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Original Research

Investigating the Effects of Technical Parameters of Forest Road Planning and Building on Traffic Noise Reduction

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Abstract

This study was conducted to investigate the effect of longitudinal slope, type of surfacing layer, and forest stand status at the edge of the road on traffic noise reduction. Three types of vehicles, including a Land Rover, motorcar, and small truck were selected for this study. Noise intensity was recorded on eight measurement sites with distances of 0, 10, 20, 30, 40, 50, 75, and 100 meters from a forest road in an open area without trees, a pure stand of Alder, and a mixed stand. Results showed that the noise intensity of the Nissan was significantly more than that of Land Rover and Pride. Besides, traffic noise on the dirt road was more than that of the asphalt road. Vehicle noise intensity increased with increasing longitudinal slope of the road. The noise intensity produced by traffic in an open area was more than that in pure stands of Alder and mixed stands. Vehicle noise intensity decreased with increasing distances from the road.

Keywords: road, forest ecosystem, traffic noise, sound meter, Neka-Zalemrood

Introduction

Forest roads are manmade structures in natural habitat that are constructed for ecosystem conservation and management, recreation, and utilization of the timber and non timber forest products [1, 2]. It has been prove that the ecological consequences of a forest road increase with increasing road width, length, and traffic flow [3, 4]. On public roads, the direct consequence of vehicle traffic and noise pollution on wildlife habitat not only appears in the short term, but also may be caused in long-term [5, 6].

Nowadays, vehicles are quiter as compared to previous generation, but traffic flow has increased and this intensifies noise pollution [6, 7]. Indeed, traffic noise in transportation corridors is one of the most important environmental problems in the forest ecosystem [8]. The perception of noise depends on the sound frequency and level, the increment being situated between 10-135 dB and 2-19 kHz [9, 10].

Rabin et al. [11] reported that the anthropogenic noise can affect animal communication. It was proven that among the pure and mixed plantations of *Robinia pseudoacasia* and *Pinus eldarica*, mixed stands had the best effect on noise pollution reduction, which was 16.91 dB in 100 meters [2]. In another study, mammal surveys indicated there was an increase in species richness once traffic noise reached ambient levels (40 dB) and traffic light penetration ceased [12]. Nowadays, a road traffic noise prediction model has been developed based on local environmental standards, vehicle type, and traffic conditions in GIS. Application of this system has improved the efficiency and accuracy of traffic noise assessment and design [9].

Maps of tree volume per hectare and terrain features are vital data layers in route selection, because they may have

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a valuable role in traffic noise reduction [13, 14]. It was demonstrated that the high density of trees at the edge of roads as well as hard terrain can decrease the noise influence into forest interior [15]. In steep slope of roads and on dirt surface vehicles consume more energy in upward movement and consequently produce more noise [12]. Moreover, the amount of noise pollution is affected by geometry properties of road and surface type [16]. The aim of this paper was to measure traffic noise in an area of the Hyrcanian forests and to use this field-based data to evaluate the effects of road geometry properties and planning status on noise level reduction.

Materials and Methods

Study Area

The study area (Neka-Zalemrood forests) is located within the northern broadleaved forests of Iran (36º25′ to 36º29′N latitude and 53º25′ to 53º31′E longitude), in the south to southeast of Neka city, and covers 1,3511 ha (Fig. 1). Minimum altitude is about 350 m and the maximum is 1,430 m. The general aspect of the hillside is north and its average slope is 25%. The average temperature is from 28.4ºC in July to 0.4ºC in February. Mean annual air temperature is 15.3ºC. The region receives 1,110 mm of precipitation annually. Minimum and maximum rainfall is 64 to 201 mm, which occurred in August and February, respectively. The mean relative air humidity is 80%. The growing season lasts 240 days from April to November. The total length of forest roads in study area is about 11.5 km. The mixed forest stands in our study area was irregular uneven aged deciduous stands with mean density of 140 trees per hectare. This forest was under the management of a single tree selection cutting method. The main woody species in mixed stands are *Carpinus betulus*, *Parottia persica*, *Ulmus glabra* Huds, *Acer velutinum* Boiss, and *Alnus glutinosa* L. The density and diameter at breast height of Alder trees in our study area was 170 trees per hectare and 40 cm. The distribution and density of the pure stand of *Alnus subcordata* was clearly related to distance from the road.

Data Collection

Three types of vehicles, including a Land Rover, a Pride sedan, and a Nissan truck were selected for this study. The engine power of these vehicles is 71 hp (horse power), 63 hp, and 95 hp, and the number of cylinders is 4, 4, and 6, respectively. Indeed, we produced traffic by using the cars mentioned. The noise level was taken using a digital sound-level meter with accuracy ±1.5 dB and resolution 0.1 dB. The digital sound-level meter has been designed to meet the measurement requirements of safety engineers, health and industrial safety offices, and sound quality control in various environments. The longitudinal slopes of dirt and asphalt roads were measured using a clinometer and then classified into 2-5% and 5-8%. In this research, the noise intensity was recorded concurrently in 3 replications on eight transects with distances of 0, 10, 20, 30, 40, 50, 75, and 100 m from forest road in open areas without trees, pure stands of Alder, and mixed stands. At every stand the diameter at breast height, height, and volume of trees were measured in 1,000 m^2 plots using selective systematic statistical method. The heights of the noise meter and noise source were the same (Fig. 2).

Statistical Analysis

The SAS package was used to perform all statistical analyses. Significant differences among treatment means were tested using analysis of variance (ANOVA). Wherever treatment effects were significant, Duncan's Multiple Range Test was carried out to compare the means. The values found for the sound levels in dB under traffic were compared statistically at 0.05 significance levels. In addition, the diagrams were designed in Excel software.

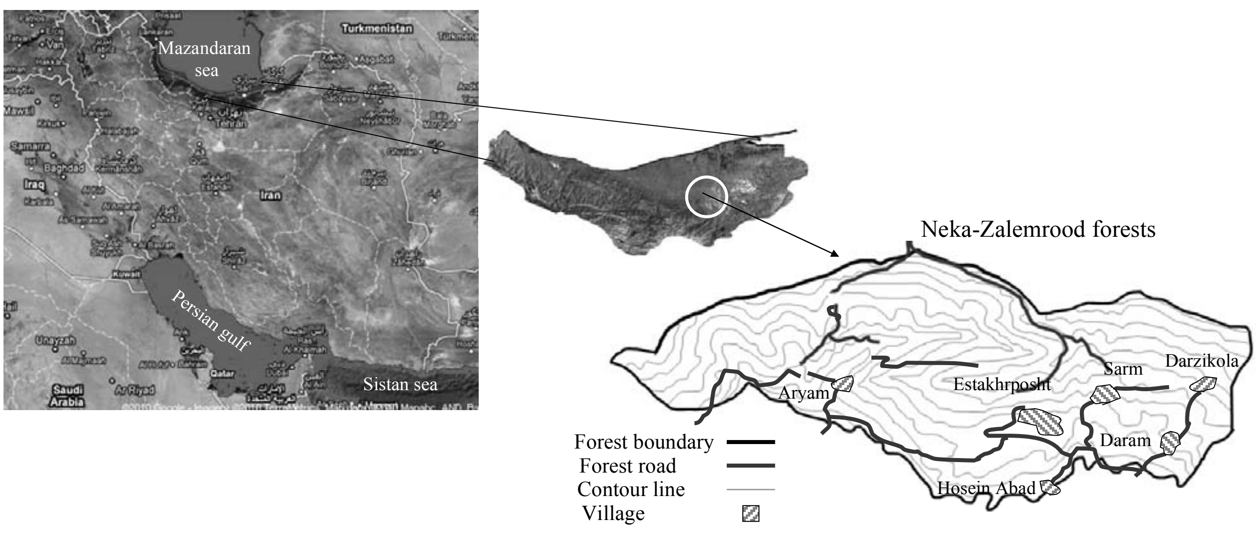

Fig. 1. The geographical position of the study area.

Table 1. ANOVA for the effect of independent variables and their interactions on noise levels produced from studied vehicles on a forest road.

Sources	DF	SS	MS	F
Vehicle type	2	6993.488	3496.744	397.29***
Road surface type	1	378.685	378.685	43.03***
Longitudinal slope of road	1	682.667	682.667	77.56***
Forest stand status	2	3840.461	1920.230	218.17***
Distances to road	7	132069.255	18867.036	143.63***
Vehicle type × surface type	2	16.294	8.147	0.93^{ns}
Surface type × Longitudinal slope	1	6.338	6.338	0.72^{ns}
Forest stand status × Distances to road	14	1670.502	119.322	13.56***
Vehicle type × Longitudinal slope	2	29.312	14.656	1.67^{ns}

SS – sum of squares, MS – mean square, ***significant in probability level of 0.1%; ns – not significant

Results and Discussion

It was found that the surface type, vehicle type, stand status, longitudinal slope, and the distances from the road had significant effects on noise level produced from the traffic on forest roads (P<0.001). A presentation of the analysis of variance is given in Table 1. Moreover, the interaction effects of forest stand status and distances to road on noise level was significant at probability level of 0.1% (Table 1). Results of this study indicated that vehicle noise intensity decreased with increasing distances from the road (Fig. 3). Noise reduction by biological and physical barriers were measured and compared to that of the control by Fathi Najafabadi et al. [17]. These barriers consisted of broad leaf cover, evergreen cover, plain wall, porous wall, and fences with vegetation cover. The control site was an open area. The results of the study showed that the plain wall was the most effective and the porous wall was the least effective barrier against noise pollution.

The noise intensity produced by traffic in an open area was more than that in pure stands of Alder and mixed stands (Fig. 4). The effects of noise are seldom catastrophic, and are often only transitory, but adverse effects can be cumulative with prolonged or repeated exposure [18]. Al-Mutairi et al. [19] in a small country along the Persian Gulf, found that on local/collector streets, noise ranged between 56.0 to 79.2 dBA and 55.3 to 76.4 dBA; on arterial streets, 62.3 to 89.2 dBA and 59.6 to 78.9 dBA; and on

Fig. 2. The vehicles, pure stand of Alder, mixed stand, and open area in research site.

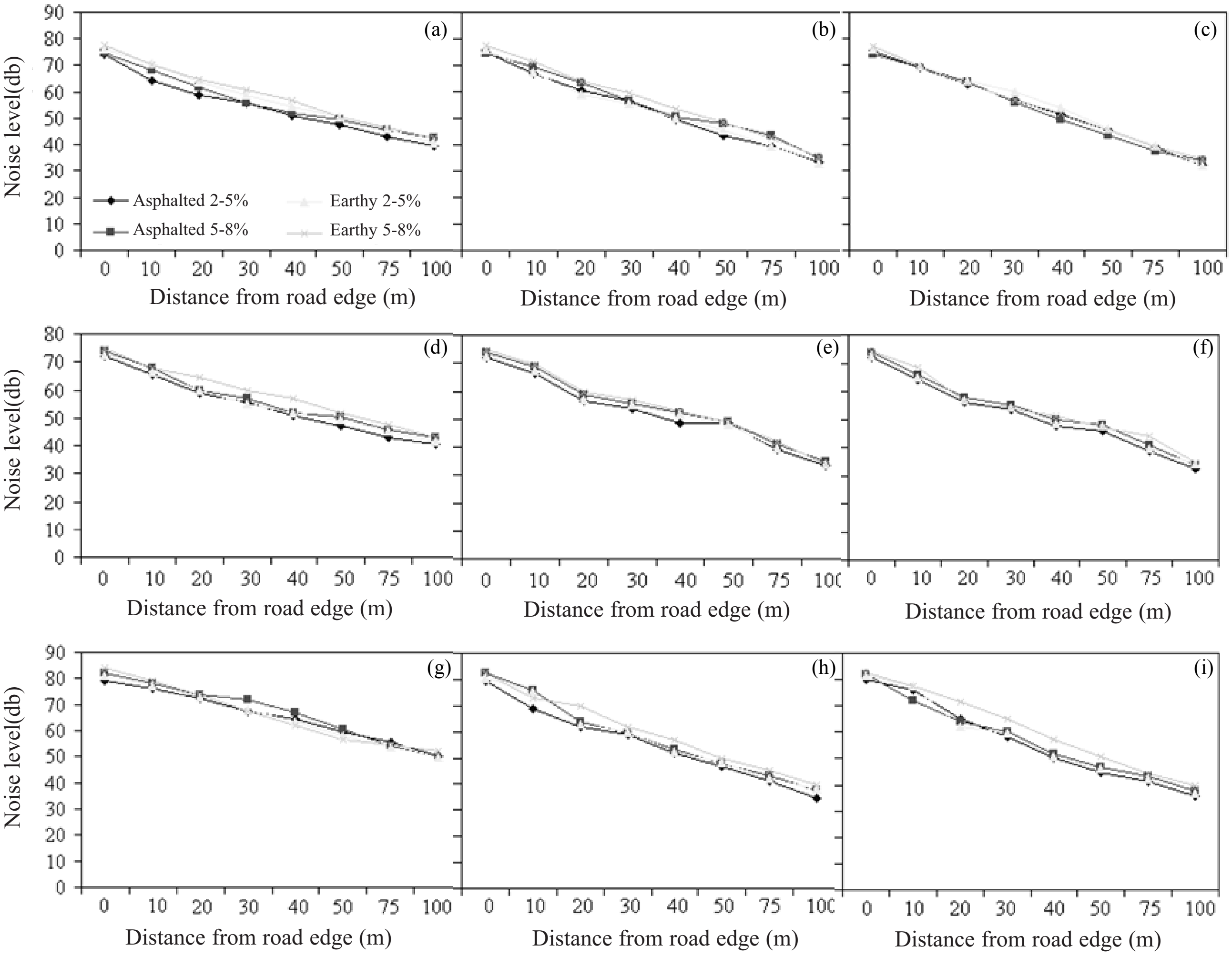

Fig. 3. Effects of distance on sound pressure levels in treatment: (a) Land Rover in an open area, (b) Land Rover in a stand of pure alder, (c) Land Rover in mixed stand, (d) Pride in an open area, (e) Pride in a stand of pure alder, (f) Pride in a mixed stand, (g) Nissan in an open area, (h) Nissan in a stand of pure alder, (i) Nissan in a mixed stand

freeways, 66.7 to 94.8 dBA and 64.9 to 89.1 dBA during peak and off-peak hours, respectively. Rheindt [20] found a relationship between dominant frequency and decline in abundance toward the motorway, which indicates that having a higher-pitched song with frequencies well above those of traffic noise makes a bird less susceptible to noise pollution.

Results showed that the noise intensity of the Nissan was significantly more than that of the Land Rover and Pride (Fig. 5). Besides, traffic noise on the dirt road was more than that of the asphalt road (Fig. 6). Vehicle noise intensity increased with increasing of longitudinal slope of the road (Fig. 7). Vehicles in steep roads produce more noise pollution. Hence, this factor should be considered when a road is designed [21]. Mehravaran et al. [22] reported that reducing speeds to half decreases road noise levels up to 6 dB.

The use of natural vegetation as a noise barrier is a choice to be considered due to easy maintenance and economical contributions [6]. The effects of noise pollution are various and mostly depend on noise intensity, frequency, and period of time in manifests [23]. Faunal crossings at motorways are subject to high noise levels, but their frequency of use is not affected in any consistent way by the range of noise levels encountered in the Iglesias et al. [24] study.

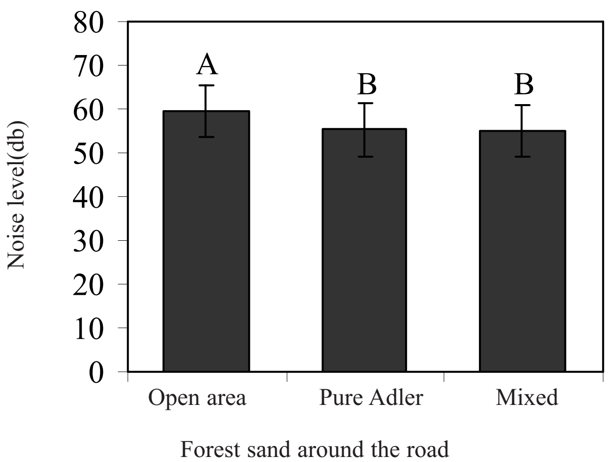

Fig. 4. Effects of vegetation type on sound pressure levels in 0-100 m of the road.

Conclusions

Longitudinal slope of road, surface types, and vegetation type at the edge of the road and vehicle conditions offer unique challenges in applying many of the road traffic noise measurement methods. We concluded that the noise intensity of Nissan was more than that of Land Rover and Pride.

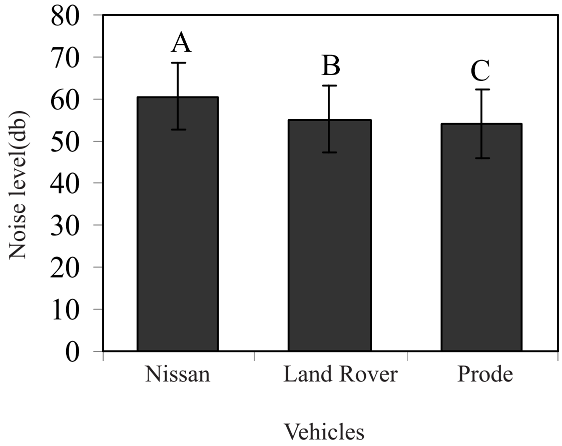

Fig. 5. Effects of vehicle type on sound pressure levels 0-100 m from the road.

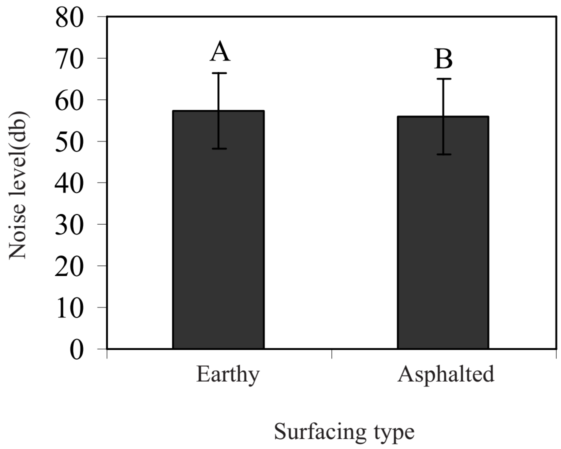

Fig. 6. Effects of surface type on sound pressure levels 0-100 m from the road.

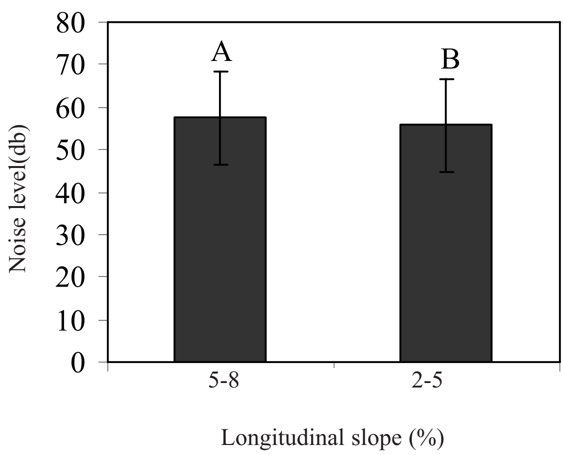

Fig. 7. Effects of longitudinal slope on sound pressure levels 0-100 m from the road.

Besides, traffic noise on a dirt road was more than that of the asphalt road. Vehicle noise intensity increased with increasing longitudinal slope of the road. Vegetation can decrease satisfactorily the intensity of traffic noise. Vehicle noise intensity decreased with increasing distances from the road.

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