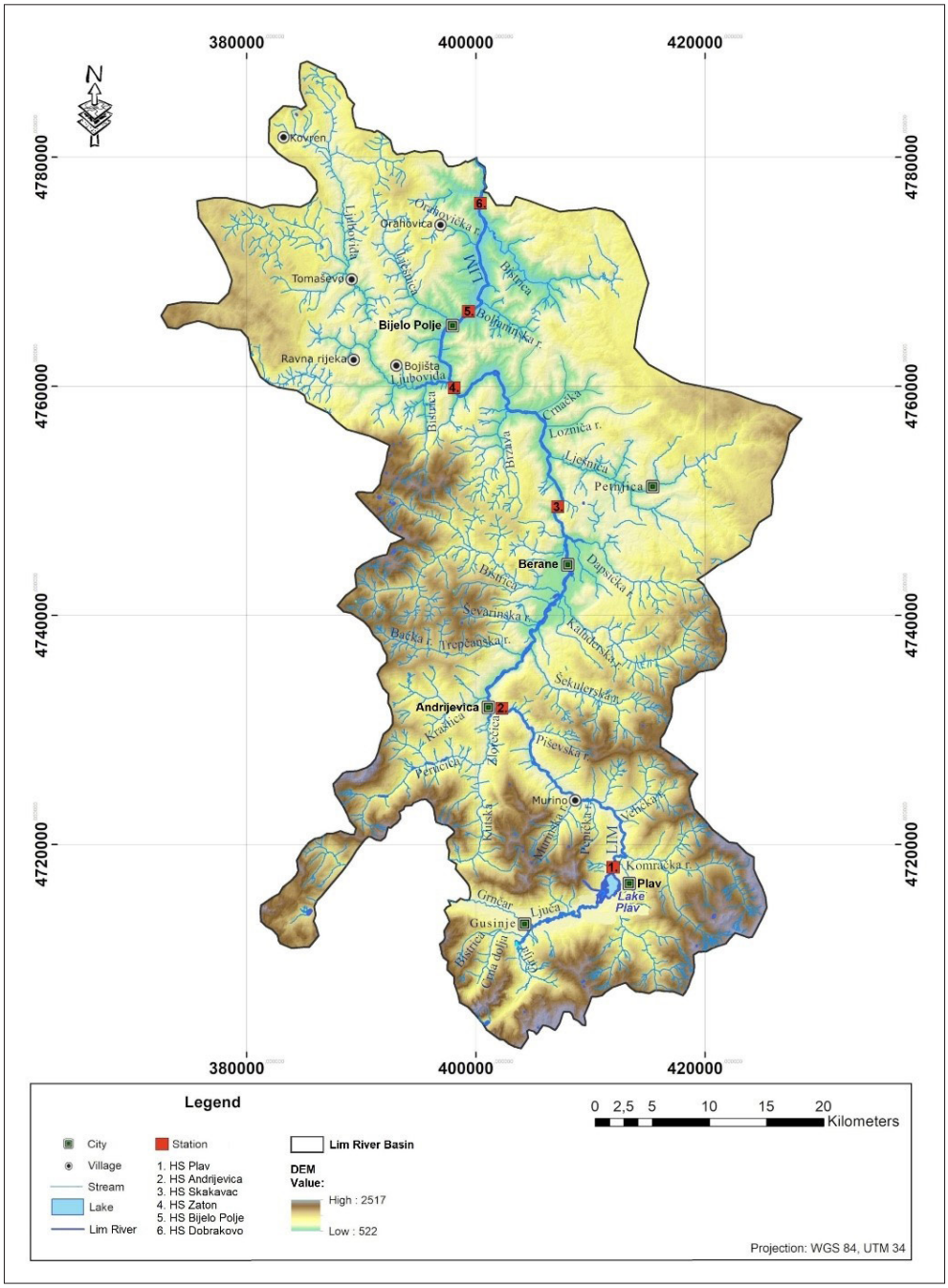

Figure 2. Map of the Montenegrin part of the Lim River with control stations

According to the Köppenclassification, the area of theMontenegrin part of the Lim River valleyis characterized by the climate Cs''bx''. In this subtype of the transitional type of the etesian climate, the influence of continentality on the precipitation regime is stronger. In the higher mountain areas covered by the study, mostly 1000 m above sea level, the climate is increasingly harsh. These are variants of moderately cold climates - Dfs''bx'', Dfs''cx'', Dfwbx'', Dfwcx'' (Burić et al., 2014).

Lim is characterized by anival-pluvial feeding regime. The natural water regime of Lim is uneven and does not meet the needs of users. The flows are minimal in the summer vegetation period of the year when the total needs of users are the greatest (Hrvačević, 2004; Burić, 2010).

The expanded Montenegrin part of the Lim River valley enabled urban development (Plav, Andrijevica,Berane, and BijeloPolje). In the middle of the 20th century, the water quality in the Montenegrin part of Lim River was endangered by the process of urbanization, industrialization, agriculture, construction of traffic infrastructure, unregulated landfills, and wastewater.The north and northeast of Montenegro and this area have been experiencing depopulation and economic stagnation for the last three decades. However, today we have many generalpressures (households, production and consumption of all forms of energy in stationary or mobile sources, industry, various stationary and mobile activities, technological waste) that threaten this river. In addition to physical pollution, chemical contamination is nowhere less important, mainly due to anthropogenic activity (nitrates, nitrites and ammonia can be found in increasing quantities).

Methodology and Data

Data from the Institute of Hydrometeorology and Seismology of Montenegro (IHMS) from the Annual Reports on Water Quality[2] were used to assess water quality. Data from six water quality control stations were processed: Plav, Andrijevica, Skakavac, Zaton, BijeloPolje, Dobrakovo (Figure 2) from 2010 to 2018 in Montenegro.

In order to calculate water quality, the Serbian Water Quality Index (SWQI) method was used. The Serbian Water Quality Index is based on the primary method of the Water Quality Index and was developed by the Serbian Environmental Protection Agency (SEPA; Jakovljević, 2012; Durlević, 2020).

[2] http://www.meteo.co.me/page.php?id=57

The Water Quality Index (WQI) method combines standardized values (qi) of ten parameters, which specify the properties of surface waters to calculate a unique index value (Kankal et al., 2012). This method uses ten physical, chemical, and microbiological parameters (temperature, pH value, electrical conductivity, oxygen saturation, BOD_5, suspended solids, total nitrogen oxides, orthophosphates, ammonium, coliform bacteria) and summarizes them in a water quality index number. The impact of the ten listed physical, chemical, and microbiological parameters is not the same. Therefore, each has an assigned weight factor and an estimate of the number of points contributing to the water quality threat. By adding the products qi and wi, we come to the value of index 100 as the ideal sum of the values of all parameters (Summary of Oregon Water Quality Index Report, 1996-2005; Khan et al., 2005; Lumb et al., 2006; Veljković et al., 2008; Milijašević Joksimović et al., 2018; Breabăn et al., 2012; Babić et al., 2019).

The number and type of parameters and their weighting coefficients can vary (be adjusted) according to local or regional conditions (Hurley et al., 2012; Garcia et al., 2018). In case we do not have the value of a parameter, the value of the arithmetically calculated WQI is corrected by multiplying the index by the value 1/k, where k is the sum of the arithmetically calculated weight factors of the available parameters (Veljković et al., 2008).

The arithmetic sequence for the Serbian Water Quality Index (SWQI) is calculated according to the following formula:

$$SWQI = 1/100 \left(\sum_{i=1}^{10} q_i \times w_i\right)$$

where***SWQI*** is the water quality index and the number on a continuous scale from 0 to 100, q_i - water quality of the appropriate parameter, w_i - weight prescribed by the appropriate parameter (Veljković et al., 2008).

The final calculation of the SWQI value was performed using a calculator available on the website of the Serbian Environmental Protection Agency (SEPA)[3]. According to the SEPA recommendations, the total nitrogen oxide parameter can be replaced with a set of parameters Nitrates + Nitrites.

[3] http://www.sepa.gov.rs/index.php?menu=46&id=8012&akcija=showExternal

Table 1. Classification of surface water quality by the Serbian Water Quality Index (SWQI) method

Water quality	Class intervals	Color symbol
Excellent	90-100	
Very good	84-89	
Good	72-83	
Bad	39-71	
Very bad	0-38	

Source: www.sepa.gov.rs

The classification of surface water values according to the SWQI method is divided into the following qualityclasses: very bad (0–38), bad (39–71), good (72–83), very good (84–89), excellent (90–100) (SEPA).

Results

The results of the research presented in Table 2 show the calculated annual and average values of the Serbian Water Quality Index (SWQI) at six control stations at the Montenegrin part of the Lim River for the period from 2010 to 2018.

The water quality at the Plav control station was classified as excellent (2010, 2011, 2012, 2013, 2015, 2016, 2018) and very good (2014, 2017). Values ranged from the lowest 85 (2017) to the highest 95 (2010, 2016). According to the average SWQI results during the entire research period, water quality at the Plav station can be classified as excellent (91).

According to the average SWQI results during the entire research period, water quality at the Andrijevica station can be classified as excellent (90). Excellent water quality at this control station was not recorded in 2012, 2014, and 2017. Values ranged from the lowest 81 (2014) to the highest 94 (2018).

The water quality at the Skakavac control station was classified as very good (2011, 2012, 2014, 2015, 2017, 2018), good (2013, 2016), and excellent (2010). Values ranged from the lowest 80 (2016) to the highest 91 (2010). According to the average SWQI results during the entire research period, water quality at the Skakavac station can be classified as very good (86).

The water quality at the Zaton control station was classified as very good (2010, 2011, 2014, 2015, 2017, 2018), excellent (2012, 2013), good (2016).

Values ranged from the lowest 82 (2016) to the highest 91 (2013). According to the average SWQI results during the entire research period, water quality at the Zaton station can be classified as very good (87).

The water quality at the BijeloPolje control station was classified as very good (2010, 2013, 2015, 2018) and good (2011, 2012, 2014, 2016, 2017). Values ranged from the lowest 70 (2011) to the highest 89 (2013, 2018). According to the average SWQI results during the entire research period, water quality at the BijeloPolje station can be classified as very good (84).

The water quality at the Dobrakovo control station was classified as good (2010, 2011, 2012, 2014, 2015, 2016) and very good (2013, 2017, 2018). Values ranged from the lowest 73 (2014) to the highest 88 (2013, 2018). According to the average SWQI results during the entire research period, the water quality at the Dobrakovo station can be classified as good (81).

According to the average SWQI values during the entire research period at all control stations, the water quality was classified as very good (2010, 2011, 2012, 2013, 2015, 2016, 2017), excellent (2018), and good (2014). Values ranged from the lowest 83 (2014) to the highest 90 (2018). According to the average SWQI during the entire research period, the water quality at all control stations can be classified as very good (87).

Table 2. Average annual SWQI at control stations in the Montenegrin part of the Lim River

CS	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*Average*
Plav	*95*	*91*	*92*	*92*	*88*	*92*	*95*	*85*	*91*	*91*
Andrijevica	*93*	*90*	*89*	*93*	*81*	*91*	*91*	*88*	*94*	*90*
Skakavac	*91*	*87*	*87*	*83*	*86*	*86*	*80*	*85*	*89*	*86*
Zaton	*89*	*84*	*90*	*91*	*85*	*87*	*82*	*84*	*89*	*87*
BijeloPolje	*87*	*79*	*83*	*89*	*82*	*85*	*83*	*83*	*89*	*84*
Dobrakovo	*81*	*79*	*77*	*88*	*73*	*81*	*82*	*84*	*88*	*81*
Average	*89*	*85*	*86*	*89*	*83*	*87*	*86*	*85*	*90*	*87*

Discussion

In the case of the Montenegrin part of the Lim River, it should be said that the index is not adapted to a specific purpose but is a general index for determining the overall water quality. From the results, we can clearly see how the water quality decreases downstream from the source. According

to SWQI values and classification in the upper course of Lim, at the control stations Plav and Andrijevica, the water has excellent quality. Downstream, passing through the urban areas of Berane and BijeloPolje at the control stations Skakavac, Zaton, BijeloPolje, Dobrakovo, the water quality shifts to classes - very good and good quality. The lower water quality is a consequence of general pressures from households, production, and consumption of all forms of energy in stationary or mobile sources, industry, various mobile activities, communal and technological waste. The average values at all control stations for the research period of eight years indicate that the quality can be classified as very good (87).

In addition to the numerous advantages provided by this method, such as adaptability at the local and regional level and the combination of several parameters in one index number, this method still partially shows the ecological condition of the river. The obtained results should be considered questionable and accepted with reservation because the Serbian Water Quality Index (SWQI) method provides information on organic load but not on inorganic pollution (e.g. heavy metals). This method and the results can serve as a good basis for the general annual review of organic load in the Montenegrin part of the Lim River.

Conclusion

This paper underlines the complexity of the assessment of water quality. It confirms the importance of the Serbian Water Quality Index (SWQI) as a useful method for presenting water quality information despite its many advantages and disadvantages. In order to achieve relevant results, it is necessary to develop and apply a Water Quality Index (WQI) methodology that would include inorganic parameters. Therefore, in future research, it would be desirable to apply the Canadian Water Quality Index (CWQI) method, which uses multiple parameters and includes inorganic parameters.

Also, the results of this research according to SWQI, as expected, show that water has excellent quality in the upper course of the Montenegrin Lim River, at the control stations Plav and Andrijevica. Downstream, passing through the urban areas of Berane and BijeloPolje at the control stations Skakavac, Zaton, BijeloPolje, Dobrakovo, the water quality enters the class of very good and good quality. The results of average SWQI values at all control stations for the research period of eight years indicate that the quality in the Montenegrin part of the Lim River can be classified as very good (87).

The quality of water at the river can become a limiting factor for development due to the negative anthropogenic impact and a threat to human health and the sustainability of natural ecosystems. Therefore, devising a strategy for the regulation, use, and protection of this essential water resource is of particular importance. Bearing in mind the current state of the river, numerous problems have been identified, which must be resolved in the coming years.

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