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Evaluation of Road Traffic Noise Pollution Using the Inverse Distance Weighted (IDW) Interpolation Method in the Municipality of Ain Benian, Algiers, Algeria

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Abstract

Urban road traffic noise has become a growing public health concern in North African cities, yet systematic acoustic assessments remain rare in this region. This study maps noise exposure in Ain Benian municipality (Algiers, Algeria) through georeferenced field measurements at 63 sampling points distributed across three urban zones, conducted during morning, midday, and evening periods. A resident perception survey (n = 170) complemented the acoustic dataset. Continuous noise maps were produced by Inverse Distance Weighting (IDW) spatial interpolation in ArcGIS and cross-validated using leave-one-out cross-validation (LOOCV; RMSE ≈ 5.1 dB(A)). Recorded levels peaked at 77–78 dB(A) during commuting hours and fell to roughly 65 dB(A) at midday — a difference of more than 12 dB pointing squarely to traffic as the controlling factor. Eighty-nine percent of stations exceeded the Algerian daytime threshold of 70 dB(A), and spatial analysis shows that close to half the municipality experiences levels above 75 dB(A), predominantly along the RN11 and CW111 corridors. An indicative day-evening-night level (Lden) was estimated for contextual purposes only; given the absence of nocturnal measurements, it carries appreciable uncertainty and is not intended for regulatory use. The results underline the severity of the noise situation in Ain Benian and the urgency of targeted intervention in traffic management and urban planning.

1 Introduction

Road traffic noise ranks among the most pervasive environmental stressors in contemporary cities. Prolonged exposure has been linked to cardiovascular disorders, sleep disruption, and impaired cognitive development in children — consequences that are no longer disputed in the epidemiological literature (Münzel et al. 2021; Münzel et al. 2024; Cole-Hunter et al. 2022). In Europe, the EEA estimates that over 100 million people are exposed to harmful noise levels from transport alone (EEA 2020), and the situation in rapidly motorising developing countries is arguably worse, compounded by the near-absence of monitoring infrastructure.

Algeria is a case in point. Despite accelerating urbanisation and steady growth in private vehicle ownership, published studies on urban noise remain scarce. The few available assessments — notably Bouzir and Zemmouri's work in Biskra (2017) — cover only isolated cities and rely on conventional sound level meters, limiting spatial coverage. No acoustic mapping study had been conducted in the Greater Algiers coastal area prior to this work.

The municipality of Ain Benian, situated roughly 15 km west of central Algiers, seemed a particularly relevant study site. Traversed by two heavily loaded corridors (RN11 and CW111) and experiencing a demographic growth rate of 5.12% per year between 2008 and 2020 (ONS 2020), it concentrates the conditions most likely to generate severe noise exposure. The present study set out to: (1) measure road traffic noise at 63 georeferenced points across three daily periods; (2) generate spatially continuous noise maps by IDW interpolation validated through LOOCV; (3) characterise temporal variability and

identify critical exposure zones; and (4) derive indicative health risk estimates using WHO (2018) dose–response functions.

2 Materials and Methods

2.1 Study Area

The study was conducted in the municipality of Ain Benian, located along the Algerian Mediterranean coast, approximately 15 km west of Algiers (Fig. 1). The municipality covers an area of 1,326.5 ha and has experienced rapid demographic growth (5.12% annual rate, 2008–2020; ONS 2020). It is crossed by National Road RN11 and Wilaya Road CW111, which constitute the primary noise sources. The climate is Mediterranean (Csa, Köppen–Geiger), with hot dry summers; prevailing north-westerly winds influence both pollutant dispersion and noise propagation.

2.2 Zoning of the Study Area

To facilitate systematic data collection and spatial analysis, Ain Benian was subdivided into three zones corresponding to POS 129, 130, and 131 (Fig. 2). This zoning strategy enabled organised field measurements, identification of local noise factors, and enhanced spatial analysis accuracy by ensuring balanced distribution of measurement points across the municipality.

2.3 Study Approach and GIS

This study applied an integrated environmental monitoring framework combining georeferenced mobile acoustic measurements and GIS-based spatial analysis. Spatial data processing was conducted using ArcGIS to integrate acoustic and GPS datasets, manage geographic layers, and generate thematic noise maps for environmental interpretation and decision support.

2.4 Data Collection

Noise measurements were conducted at 63 georeferenced locations using the NoiseTube smartphone-based application (Maisonneuve et al. 2009, 2010). Geographic localisation was carried out using the GeoTracker mobile application (real-time GPS recording, GPX/KML/CSV export). A preliminary calibration against a Class 2 sound level meter (IEC 61672-1) at four reference levels (60, 70, 80, and 90 dB(A)) yielded a mean absolute deviation of 1.8 dB(A); a correction offset of + 1.8 dB(A) was applied systematically to all measurements prior to spatial analysis (D'Hondt et al. 2013; Zamora et al. 2017).

Each measurement lasted 10–15 minutes with 1-second resolution. Data were collected during three periods: morning (07:00–09:00), midday (10:00–12:00), and evening (16:00–18:00). The 63 measurement points were distributed across the three zones to capture spatial variability in noise exposure (Fig. 4).

2.5 Noise Perception Survey

A structured survey was conducted among 170 residents to evaluate citizens' perception of environmental noise and daily mobility patterns. The questionnaire collected data on: (i) demographic characteristics; (ii) primary transport modes; (iii) frequency and timing of travel; and (iv) awareness of noise pollution and its quality-of-life impact.

2.6 Spatial Interpolation Using IDW

The Inverse Distance Weighting (IDW) method was used to generate continuous noise surfaces from discrete point measurements. IDW assumes that closer points have a stronger influence on estimated values than more distant ones, following the mathematical formulation (Eq. 1):

$\hat{Z}(x_o) = \Sigma\, w_i\, Z(x_i) / \Sigma\, w_i$, *where* $w_i = 1 / d(x_o, x_i)$ *(Eq. 1)*

A sensitivity analysis was performed testing values of p = 1, 2, and 3 (Fig. 5a). Although p = 3 yields the lowest RMSE, the improvement over p = 2 is marginal (0.15 dB(A)), while producing sharper discontinuities less appropriate for continuous urban noise mapping. The conventional value of p = 2 was therefore retained (Murphy and King 2016). LOOCV (Fig. 5b) yielded RMSE values of 5.09 dB(A) (morning), 5.09 dB(A) (midday), and 5.18 dB(A) (evening).

2.7 Classification of Noise Levels

Noise surfaces were classified into five categories following established thresholds (Hammer et al. 2013; Murphy and King 2016) to identify zones of varying exposure (Table 1).

Table 1
Classification of noise levels and associated health impacts

Noise level (dB)	Colour code	Category	Impact
< 55	Green	Very low	Acceptable
55–65	Yellow	Low	Moderate comfort
65–75	Orange	Moderate	Occasional disturbance
75–85	Light red	High	Significant disturbance
> 85	Dark red	Very high	Health risk

2.8 Day-Evening-Night Level (Lden) Estimation

To contextualise results within the WHO (2018) health impact framework, an indicative Lden was estimated using the standard formula defined in Directive 2002/49/EC (European Parliament 2002). As no dedicated night-time measurements were performed, Lnight was estimated from comparable

Mediterranean coastal city studies (Kechiche et al. 2026; Köklü et al. 2024). This estimate was used solely for indicative health risk calculations and should not be considered a precise regulatory metric.

2.9 Limitations of the Measurement Approach

Four limitations should be acknowledged upfront. First, smartphone-based measurements, although calibrated, are less precise than certified instruments. Second, no direct traffic flow data were collected, limiting quantitative analysis of the traffic–noise relationship. Third, night-time measurements were not conducted, preventing accurate Lden calculation. Finally, IDW interpolation does not account for urban morphology or physical barriers.

3 Results and Discussion

3.1 Descriptive Statistics of Noise Measurements

Noise levels were measured at 63 points during three distinct periods. Descriptive statistics are presented in Table 2 and Fig. 6.

Table 2
Descriptive statistics of noise measurements by period

Period	Mean dB(A)	Median	Min	Max	SD dB(A)
Morning (07:00–09:00)	77.5	78.0	62	90	6.8
Midday (10:00–12:00)	65.3	66.0	50	78	5.4
Evening (16:00–18:00)	77.4	77.5	61	91	6.9

During the morning peak (07:00–09:00), the mean noise level was 77.5 dB(A) (SD = 6.8 dB) with a median of 78 dB(A) and range of 62–90 dB(A). Distribution analysis revealed that 60% of measurement points fell between 70 and 80 dB(A), 27% between 80 and 90 dB(A), and one point exceeded 90 dB(A). A total of 89% of measurement points surpassed the Algerian regulatory daytime threshold of 70 dB(A) (Algerian Official Journal 1993).

During the midday period (10:00–12:00), noise exposure decreased notably. The mean level dropped to 65.3 dB(A), representing an average reduction of 12.2 dB compared to the morning — a figure that reflects lower traffic volumes during off-peak hours and constitutes the strongest evidence in this study for the dominant role of road traffic.

During the evening peak (16:00–18:00), noise levels closely resembled the morning peak, with a mean of 77.4 dB(A), confirming the two-peak daily pattern characteristic of commuter-driven urban noise.

3.2 Indicative Health Risk Assessment

To contextualise the recorded noise levels within a public health framework, an indicative health risk assessment was conducted using WHO (2018) dose–response functions. This assessment is indicative rather than definitive: no dedicated night-time measurements were performed, and the Lden metric could not be directly calculated from the available data.

An approximate Lden of 77.3 dB(A) was estimated by combining the measured daytime and evening mean values with a modelled night-time level of 65.9 dB(A), derived from comparable Mediterranean coastal city studies (Kechiche et al. 2026; Köklü et al. 2024). The corresponding Lnight value substantially exceeds the WHO (2018) recommended threshold of 45 dB(A), suggesting elevated sleep disturbance risk. Applying WHO (2018) dose–response relationships, the proportion of residents potentially highly annoyed may reach approximately 85% of the exposed population (~ 33,000 inhabitants). These figures are indicative, subject to uncertainty from the absence of measured Lnight data and from applying European functions to a North African context where building insulation standards and adaptive behaviours may differ.

3.3 Noise Mapping via IDW Interpolation

Spatial interpolation using the IDW method generated thematic noise maps for each measurement period across the municipality.

Morning map (07:00–09:00): Dark red zones (> 85 dB(A)) were identified along RN11, major intersections, and central urban areas, covering approximately 15% of the municipality. Light red zones (75–85 dB(A)) accounted for ~ 35%, primarily in residential areas adjacent to RN11. Approximately 50% of the municipality exceeded 75 dB(A), far above regulatory thresholds (Fig. 8).

Midday map (10:00–12:00): Red zones (> 75 dB(A)) were limited to main roads (~ 5%). Yellow zones (55–65 dB(A)) represented ~ 45%, and green zones (< 55 dB(A)) appeared in peripheral and coastal areas (~ 20%), reflecting significant acoustic improvement during off-peak hours (Fig. 9).

Evening map (16:00–18:00): The evening map mirrored the morning pattern, confirming the cyclical nature of noise pollution linked to peak traffic periods (Fig. 10).

3.4 Spatial Analysis of Noise Generators

Overlaying acoustic maps with urban infrastructure identified primary noise sources: (1) RN11, acting as the principal noise corridor; (2) CW111, with moderate to high noise impact; (3) dense built-up areas, which amplify and reverberate noise; and (4) intersections and crossroads, producing localised noise peaks. Green spaces and the Bainem forest provide a noise-buffering effect, while the coastal frontage facilitates sound dissipation. The 12.2 dB decrease between peak and midday hours confirms road traffic as the main driver of urban noise dynamics.

3.5 Discussion

The noise levels recorded in Ain Benian are high by any standard. Mean values of 77.5 and 77.4 dB(A) during the morning and evening peaks exceed the Algerian regulatory limit of 70 dB(A) (Algerian Official Journal 1993) by roughly 7 dB. What is perhaps more telling is the 12.2 dB drop at midday: such a consistent reduction across all three zones points squarely to traffic volume as the controlling variable.

Comparing our results with similar studies in the region (Table 3) puts these figures in perspective. The mean peak level of 77.5 dB(A) exceeds what Bouzir and Zemmouri (2017) reported in Biskra (72.3 dB(A)) and sits above the range documented in mid-sized Turkish coastal cities (Köklü et al. 2024). It aligns roughly with values from Sousse, Tunisia (Kechiche et al. 2026) and Beirut (Al-Shaar et al. 2021) — two cities known for dense, poorly regulated urban traffic. Within Algeria, Ain Benian appears to represent the upper end of recorded noise levels.

Table 3
Comparative noise levels in Mediterranean and North African cities

City / Country	Method	Road / Context	Peak dB(A)	Off-peak dB(A)	Reference
Ain Benian, Algeria	NoiseTube + IDW	RN11 — coastal urban	77.5	65.3	Present study
Biskra, Algeria	Sound level meter	Urban arterials	72.3	63.1	Bouzir and Zemmouri (2017)
Sousse, Tunisia	Class 1 SLM	Major urban roads	~ 76	~ 65	Kechiche et al. (2026)
Izmir, Turkey	SLM + mapping	Coastal arterials	70–73	62–66	Köklü et al. (2024)
Beirut, Lebanon	SLM	Urban traffic roads	~ 75	~ 64	Al-Shaar et al. (2021)

The decision to use IDW rather than Kriging deserves a brief comment. With 63 unevenly distributed points in a dense urban environment where noise can shift sharply over a few metres, fitting a stable variogram is not straightforward. IDW is transparent, reproducible, and has been validated in a substantial body of urban noise mapping studies (Murphy and King 2016; Wickramathilaka et al. 2024; Suárez and Barros 2014). The LOOCV results (RMSE = 5.09–5.18 dB(A)) are consistent with comparable configurations in the literature. The absence of traffic count data is a limitation we cannot sidestep: we can show that noise follows traffic rhythms, but quantifying the flow-to-Leq relationship requires dedicated counters or video-based detection, which should feature in follow-up work.

3.6 Study Limitations

Four limitations are worth stating plainly. First, NoiseTube measurements, while calibrated against a Class 2 meter and corrected by + 1.8 dB(A), remain indicative rather than regulatory-grade; they capture spatial patterns reliably but should not be used directly for compliance assessment. Second, night-time data were not collected. The Lnight estimate used in Section 3.2 was borrowed from comparable

Mediterranean coastal studies — a reasonable approximation, but one that introduces uncertainty that only dedicated nocturnal measurements can eliminate. Third, we had no meteorological data and could not correct for wind or temperature gradients, which may have added variability along the coastal frontage. Fourth, with 170 survey respondents from three zones, the perception data give a useful qualitative picture but do not allow robust socio-demographic disaggregation across the full municipality. Despite these caveats, the combination of 63 georeferenced measurement points, LOOCV model validation, and resident survey data provides a methodological basis that is both reproducible and transferable to similar North African urban contexts.

4 Conclusion

This study characterised road traffic noise in Ain Benian — a coastal Algiers municipality with no prior acoustic mapping record — and the picture that emerged is unambiguous. During morning and evening commuting hours, noise levels averaged around 77–78 dB(A) at 89% of measurement stations, exceeding the national daytime limit of 70 dB(A). Spatial analysis shows that nearly half the municipality is exposed above 75 dB(A), concentrated along RN11 and at major intersections. The 12.2 dB midday reduction leaves little doubt that road traffic governs the acoustic environment of this city.

The GIS-IDW framework applied here proved workable in a resource-limited setting. Smartphone-based measurements, once calibrated and georeferenced, yielded spatially coherent maps with LOOCV errors in the range of 5 dB(A) — acceptable for identifying exposure zones and planning priorities. Future studies should close the identified gaps through continuous 24-hour monitoring with calibrated instruments and simultaneous traffic enumeration. On the policy side, the findings point to concrete needs: better management of peak flows on RN11, noise barriers at the most exposed intersections, and stronger enforcement of the 1993 noise decree — a regulatory instrument whose thresholds are already routinely exceeded across much of the municipality.

Declarations

Ethics approval This study was conducted in accordance with the Declaration of Helsinki. The noise perception survey was administered to voluntary participants informed of the study objectives. Verbal informed consent was obtained from all respondents. No personally identifiable information was collected. The study was conducted in accordance with applicable Algerian research ethics norms (Loi n° 83-03).

Competing interests The authors declare no competing interests.

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Authors' contributions Bouchama Leila: Conceptualization, Methodology, Validation, Visualization, Supervision, Writing – Review & Editing, Formal Analysis. Kara Achira Roumaissa: Investigation,

Resources, Data Curation, Formal Analysis, Writing – Original Draft. Lamouri Wissal: Investigation, Resources, Data Curation, Writing – Original Draft.

Data availability The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

Ethics approval: This study involving human participants (fieldwork and questionnaire-based data collection) was conducted with official authorization from the University of Science and Technology Houari Boumediene (USTHB), Algeria, in accordance with institutional guidelines for research involving human subjects. Consent to participate: Informed consent was obtained from all individual participants included in the study. Participation was voluntary, and participants were informed of the purpose of the research. All procedures performed in this study were in accordance with the ethical standards of the institution and with the 1964 Helsinki Declaration and its later amendments.

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Figures

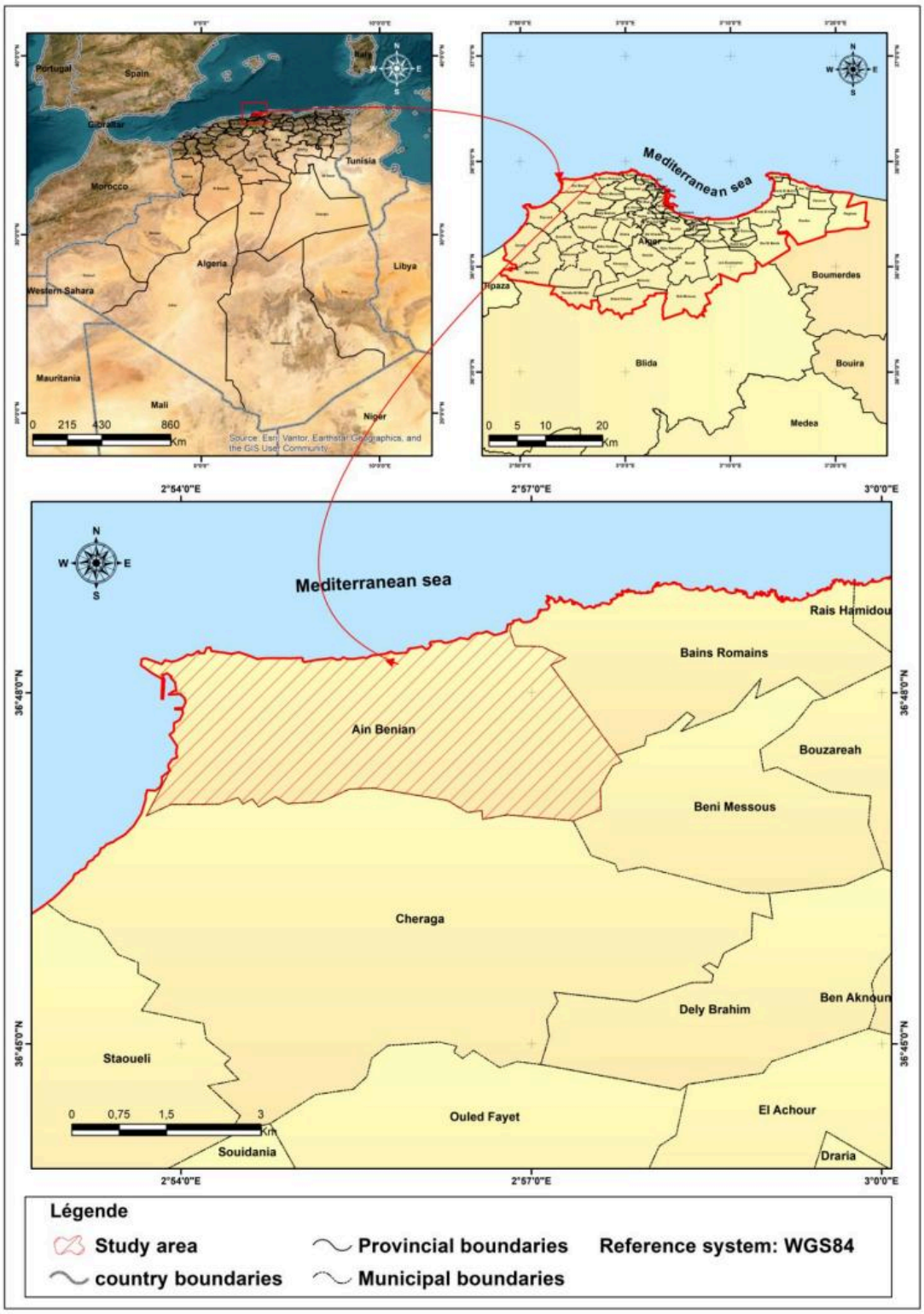


Figure 1

Location map of the study area — Municipality of Ain Benian, Algiers, Algeria. Note: Map lines delineate study areas and do not necessarily depict accepted national boundaries.

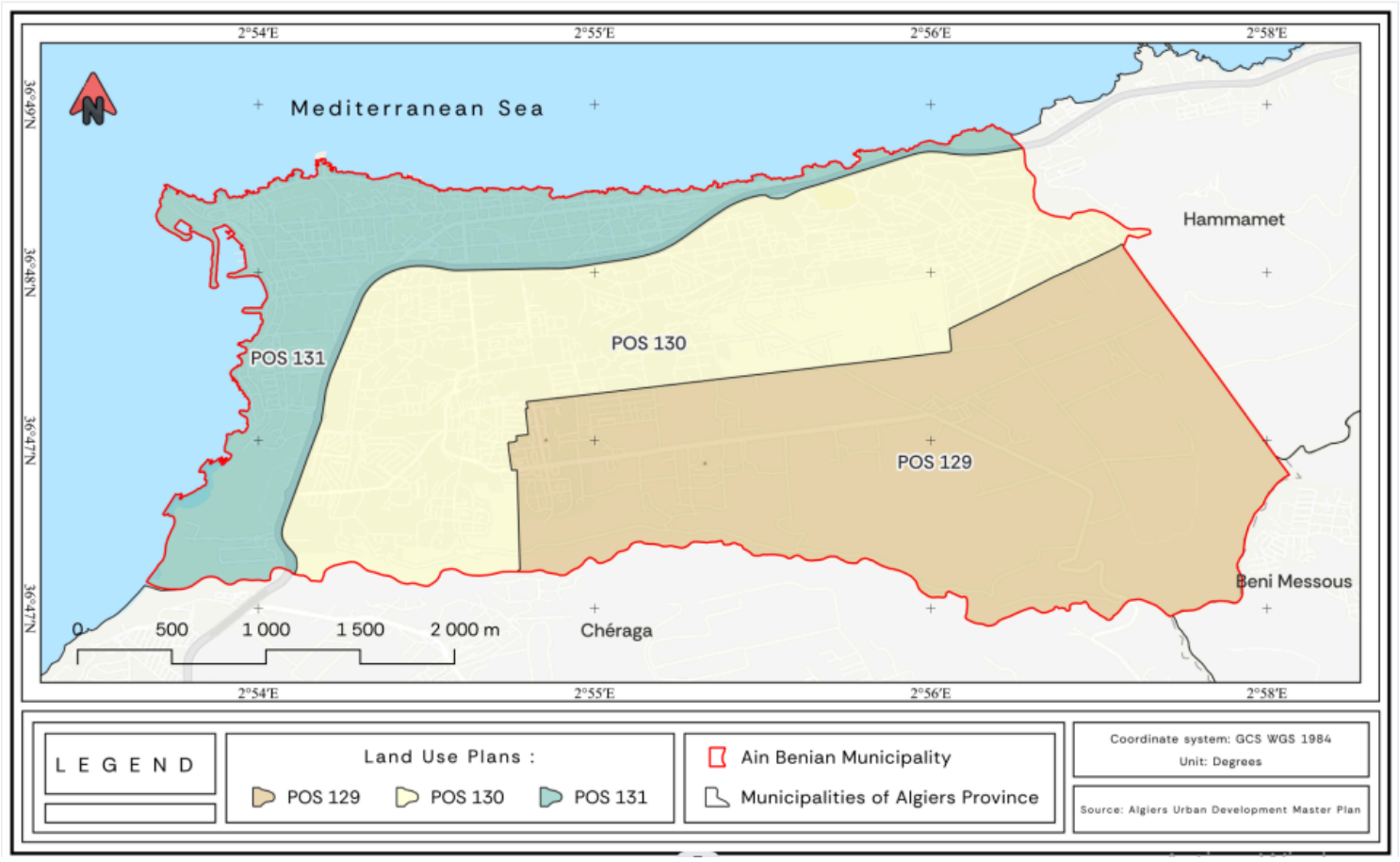


Figure 2

Zoning of Ain Benian municipality into POS 129, 130, and 131. Note: Map lines delineate study areas and do not necessarily depict accepted national boundaries.

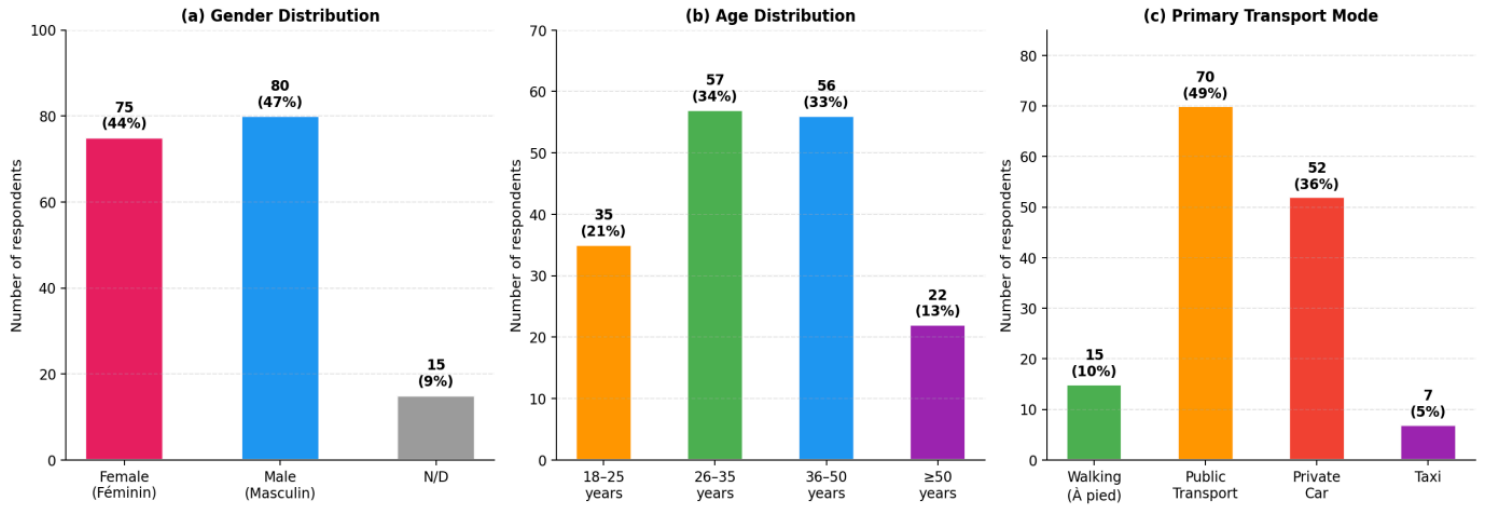


Figure 3

Survey results: (a) gender distribution, (b) age distribution, and (c) primary transport mode among 170 respondents (Ain Benian, 2024).

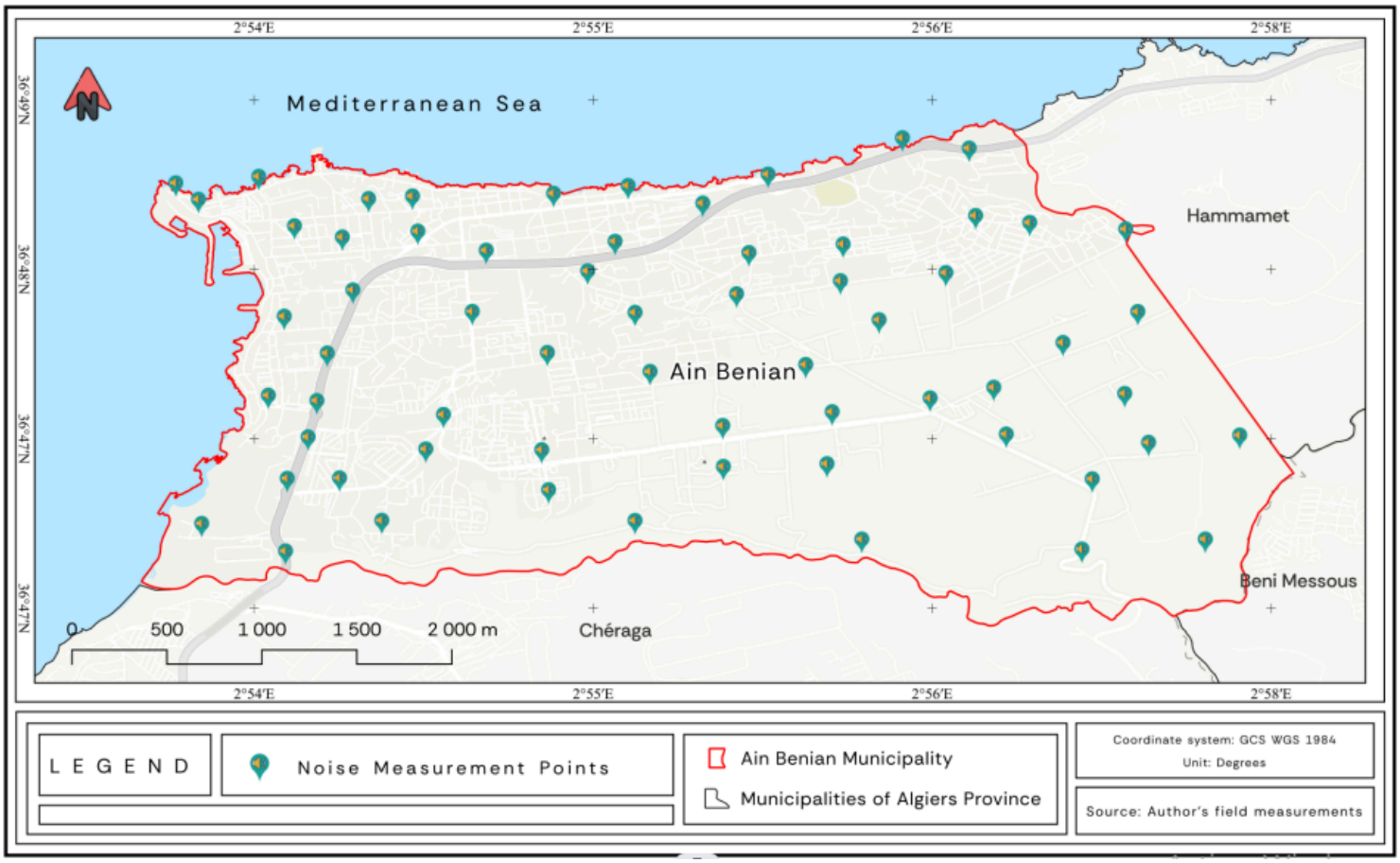


Figure 4

Location map of the 63 measurement stations across Ain Benian municipality.

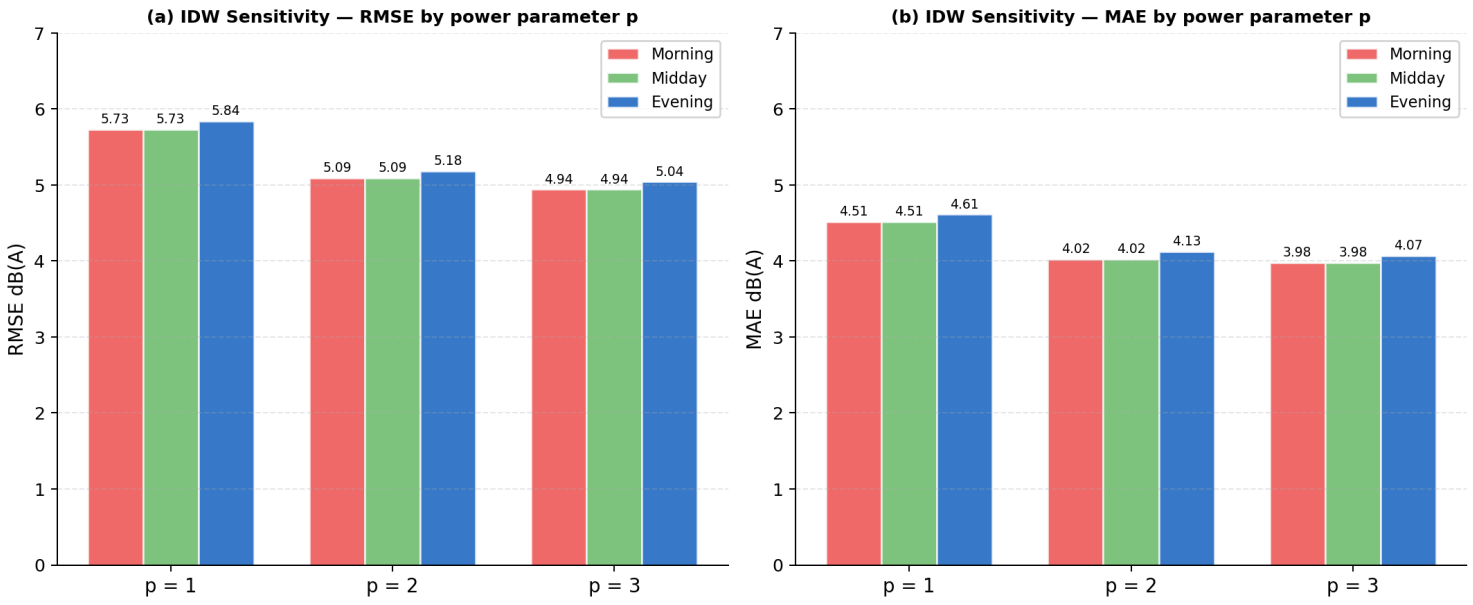


Figure 5

Fig. 5a *Sensitivity analysis of the IDW power parameter (p = 1, 2, 3): RMSE and MAE values for the three measurement periods. p = 2 was selected as the optimal value.*

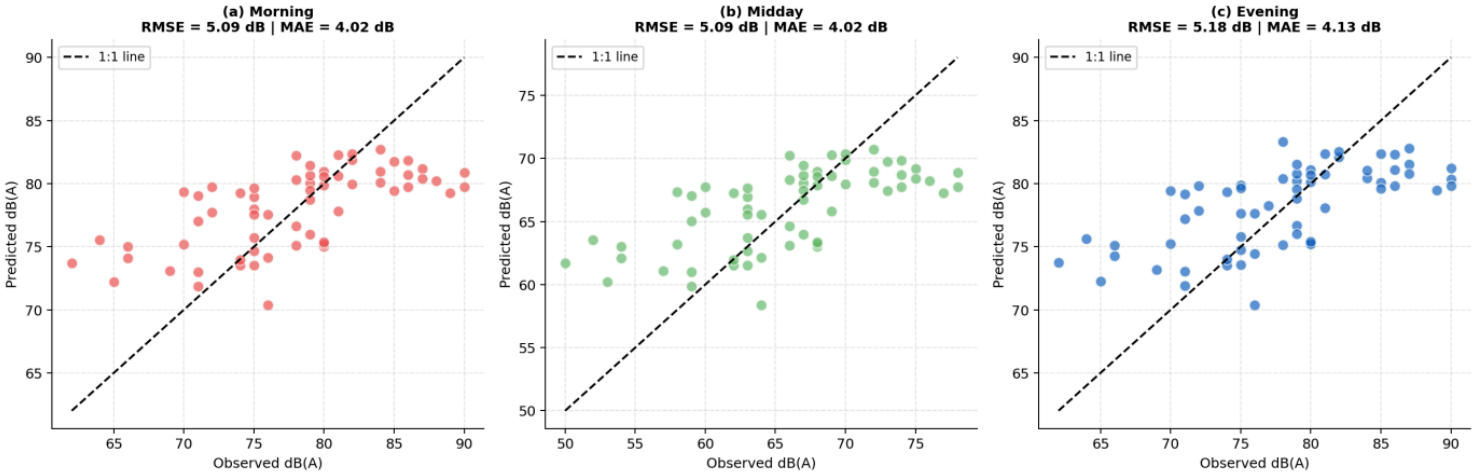


Figure 6

Fig. 5b *Leave-one-out cross-validation (LOOCV) results: predicted vs. observed noise levels for morning, midday, and evening periods. RMSE = 5.09 dB(A) (morning and midday), 5.18 dB(A) (evening).*

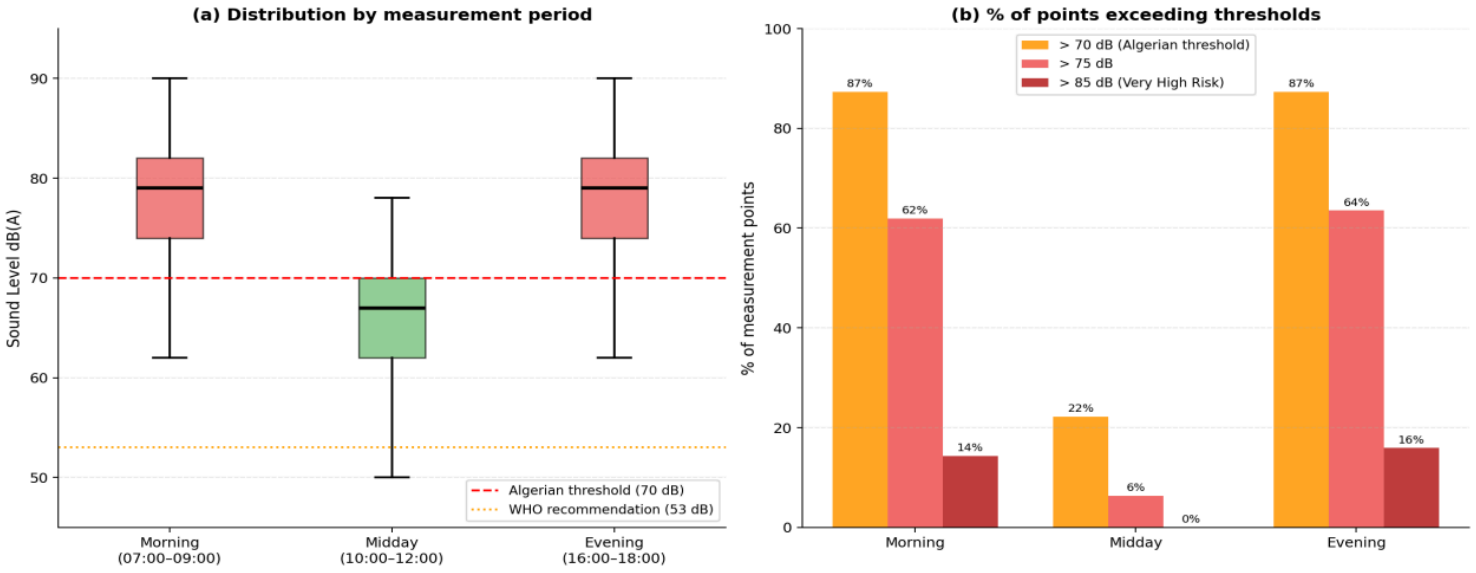


Figure 7

Fig. 6 *(a) Boxplot distribution of noise levels by measurement period with WHO (53 dB) and Algerian (70 dB) regulatory thresholds; (b) percentage of measurement points exceeding noise thresholds by period.*

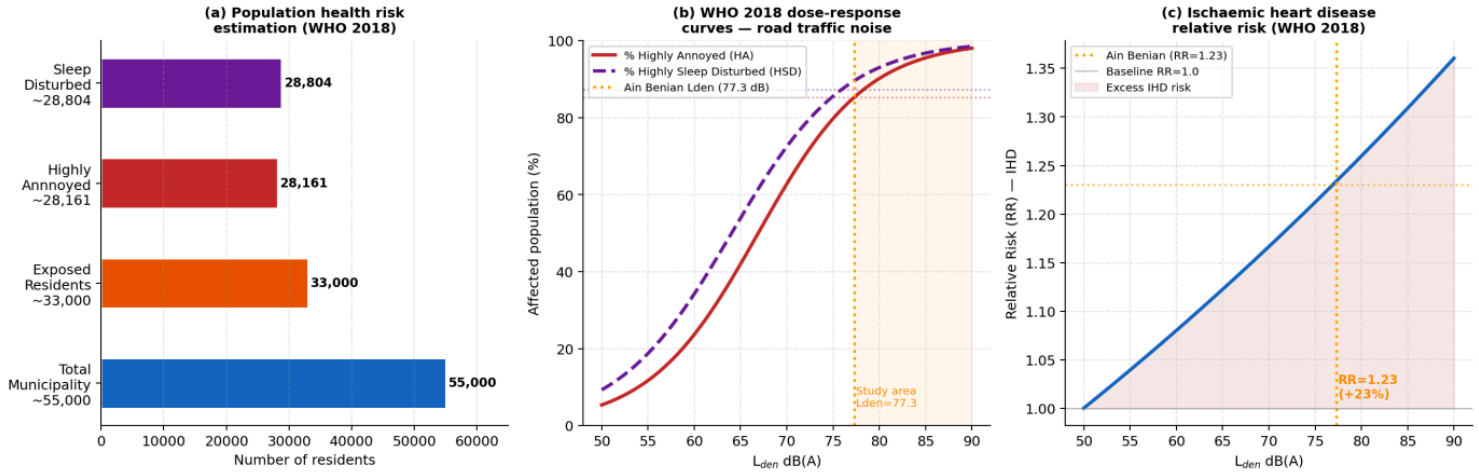


Figure 8

Fig. 7 *Indicative health risk assessment based on WHO (2018) dose–response functions applied to estimated Lden: (a) estimated number of residents potentially affected; (b) % highly annoyed and % with sleep disturbance risk; (c) relative risk for ischaemic heart disease. Note: values are indicative estimates subject to the limitations described in the text.*

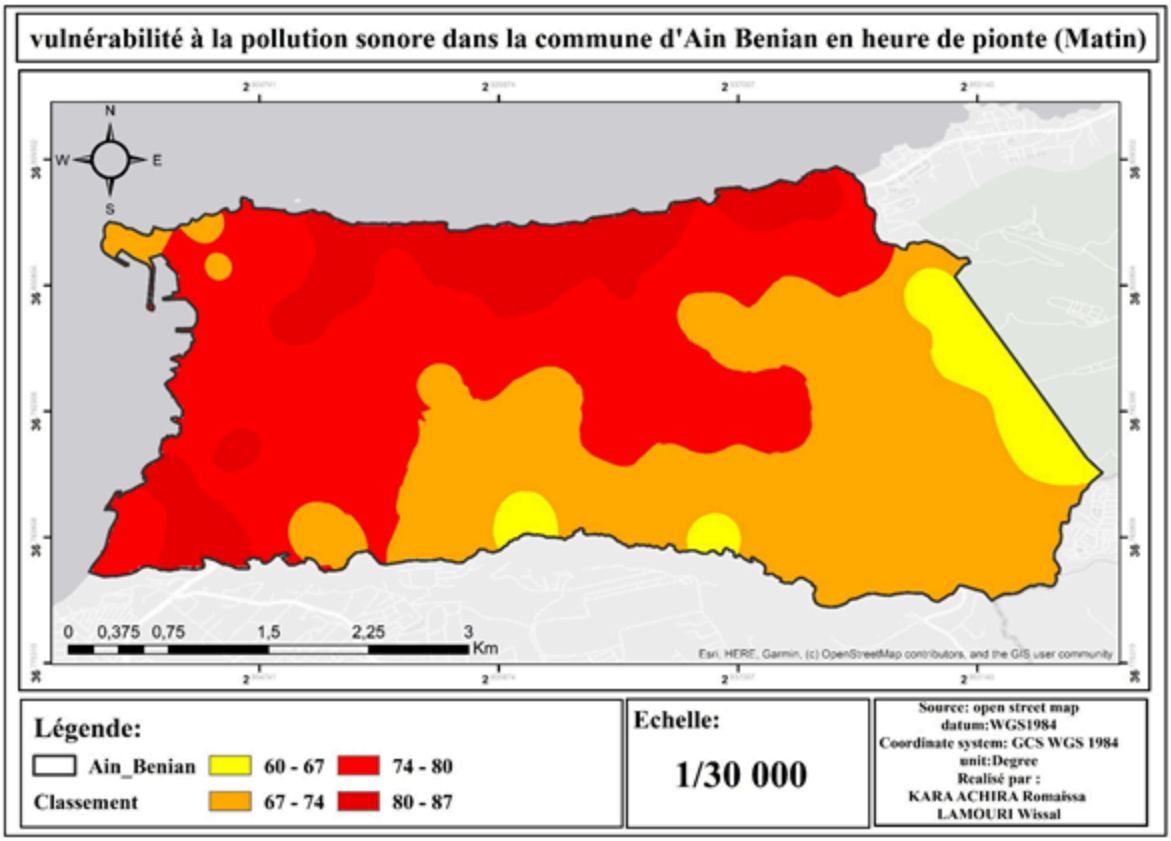


Figure 9

Fig. 8 *Noise vulnerability map — Morning period (07:00–09:00). Note: Map lines delineate study areas and do not necessarily depict accepted national boundaries.*

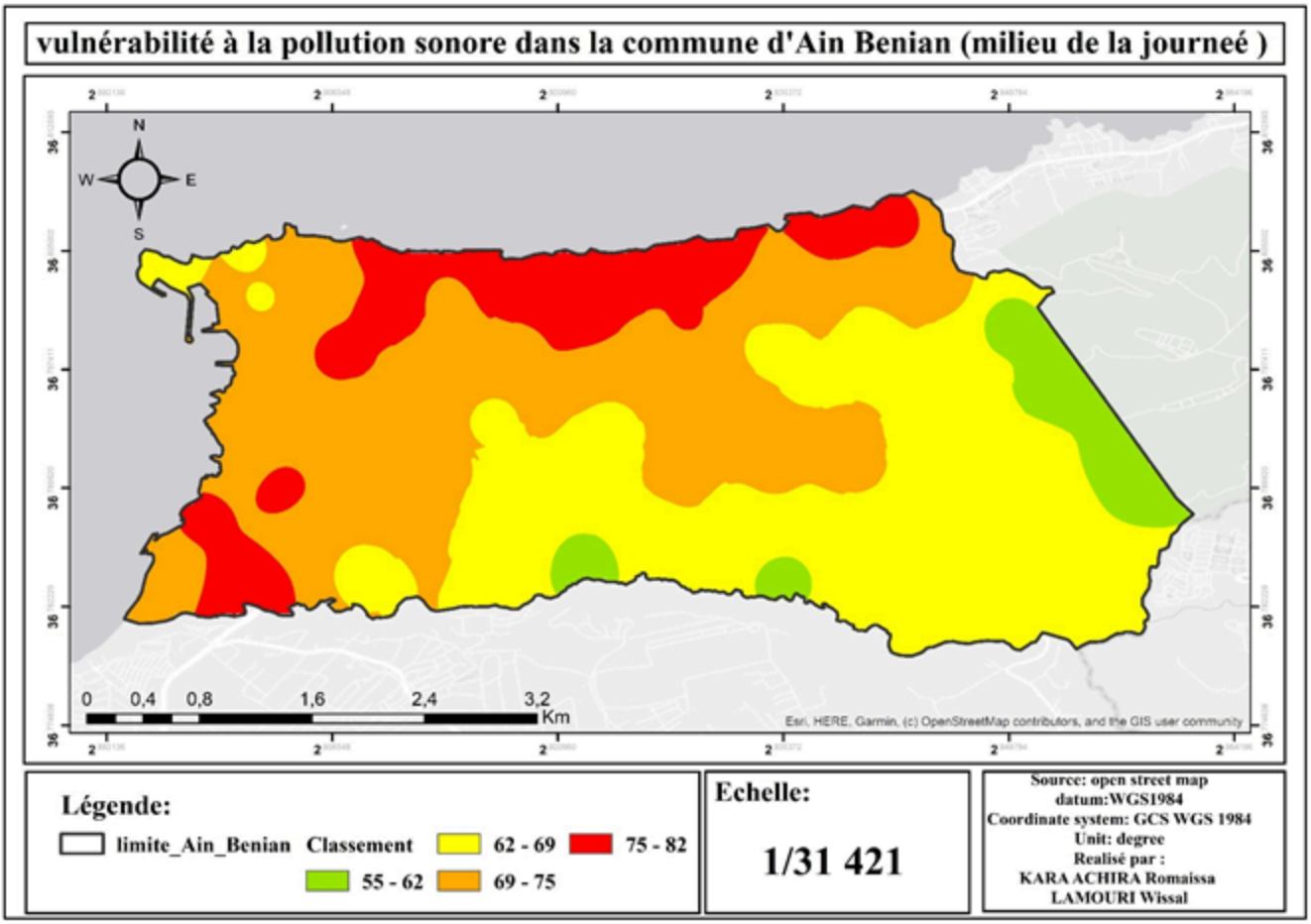


Figure 10

Fig. 9 *Noise vulnerability map — Midday period (10:00–12:00). Note: Map lines delineate study areas and do not necessarily depict accepted national boundaries.*

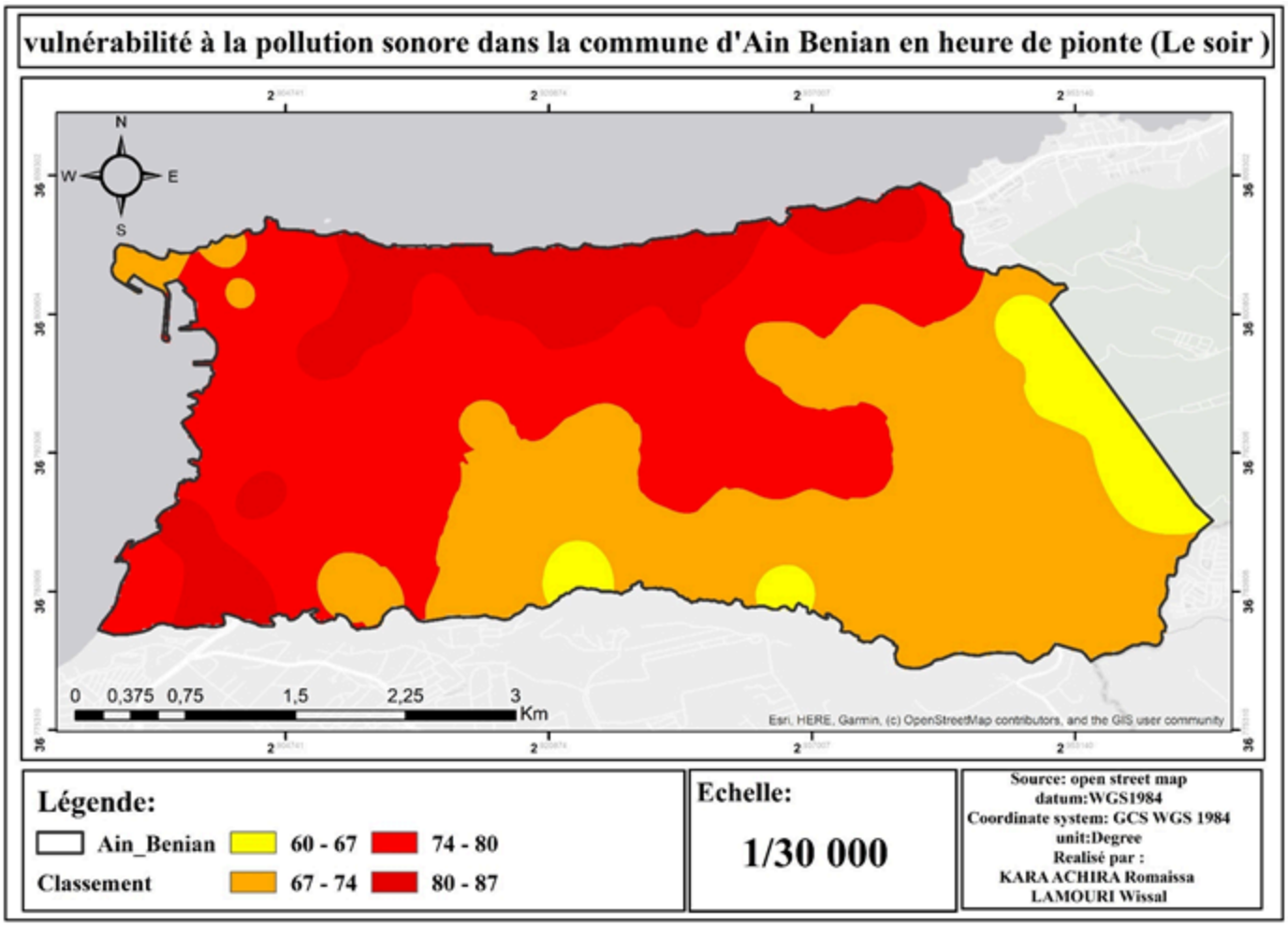


Figure 11

Fig. 10 *Noise vulnerability map — Evening period (16:00–18:00). Note: Map lines delineate study areas and do not necessarily depict accepted national boundaries.*

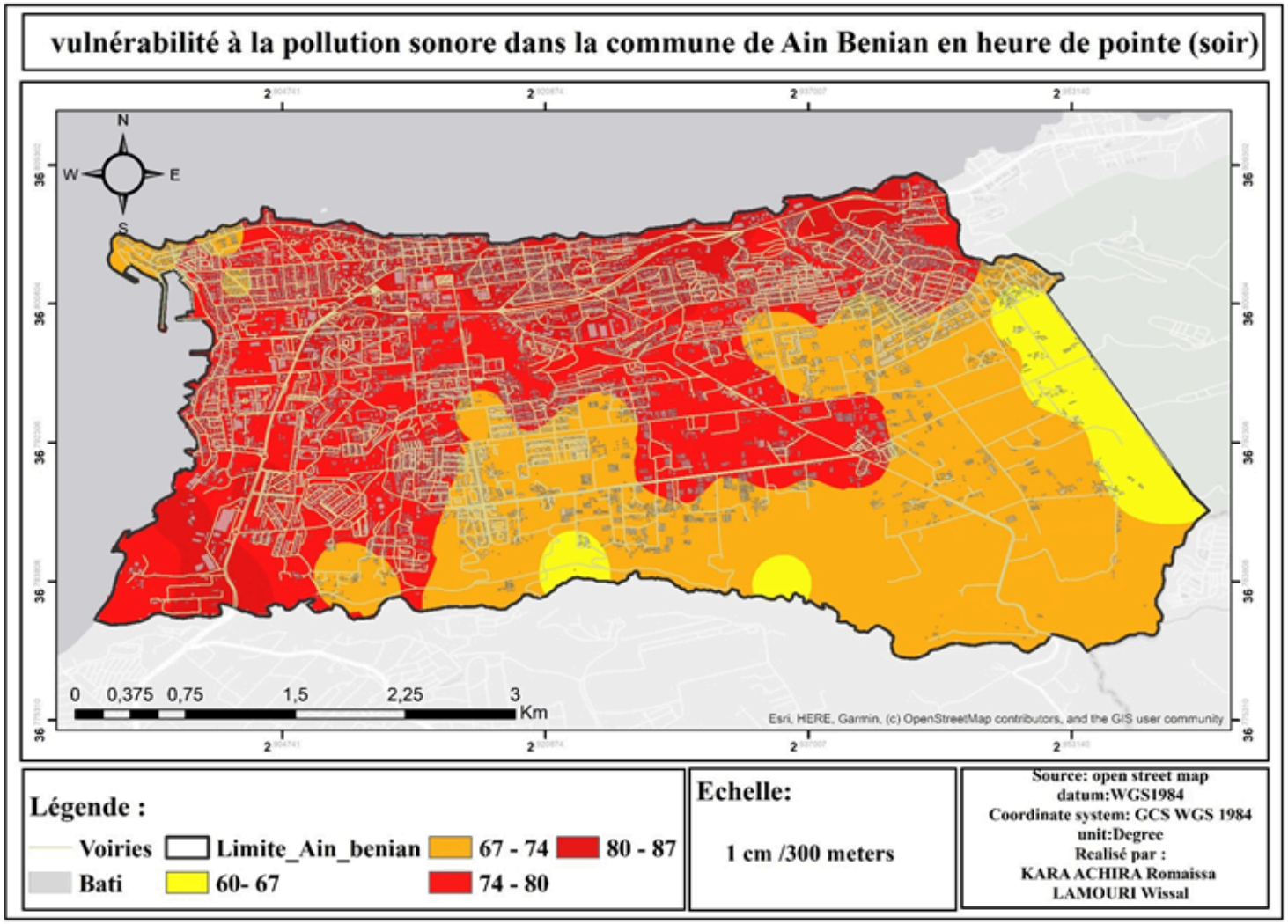


Figure 12

Fig. 11 *Summary noise map and spatial distribution of exposure zones in Ain Benian. Note: Map lines delineate study areas and do not necessarily depict accepted national boundaries.*

Supplementary Files

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- 2EMASFiguresSepare.docx