Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XV, 2026
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

GIS-BASED NOISE MAPPING OF NATURA 2000 SITES EXPOSED TO A1 MOTORWAY TRAFFIC IN ROMANIA

Cristina CĂLIN, Răzvan Lucian VOICU, Sorin Mihai CÎMPEANU

University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Land Reclamation and Environmental Engineering, 59 Mărăști Blvd, District 1, 011464, Bucharest, Romania

Corresponding author email: voicu_razvan2000@yahoo.com

Abstract

GIS-based noise mapping provides a spatially explicit approach for assessing traffic-related acoustic pressure in protected areas. This study compares two Natura 2000 sites located along the A1 motorway in Romania: ROSAC0138 Bolintin Forest, directly crossed by the motorway, and ROSAC0106/ROSPA0161 Middle Argeș Floodplain, located in its proximity. Strategic noise maps were generated for Lden/Lzsn and Lnight/Lnoapte using 2022 traffic data, and the resulting noise contours were integrated in GIS with protected-area boundaries. The analysis quantified the surface of each site exposed to noise levels above 50 dB. Results indicate a clear contrast: in Bolintin Forest, approximately 443 ha, representing 7.8% of the site, are exposed above 50 dB, whereas in Middle Argeș Floodplain only 6.8 ha, representing 0.18% of the site, exceed this threshold. The study demonstrates the usefulness of GIS-based noise mapping for identifying acoustic exposure zones and supporting Natura 2000 management planning.

Key words*: acoustic exposure, GIS, motorway traffic, Natura 2000, noise mapping.*

INTRODUCTION

Road infrastructure is one of the most widespread sources of anthropogenic disturbance in landscapes. In addition to physical habitat loss and fragmentation, roads generate noise, artificial light, pollution, animal mortality and increased human accessibility (Forman & Alexander, 1998). Traffic noise is particularly relevant for protected areas because it extends beyond the road corridor and may modify the acoustic environment of habitats that otherwise appear structurally intact.

Chronic anthropogenic noise can affect terrestrial organisms by masking acoustic signals, altering vigilance and foraging behaviour, changing habitat use and reducing breeding performance (Slabbekoorn & Ripmeester, 2008; Barber et al., 2010; Kight & Swaddle, 2011; Francis & Barber, 2013; Shannon et al., 2014; 2016). These effects are not uniform across taxa or habitats, but the acoustic footprint of roads is increasingly recognised as an important component of infrastructure-related pressure on biodiversity.

Empirical studies have shown that traffic noise can reduce the density of breeding birds near roads and can alter habitat use even where the physical structure of the habitat remains apparently suitable (Reijnen et al., 1995; 1996; Parris & Schneider, 2008).

Experimental work using phantom-road approaches has further demonstrated that traffic noise alone may reduce habitat quality by changing bird distribution and behaviour (McClure et al., 2013; Ware et al., 2015).

Protected areas are not necessarily protected from noise. Buxton et al. (2017) showed that anthropogenic noise is pervasive in many protected areas, while studies in national parks and natural landscapes have demonstrated that soundscape quality may be degraded by roads, visitors and other human activities (Iglesias Merchan et al., 2014). For Natura 2000 sites, established under the Habitats Directive and the Birds Directive, the issue is relevant because conservation effectiveness depends not only on legal designation, but also on the functional quality of habitats and ecological processes (Council of the European Communities, 1992; European Parliament and Council, 2009).

Noise mapping has traditionally been used for human exposure and environmental noise management. However, when integrated in GIS with protected-area boundaries, strategic noise contours can also provide useful spatial information for conservation planning. GIS-based noise mapping can identify acoustic

exposure zones, compare infrastructure-related pressure between sites and support the prioritisation of management measures.

This study compares two Natura 2000 sites located along the A1 motorway in Romania (Figure 1), selected because they represent contrasting spatial relationships with the same transport corridor. ROSAC0138 Bolintin Forest is directly crossed by the motorway, whereas ROSAC0106/ROSPA0161 Middle Argeș Floodplain is located in motorway proximity without being directly crossed. The objective was to assess and compare the spatial extent of motorway-related acoustic exposure using GIS-based overlay analysis of strategic noise contours and protected-area boundaries.

MATERIALS AND METHODS

Study design and study sites

The study was designed as a comparative GIS-based assessment of motorway traffic noise exposure in Natura 2000 sites. The comparison was structured around two spatial configurations (Table 1): direct crossing, represented by Bolintin Forest, and proximity exposure, represented by Middle Argeș Floodplain. This design allows the spatial effect of motorway crossing to be distinguished from the effect of motorway proximity.

ROSAC0138 Bolintin Forest is located in the continental biogeographical region, in the lower Argeș plain landscape. According to the source documentation, the site has a total area of 5,638 ha and includes an important forested component dominated by *Quercus robur*. The A1 motorway crosses the site in two sectors, between km 36+000 and km 42+000 and between km 43+000 and km 45+477. The site-specific conservation context was considered with reference to ANANP Decision No. 319/19.07.2021.

ROSAC0106/ROSPA0161 Middle Argeș Floodplain has double conservation status, being designated as both a Special Area of Conservation and a Special Protection Area. The site covers 3,648.94 ha and includes riparian, aquatic and floodplain habitats important for bird species (MEWF, 2020 – Note No. 13916/CA/17.09.2020). In this case, the A1 motorway does not cross the protected area, but runs in its proximity over approximately 41.1 km, between km 35+600 and km 76+700, at distances ranging from approximately 185 m to 2,145 m from the site boundary. The conservation context was considered with reference to ANANP Decision No. 414/16.09.2020, ANANP Decision No. 379/20.06.2023 and the Ministry note for ROSPA0161.

Table 1. Spatial configuration of the Natura 2000 sites analysed in relation to the A1 motorway

Natura 2000 site	Code	Area (ha)	Spatial relation with A1	Relevant motorway sector
Bolintin Forest	ROSAC0138	5,638	Directly crossed	km 36+000-42+000; km 43+000-45+477
Middle Argeș Floodplain	ROSAC0106 / ROSPA0161	3,648.94	In proximity only	km 35+600-76+700; 185-2,145 m from site boundary

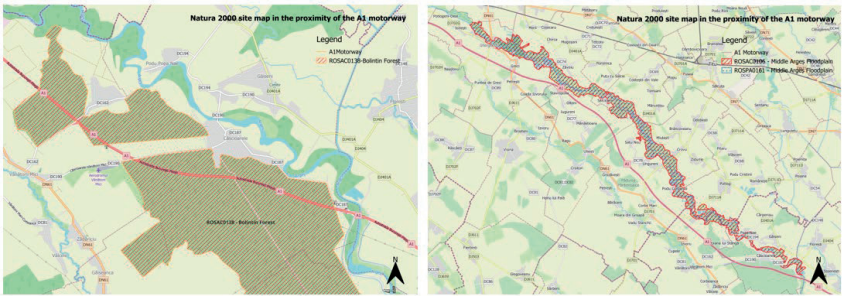


Figure 1. Spatial relationship between the A1 motorway and the analysed Natura 2000 sites

Noise indicators and input data

Noise exposure was assessed using two strategic noise indicators: Lden/Lzsn, corresponding to the day-evening-night noise indicator, and Lnight/Lnoapte, corresponding to the night-time noise indicator (SR ISO 1996-2:2018). Traffic

input data were derived from the 2022 General Traffic Census for Romanian roads, provided by CNAIR SA – CESTRIN (Table 2). The traffic dataset included annual traffic volumes and vehicle-class distribution by time interval.

Table 2. Main A1 motorway traffic input sectors used for the GIS-based noise-mapping assessment

Motorway sector	Census post km	Length (km)	Total vehicles in 2022	Used for site
A1 km 30+510-49+208	36.050	18.698	14,556,200	Bolintin Forest; Middle Argeș Floodplain
A1 km 49+208-70+460	49.208	21.252	11,992,440	Middle Argeș Floodplain
A1 km 70+460-94+393	85.600	23.933	10,898,900	Middle Argeș Floodplain

The modelling used the legal speed limit for the motorway sector, continuous pulsating traffic flow, asphalt pavement as reference road surface and meteorological conditions favourable to sound propagation. The original technical documentation indicates the use of the NMPB Routes-96 method for road-traffic noise calculation, in accordance with the methodological framework cited in Romanian environmental-noise legislation. CNOSSOS-EU is included in the references as the current common European methodological framework (Kephalopoulos et al., 2012; Directive 2002/49/EC).

GIS processing and exposure assessment

The strategic noise maps were integrated in a GIS environment together with the boundaries of the two Natura 2000 sites. Noise contours corresponding to Lden/Lzsn and Lnight/Lnoapte were overlaid with the protected-area polygons to identify and quantify areas exposed to noise levels above 50 dB (OMEWF No. 2328/2021). For each site, the exposed surface was calculated in hectares and expressed as a percentage of the total site area. This metric was used as a noise-exposure ratio for comparing the two spatial configurations.

The 50 dB threshold was used as a spatial comparison threshold for identifying areas exposed to noticeable road-traffic noise in the available strategic noise-map classes. It should not be interpreted as a universal ecological limit for all taxa. Species-specific responses to noise vary substantially, and the ecological relevance of exposure depends on species, habitat, season, behavioural context and the temporal pattern of noise.

RESULTS AND DISCUSSIONS

GIS-based exposure patterns

The spatial overlay analysis revealed a strong contrast between the two Natura 2000 sites. In Bolintin Forest, where the A1 motorway directly crosses the protected area, the noise contours extend inside the site as a continuous corridor along the motorway (Figure 2). In Middle Argeș Floodplain, the motorway runs parallel to or near the site boundary for a longer distance, but most of the protected area remains outside the >50 dB exposure zone (Figure 3).

This contrast indicates that motorway proximity alone does not necessarily generate extensive acoustic exposure within a protected area (Table 3). Site geometry, distance from the road, the position of the road relative to the protected-area boundary and direct crossing of habitat blocks strongly influence the spatial footprint of traffic noise. This interpretation is consistent with studies showing that the spatial extent of noise impact depends not only on source strength, but also on landscape configuration, sound propagation conditions and the behavioural sensitivity of target species (Barber et al., 2010; Francis & Barber, 2013; Iglesias Merchan et al., 2014; Ware et al., 2015).

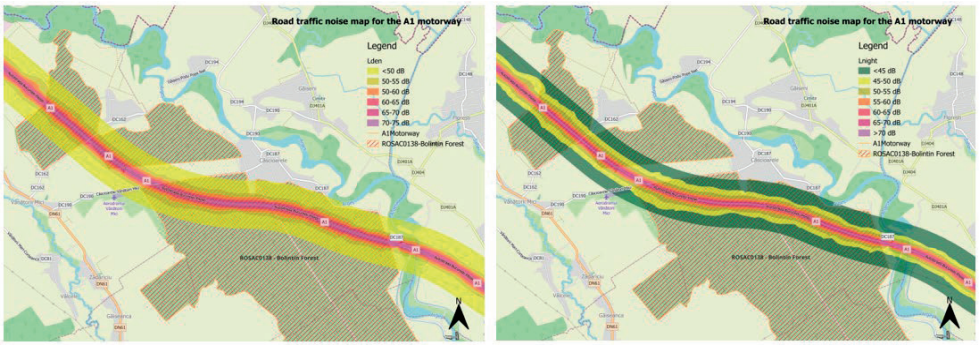


Figure 2. GIS-based noise maps for the A1 motorway in the Bolintin Forest area: Lden/Lzsn and Lnight/Lnoapte

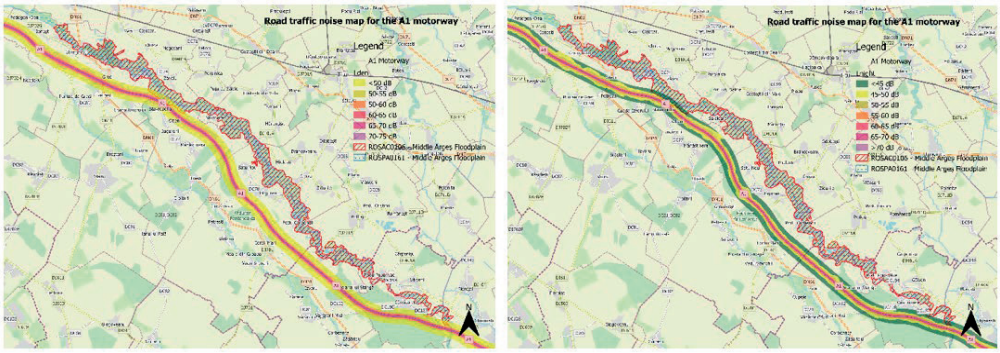


Figure 3. GIS-based noise maps for the A1 motorway in the Middle Argeș Floodplain area: Lden/Lzsn and Lnight/Lnoapte

Table 3. Comparative GIS interpretation of motorway-related acoustic exposure in the two Natura 2000 sites

Indicator	Bolintin Forest	Middle Argeș Floodplain	Interpretation
Spatial relationship with A1	Directly crossed	In proximity only	Direct crossing produces stronger overlap between noise contours and the protected area.
Area exposed above 50 dB	443 ha	6.8 ha	The absolute exposed area is much larger in Bolintin Forest.
Share of site exposed above 50 dB	7.8%	0.18%	The exposure ratio is approximately 43 times higher in Bolintin Forest.
Management relevance	Priority corridor for field validation	Periodic reassessment recommended	GIS layers can support prioritisation of field checks and mitigation analysis.

Direct crossing versus proximity

In Bolintin Forest, the A1 motorway intersects the protected area in two sectors.

The noise maps show that the >50 dB contours penetrate the site along the motorway corridor.

According to the source calculation, the average distance to the 50 dB contour was approximately 249.32 m for carriageway 1 and 249.81 m for carriageway 2 in the case of Lden/Lzsn.

For Lnight/Lnoapte, the corresponding distances were approximately 240.08 m and 240.79 m. The estimated area exposed above 50 dB was approximately 443 ha, corresponding to 7.8% of the total site area.

In Middle Argeș Floodplain, the motorway is located close to the protected area, but does not intersect it directly. The GIS overlay shows that almost the entire site lies outside the >50 dB noise contours. Only approximately 6.8 ha, corresponding to about 0.18% of the site area, were estimated to exceed the 50 dB threshold, in the area corresponding to km 65-66 on carriageway 1.

The comparison indicates that the direct-crossing configuration produces a substantially higher exposure ratio than proximity exposure. In relative terms, the proportion of Bolintin Forest exposed above 50 dB is about 43 times

higher than that calculated for Middle Argeș Floodplain. This result supports the use of GIS-based exposure metrics as a screening tool for identifying Natura 2000 sites where road-traffic noise should be considered in management planning.

Management relevance and limitations

Acoustic exposure should not be interpreted in isolation. A motorway corridor may simultaneously generate sound disturbance, reduce habitat permeability, increase wildlife mortality, create edge effects and facilitate human

access. Therefore, in directly crossed sites such as Bolintin Forest, noise mapping should ideally be integrated with road-fragmentation analysis, habitat maps, wildlife movement data and roadkill monitoring.

For Bolintin Forest, the main management priority is the motorway corridor crossing the site. Potential measures include field validation of noise levels, roadkill monitoring, assessment of wildlife crossing needs, evaluation of existing culverts or bridges and analysis of whether acoustic mitigation measures are technically and ecologically justified. For Middle Argeș Floodplain, the current model suggests limited exposure above 50 dB; however, periodic reassessment is recommended if traffic volumes increase or if new infrastructure developments occur.

The main limitation of the study is that it assesses acoustic exposure rather than direct biological response. The findings therefore indicate potential pressure zones, not confirmed ecological impact. Future analyses should integrate GIS noise layers with habitat distribution, species occurrence, breeding sites, seasonal sensitivity, roadkill data and, where possible, field-based acoustic measurements.

Integration with Natura 2000 management

The GIS-based outputs are most useful when treated as a first-level screening layer rather than as a final ecological diagnosis. For protected-area management, the value of the method lies in its capacity to identify where field verification should start. In the directly crossed site, the motorway corridor can be prioritised for site visits, comparison with existing culverts and bridges, and verification of whether wildlife movement routes intersect the acoustic exposure zone.

The approach also supports future integration with other spatial datasets. Noise-exposure layers can be overlaid with forest habitats, riparian habitats, breeding or feeding areas, species records and connectivity corridors. Such integration would allow managers to distinguish between areas where noise exposure is spatially present but ecologically less relevant and areas where exposure overlaps with sensitive ecological functions.

Because this study uses modelled strategic noise contours, its conclusions should remain spatial and comparative. A stronger ecological interpretation would require field-based sound measurements, seasonal monitoring, species-specific sensitivity assessment and validation against biological indicators. Nevertheless, the comparison demonstrates that the same motorway may generate very different exposure patterns depending on its position relative to the protected-area boundary.

CONCLUSIONS

This study demonstrates that GIS-based noise mapping can provide a useful spatial framework for assessing motorway-related acoustic exposure in Natura 2000 sites. The comparison between Bolintin Forest and Middle Argeș Floodplain shows that the spatial relationship between the motorway and the protected-area boundary strongly influences the extent of acoustic exposure. A direct motorway crossing generated a much larger exposed area than motorway proximity alone.

In Bolintin Forest, approximately 443 ha, or 7.8% of the site, were estimated to be exposed to noise levels above 50 dB, while in Middle Argeș Floodplain only 6.8 ha, or 0.18%, exceeded the same threshold. These results support the integration of GIS-based noise exposure indicators into Natura 2000 management planning, particularly for protected areas crossed by major transport infrastructure.

The study should be regarded as a spatial screening and management-support analysis. For ecological interpretation, modelled noise exposure should be combined with habitat and

species data, field measurements, roadkill monitoring and connectivity assessments.

ACKNOWLEDGEMENTS

This study was developed as part of the doctoral research of Cristina Călin, carried out within the Doctoral School of Engineering and Management of Plant and Animal Resources - University of Agronomic Sciences and Veterinary Medicine of Bucharest.

REFERENCES

ANANP. (2020). Decision No. 414/16.09.2020 regarding the methodological norms for implementing the conservation objectives for ROSCI0106 Lunca Mijlocie a Argeșului. National Agency for Natural Protected Areas.

ANANP. (2021). Decision No. 319/19.07.2021 regarding the methodological norms for implementing the conservation objectives for ROSCI0138/ROSAC0138 Pădurea Bolintin. National Agency for Natural Protected Areas.

ANANP. (2023). Decision No. 379/20.06.2023 amending Decision No. 414/16.09.2020 regarding conservation objectives for ROSCI0106/ROSAC0106 Lunca Mijlocie a Argeșului. National Agency for Natural Protected Areas.

Barber, J. R., Crooks, K. R., & Fristrup, K. M. (2010). The costs of chronic noise exposure for terrestrial organisms. *Trends in Ecology & Evolution*, 25(3), 180-189. https://doi.org/10.1016/j.tree.2009.08.002

Buxton, R. T., McKenna, M. F., Mennitt, D., Fristrup, K., Crooks, K., Angeloni, L., & Wittemyer, G. (2017). Noise pollution is pervasive in U.S. protected areas. *Science*, 356(6337), 531-533. https://doi.org/10.1126/science.aah4783

CNAIR SA - CESTRIN. (2022). General Traffic Census for Romanian roads. Traffic dataset used for the A1 motorway sectors analysed in this study.

Forman, R. T. T., & Alexander, L. E. (1998). Roads and their major ecological effects. *Annual Review of Ecology and Systematics*, 29, 207-231. https://doi.org/10.1146/annurev.ecolsys.29.1.207

Francis, C. D., & Barber, J. R. (2013). A framework for understanding noise impacts on wildlife: An urgent conservation priority. *Frontiers in Ecology and the Environment*, 11(6), 305-313. https://doi.org/10.1890/120183

Iglesias Merchan, C., Diaz-Balteiro, L., & Soliño, M. (2014). Noise pollution in national parks: Soundscape and economic valuation. *Landscape and Urban Planning*, 123, 1-9. https://doi.org/10.1016/j.landurbplan.2013.11.006

Kephalopoulos, S., Paviotti, M., & Anfosso-Lédée, F. (2012). Common Noise Assessment Methods in Europe (CNOSSOS-EU). *Publications Office of the European Union*. https://doi.org/10.2788/31776

Kight, C. R., & Swaddle, J. P. (2011). How and why environmental noise impacts animals: An integrative, mechanistic review. *Ecology Letters*, 14(10), 1052-1061. https://doi.org/10.1111/j.1461-0248.2011.01664.x

Council of the European Communities (1992). Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. *Official Journal of the European Communities.*

European Parliament and Council (2002). Directive 2002/49/EC relating to the assessment and management of environmental noise. *Official Journal of the European Communities.*

European Parliament and Council (2009). Directive 2009/147/EC on the conservation of wild birds. *Official Journal of the European Union.*

Law No. 121/2019 on the assessment and management of environmental noise, with subsequent amendments. Official Gazette of Romania.

Ministry of Environment, Waters and Forests (2020). Note No. 13916/CA/17.09.2020 regarding the minimum special protection and conservation measures for ROSPA0161 Middle Argeș Floodplain.

Order of the Ministry of Environment, Waters and Forests No. 2328/2021 approving limit values for Lzsn, Lnight, Lday and Levening.

SR ISO 1996-2:2018. Acoustics - Description, measurement and assessment of environmental noise - Part 2: Determination of sound pressure levels.

McClure, C. J. W., Ware, H. E., Carlisle, J., Kaltenecker, G., & Barber, J. R. (2013). An experimental investigation into the effects of traffic noise on distributions of birds: Avoiding the phantom road. *Proceedings of the Royal Society B: Biological Sciences*, 280(1773), 20132290. https://doi.org/10.1098/rspb.2013.2290

Parris, K. M., & Schneider, A. (2008). Impacts of traffic noise and traffic volume on birds of roadside habitats. *Ecology and Society*, 14(1), 29. https://doi.org/10.5751/ES-02761-140129

Reijnen, R., Foppen, R., Ter Braak, C., & Thissen, J. (1995). The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to proximity of main roads. *Journal of Applied Ecology*, 32(1), 187-202. https://doi.org/10.2307/2404428

Reijnen, R., Foppen, R., & Meeuwsen, H. (1996). The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. *Biological Conservation*, 75(3), 255-260. https://doi.org/10.1016/0006-3207(95)00074-7

Slabbekoorn, H., & Ripmeester, E. A. P. (2008). Birdsong and anthropogenic noise: Implications and applications for conservation. *Molecular Ecology*, 17(1), 72-83. https://doi.org/10.1111/j.1365-294X.2007.03487.x

Shannon, G., Angeloni, L. M., Wittemyer, G., Fristrup, K. M., & Crooks, K. R. (2014). Road traffic noise

modifies behaviour of a keystone species. *Animal Behaviour*, 94, 135-141. https://doi.org/10.1016/j.anbehav.2014.06.004

Shannon, G., McKenna, M. F., Angeloni, L. M., Crooks, K. R., Fristrup, K. M., Brown, E., Warner, K. A., Nelson, M. D., White, C., Briggs, J., McFarland, S., & Wittemyer, G. (2016). A synthesis of two decades of research documenting the effects of noise on wildlife. *Biological Reviews*, 91(4), 982-1005. https://doi.org/10.1111/brv.12207

Ware, H. E., McClure, C. J. W., Carlisle, J. D., & Barber, J. R. (2015). A phantom road experiment reveals traffic noise is an invisible source of habitat degradation. *Proceedings of the National Academy of Sciences*, 112(39), 12105-12109. https://doi.org/10.1073/pnas.1504710112