

Review

Intangible Mosaic of Sacred Soundscapes in Medieval Serbia

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Abstract: Religious practice in Serbia has taken place using both indoors and outdoors sacred sites ever since the adoption of Christianity in medieval times. However, previous archaeoacoustic research was focused on historic church acoustics, excluding the open-air soundscapes of sacred sites. The goal of this review paper is to shed light on the varieties of sacred soundscapes that have supported the various needs of Orthodox Christian practice in medieval Serbia. First, in relation to the acoustic requirements of the religious service, we compare the acoustic properties of masonry and wooden churches based on the published archaeoacoustic studies of medieval churches and musicological studies of the medieval art of chanting. Second, we provide an overview of the ethnological and historical studies that address the outdoor sacred soundscapes and investigate the religious sound markers of large percussion instruments, such as bells and semantra, the open-air litany procession that has been practiced during the annual celebration of a patron saint's day in rural areas, and the medieval assemblies that took place on the sacred sites. This paper finally points out that the archaeoacoustic studies of sacred soundscapes should not be limited to church acoustics but also include open-air sacred sites to provide a complete analysis of the aural environment of religious practice and thus contribute to understanding the acoustic intention of medieval builders, as well as the aural experience of both clergy and laity.



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1. Introduction

The studies of aural environments of medieval sacred places are dominantly focused on indoor soundscapes. Although the corpus of studies has gradually increased, there is a striking imbalance between the number conducted for sacred places in the Latin West and the Byzantine East. While the numerous churches in Western and Central Europe are thoroughly studied [1–3], the aural aspects of Byzantine and Balkan medieval churches are addressed in few research projects. Hagia Sophia in Istanbul was of particular interest over last few decades. The CAHRISMA project (Conservation of the Acoustical Heritage by the Revival and Identification of the Sinan's Mosque's Acoustics) considered it together with two other Byzantine churches, testing virtual acoustic models and providing auralization, aiming to visually and sonically revive architectural heritage [4]. The project "Icons of Sound" examined acoustic models, liturgical texts, and melodic structures to illuminate how the sung liturgy and architectural acoustics worked together, creating an aural experience that facilitated mystical transcendence for the congregation [5]. It was essential that everyone could clearly hear both spoken and sung words in the church [6]. As a part of the same project, the acoustics of Hagia Sophia was recreated in a concert hall setting via the live auralization technique, thus, together with a Byzantine chant performance, providing the sonic experience of this early medieval temple for a wide audience [7]. The recent acoustic simulation of Hagia Sophia tested how the acoustic

conditions change with occupation and the new finishing materials used in restoration works, emphasizing that the current state of Hagia Sophia's mid- and low-frequency reverberation time (T30) averages around 9 s [8]. The study of another early Byzantine church, San Vitale in Ravenna, emphasized that its long reverberation time of 4.6 s favors musical performance rather than speech [9]. Byzantine churches in Thessaloniki, the second largest city of the Byzantine Empire after Constantinople, were acoustically studied, which included the impulse response measurements of 11 churches [10–12] and the examination of two acoustic models in order to comprehend the changes in church acoustics that occurred from shifts from the basilica-type to cross-plan churches with a central dome [13]. The recent archaeoacoustic project, "Soundscapes of Byzantium", took a step further, investigating the connections of church acoustics, Byzantine chanting tradition, and wall paintings (the representations of hymns and hymnographers in particular) in eight churches built from the 5th to the 14th century in Thessaloniki [14–16]. The acoustic measurements supported what was up to that point considered only as a metaphorical interpretation: the intermingling of human and angelic voices. It was argued that the presence of angelic voices corresponded to the distinct aural phenomena that were observed in Thessaloniki churches, such as melodically synchronous overtones, disconnected flutter echo, and unique reverberation patterns [17]. In comparison with Hagia Sophia in Istanbul, Byzantine churches in Thessaloniki have an exceptionally low reverberation time (lower than 3 s), which makes them more suitable for spoken word [15]. Even lower reverberation times are measured in a recent study of five Byzantine churches in Albania; however, they reported low speech clarity [18]. Similar is found for the Byzantine churches in Cappadocia, for which the virtual acoustical models were tested to explore the effect of architectural changes on church acoustics [19].

The study of the impact of sound outside medieval churches and monasteries on the open-air surrounding landscape has been very limited and focused mostly on bell ringing in towns and villages [20,21] or the audibility range of bells with mapping using the Geographic Information System (GIS) [22,23], or addressed briefly in general [15,24]. However, a recent study of medieval Italian soundscapes explored the reach of bell sounds in rural areas that surround various monastic complexes. Combining catchment, viewshed, and sound-mapping analysis, it was shown that in some cases, sites that were outside the 30-minute travel threshold from the monastery and the visibility area were still within audibility range. This finding emphasizes the communicative capacity of soundscapes in medieval monastic landscapes [25]. In addition, research into open-air medieval assemblies, which often took place at sacred sites, points out that practical and ceremonial needs include the acoustic properties of these open-air medieval places of gathering [26].

This review paper strives to outline the variety of sacred soundscapes that compose the intangible mosaic of acoustic environments nurtured since the medieval times in Serbia. The reason for this is that, as we will show in this paper, the published interdisciplinary archaeoacoustic studies are exclusively focused on church acoustics in Serbia, leaving aside all open-air soundscapes despite their important role in Serbian religious practice. Therefore, we tend to draw attention to the variety of medieval sacred soundscapes and contribute by expanding the interests of archaeoacoustic research to an outdoor aural environment by providing a review of both the studies of medieval church acoustics and the studies that are a bit more distantly related to open-air sacred soundscapes.

The sacred art and architecture of medieval Serbia developed under the influence of both the Byzantine East and Latin West ever since the adoption of Christianity. In addition to churches and their specific indoor sonic environment, medieval sacred soundscapes also include open-air sanctuaries and related religious practices. In this paper, we are particularly focused on the period from the late 12th century when the Nemanjić dynasty came to the throne until the fall of Serbia under Ottoman rule in the mid-15th century, because this period was fundamental for the development of the Serbian Orthodox Church as well as sacred architecture. Rapid developments in church architecture started with the endowments of Stefan Nemanja, the eponymous founder of the Nemanjić dynasty. When

he inherited power, his son Stefan the First-Crowned obtained the crown from Roman Pope in 1217, and his other son—later known as Saint Sava—initiated the autocephalous status for the Serbian Orthodox Church that became an independent Archbishopric of Žiča in 1219. Consequently, the close interactions between the medieval Serbian state and the Serbian Orthodox Church led to the spread of Christianity in the region and the foundation of numerous monasteries.

In this paper, we first review the archaeoacoustic studies of indoor sacred soundscapes, focusing on the characteristics of sound content in religious practice and its correlation with medieval church acoustics, including both larger monastic churches built from masonry and smaller local churches built from wood. Then, in the next section, we review the studies that considered the outdoor sacred soundscapes and related practices: 1. the usage of large percussion instruments (bells and semantra); 2. litanies in rural areas; and 3. medieval state and church assemblies. In conclusion, we point out that the archaeoacoustic studies of medieval sacred soundscapes should not be limited to church acoustics but also include open-air soundscapes to provide a complete analysis of the aural environment of the religious practice, thus contributing to understanding the acoustic intention of medieval builders as well as the aural experience of both clergy and laity.

2. Indoor Sacred Soundscapes

2.1. *The Aspect of Sound in the Medieval Serbian Churches*

Considering the acoustical problems, it is necessary to keep in mind the basic purpose of the examined space, as well as its end users' expectations regarding the sonic environment. The Serbian Orthodox Church adopted the Byzantine comprehension of sacred space as an ideal image of the universe in which sound consequently contributed to the overall religious experience. Saint Sava, the first archbishop of the Serbian Orthodox Church and the youngest son of the Grand Prince Stefan Nemanja, referred to the sound of divine service as the very soul of the sacred place [27]. The divine service, as the most significant religious act, has three main purposes: to spread the Christian faith and lift the faithful's spirit to God; to facilitate and induce praying, expressed in both spoken pious conversation with God and ecclesiastical chanting; and to induce redemption and the unification of man and God through faith, and a Christian life full of virtues, prayer, and secrets [28]. In other words, both spoken and chanted word has been important in Orthodox Christian religious practice.

Along with Christian faith, Byzantine chanting tradition was adopted in medieval Serbia. This monophonic *a cappella* chant is based on recognizable musical formulas, with a gradual melodic flow and using musical intervals smaller than a semitone [29]. Each spoken word is given the quality of a song so that the chanting highlights the essence of the lyrics. Saint John of Damascus systematized church chanting in the *Octoechos*, the church book for chanters that contains eight voices or modes, each "ruling" the divine service for a week. The adoption of the eight modes of the antique music enabled the expression of a variety of feelings in Byzantine chanting in accordance with the liturgical cycle [30]. The spiritual importance of chanting is also emphasized by medieval hagiographers: Teodosije wrote that while on his deathbed, Stefan Nemanja (later canonized as Saint Simeon) requested to be escorted with monks' chanting, until finally he looked as if he himself "chanted an angel song with angels" [31]. The chanting was expected to be acoustically intensified inside a church by blurring and dissolving sound into an immersive acoustic experience, thus enhancing the stimuli of vision and scent [32].

To achieve the adequate dynamics and variability of the divine service, the chanting of psalms is combined with Bible reading, common prayers, and the sermon. From the ambo—the elevated stand opposite of the Royal Doors in the naos (or today, occasionally from the southern choir)—gospels are read and litanies are spoken. During the divine service, the faithful stand facing the altar, occasionally bowing, kneeling, and lifting their arms and eyes to the sky [28]. As the aim was to convey the teaching, it was of the utmost importance that the speech was clear and intelligible [33]. Since both spoken and chanted

word was essential in Orthodox divine service, the church space was expected to not only acoustically facilitate the intelligibility of spoken word but also intensify a spiritual experience through chanted melodies.

2.2. Church Acoustics

2.2.1. Monastic Churches

The acoustics of medieval monastic churches have been studied in the last several decades, including the acoustic vessels embedded in the massive walls and the acoustics of the church's interior space.

Acoustic vessels are found in 15 medieval churches that are now under the jurisdiction of the Serbian Orthodox Church in what today is Serbia. Several of them have been examined theoretically [34], but only the ones from two churches—in the villages Komarane [35] and Trg [36]—have been tested in the laboratory. The resonant frequency of the tested vessels is in the range of a male voice. However, from the archaeoacoustic point of view, it is not only the question of acoustic efficiency that is important but the ideas that lie beneath the building practice of embedding acoustic vessels into church walls [37]. Therefore, it is necessary to include an analysis of all available vessels from medieval Serbia in order to arrive at a statistically justified conclusion to contribute to the existing body of knowledge on acoustic vessel practices in medieval Europe [38–40], possibly leading to a better understanding of the transmission of this practice between East and West.

Previous acoustic measurements of monastic churches built in medieval Serbia included Lazarica church [41] and the monastic churches of Ljubostinja Monastery and Naupara Monastery [42], Manasija Monastery, Ravanica Monastery, and Pavlovac Monastery [33]. All these churches were built in the Morava architectural style (1371–1456), which is considered to be the climax of church building in Serbia. They have a triconch plan combined with a developed or compressed inscribed cross, chanting apses on the northern and southern side, and a central dome (Figure 1). The developed inscribed cross plan has four columns supporting the central dome, which enabled building a larger church, as can be observed in Figure 1. For the purpose of comparison, Manasija church (Figure 1, second from the right) has a volume of about 4000 cubic meters, while the smallest one also built in the Morava style is Pavlovac church (Figure 1, the first one from right), which has a volume of about 400 cubic meters.

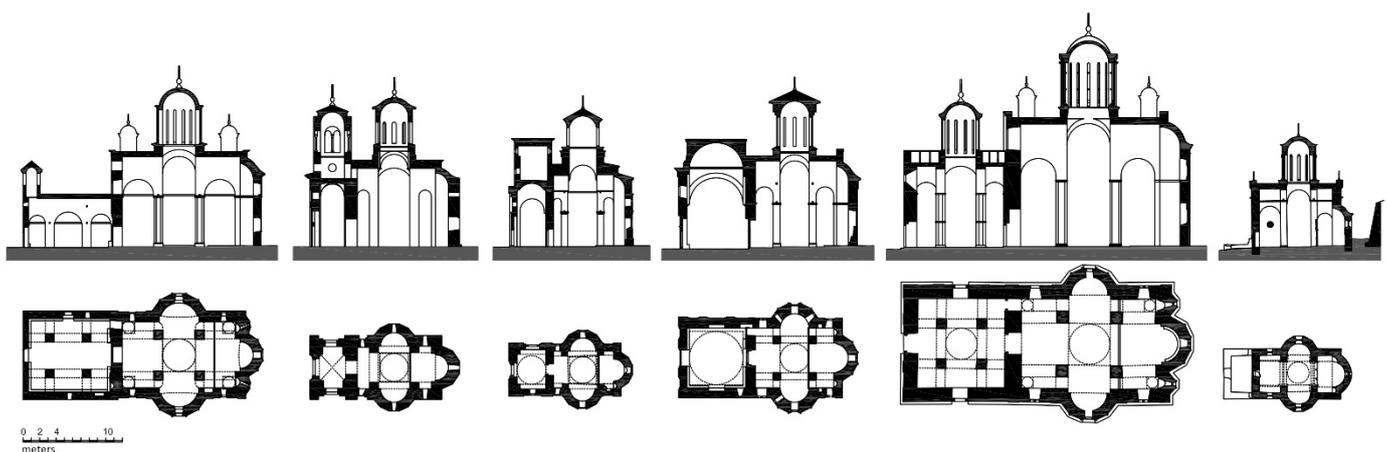


Figure 1. Plans and longitudinal sections of the Morava-style medieval churches (range of years of building), from the left to the right: Ravanica (1375–1377), Lazarica (1377–1380), Naupara (1377–1382), Ljubostinja (1381–1388), Manasija (1407–1427), and Pavlovac (1410–1425).

When discussing acoustics, it is important to note the finishing of large surfaces. Medieval monastic churches in Serbia usually have stone floors and fresco painted walls from the floor to the apex of the dome. However, the level of fresco paintings preservation varies from one church to another. Figure 2 shows the case of Ravanica monastic church,

in which the upper zone of the wall paintings is significantly damaged and large areas are mortared as a part of conservation works. There are also churches that have no wall paintings at all, such as Lazarica and Pavlovac. The iconostases (the screens separating the naos from the sanctuary apse) are found today made of stone with a height of about 2.5 m (as in medieval times), or made of wood and significantly taller, with a large wooden cross on top. The church furniture is made of wood, and is dominantly located in the apses and under the central dome.



Figure 2. The nave interior of the Ravanica monastic church: view towards the altar (**left and middle**) and upwards to the central dome (**right**) (photo: Zorana Đorđević).

Acoustic measurements of impulse responses were carried out for all of the above-mentioned churches using EASERA acoustic software (Version 1.0b (2005), SDA—Software Design Anherth GmbH, Germany). The level of measured background noise in all churches was extremely low, ranging from 21 to 23 dBA, which was expected considering that the locations of the churches are isolated from any external sources of noise, far from urban areas. The only exception is the Lazarica church, which is located in an urban environment, and where the background noise level during measurement was 26 dBA.

Interesting conclusions can be drawn from the comparison of acoustic parameters of churches of different volumes (Table 1), such as Ljubostinja (circa 1500 m³) and Naupara (circa 500 m³). Although Ljubostinja church has a volume three times larger than that of Naupara, differences in the average reverberation times between the two churches are not so pronounced. This can be explained by the fact that Ljubostinja has more wooden surfaces within the naos, which is an additional reason for the even higher average absorption coefficient of the Ljubostinja naos compared with the same area in Naupara. The significantly shorter-than-expected reverberation time in Ljubostinja could be explained by the columns in the naos, which are dominant acoustic diffraction elements. Sound diffraction exerts its own impact on shortening reverberation time due to an overall shortening of the average path distance that sound waves pass. Such acoustical situations increase the possibility of significantly different behavior in sound fields (that can result in the shortening of reverberation time), which cannot be observed simply by comparing only the overall volumes of two or more spaces. The similar reverberation times in both churches' naos might indicate similar values of acoustic parameters that describe speech intelligibility; however, this is not the case (Table 1). Namely, Speech Transmission Index (STI) which was derived from the impulse response measurement using EASERA software, has much greater values for Naupara, indicating noticeably higher levels of speech intelligibility for this church. Such a

situation can be explained by its smaller interior volume and the reduced path distances that sound waves pass in Naupara, resulting in the greater part of the reflection energy arriving to the listener within the ear's integration time zone (first 50 ms after the arrival of direct sound). The sound energy that reaches listeners within this time zone is considered as useful in the sense of speech intelligibility. More energy comes to a listener after this period, which is characteristic for Ljubostinja, distracting the speech recognition process and resulting in lesser values in speech intelligibility parameters. It is notable that the best speech intelligibility is under the central dome of the Naupara naos, which is close enough to a listener to provide reflection that improves overall speech intelligibility. Finally, acoustic parameters clearly indicate a significant reduction in speech intelligibility in the case of sound field excitation from the altar. Singing in the altar area behind the iconostasis has a specific role in Orthodox divine service, with the main intention of encouraging a sense of the holy mystery, while the comprehensibility of spoken and sung text is not so important [42].

Table 1. Mean values of acoustic parameters for naos based on the in situ acoustic measurements.

Architectural Style	Church (Year of Building Completion)	Volume [m ³]	T ₃₀ [s] @500 Hz	EDT[s] @500 Hz	STI	Cited From	
Raška architectural style	Trg (1382)	400	0.61	0.63	0.738	[36]	
Morava architectural style	developed inscribed cross plan	Ravanica (1377)	1800	1.56	2.09	0.499	[33]
		Ljubostinja (1388)	1500	1.79	1.41	0.554	[42]
		Manasija (1418)	4000	3.60	4.22	0.406	[33]
	compressed inscribed cross plan	Lazarica (1381)	720	2.13	2.35	0.473	[41]
		Naupara (1382)	500	1.61	1.19	0.623	[42]
	Pavlovac (1425)	380	2.04	2.09	0.559	[33]	
Wooden church	Brzan (19th century)	200	0.84	0.94	0.735	[33]	

In the case of Lazarica church, the STI parameter indicates that intelligibility under the dome highly depends on the position of the sound source. When the excitation signal was from the altar, the STI parameter had a value of 0.491 when measured directly under the dome, and when the excitation was from the chanting apse, the STI for the same receiver position was 0.673. Such a situation can be explained with specific relations between chanting apse and the “under the dome” position. A person standing under the dome is in front of the chanting apse, having the highest “direct to reflected” sound ratio, which directly impacts speech intelligibility, while there is a physical barrier (iconostasis) between the sound source in the altar and the same receiver position [41].

In addition to the comparison of acoustic parameters, the subjective assessment of church acoustics provides valuable additional information on the experience of sound in a sacred place. A comparative analysis of acoustic parameters measured in three monastic churches built from masonry—Manasija, Ravanica, and Pavlovac—along with a wooden church in Brzan village was conducted together with a subjective assessment of sound field characteristics with 119 respondents, aged 15 to 61, based on listening to the auralization files of Byzantine chanting and speech. Pavlovac church is perceived as the largest space by 39% of respondents, ahead of the Manasija church, which has a nearly 8-times-larger volume than Pavlovac. Such an unexpected result is due to the acoustic influence of the dome. A listener beneath the dome in Pavlovac church observes acoustic phenomena that are not so audibly conspicuous in higher churches, such as Ravanica and Manasija. The dome directs the sound waves towards its geometric focus, producing a unique play of late delays and consequential changes of the phase differences of the reflected sound waves, finally resulting in a subjective perception of a much larger space than it actually is. The

results of acoustic measurements support this as well. The subjective evaluation of speech intelligibility and the STI parameter are matching. They are both inversely proportional to the sizes of the church, so that their values decrease as the volume grows. This is fairly logical situation, since higher amounts of late sound energy coming to the listener, which is a characteristic of larger spaces, is the main reason for decreases in overall speech intelligibility. The results of the subjective evaluation suggest the same: the smallest church (Brzan) is evaluated as “the best”, while the biggest one (Manasija) is seen as having “the worst” speech intelligibility. Additionally, different positions within the same church are characterized by different values of STI parameter. Thus, the speech generated inside the naos, in the case of Ravanica and Manasija, is almost completely incomprehensible in the narthex: most of the respondents (85%) were evaluated as “unsatisfied” in those positions regarding speech intelligibility [33].

Changes to the original church interior might dramatically affect the experience of sound. For example, the Trg church deviates from the expected values of the reverberation time. The average RT @ 500 Hz for small churches of overall volume similar to the volume of Trg church (around 400 m³) is around 1.6 s [43]. However, the average measured values of the T30 parameter in Trg church is 0.60 s at the octave with the central frequency of 500 Hz. This might be due to the presence of wooden furniture but also a thick layer of carpets that authors were not allowed to remove during the acoustic measurements. Such floor carpeting, often justified by the necessary thermal insulation of the church floor, produces a significant deviation from the original acoustic condition of the church. Accordingly, it should be noted that the “original” reverberation time of the church could be even higher than 30% in the higher frequency range but not significant in the lower frequency range [36].

Additionally, Trg church is a good illustration for an acoustic situation where the Early Decay Time (EDT) parameter has consistently greater values than the T30 parameter in the case of sound excitation from the altar area, while in the case of excitation from the naos, the situation is the opposite. Since EDT correlates with reverberance, or as a perceived reverberation during music play or speech (at least as perceived by the audience), the conclusion is that overall perceived reverberance inside of the church is greater in the case of chanting from altar, then from the naos. In other words, divine service from the naos position has a tendency toward intimacy due to the nearness of the talker and listener, while the performance from the altar causes difficulty in locating a sound source, thus adding to the sense of mystery of the religious service. The same conclusion can be drawn for most of the other analyzed medieval churches (Table 1).

2.2.2. Wooden Churches

Wooden churches have been built in Serbia since the medieval times. The earliest recorded mention of log churches in Serbian lands was in the Life of Saint Sava, written in the 14th century. The hagiographer Teodosije wrote that Saint Sava himself encouraged people to build wooden churches whenever needed [31]. Under the Ottoman rule in Serbia from the 15th to the 19th century, wooden churches retained their simple architecture that allowed them to be easily repaired, disassembled, and transferred to another well-hidden location [36]. Therefore, the shape of wooden churches did not change from the medieval period. That entitles us, in the scope of this paper, to examine the archaeoacoustic studies of log churches built after medieval period, because turbulent historical circumstances, including uprisings and migrations, left us with log churches not older than the 17th century [44]. There are about 40 wooden churches preserved today in Serbia. After the First (1804) and the Second (1815) Uprising, and particularly after the official Ottoman recognition of liberty to fully practice Orthodox religion (Hatisherif from 1830), the revitalization of wooden churches began.

Although traditionally called log churches, these buildings are not made of logs but planks. Usually, the oak tree was used, as it is perceived as the most durable building material and provides good sound insulation, rousing feelings of warmth and intimacy [44].

The architecture is quite simple: single-nave church, consisting of narthex, nave, and apse, and a high roof with eaves. The log church in Brzan village (Figure 3), built in the first half of 19th century, is particularly interesting as it was equipped with acoustic vessels—ceramic jugs pierced on the bottom. These vessels used to hang from the roof beams, between the roof and the false wooden vault made in a trough shape. As previously mentioned, the acoustic vessels were usually embedded in the masonry walls of medieval churches. The case of Brzan church suggests that the same acoustic practice was applied in wooden architecture as well. The vessels could not be embedded in thin wooden walls but they were hung on the roof beams. When Brzan church was reconstructed in 1960s, mortar was peeled from the interior walls, leaving the visible notches on the wooden planks that are usually made to apply the mortar on the wood. The iconostasis, reaching the ceiling, is also made of wood, and the floor is paved using bricks. Pavlović, who led the reconstruction, wrote that the Brzan church was an acoustical space [45].



Figure 3. Wooden church in Brzan village: acoustic vessels hanging on the roof construction as found during the reconstruction works in the 1960s (left), church exterior (middle), church interior (right) (photo: Institute for the Protection of Cultural Monuments of Serbia (left), Zorana Đorđević (middle and right)).

The results of the on-site acoustical impulse response measurement in the Brzan church are presented in Table 2 [33]. The values of the obtained parameters are quite expected for that type of building. Wooden churches are characterized by small volumes and an interior design that is completely different in its acoustic properties from masonry churches. That is the main reason for their very specific acoustics. The main acoustic properties of wooden churches are extremely high intelligibility of speech ($STI = 0.735$, the borderline case of speech intelligibility that might be qualified as “almost excellent”), as well as the overall feeling of acoustic intimacy and warmth that the present believers have during the service [33]. On the other hand, the acoustic ambience of wooden churches lacks a pronounced sacral moment, which is reflected in longer times of reverberation and various psycho-acoustic phenomena that occur due to the existence of specific architectural elements, especially the dome.

Wooden churches could not be characterized by a “huge” and “divine” sound due to their fairly small reverberation time compared with masonry churches. Yet, the warm and intimate acoustics of this ambience with high intelligibility of speech fully corresponded to the basic task of wooden churches—to provide a suitable aural environment to communicate religious ideas to the congregation.

Table 2. Acoustic parameters measured in the wooden church in Brzan village: Reverberation Time (T_{30}), Early Decay Time (EDT), Articulation Loss of Consonants (AL_{cons}), Bass Ratio (BR), and Average Sound Absorption Coefficient ($\bar{\alpha}$) [33].

T_{30} [s]	EDT [s]	AL_{cons} [%]	STI	BR	$\bar{\alpha}$
0.84	0.94	3.2	0.735	1.02	0.18

3. Outdoor Sacred Soundscapes

While *semantra* were traditionally used in Byzantium, bells were introduced gradually to the liturgical practice of the Eastern Church. Religious soundscapes in the medieval Serbian state under the Nemanjić dynasty and their successors were actively created by both *semantra* and bells. The sound of these large percussion instruments could be heard from various distances around a sacred site, depending on terrain configuration, vegetation, and weather conditions. In addition to accommodating these particular sounds, outdoor sacred soundscapes had a role in the religious activity of a village's patron saint's day celebration, which includes a litany procession from one sacred tree to another around a village. Open-air soundscapes of sacred sites were also important for the medieval state and church assemblies that usually took place in the vicinity of a (monastic) church. In this section, we will investigate the sacred soundscapes in medieval Serbia regarding the use of *semantra* and bells, litany processions, and finally the state and church assemblies.

3.1. *Semantra* and Bells

As a traditional instrument in Byzantium, the *semantron* was adopted in medieval Serbia, known under the names of *klepalo* and *bilo* [46]. The *klepalo* is a wooden board played with wooden mallets. As Figure 4 shows, today we find two types of *klepalo*—a thin and long plank, which is played while a person leans it on their shoulder, or a massive piece of wood hanging on ropes outdoors, usually in the vicinity of the bell tower or church entrance. The *bilo* is made of bronze plates, which are played with metal hammers while hanging. These three types of *semantra* were mentioned in the Hilandar Monastery *typikon*, drafted by Saint Sava in 13th century based on the model of the rule of the Evergetis Monastery in Constantinople. The Hilandar *typikon* recommends to follow the custom of playing the *klepalo* and *bilo* as the first call to divine service, which would then be carried on with bell ringing [27]. As Rodriguez noted, the Evergetis *typikon* does not mention bells; however, Saint Sava did mention them in the place which the former refers to the bronze *semantron* (probably *bilo*). Arguing further that bell ringing was introduced earlier in medieval Serbia than in Byzantium, Rodriguez pointed out that monuments, such as the endowments of St. Sava's father, the Grand Prince Stefan Nemanja, such as the monastic church of Saint Nicholas near Kuršumljija (1159–1166) and Đurđevi Stupovi (1166), were both originally built with bell towers. However, while bell ringing did not assume the role of *semantra*, these percussion instruments were used in conjunction throughout the medieval period, creating an eclectic religious soundscape [47]. Listing and analyzing the extant bells from medieval Serbia and the wider region, Rodriguez concluded that the pealing of bells had an important role in the local religious soundscape [48].

The sound of bells and *semantra* have reverberated for long distances, broadcasting an auditory message across rural landscapes—marking the canonical hours, summoning the congregation to pray, alerting to danger, and informing of important events. The number of hits depended on the message that was conveyed [46]. However, the quality of the aural communication varied, depending on both the acoustic environment and sociocultural context [49]. Therefore, extensive archaeoacoustic research is necessary to draw conclusions on the quality of this eclectic religious soundscape.

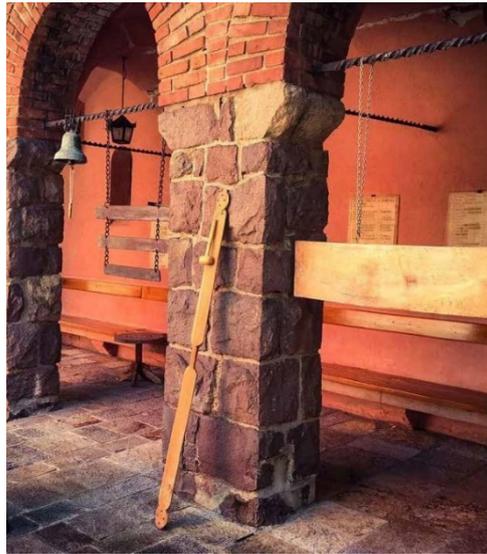


Figure 4. The setting of large percussion instruments in the Žiča monastery. From left to right: bell, *bilo*, *klepalce* or manual *klepalo*, *klepalo* (photo: Zorana Đorđević).

The meaning of the sound of the bell and *semantron* has been investigated more thoroughly, pointing out that these sounds were perceived as a sign of divine presence [50]. Symbolic interpretations of *semantron* in early Byzantine texts compared them to angelic trumpets that will “awaken all peoples on the doomsday” and described them as calling monks and Christ’s soldiers to the invisible warfare with demonic forces [51]. The sound of bells has been a part of the manifestation of sacrality ever since they became a central element of Christian identity; however, its social and spiritual meanings varied markedly depending on the context, use, and sound reception [52]. It provided local cohesion, social inclusion, and a sense of a place within the acoustic range [53], provoking the feeling of attachment to locality as an intended emotional response to sound [22], relating people strongly to their surroundings, shaping the identity of places by defining or delimiting their use [54], and producing spiritual community in medieval times [52].

Under the Ottoman rule of the Serbian territories, bells were forbidden and systematically destroyed for religious reasons [47,55]. This resulted in the more frequent use of *kelpalo* and *bilo*. Since people tended to save bells as sacred objects by hiding them, throwing them into wells and rivers or burying them in the ground, some bells were successfully preserved and reintroduced after the liberation. Their significance grew beyond religious needs and they became a symbol of the freedom and unity of the Serbian people. However, during the First World War, the Austro-Hungarian authority ordered taking-away all Serbian bells to melt them for arms. For this reason, there are not many medieval bells preserved today [48,56].

3.2. Litany Procession

Zavetina is a day devoted to a patron saint who protects a village. When a misfortune befalls the village—disease, flood or drought—the villagers would take a vow (*zavet* in Serbian) to a saint to celebrate his/her day if in return he/she protects them from the occurring accident. This vow would then pass on to their descendants [57]. An essential role in the celebration of *Zavetina* is placed on *Zapis*—a sacred tree with a cross incurved into its bark. This open-air sacred place is a primitive temple where people prayed and made sacrifices. Each village has several sacred trees. The main *Zapis* is usually located in a village center, while others are located on a village border, often on private properties [58].

The most important part of the *Zavetina* celebration is a litany procession that starts with a gathering of villagers around the main *Zapis*. Then, a priest reads a prayer while villagers carry red flags, crosses, and icons around the sacred tree (Figure 5). After completing

three circles around the *Zapis*, the congregation goes around the village borders, visiting all the sacred trees and repeating the same activities of three times circling around each sacred tree while a priest reads a prayer. Then, they would decorate the tree and renew the cross in its bark by recurving it. Consecrating the sacred trees on the village borders, the area inside or along the circle is separated as sacred, leaving as profane everything that remains outside the circle [59]. The intention of drawing this imagined circle around a village is to protect its inhabitants from various misfortunes. The litany procession was welcome to go across the crop fields to influence the abundant harvest. There was also a belief that litany can contribute to healing people, who were therefore brought onto the procession path [60]. The litany completes in front of the main *Zapis* with the common feast, followed by numerous rite activities, including breaking the festive cake, naming the hosts by the priest, and giving toasts [59].



Figure 5. Litany on Saint Marco's Day in the village Lužnice (photo: Marija Dragišić).

Each village in Serbia used to have its own *Zavetina*, which would usually be in the period from Easter to Saint Peter's Day [61]. In this period, from April to July, crops need rain the most. Therefore, during the celebration of *Zavetina*, the villagers prayed and practiced various rite activities for summoning the rain. The congregation in litany sung a prayer to invoke rain. These songs were sung in unison and with strong voice by all the villagers. One of such songs is noted in the village Boljevac, in eastern Serbia [59]:

I carry a cross, praying to God,
 Lord, Lord, have mercy!
 We pass across the field
 Additionally, clouds pass across the sky,
 Lord, Lord, have mercy!
 We pray to God:
 To give us morning dew,
 Lord, Lord, have mercy!
 To mow our fields,
 Lord, Lord, have mercy!
 To make a sheaf from two ears of wheat,
 Lord, Lord, have mercy!
 A cask of wine from two clusters,
 Lord, Lord, have mercy!

(In Serbian: Крста носим, Бога молим, Господе, господе, помилуј! Ми идемо преко поља, А облаци преко неба, Господе, господе, помилуј! Ми се Богу помолисмо: Да удари

етња роса, Господе, господе, помилуј! Да пороси поља наша, Од два класа шиник жита, Од две гице, чабар вина, Господе, господе, помилуј!

Litany included two types of sound events: priestly prayer and the common singing of the villagers. Taking place outside populated areas—on meadows, fields, and forest slopes—acoustically implies the absence of reflections and good speech intelligibility but also the need to speak in elevated levels so that information would be conveyed to the congregation and encourage the unity of a village community. Usually, each household had at least one participant in the litany to ensure being included in the prayer and having a good harvest [62]. Thus, the number of people depended on the size of a village. In addition to the aim of gathering the community, litanies were also meant to protect the village from an atmospheric disaster. Collective singing was used to propitiate the forces of nature. It was often performed on the move while the litany was passing from one sacred place to another around the village using the shortest route, even if it meant crossing the crop field. In some villages, the litany goes through a river, with the villagers believing that it would summon rain. Consequently, the collective singing could be heard with different intensities on different parts of the route, thus announcing the arrival of the litany to a certain place. At the head of the procession, in some cases, was a man who struck the *klepalo* [62], thus giving a loud rhythmic component while ensuring that the sound of the litany reached the distant places of the landscape—houses at the far ends of the village, and behind hills, forests, and rivers. The gathering of all the participants of the litany around the sacred tree was followed with prayer and the addressing of the priest. The sacred tree has always been located in a quiet area, which is suitable for people addressing each other with intelligibility and a sense of intimacy.

3.3. Open-Air Assemblies Related to the State and the Church

Sacred places in medieval Serbia were also used for various gatherings. The most important one was the state assembly—the representative body of medieval Serbia. To discuss the acoustics of open-air sacred places where the medieval assemblies were held, it is essential to know the purpose of these assemblies, the approximate number of participants, and the physical characteristics of the location.

The state assembly gathered the high clergy of the Serbian Orthodox Church, including all the bishops headed by the archbishop (from the mid-14th century, the patriarch) and an equal number of hegumens or elders of Serbia's most renowned medieval monasteries. Towards the end of the 14th century, the assembly consisted of the 29 most prominent representatives of the Serbian Orthodox Church—the archbishop, 14 bishops, and 14 hegumens. In addition to the clergy, the state assembly included the representatives of the state's civil and military administration, which was, at the most, two or three times the number of the representatives of the church assemblies. If the ruler was absent, he was substituted by his wife. The total number of the assembly participants was limited to about 100 of the most influential persons in the state. The participants were divided into groups and seated around separate tables [63].

The state assemblies were initiated by the ruler, who chose the time and place, usually in the capital or in a monastery [64]. On these occasions, rulers were crowned; heirs to the crown were proclaimed; deceased rulers were canonized; church dignitaries, archbishops, and patriarchs were elected; laws were passed; wars were declared; and decisions on important state issues were made. Prior to making the decision, the ruler was obliged to discuss the matter with the most prominent representatives, after which he would announce his decision to the assembly. For example, on the first state assembly in the town of Ras, which was summoned by the progenitor of the Nemanjić dynasty, Stefan Nemanja, both political and religious debate was on the matter of heresy. Later assemblies also show that accordance on state matters often came through long debates, and the assembly could take several days. On the second assembly held in 1196 outside the Saint Peter's Church in Ras, Nemanja abdicated and appointed his middle son Stefan as heir. To do so, Nemanja needed the support of the assembly, because appointing the younger son as a successor

was in breach of tradition and custom laws regarding the rights of the firstborn son and as such needed to be ratified by the state representative body. On this occasion, Nemanja gave a short speech to the assembly. Although the Church did not limit the sovereignty of the ruler, it had the obligation of the ethical supervision but could not deprive the ruler of the throne. On the other hand, the ruler proposed and then the state assembly elected the new archbishop. For that purpose, the assembly would summon at least twice—the first time to elect the archbishop and the second time to attend the church ceremony and the celebration. However, the assembly did not always approve the ruler's suggestion for the archbishop. During the rule of the king Milutin Nemanjić (1282–1321), the assembly was summoned three times in one year to elect a suitable archbishop [63].

In addition to the state assemblies, there were also the church assemblies and the church–people's assemblies. With the foundation of the Serbian autocephalous Archiepiscopacy in 1219, Saint Sava became the first archbishop of the Serbian Orthodox Church. He had introduced the church assemblies, which became particularly important after Serbia fell under Ottoman rule in 1459, as they also took over the role of the medieval Serbian state assemblies [65].

The third type was the church–people's assembly, which included high clergy, the royal family, and nobility, but also a significant number of poor people. The Church organized them, supported by the ruler, with a clear aim to enhance the reputation of both the Church and the Serbian State. One of the great church–people's assemblies was organized for the transportation of the relics of Saint Luke the Evangelist in 1453. When the relics, which were believed to have miraculous power, arrived in Serbia from Epirus where they were purchased, they were welcomed by a great solemn procession of the state and church officials, as well as numerous common people. The relics were transported to the capital of Smederevo, where they were then carried through and around the city while the procession attendees chanted church songs. Finally, the relics were placed at the Smederevo Metropolitan Church [63].

In all three types of assemblies described above, people gathered in the immediate vicinity of churches or monasteries. The sacrality of these spaces emphasized the importance of the assembly for the wider community, as well as the mutual dependence of the state and the church. This kind of event had such significance that it was occasionally presented on church frescos (Figure 6). The priority of these assemblies was to convey a message, decision, or regulation; thus, the intelligibility of speech was particularly important. The proximity of monastic buildings or church walls, certainly without any ceiling, created a specific acoustic environment. Reflective surfaces were sound reflectors (usually high stone walls), which significantly enhanced sound by stimulating the reflected sound in the area of temporal integration of the sense of hearing. At the same time, open-air places implied the absence of all those acoustic anomalies and problems that negatively affected speech intelligibility, especially the existence of pronounced late reflections (over 50 ms) and excessive reverberation times. Additionally, it is reasonable to assume that the address of the speakers, who always had a strong authority in relation to the people present, meant a quiet and peaceful environment, without noise and the murmur of voices. Given the absence of any unnatural noise sources in medieval times, this parameter of interfering with speech intelligibility (high levels of ambient noise) was also reduced to a minimum. In that sense, this type of gathering, with the default address of the speaker with an increased level of voice, provided high speech intelligibility, which was certainly the basic acoustic requirement. Additionally, this acoustic ambience can be described as intimate, in the sense that it formed a sound environment of close connection with the speaker, who was in the immediate vicinity of the people present.



Figure 6. Fresco The Assembly of the Saint Simeon the Myrrh-Gusher in the Patriarchy in Peć (photo: William Taylor Hostetter, Institute for the Protection of Cultural Monuments of Serbia).

4. Discussion

The above review of archaeoacoustic studies of medieval churches in Section 2 and the review of studies that corroborate the need for including the open-air soundscapes in archaeoacoustic analysis of sacred sites in Section 3 of this paper, impose some questions that need to be further discussed: 1. Are there acoustic characteristics common to all tested Serbian medieval churches? 2. do they have the optimal reverberation time for the medieval religious practice? and 3. what should be included in the archaeoacoustic open-air soundscape studies? We will further discuss these questions in the same order.

Both spoken and chanted words have been important in religious practice in medieval Serbia. It has been equally important that the acoustical environment supports the intelligibility of speech but also adds to the spiritual experience of the religious chanting. Previous archaeoacoustic research showed that this balance was achieved to a variable extent. To examine it, it is inevitable to include at least acoustic parameters, such as reverberation time, early decay time, and speech transmission index. The acoustic analysis of medieval Serbian churches indicates some specificities: although they differ significantly in terms of volume, objective and subjective analyses indicate an acoustic environment that fully corresponds to the basic purpose of these buildings—a sacred sound environment with preserved speech intelligibility. The analysis of churches built in the Morava architectural style pointed out that even when the churches have significantly different volumes (for example, Ljubostinja has a volume three times larger than that of Naupara), RT differences are not necessarily pronounced. The reason might lie in the macrogeometry (columns supporting the central dome) or microgeometry (wooden furniture, carpets). Intelligibility of speech differs among the researched churches depending on the sound source position. It is significantly reduced when the sound source is in the altar, divided from the naos with the iconostasis. It also decreases as the church volume grows. One of the main architectural features of churches built in the Morava style is the central dome, which has its footprint on the acoustic quality of the space. The dome produces a unique play of late sound delays, finally resulting in a subjective perception of a much larger space than it is, which also sonically adds to the spiritual experience of the religious service. This effect is particu-

larly pronounced in Pavlovac church, the smallest one examined. In the case of wooden churches, this acoustic–spiritual effect is missing; however, the speech intelligibility is very high. However, to provide a higher resolution image of medieval church acoustics in Serbia and the proclaimed goal to obtain a balance between speech intelligibility and spiritual experience, it is important to include churches built in other medieval architectural styles.

When considering a broader picture, it is important to note that Serbian medieval churches, even the largest ones, such as Manasija, are significantly smaller than early Byzantine churches, such as Hagia Sophia in Istanbul, which is 150,000 cubic meters [8] or Hagia Sophia in Thessaloniki, which is 15,250 cubic meters [11]; however, they are comparable to late Byzantine churches, which are reported to range from 250 to 3000 cubic meters [10,18,19,66]. Thus, although the study of reverberation times in Serbian Orthodox churches noted their values without recommending the optimum reverberation time for Byzantine chanting tradition, which had been practiced in medieval Serbia [67], there are several recommendations for an optimal reverberation time in churches that should be discussed regarding Serbian medieval churches. Testing of the subjective preference of reverberation that is considered pleasing in relation to Byzantine chanting showed a clear preference for having a reverberation time of 4 s [32]. The Perez-Minana formula for speech in occidental churches $T = 0.08 \sqrt[3]{V}$ [68] gives significantly lower results compared with those that were measured in Serbian medieval churches. Thus, applying this formula for Manasija church ($V = 4000 \text{ m}^3$) gives the reverberation time value of 1.3 s, while the measured RT30 @500 Hz is 3.6 s. Another calculation for the optimal reverberation time for liturgical music at mid-frequency range was recommended by Leo Beranek, according to Adeeb and Sü Gül, and is calculated as $RT = 0.55 \times \log_{10}(\text{Vol.}) - 0.14$ [19]. For the analyzed Serbian churches (400–4000 m^3), that would mean that the RT should be between 1.2 and 1.8 s, which matches three out of eight studied churches (see Table 1).

The variety of sacred soundscapes in medieval Serbia supported the religious needs that go beyond a church space and included the surrounding landscape—in the vicinity of a church or monastery in the case of state/church assemblies or outlining the protective circle of sacred places around a village, thus spiritually uniting the community for a common goal (protecting from disease, summoning rain, ensuring fruitful yield). These soundscapes were permeated with the sound of large percussion instruments—bells and semantra—that conveyed various messages over a great distance, maintaining the connection between the wider community and the monastery but also giving a pulse to monastic life itself. Therefore, to understand the aural environment of medieval rural areas, in addition to church acoustics, it is necessary to include the multidisciplinary archaeoacoustic examination of the open-air soundscapes of sacred sites, starting from mapping the range of bell and semantron sounds, their relation to visual reach, and their capacity for communication. As pointed out in this paper, the existing studies of medieval Serbian soundscapes mainly addressed the sound aspect from a monodisciplinary point of view—anthropology, ethnology, and history. However, a multidisciplinary approach is key to researching past sound environments because it is a complex question that needs to be examined from various sources, including the fields of acoustics, archaeology, the history of art and architecture, anthropology, and musicology.

5. Conclusions

In this paper, we strived to argue the need for expanding the archaeoacoustic research of medieval Serbian sacred sites to open-air surrounding soundscapes, in addition to church acoustics. Therefore, to outline the mosaic of sacred aural environments in medieval Serbia, we reviewed the archaeoacoustic studies of medieval Serbian churches, both monastic and village, and we examined the studies that addressed outdoor sacred soundscapes. This review paper points out that open-air sacred soundscapes have not been acoustically measured in Serbia so far; however, their investigation would remarkably advance our understanding of sonic environments in sacred medieval sites.

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