IMPACTS OF THE VOLCANIC ERUPTIONS OF VESUVIUS (1771) AND ICELANDIC LAKI FISSURE ERUPTION (1783-1784) ON THE BOSNIAN EYALET IN THE NORTHWESTERN PART OF OTTOMAN EMPIRE

UTJECAJI VULKANSKIH ERUPCIJA VEZUVA (1771.) I ISLANDSKE VULKANSKE PUKOTINE LAKI (1783-1784.) NA PROSTOR BOSANSKOG EJALETA U SJEVEROZAPADNOM DIJELU OSMANSKOG CARSTVA

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Summary

This paper presents a pioneering study about the impacts of the volcanic eruptions of Vesuvius (1771) and Icelandic Laki fissure eruption (1783-1784) on the northwestern part of Ottoman Empire, using the Bosnian eyalet as a case study, drawing from the available source material of different types and provenance and appropriate scholarly literature to clarify the impact of these eruptions on the area of the Bosnian eyalet.

Keywords: volcanic eruption, Vesuvius, Laki, Bosnia eyalet, historical climatology, environmental history, Ottoman Empire

Ključne riječi: vulkanska erupcija, Vezuv, Laki, Bosanski ejalet, historijska klimatologija, ekohistorija (povijest okoliša), Osmansko Carstvo

INTRODUCTION

During the period of the Little Ice Age, volcanic eruptions affected the climate of the northwestern part of the Ottoman Empire, more precisely the Bosnian eyalet. Certainly, these influences were not the same in all areas. In this paper, we primarily examine the extent of the influence of volcanic eruptions from the second half of the 18th century; that is, the eruptions of Mount Vesuvius[1] in 1771 and the volcanic fissure eruption of Laki (Lakagígar)[2] from 1783 – 1784.[3] Numerous studies about the impact of

[1] Vesuvius is a strato volcano in the south of Italy (east of Naples).

[2] Lakagígar - in literature often referred to as Laki – is actually a volcanic fissure in the south of Iceland. The crater is a part of Grímsvötn volcanic system.

[3] It is the same year of Asama volcano eruption in Japan. (Maya Yasui; Takehiro Koyaguchi, "Sequence and eruptive style of the 1783 eruption of Asama Volcano, central Japan: a case study of an andesitic explosive eruption generating fountain-fed lava flow, pumice fall,

these eruptions on the climates of different areas have been published in the professional literature. We chose to focus this study on the Bosnian eyalet because the historical source materials indicate that these two eruptions in the second half of the 18th century had a special and very specific effect on this area compared to other areas. So far, no research has been published on the effects of the 1771 and 1783 – 1784 volcanic eruptions on the Bosnian eyalet. Articles by Krešimir Kužić[4] and Jelena Mrgić[5] are useful for the neighboring areas.

The authors of this article apply historical climatology theory and methods to identify and assess the effects of these two volcanic eruptions, which importantly took place within the climatological period known as the Little Ice Age.

In the context of this paper, it is worth explaining the character of the source material used, as there are no (or still not found) sources that deal exclusively and systematically with the weather and / or climate of the Bosnian eyalet at the end of the 18th century. Nor were there instrumental measurements. Instead, the testimonies of contemporary authors are scoured for evidence. As these were mostly chronicles and annals, they commented on some extreme weather and environmental events that the authors believed were worth recording, providing data of great usefulness for this analysis. In addition, the registry books (of which only a few are available for the period discussed in the article) provided some documentation useful to this study.

LITTLE ICE AGE

The term "Little Ice Age" gave rise to a complex concept that over time became the subject of research in many scientific fields. Although it is very difficult in one place and in a small-scale work to precisely and completely clarify all that the Little Ice Age entailed, here the authors provide introductory information about the Little Ice Age to make it possible to understand the context of this paper.

François E. Matthes first used the term "Little Ice Age" (LIA) in 1939[6] to describe the glacial progress in the Sierra Nevada mountains of California during the Holocene. This term soon became widely used in scientific studies, but there was a terminological critique of those who pointed out the exclusivity of the term[7], emphasizing other phenomena outside the scope of exclusively glacial issues. The term "Little Ice Age"[8] has thus become closely related to climate almost from the very beginning of its appearance in the scientific literature. In addition, it was particularly attached to the cold periods. Thus, the concept of the "Little Ice Age" in research today has shifted mainly to climate research, while much less research is focused on glaciers.[9] Although the term itself was used for the period of expansion of

scoria flow and forming a cone", *Bulletin of Volcanol*ogy 66, (2004): 243–262).

4 Krešimir Kužić, "Atmosferski utjecaj erupcije vulkana Lakija na Hrvatsku 1783. godine", *Geoadria, Vol .11, No. 1,* (2006): 3–15.

5 Jelena Mrgić, "Intemperate weather in violent times – narratives from the Western Balkans during the Little Ice Age (17 – 18th centuries)", *Cuadernos de Investigacion Geografica/Geographical Research Letters, 44, 1 ,* (2018): 162. In the context of researching impacts of volcano eruptions on the northwestern part of Ottoman Empire there is also one Mrgić's paper that thematize marginal notes on the eruption of the Vesuvius in 1631. [(Jelena Mrgić, "Let it be known when ash fell from the skies to the Earth…Serbian marginal notes on the eruption of the Vesuvius in 1631 AD", Études balkaniques, No. 3, (2007): 107 – 112)].

6 François E. Matthes, "Report of the Committee on Glaciers", *Transactions: American Geophysical Union, 20, 4,* (1939): 518–523.

7 Astrid E. J. Ogilvie, Trausti Jonsson, ""Little Ice Age" Research: A Perspective from Iceland", *Climatic Change, 48*, *1,* (2001): 9–52.

8 Sam White, "The Real Little Ice Age," *Journal of Interdisciplinary History*, 44 (2013): 327–352; Dagomar Degroot. *The Frigid Golden Age: Climate Change, the Little Ice Age, and the Dutch Republic, 1560-1720* (Cambridge: Cambridge University Press, 2018).

9 This sequence of events resulted in the creation of the confusion. This confusion prompted the authors in writing the papers that argue for the inappropriateness of the terminological determinant and emphasize caution in the use of the term. Also, several authors consider that the term should be avoided due the limited utility, and some of them judged the term as open misconception because it refers to something it does not actually represent (a real ice age). Discussions also included proposals to remove the term from use. [(John A. Matthews, Keith R. Briffa, "The Little Ice Age": Re-evaluation of an evolving concept", *Geografiska Annaler: Series A: Physical Geography,* 87, 1, (2005): 17; Helmut E. Landsberg, "Historical weather data and early meteorological observations", *Paleoclimate analysis and modeling,* ed. A. D. Hecht, (New York: John Wiley, 1985), 27–70; Philip D. Jones, Raymoned S. Bradley, "Climatic variations over the last 500 years", *Climate Since A. D. 1500*, ed. Philip D. Jones, Raymoned S. Bradley, (London/New York: Routledge, 1992), 649–665; Michael E. Mann, Phill D. Jones, "Climate over past millennia", *Reviews of Geophysics, 42, 2,* (2004): 1–42; Stephen C. Porter, George H. Denton, "Chronology of Neoglaciation in the North American Cordillera", *American Journal of Science, 265*, (1967): 177–210)].

most of the world's glaciers, controversy continues[10] over the link between lower temperatures and glacial formation. Nevertheless, it was finally established as a global climatological event and in this paper, it is taken as a climatological foundation for the indicated period of study.

The Little Ice Age is conceptually constructed in comparison to the earlier medieval warming period[11] and defined as a general term for global cooling and the climate variable period. However, there are discussions about the static significance of such a defined temperature depression.[12] The Little Ice Age is not quite consistently defined because it was not continuously cold, exhibiting very pronounced climatic variability including warm extremes.[13] The beginning of the Little Ice Age is variously dated between 1300 and 1450, while its end is variously dated between 1850 and 1900.[14] As noted above, within this period locally differentiated episodes of weather extremes are noticeable. This was the last period when the lowest summer insolation of the northern hemisphere caused the advance of mountain glaciers[15], which descended lowest after the last Würmian glacial, and remained at that height until the end of the nineteenth century when their abrupt retreat began.[16]

Today, the concept of the Little Ice Age has been extended in the professional literature to include the so-called "Little Ice Age - type events". An up-to-date assessment of the characteristics of the Little Ice Age as a glacial and climatic concept was also made possible by the availability of information from historical documentary and proxy (indirect) testimonies related to glacial and climatic variability during that period. Furthermore, the context in which Little Ice Age research takes place has expanded with increasing knowledge of the nature of Holocene events and accelerating the development of reconstructions of parallel climatic influences (such as changes in solar radiation and volcanic activity). This is therefore no longer a unique phase in the history of glaciers and climates, but can be considered a fundamental test case to understand events of centuries and millennia that affect the earth-atmosphere and ocean systems during the Holocene. Precisely for this reason, the Little Ice Age is a concept worth examining on multiple levels. By no means should the glacial and climatic concepts of the Little Ice Age be equated. There is a more complex definition of the concept from a climatic point of view in relation to the glacial one due to greater temporal and spatial variability, which was one of the most controversial issues of the conceptualization of the Little Ice Age.[17] There are other contexts of the Little Ice Age that are representative of the Little Ice Age - Type Impact (LIATIMP) research.[18]

The sustainability of the concept of the Little Ice Age depends, among other things, on the inclusion of spacio-temporal complexities (both climatic and glacial) to the extent allowed, as well as on the

[10] Discussions about those controversies had a great deal of influence to determine the terminology associated with this period. (Ulf Büntgen, Lena Hellman, "The Little Ice Age in Scientific Perspective: Cold Spells and Caveats, Journal of Interdisciplinary History, 44, 3, (2014): 335).

[11] John. F. Richards, *The Unending Frontier: An Environmental History of the Early Modern World*, (Berkeley/Los Angeles/London: University of California Press, 2003), 60.

[12] Mathew J. Owens, Mike Lockwood, Ed Hawkins, Ilya Usoskin, Gareth S. Jones, Luke Barnard, Andrew Schurer, John Fasullo, "The Maunder minimum and the Little Ice Age: An update from recent reconstructions and climate simulations", *Journal of Space Weather and Space Climate, 7, A33*, (2017): 3–4.

[13] Chantal Camenisch, Christian Rohr, "When the weather turned bad. The research of climate impacts on society and economy during the Little Ice Age i Europe. An overview", *Cuadernos de Investigavión Geográfica/Geographical Research Letters, 44, 1,* (2018): 100.

[14] Mann, Jones, "Climate over past millennia", 32.

[15] Philip Hughes, Little Ice Age glaciers and climate in the Mediterranean mountains*: a new analysis, Cuadernos de Investigavión Geográfica/Geographical Research Letters, 44, 1,* (2018): 15; Jelena Mrgić, "Intemperate weather in violent times – narratives from the Western Balkans during the Little Ice Age (17 – 18th centuries)", *Cuadernos de Investigation Geografica/Geographical Research Letters, 44, 1 ,* (2018): 140.

[16] Tomislav Šegota, Anita Filipčić, *Klimatologija za geografe: III prerađeno izdanje*, (Zagreb: Školska knjiga, 1996), 345.

[17] Matthews, Briffa, "The "Little Ice Age"", 17–18.

[18] The term was introduced by a respectable scientist Christian Pfister in order to explain a specific type, ie a type of climate impact on society, caused by cold spring months and rainy mid-summer periods. The term mostly relates to unfavorable climate situations that influenced society. This concept is related to a concept of social vulnerability, which is a must-have in research of Little Ice Age. [(Christian Pfister, "Weeping in the snow. The second period of Little Ice Age-type Impacts, 1570 – 1630", *Kulturelle Konsequenzen der "Kleinen Eiszeit"/Cultural consequences of the "Little Ice Age": Veröffentlichungen des Max-Planck-Instituts für Geschichte*, *212, ed.* W. Behringer, H. Lehman, C. Pfister, (Gottingen: Vandenhoeck and Ruprecht, 2005), 31–86.); (Camenisch, Rohr, "When the weather turned bad", 101; Christian Pfister, Rudolf Brázdil, "Social vulnerability to climate in the "Little Ice Age": An example from Central Europe in the early 1770s", *Climate of the Past, 2*, (2006): 115–129)].

inclusion of the complete earth-atmosphere-ocean system and its factors in cooperation with paleoclimatic reconstructions with climate modeling.[19] The concept of the Little Ice Age proved resilient even though there were various controversies. So, regardless of the focus on climate it gives importance to an ever-expanding range of proxy databases (which are concentrated on studying rings up to the core of glaciers). The concept[20] is also useful for increasing awareness of climate variability and spatial differentiations, thus abandoning the earlier understanding of the Little Ice Age as a continuous and globally synchronous cold period.

IMPACTS OF VOLCANIC ERUPTIONS

Theories of volcanism confirmed by research and various techniques (such as the achievements of computer technology aiming to determine the temperature changes resulting from the addition of stratospheric volcanic aerosols[21]) are incorporated into the system of the Little Ice Age. They proved the connection of volcanic eruptions with climatic manifestations, which later caused other secondary and tertiary consequences[22] that will be discussed in more detail in the following paragraphs.[23]

During the Little Ice Age, direct and indirect effects of volcanic eruptions on the weather conditions of the Bosnian eyalet were observed by contemporaries. But their observations are sometimes difficult to determine in historical sources because the observers did not associate them with climate or to distant events like volcanic eruptions that occurred beyond the reach of their communication. Yet, with modern science we can link volcanic eruptions with climatic phenomena in remote areas retroactively.[24]

Sulfur aerosols that remained in the stratosphere, and then their radiation, led to cooling and a reduction in sunshine.[25] Volcanic eruptions emit various gases, in addition to them, some heavy metals and organic compounds are released. Along with volcanic ash, the particles of glass, minerals and stone are released, too.[26] The effects of the eruption mainly result from the release of large amounts of sulfur dioxide (SO2) and hydrogen sulfide (H2S) and their conversion into aerosols. In the lower atmosphere, the particles are removed within a few weeks and have no long-term effects. However, particles that formed in the stratosphere, higher than fifteen kilometers above sea level, can persist for several years. Aerosols heat the stratosphere but also cool the surface of the earth.[27] In this way, the volcanic eruptions can temporarily cause global cooling and a change in precipitation patterns.[28] Specifically, volcanic eruptions can lead to a trend of colder summers as well as warmer winters in the northern hemisphere, and can weaken African and Asian summer monsoons.[29]

19 Matthews, Briffa, "The "Little Ice Age"", 17.

20 With the introduction of the characteristics of climate change (which includes temporal-spatial determinants), the concept of the Little Ice Age is complicated, so the concepts of the so-called "Little Ice Age - type events" and "Little Ice Age - Type Impact" got a significant role. Thus, the main challenges of the concept are improving the understanding of temporal and spatial matrices, understanding the factors and mechanisms of influence that caused the "Little Ice Age - type events" during the Holocene, as well as properly understanding the role and importance of the concept of "Little Ice Age - type impact". Therefore, it is necessary to understand them in accordance with the general concept of the Little Ice Age in relation to society and to place and valorize them in a purposeful way. [(Pfister, Weeping in the Snow, 32–33)].

21 Ie,. James B. Pollack, Owen B. Toon, Carl Sagan, Audrey Summers, Betty Baldwin, Warren Van Camp, "Volcanic Explosions and Climatic Change: A Theoretical Assessment", *Journal of Geophysical Research, 81, 6,* (1976): 1071–1083.

22 See, ie Eugenija Žuškin, Jadranka Mustajbegović, Jagoda Doko Jelinić, Jasna Pucarin-Cvetković, Milan Milošević, "Učinci vulkanskih erupcija na okoliš i zdravlje", *Arhiv za higijenu rada i toksikologiju, 58, 4,* (2007): 479–486.

23 Ema Pašić, *Malo ledeno doba od 17. do početka 19. stoljeća na prostoru Bosanskog ejaleta/Little Ice Age from the 17th to the beginning of the 19th century on the area of the Bosnian Eyalet,* Master's thesis, (Zagreb: Faculty of Humanities and Social Sciences, 2019), 16.

24 The same, 47–48.

25 Ognjen Bonacci, "Utjecaj erupcija vulkana na klimu", *Hrvatske vode, Časopis za vodno gospodarstvo, 90, 22,* (2014): 347−351.

26 Eugenija Žuškin, Jadranka Mustajbegović, Jagoda Doko Jelinić, Jasna Pucarin-Cvetković, Milan Milošević, "Učinci vulkanskih erupcija na okoliš i zdravlje", *Arhiv za higijenu rada i toksikologiju, 58, 4,* (2007), 480.

27 Jürg Luterbacher, Christian Pfister, "The year without a summer", *Nature Geoscience, 8*, Macmillan Publishers, 2015, 246.

28 Jürg Luterbacher, Christian Pfister, "The year without a summer", *Nature Geoscience, 8*, Macmillan Publishers, 2015, 246.

29 Bonacci, "Utjecaj erupcija", 347.

The effects of such volcanic eruptions are not uniform for all areas and as such can be observed only within a relatively narrow area.[30] Of course, post-eruptive impacts on remote areas came in waves, so volcanic eruptions could be associated with long-lasting amplified effects of the Little Ice Age that manifested not only through pollution and through the onset of famine, but consequently through disease.[31] The consequences of unregulated cold and humid conditions during summer and as a result of eruptive actions used to be unpleasant for the population, both economically and socially. Modeling the interaction of climate and society (albeit simplified) suggests that extreme events, such as those caused by volcanic eruptions can have a number of consequences.[32] Thus, post eruptive periods show opportunities to create an extraordinary case study to explore different direct and indirect interactions between climate variability and humans.

ATMOSPHERIC EFFECTS OF VESUVIUS (1771) AND LAKI FISSURE (1783 - 1784) ERUPTIONS

Climate influences of two eruptions that occurred in the second half of the 18th century, i.e. the eruption of Vesuvius in 1771 and the volcanic fissure Laki in 1783 – 1784, are particularly interesting for research. As the previous professional literature in the field of historical climatology has successfully proven, both eruptions caused climatic conditions indicative of post-eruptive periods. Nevertheless, it would be interesting to examine here how much these eruptions affected the area of the Bosnian eyalet and whether it is possible to connect the weather patterns after the eruptions in the area of the Bosnian eyalet with the weather patterns in other nearby areas. The 1771 Vesuvius eruption was significantly weaker, shorter and less destructive than 1783 – 1784 Laki fissure eruption. So far, the professional literature has dealt much less with the impacts of the Vesuvius eruption on climate in general, compared to the climate impacts of the Laki fissure eruption, on which a large number of studies have been written. This is of course quite justified since the eruption of the Laki fissure had a much larger and more direct impact on the climate of a wide area globally.[33]

In the case of Bosnian eyalet area, it is certain that the Laki fissure eruption, which lasted for eight months (June 8, 1783 to February 7, 1784) did not cause any *direct* consequences. That is, the population of the Bosnian eyalet did not feel the direct or the harmful effects of the eruptive fog, which in some cases was very dangerous for the population. However, there was a documentable impact of the eruption on the climate in the case of the Bosnian eyalet area in the months and years following. This can be established based on testimonies from the original material, as well as based on dendrochronological and dendroclimatological analyses, which are quite clear parameters in such analyses, as they can effectively identify precipitation and temperature amplitudes in the thematic period.

Unlike most areas in Europe that suffered significantly from the eruptions' secondary and tertiary consequences, there was no noticeable damage in the Bosnian eyalet to that extent, which does not mean that there was no impact at all. First of all, it is worth mentioning that before this eruption, a plague

30 Luterbacher, Pfister, "The year without a summer", 246.

31 Krešimir Kužić, "Posljedice erupcije vulkana Huaynaputina godine 1600. na hrvatske zemlje", *Ekonomska i ekohistorija: časopis za gospodarsku povijest i povijest okoliša, 9, 1,* (2013): 105.

32 Luterbacher, Pfister, "The year without a summer", 246.

33 See more Katrin Kleemann, "The Laki eruption and strange weather phenomena in the German territories in the summer of 1783", Poster, *8th ESEH Conference*, (2015); Rudolf Brázdil, Ladislava Řezníčková, Hubert Valášek, Lukáš Dolák, Oldřich Kotyza, "Climatic and other responses to the Lakagigar 1783 and Tambora 1815 volcanic eruptions in the Czech Lands", *Geografie 122(2),* (2017): 147–168; Thorvaldur Thordarson, Stephen Self, "Atmosphere and environmental effects of the 1783-1784 Laki eruption: A review and reassessment", *Journal of Geophysical Research: Atmospheres Vol. 108, No. D1,* (2003); Krešimir Kužić, "Atmosferski utjecaj erupcije vulkana Lakija na Hrvatsku 1783. godine", *Geoadria, Vol .11, No. 1,* (2006): 3–15; Alan Robock, Michael J. Mills, Anja Schmidt, "Modeling the 1783–1784 Laki Eruption in Iceland: 2. Climate Impacts", *Journal of Geophysical Research: Atmospheres Vol. 124, No. 13,* (2019); Ricardo M Trigo, José M. Vaquero, R.B.Stothers, "Witnessing the impact of the 1783–1784 Laki eruption in the Southern Hemisphere", *Climatic Change 99(3)*, (2010): 535–546; Katrin Kleemann."Telling Stories of a Changed Climate: The Laki Fissure Eruption and the Interdisciplinarity of Climate History," edited by Katrin Kleemann and Jeroen Oomen, *RCC Perspectives: Transformations in Environment and Society* 2019, no. 4, 33–42.

reigned in the Bosnian eyalet in 1782, taking a large number of lives, so the population was reduced by these circumstances.[34] This is important from food resources point of view, food supply being extremely important in the early modern age. As such, this could have significantly influenced the recording of contemporary authors who reported on the years after the eruption.

After the eruption, the consequences that followed proved to be very indicative and model setting when it comes to climatic variability caused by eruptive actions. Based on the tree ring width analysis (TRW), a deviation from the reconstructed average was shown. The observed standard deviation (SD) in terms of solar radiation for 1786 in the Bosnian eyalet showed a reduced solar radiation in the summer season of that year.[35] Then the lack of sun, as well as unfavorable precipitation (too much rain) caused serious consequences.[36] Such was not the case with the previous summer seasons of 1784 and 1785, which were without a significant reduction in solar radiation, although the contemporary author of these events, Mula Mustafa Bašeskija, states that in 1785 trees blossomed much later in season, with a significant delay, which could also be attributed to variable patterns characteristic of the post eruptive state.[37]

The same situation was repeated in the climatic sense of the crucial year of 1786, when, as Bašeskija states: *"The trees blossomed very late in April, two days before St. George's Day. On Tuesday, the 4th day of Rajab in 1200, such a strong wind blew and destroyed the minarets of Kadina and Ajas-pasha mahallah mosques. The wind uprooted many fruit trees in the gardens and everyone suffered harm. Some less, some more ... On the first day when the sun set in the constellation of Gemini, heavy and abundant snow fell throughout the day... This year it rained all summer so that the mountains and rocks became green. The grass did not turn yellow, but green. The fruit was struck by a disease, and the watermelon was sown late. People were afraid that it would bear no fruit, because if the weather was nice for three or four days in a row, then the rain would follow for many days. Cucumbers gave birth, and watermelon and melon were almost non-existent. The grains were hastily picked and harvested with great difficulty."*[38]

That year, due to reduced solar radiation and climatic variability with snow in summer and heavy rainfall, there was a disruption of the cycle on which the lives of early modern humans depended. Precipitation affected crops and certainly favored the development of plant diseases that are evident based on this testimony. So the harvest was easily compromised by certain combinations of weather patterns.[39] It could be inferred that the volcanic eruption in this case caused an extreme disturbance with further far-reaching consequences.

Unlike the 1783 – 1784 Laki eruption, which was repeatedly analyzed in the context of weather and climatic influences in different areas, the May 1771 Mount Vesuvius eruption had very few reviews.

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34 The author Mula Mustafa Bašeskija, a contemporary of these events, states that a plague broke out that took a large number of lives. He describes a large number of funerals (and prayers at funerals) took place in front of Sarajevo mosques. The plague raged for a long time among all ranks of society and even his two children died from it. According to his testimony, the death rate decreased and increased during that period of the infection, after which it finally stopped after a year. [Mula Mustafa Ševki Bašeskija, Ljetopis (1746 – 1804) / Chronicle (1746 – 1804), translated by Mehmed Mujezinović, (Sarajevo: Sarajevo Publishing, 1997), 217–218)]; Bono Benić also talks about these events. He states that 1782 Sarajevo plague slowly killed the population, especially the younger population, and the following year it spread to Visoko, Kreševo, Fojnica, Zenica, Travnik, Sutjeska and in the surrounding villages. He describes how many people died by January 1784 and how these were enormous troubles for the population. [Bono Benić, Ljetopis sutješkog samostana / The annals of the Sutjeska monastery, prepared by fra. Ignacije Gavran, edited by Ivan Lovrenović, (Zagreb: Synopsis, 2003), 329 – 330)]. That this was a really difficult period is confirmed by the testimony of Marijan Bogdanović, who was not able to write his Chronicle because those three years were, among other things, when the plague reigned and the situation was very difficult. [(Marijan Bogdanović, Ljetopis kreševskoga samostana / The annals of the Kreševo monastery, prepared and translated by dr. Fra. Ignacije Gavran, Synopsis, (Sarajevo, Zagreb: 2003), 209)]. Also, famine and plague in the area of Brotnjo (Čitluk) were recorded in the period from August 1783 to the end of January 1784. Then 62 people died. [(Robert Jolić, *Stanovništvo Brotnja u tursko doba*, (Čitluk: Općinsko vijeće Čitluk, 2009), 288-289)].

35 Simon Poljanšek, Andrej Ceglar, Tom Levanič, "Long-term summer sunshine/moisture stress reconstruction from tree-ring widths from Bosnia and Herzegovina", *Climate of the Past, 9*, (2013): 33.

36 Bašeskija, *Ljetopis/Chronicle*, 246.

37 Bašeskija, *Ljetopis/Chronicle,* 252.

38 Bašeskija, *Ljetopis/Chronicle*, 245–246.

39 Mrgić, "Wine or "Raki" – The Interplay of Climate and Society in Early Modern Ottoman Bosnia", *Environment & History, Vol. 17, No. 4,* (2011): 622.

Certainly, the effects of Vesuvius eruption on the temporal patterns in the Bosnian eyalet area were very indicative which could not be said for the wider European area). Although it was not a strong eruption with broader implications (as the previously analyzed Laki fissure eruption), it could be assumed that it caused significant effects in the area of the Bosnian eyelet.

The atmospheric influences of the eruption to the Bosnian eyalet (through climatic manifestations) began to be felt as early as the summer of 1771. In fact, after a dry period, as Marijan Bogdanović, a contemporary author of the period, states " *the storms began with very strong winds and the rains that did more harm than good.*"[40] According to him, the rains fell every day during that summer period, and there were great cold periods that did not stop until the middle of the month, which, as Bogdanović states, "*... harmed the fields, so we ordered public prayers for good weather.*"[41] However, the situation did not improve, the effects of the eruption were further reflected through the cooling period, and according to sources "*... although the Sun is at a great height towards us, it was cold due to constant rains from the north on big mountains, covered with snow, so many of the monastery folks threw cloaks on their backs.*"[42]; *"The cold, northern winds began to blow and a lot of rain fell. So the folks put on their winter clothes and kept their backs warm. This is how it went for the next ten days and only then the skies cleared."[43] Then more rains continued, and in parallel, the crops were much endangered.[44]* The weather was relatively unfavorable in July as well, as evidenced by Bogdanović statement *"We are very disturbed, however, by the weather conditions".[45]* In 1771, the effects of the Mount Vesuvius eruption continued - it was constantly cold and the rain would not stop, as the sources say *"it rained when it's not its time*"[46] After that, there was a period of several days of nice weather, followed again by storms and rains which (as shown in the original testimonies), disturbed the population.[47] The end of July was changeable with rains, and August unusually cold with wind, but with less precipitation.[48] The tertiary consequences of the eruption were also reflected at the end of that year, i.e. cases of plague and childhood diseases were recorded in the Bosnian eyalet.[49]

In the summer of 1772, the temperature drop and decrease of sunshine hours per day, confirmed by tree growth research, could easily be attributed to the effects of volcanic emissions.[50] On the other hand, the disruption of the cycle that year is also visible in the winter season, too. There were deviations and disrupted patterns in seasonal temperature and precipitation, characteristic of the seasons.[51] This is certainly one of the volcanic eruptions side-effects on the climate. Judging by the analyses of dendroclimatology from 1741 until 1771, there were no low-temperature extremes during the summer season on the scale that had occurred in 1772.[52] Famine and the crisis of mortality were visible in 1772 in Vrgorac in the Venetian Republic, in the immediate vicinity of the Ottoman Empire.[53]

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40 Bogdanović, *Ljetopis/The annals*, 179.
41 Bogdanović, *Ljetopis/The annals*, 179.
42 Bogdanović, *Ljetopis/The annals,* 180.
43 Jako Baltić, *Godišnjak od događaja crkvenih, svietskih i promine vrimena u Bosni/The annals of church and world events and time changes in Bosnia* (prepared by fra. Andrija Zirdum), (Sarajevo, Zagreb: Synopsis, 2003), 61.
44 Bogdanović, *Ljetopis/The annals,* 180–181.
45 Bogdanović, *Ljetopis/The annals,* 180, 182.
46 Bogdanović, *Ljetopis/The annals,* 180, 182.
47 Bogdanović, *Ljetopis/The annals,* 180, 182.
48 Bogdanović, *Ljetopis/The annals,* 180, 182–184.
49 Bašeskija, *Ljetopis/Chronicle*, 109.
50 Poljanšek, Ceglar, Levanič, "Long-term summer sunshine/moisture stress", 36.
51 Bašeskija, *Ljetopis/Chronicle*, 108–110.
52 Pašić*, Malo ledeno doba/Little Ice Age*, 39.
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Therefore, we could say that in addition to climate effect to moisture stress the post-eruptive period caused colder temperatures as well.[54] Everything analyzed here indicates that there is a correlation between the events in the area of the Bosnian eyalet with the eruption of Mount Vesuvius in 1771.[55]

TERTIARY CONSEQUENCES OF VOLCANIC ERUPTIONS

As it turns out, both analyzed eruptions had some effects on the climate of the Bosnian eyalet. Consequently, they led to effects that influenced the local population. As the research of the tertiary consequences of volcanic eruptions is an issue that should be treated systematically in accordance with the considered area, in this case the four-row model of Daniel Krämer[56] will be used. Below, the authors examine how climatic events, especially extreme ones - such as those caused by volcanic eruptions - can affect society and what are the social coping strategies for such extreme climatic events.[57]

Climate effect models[58] are often framed as cause-and-effect relationships, and climate patterns have a primary or biophysical impact on agricultural production or on epidemics of both humans and animals. These effects certainly have effects caused by first-order impacts such as changes in prices of food and/or raw materials, which in turn can be implied to the wider economic and social sphere, or to third-order impacts. This model is particularly suitable in the context of investigating the interactions of extreme climate events and population reactions, since volcanic eruptions have indeed caused extreme and unpredictable climate events.[59]

According to the model, the further away from the influence of the first order, the greater the complexity of the factors that mask the climate effects, but they will also be the focus. In this case, it is very easy to investigate the effects of short-term effects, i.e. post eruptive effects, while dealing with long-term effects is a much more complex process.[60]

The biophysical effects of extreme climatic events had an impact on the population, endangering primary production like food, fodder and firewood. After the eruptions of Vesuvius in 1771 and Laki fissure in 1783 – 1784, the secondary climate disturbances led to the tertiary consequences of these events, creating conditions of threat, scarcity and shortages. The secondary effects of the eruption that shifted the seasonal temperature and precipitation patterns in the cases of these eruptions did not lead to acute conditions in the history of the Bosnian eyalet, but certainly led to very difficult conditions worth analyzing on this occasion.

When analyzing the biophysical effects, the vulnerability of the population of the Bosnian eyalet to hunger should certainly be examined. As a heuristic tool suitable for researching one of the most indicative tertiary consequences of volcanic eruptions - famine, the “Famine Vulnerability Analysis Model” (FVAM) stands out.[61] The application of this model refers to presentation of the assessment of population vulnerability to hunger through a number of factors (social and environmental, i.e. population, politics, economy, agriculture and environment / climate). According to the mentioned model, there are 33 of these indicator factors, so the overall vulnerability rating ranges from -33 (minimum vulnerability) to

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54 Poljanšek, Ceglar, Levanič, “Long term January – March and May – August temperature reconstructions from tree-ring records from Bosnia and Herzegovina” *Climate of the Past Discussions, 8,* (2012): 4401–4442.

55 Poljanšek, Ceglar, Levanič, “Long-term summer sunshine/moisture stress”, 35.

56 Daniel Krämer, *Menschen grasten nun mit dem Vieh: Die letzte grosse Hungerkrise der Schweiz 1816/1817,* (Basel: Schwabe Verlag, 2015).

57 Pašić, *Malo ledeno doba/Little Ice Age*, 50.

58 Luterbacher, Pfister, “The year without a summer”, 248.

59 The same, 50.

60 Pfister, “Climate”, *Encyclopedia of World Environmental History 1,* ed. S. Krech, J. R. Mc. Neill; C. Merchant, (New York: Routledge, 2003), 233–238.

61 It was formed and presented by Steven Engler in the work “Developing a historically based” Famine Vulnerability Analysis Model (FVAM) - An interdisciplinary approach “. It is designed to study the wide range of famines in a given time and space and contains implications that are important for the availability, handling and analysis of historical famine data, their comparison with others, analyzing livelihoods and their socio-economic context before initial triggers acted and influenced them. [(Steven Engler, “The Irish famine of 1740 – 1741: Famine vulnerability and” climate migration “, Climate of the Past 9 (3), (2013): 1162)].

+33 (maximum vulnerability). In addition, five types of vulnerability to hunger are classified, i.e. very resilient society (-33 to -20), resilient society (-19 to -6), society in danger (-5 to 5), vulnerable society (6 to 19) and a very vulnerable society (20 to 33).[62] As already pointed out, the basic factors for the analysis of vulnerability to hunger are the population, political factors, economic factors and agricultural factors. They need to be analyzed, in order to understand the extent of the impact of volcanic eruptions on hunger of the population, in terms of vulnerability of the population to starvation.

Thus, by analyzing the periods during which the two thematic eruptions occurred, by studying social and environmental factors valorizing their vulnerability to famine, the overall assessment of the vulnerability index of those years in the territory of Bosnian eyalet varies from 9 to 19, hence, that society is characterized as a vulnerable society.

Since the population of the Bosnian eyalet was assessed as a vulnerable one, it is worth noting that the post-eruptive effects could be very dangerous for the population. This was also shown in the cases of both eruptions. So, the biophysical effects of climatic events, that could be observed in the context of the 1771 Vesuvius eruption consequences, are visible based on the testimony of a contemporary author Marijan Bogdanović, who describes the year of 1771 like this: *"It rains every day and it significantly damages the fields. And this goes on for the whole month."*[63], stating there was anxiety and worry among the population due to weather conditions that were not expected.[64] For that year, Bašeskija states "*... the hail and ice pellets destroyed crops in some villages, no fruit survived and the price of grains increased.*"[65]

Even though the mentioned volcanic eruptions caused anomalies, when it comes to Bosnian eyalet weather patterns, they did not severely disrupt the systems of agricultural production. However, as a result of the events, the price of food increased, "*on 2nd of Majisa in 1201, after sunset, the sky became more reddish. This year, the food was quite expensive.*"[66], which mainly comes as a result of food shortages which, of course, was conditioned by primary food production. The quality of life of the Bosnian eyalet population depended on these factors. So, it should be taken into account that this society could not cope (but only adapt) with some climatic patterns. As a result, it was often endangered, precisely the second-level effect that will be discussed later.[67]

When it comes to the effects of the second order, the anomalies that most likely occurred with 1771 Vesuvius and 1783 – 1784 Laki eruptions left consequences on the socio-economic level in the Bosnian eyalet. The anomalies caused by the eruptions led to situations that required market adjustments to the new situation, which also meant an increase in market prices, especially the basic and primary foodstuffs. Of course, such a system of life consequently affected people's health as well, given a vulnerable society.[68]

Economic disturbances, i.e. the rise in prices that occurred as a post-effect of 1771 Mount Vesuvius eruption, soon became noticeable. The prices of bread and butter rose (1 *junga* of butter[69] was 25 – 30 *para*, while in 1771. the same quantity was priced at 60 *para*) and meat[70], while the wheat price in 1772 increased "*As the hail destroyed crops in some villages, no fruit was born, the grains became more expensive and the wheat was sold for 5-6 groschen (Kuruş)[71], a šinik[72] at 1.200 para."*[73] Due to

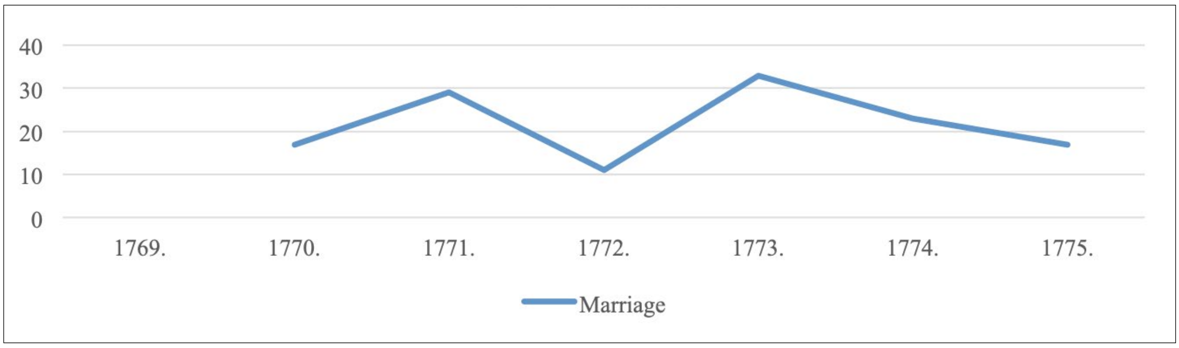
62 Engler, "The Irish famine of 1740–1741", 1163.
63 Bogdanović, *Ljetopis/The annals,* 180.
64 Bogdanović, *Ljetopis/The annals,* 182.
65 Bašeskija, *Ljetopis/Chronicle,* 115.
66 Bašeskija, *Ljetopis/Chronicle*, 252.
67 Pašić, *Malo ledeno doba/Little Ice Age,* 52.
68 Pašić, *Malo ledeno doba/Little Ice Age*, 54.
69 Junga tur. a measure of weight, especially used for butter and wool (usually an oka and a half, where the oka is a Turkish measure of weight and was about 1.28 kg). (Mehmed Mujezinović, "Rječnik turcizma i manje poznatih riječi", Ljetopis/*Chronicle (1746 – 1804)*, (1997): 464, 466).
70 Pašić, *Glad u Bosanskom ejaletu/Famine in the Bosnian Eyalet*, 106.
71 Groš lat. silver coins. (Mujezinović, "Rječnik turcizma", 462).
72 Šinik greek. grains measure (usually around 80 oka, 1 oka is approx. 1,28 kg). (Mujezinović, "Rječnik turcizma", 466, 468).
73 Bašeskija, *Ljetopis/Chronicle*, 115.

poorly yielded crops in 1773, a widespread poverty struck.[74] The effects of 1783-1784. Laki volcanic fissures were noticeable immediately after the eruption. The contemporary of those times, Mula Mustafa Bašeskija, states: "*This year the food was quite expensive.*"[75]

It would be worthwhile to examine in more detail whether (and to what extent), the biophysical conditions that arose due to the mentioned eruptions (in correlation with other actions) affected the health of Bosnian eyalet population. Certainly, the health condition of the Bosnian eyalet inhabitants was not directly endangered by the consequences of the 1771 and 1783 – 1784 eruptions. Yet, as could be seen by the effect of post-eruptive influences, and with other factors (given the vulnerability of the population and diseases that were present even before the eruption and probably harmed the immunity of the population), there was a threat to health as a tertiary effect of eruptive action and its impact on the climate. It further caused a number of conditions that contributed to the development of diseases. Lack of food, for example, decreased the resilience against disease of both humans and animals.[76] For example, in the period after the eruption, there were cases of plague, and then in 1773, a consequence, diseases among children.[77] On the other hand, there were no tendencies of a tertiary effect of the Laki volcanic fissure eruption and no significant impacts on the health of the Bosnian eyalet population. Certainly, linking the disease to post-eruptive actions could only be placed on the rank of supposition, since such conditions could be caused by a number of other circumstances that were often present at the end of the 18th century in the Bosnian eyalet.

Volcanic eruption consequences in this context also had demographic and social implications. In the case of these two volcanic eruptions, the demographic picture was not significantly disturbed, as the effects as well as the secondary and tertiary consequences were not strong enough to threaten it. However, based on the original material, i.e. registers (born/ baptized, married and deceased) from the Bosnian eyalet, certain parameters can be determined. For example, in the crisis years after the 1771 eruption, the 1772 registry of marriages in the Kreševo parish showed a decrease in the number of weddings (see Graph 1),[78] even though for that year there were no significant deviations in the number of births and deaths compared to earlier and later periods. In 1773, the number of weddings continued to grow, so in this sense, this deviation from 1772 could not be seen as a tertiary consequence of the eruption. Certainly, the question remains open, since 1772 was also the year when the effects of volcanic eruptions were at their peak.

When it comes to cultural responses to extreme events, after the analyzed eruptions, certain models of interpretation of the crisis are visible, significantly conditioned by social discourses and representa-



Graph 1 *Marriage registers of Kreševo parish from 1769 to 1775. Source: Franciscan monastery of St. Catharine Kreševo, Marriage registers of Kreševo parish 1765 – 1800*

74 Bašeskija, *Ljetopis/Chronicle*, 97.
75 Bašeskija, *Ljetopis/Chronicle*, 252.
76 Pašić, *Malo ledeno doba/Little Ice Age*, 54.
77 Bašeskija, *Ljetopis/Chronicle*, 109–118.
78 Franciscan monastery of St. Catharine Kreševo, Marriage registers of Kreševo parish 1765–1800. (signature: MAT. VJE. 1 (2 – V – 22)).

tions of climate. Social discourses and representations of climate, or weather manifestations in these cases, depended on humankind's natural struggle for existence. At the same time, one should understand that the meaning of existence then was not the same as it is today. Then, it was a struggle for survival that humans felt they could only influence but not control, and that caused fear. Regardless of different traditions that were inherited in the considered areas, the main determinants of social discourses and representations of climate then were very similar, if not the same.[79] To the early modern inhabitants of the Bosnian eyalet, the variations caused by the eruptions could only be explained as the will of God. This can be seen from the 1771 example, when "*public prayers for clear weather* were ordered".[80] So, the systems of cultural responses were based on cultural-religious elements that shaped social representations of the climate.

CONCLUSION

Clearly, there are well-founded arguments that the atmospheric effects of the 1771 Mount Vesuvius eruptions in the Bosnian eyalet were felt immediately after the eruption. At the same time, the effects of a much stronger (but also more distant) eruption of the 1783 – 1784 Laki volcanic fissures manifested retroactively. The consequences for the population of the Bosnian eyalet area of both volcanic eruptions were not direct, but indirect and primarily affected the conditions in that area. The effects of the eruptions were manifested by changes in the temperature and precipitation patterns of the Bosnian eyalet, as evidenced by contemporary observations of these events, and from the results of dendrochronological and dendroclimatological research. This certainly affected both agricultural production and the lives of the population.

Yet, as it turns out, the tertiary consequences of the eruptions were not fatal to the population to the extent that they occurred in earlier and later history. That is, disturbed temperature and precipitation patterns did not cause conditions of completely destroyed crops or consequently acute starvation from which people died. Nevertheless, the eruptions effects on the climate of the Bosnian eyalet were quite noticeable. It becomes clear that for some areas the destructive effects of eruptions (such as the Laki eruption) were mostly harmless, while within the Little Ice Age system some eruptions, (that did not cause global damage, like Vesuvius), in certain areas had almost the same repercussions as some stronger eruptions.

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***Cover* / Na naslovnici:**
Picture of Zadar from 1486 from the travelogue of Konrad von Grünemberg. View from the southwest. (From: Badische Landesbibliothek, Karlsruhe)

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