Aircraft Noise Assessment in a Mixed Urban–Residential Hamlet and the Possible Role of Tree Cover in Noise Abatement in Pajac, Lapu-Lapu City, Philippines

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ABSTRACT

Pollution is a big issue in the Philippines. However, the country has not focused its attention towards noise pollution. This study assessed the noise intensity of a hamlet located very near the airport, where aircraft takeoffs and landings occur daily. It compares the noise intensity (in decibels) between areas with tree cover and those without. The noise intensity data were derived from recording using a mobile application, Sound Meter Pro (by Mobile Essentials), installed in two Android phones, LG G3 and Asus Zenfone Max. To avoid any bias, both phones were calibrated against a laboratory sound meter before and after field samplings and against each other, since the phones were switched between two sublocations (i.e., with tree and without tree cover). Our results showed a significant difference between sound intensities recorded in areas with (mean ± S.D.: 83.94 ± 5.51, n = 10) and without tree cover (88.14 ± 6.76, n = 10). This suggests that tree cover does reduce the amount of noise generated from aircrafts in the vicinity.

Keywords: Noise pollution, noise intensity, Mactan Cebu International Airport, tree planting

INTRODUCTION

Airport expansion is an issue of intense public debate among environmental groups and affected local residents regardless of whether airport development is located in developed or in developing economies (Griggs & Howarth, 2013). The increasing demand for air travel and trade links for both international and national markets has paved the way for the establishment of more airport facilities and procurement of new aircrafts. This increasing demand, if unchecked, could lead to increasing impacts to humans and environments whether psychosocial, ecological, or physical.

Among the many disturbances impacting urban residents living near airports is environmental noise. Environmental noise is typically composed of different sources coming specifically from external and audible ones such as traffic noise, industrial facilities, construction activities, and social interventions (i.e., parties, occasions, and noise coming from residential areas).

All of these add to the cumulative problem of noise pollution. The World Health Organization in the year 1972 categorized noise as a type of pollutant (de Paiva Vianna et al., 2015). There is therefore a need to improve the quality of urban soundscapes because of the negative effects caused by noise pollution to human health (Schafer, 1977). While this is done in developed countries such as Canada, it remains to be an emergent study here in the Philippines, a developing economy where urban planning and environmental protection are limited. A study done in NAIA (Ninoy Aquino International Airport; Abaya, 2007) showed that surveyed individuals experienced different degrees of noise annoyance near the airport.

The effects of noise exposure depend upon the characteristics (i.e., frequency, intensity, and exposure time) of the noise (De Paiva Vianna et al., 2015). Around airports, aircraft noise is the main cause of noise complaints. Several studies (Schreckenberg et al., 2010a; Holt et al., 2015) describe the effect of noise coming from aircrafts on people living near the airport showing the association between annoyance and noise exposure levels. Yet the apparent annoyance itself has been found to be affected by other factors, which include background noise, frequency of flights, time of day, and noise sensitivity (van Kempen et al., 2006).

A study conducted in the locality of Frankfurt Airport revealed that among the surveyed sample in the airport, 64% of them were exposed to a mild to risky type of annoyance and considered aircraft noise as the greatest contributor of sound unpleasantness (Schreckenberg et al., 2010b). The higher the recorded aircraft noise level, the higher was the annoyance. However, the annoyance effect could vary with culture, societies, and economies.

The relationship of vegetation and sound propagation has been the focus of much consideration for a couple of years, and the common idea among acoustic specialists is to propose that trees including shrubberies are not effective for noise abatement (Watts et al., 1999). However, evidences indicated that it is not at all time true, and substantial noise decrease may be realized through the use of vegetation if all considerations are met. In areas of heavy vegetation, low-frequency proliferation however is primarily influenced by ground effect where increased reduction is expected (Albert, 2005). A belt of evergreen trees showed a strong attenuation of traffic noise (Fang & Ling, 2005). More recently, calculations were made indicating that planting of tree belts along the road could significantly reduce traffic noise in optimized conditions wherein tree densities are high enough. According to calculations done by Van Renterghem and Botteldoreen (2012), a tree belt planted 15 m deep with 2.5 stem height, planted at an average of 1-m spacing, with a diameter of 0.11 m, was found to be correspondent to a standard noise barricade with a height of 1.5 m.

Sound barriers made out of vegetation with suitable technical characteristics and high surface density would be deemed a better solution in terms of mitigating noise (Monazzam et al.,2014). Trees, bushes, and shrubs have lessened the noise generated in urban areas chiefly in big cities. Undoubtedly, noise levels can be reduced through vegetation as long as there is ample depth and density. Criteria such as the type of plant species, the height of the plant, the distance of plant growth, climatic factors (i.e., wind, temperature and humidity), and the type of sound source and its intensity (in decibels) are very crucial because noise reduction is contingent on these aforementioned factors(Pudjowati et al., 2013). It has also been mentioned that plants having thick leaves and containing a lot of petioles are perfect for sound absorption, thus providing a high point of elasticity and pulsation for this type of arrangement (Grey & Deneke, 1986).

In the Philippines, information about sound and sound absorption capacity of vegetation has not been disseminated locally due to other pressing issues such as unemployment, poverty, governance, corruption, and drug problems. There are very limited published studies pertaining to noise pollution and its effects on humans, plants, and other organisms. Nevertheless, noise pollution continues to be a problem, especially in very dense urbanized areas very proximal to domestic and international airports. One such locality is a hamlet (barangay, in vernacular) very near the Mactan Cebu International Airport (MCIA) in Mactan Island, Central Philippines. In an attempt to set in motion the emerging field of soundscape ecology, a study was conducted to measure the noise intensity of Barangay Pajac, a mixed urban–residential hamlet located very near MCIA where aircraft noise is felt by the local residents daily.

MATERIALS AND METHODS

The difference in noise recordings between areas with tree cover and areas without tree cover was examined in a hamlet across MCIA. Noise intensity was recorded in terms of decibels. Tree cover values were obtained using Google Earth Pro. Identification of the trees and their attributes such as height and dbh (diameter at breast height) were also taken.

Description of the Study Site

Barangay Pajac (10.2985° N, 123.9889° E) is one of the barangays located near MCIA. It is adjacent to the airport's runway that receives all the departing and arriving flights. The barangay has an area of 276 hectares and has 16,084 residents according to the 2010 Census of Population and Housing (NSO Office, 2012).

A cursory preliminary inspection/tour of Barangay Pajac was done sometime in November 2015. Finally, 10 recording stations were identified with their corresponding coordinates (Fig. 1). For each recording station, paired locations (i.e., area with tree canopy cover and open space) with an interval of 5 m were selected, one as a reference point (open space) to measure the unobstructed noise level (with no tree cover to filter the noise as the aircraft passes) and the other as the test point underneath the tree canopy. The smartphones were positioned at the researcher's breast height during recording procedures.

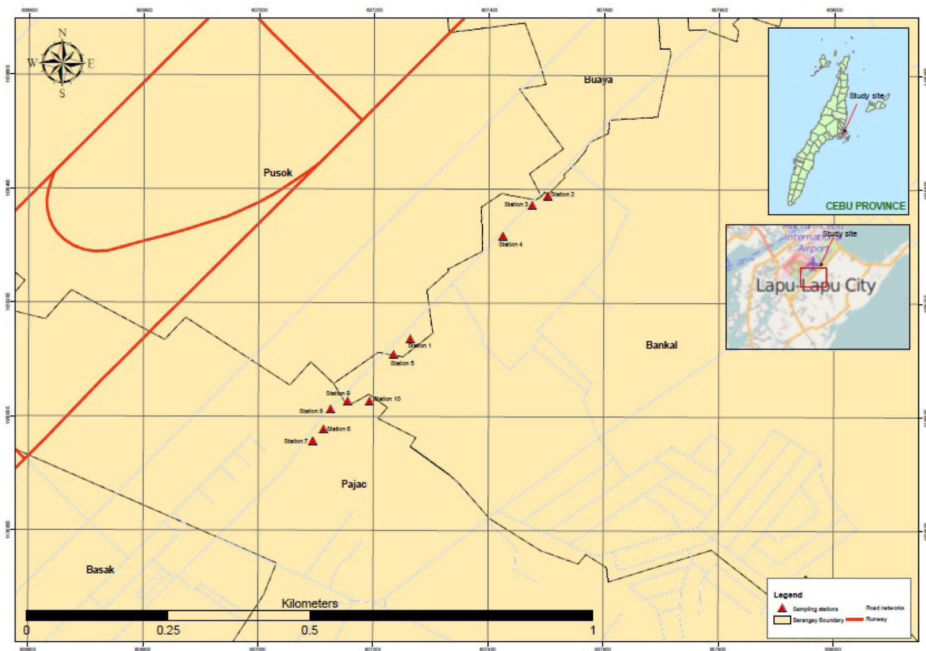

Figure 1. Map of Barangay Pajac, Lapulapu City, Mactan Island, Central Philippines.

Determining Tree Cover and Other Attributes

Measuring vegetation cover in terms of tree canopy area was done using Google Earth Pro. In a study (Jiang et al., 2015), Google Earth aerial photographs were used to obtain measures of tree cover density and boundary of the study area, demonstrating that Google Earth aerial photographs can predict landscape preference. The polygon tool was used to measure the area of the tree canopy where the sound intensity measurements took place. The perimeter and the area of the canopy were expressed in meters and square meters, respectively.

As a corollary, measuring the tree's diameter at breast height (dbh) was also done using a measuring tape 1.4 m above the ground. The measuring tape was wrapped around the trunk of the tree straight and tight. The measured length of the tape was considered the value of the circumference. The obtained measurements of the circumference were expressed in centimeters. The heights of the trees were measured using a Hilti PD-E laser range meter. Height measurements were recorded in meters.

Sound Intensity Measurements

For this study, two smartphones (brands and models: LG G3 and Asus Zenfone Max, both running on Android ver. 5.0) were installed with the application Sound Meter Pro (Ver. 2.5.1 by Mobile Essentials). A digital and portable sound meter (CEM DT-8820, Environmental Meter) was used to calibrate the sound application of the two phones. To avoid any bias from using phones with different brands, a calibration procedure was done by simply placing the phones side by side with the laboratory sound meter, recording and comparing their values. Calibration of the sound meter application was also done before and after the field sampling.

Noise recordings commenced few days after identification of recording stations. The recording stations were repeatedly visited to collect as many sound recordings (from each paired location) as possible. Samplings were done for two (2) months, every day from 11PM–3AM to gather as much data as possible. In doing sampling during the night, daytime background noise (i.e., 50–60 dB) from vehicles and other occupational noises were eradicated. The sample size was 50 recordings per station.

Figure 2 shows two graphs of noise intensity (dB) with time. The graph showed the noise intensity before and after the plane has passed. For this study, values were obtained from the peak of both recordings, when the plane was overhead, for both areas (i.e., with and without tree canopy cover). The peak values were then compared if there was a significant difference. To avoid sound recording bias, the repetitive swapping of smartphones alternately (i.e., with and without tree canopy cover) from each recording station during each sampling was done. Sampling time was deemed over after the plane has completely passed the area. The sampling areas were also situated in a quiet nonpopulous community, so during sampling, there were no other anthropogenic disturbances that could affect the sound measurements.

The meteorological conditions and the weather forecast information were requested from PAGASA ahead of the sampling schedule to ensure that noise data were not affected by any climatic events. Thus, the weather conditions during samplings were fair all throughout for all stations.

Statistical Analysis

To test whether the sound intensity collected by both phones was comparable to a laboratory sound meter, a *t*-test for dependent samples was used. To test whether there was no difference between the Asus Zenfone Max and the LG G3, a *t*-test for dependent samples assuming equal variances was used.

To test whether there was no difference between the pre–field and the post–field operating condition of the smartphones, a t-test for independent samples assuming equal variance was used. In this case, the difference (Δ) between the sound intensity of the phone and the sound meter was used in the statistical comparison.

In case the smartphones were not attuned with the laboratory sound meter, a calibration factor was introduced to make them comparable with each other. Since it was found out that the readings from the laboratory sound meter were statistically different from the two phones, a calibration factor was calculated by taking the ratio of the means of the calibration readings made with the sound meter to the corresponding readings of the two smartphones (LG G3 and ASUS Zenfone Max). A calibration factor of 1.11 was applied to all sound intensity data collected

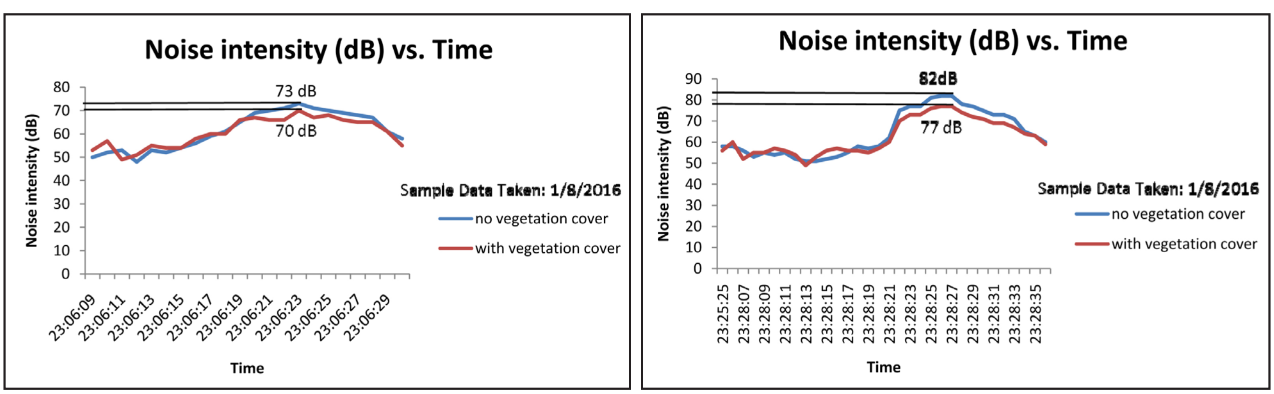

Figure 2. Samples of two sound recordings from a recording station (10º 18.310’ N, 123º 58.864’ E).

Table 1. Statistical Results of Two Sample Comparisons of Various Calibration Procedures of Sound Intensity Measurements

Comparison	*N*	*t*-Value	*p*-Value
LG G3 vs. sound meter	6	4.81	0.01*
ASUS Zenfone Max vs. soundmeter	6	7.17	0.00*
LG G3 prefield vs. postfield (using Δ)	6	–0.68	0.51
ASUS Zenfone Max prefield vs. postfield (using Δ)	6	–0.61	0.56
LG G3 vs. Asus Zenfone Max	6	–0.26	0.80

*Significant at $p = 0.05$.

using the smartphones. The value rectified the sound readings in the smartphones to be comparable with the laboratory sound meter. The calibration factor was applied before determining the statistical difference between the two sublocations (i.e., areas with and without tree cover) (Table 1).

The peak sound intensity data at points with tree and without tree cover for each recording station were averaged for each sampling visit. To test whether there was a significant difference between the peak sound intensity readings in tree versus without tree cover, a *t*-test for dependent (paired) samples assuming equal variances was used. The significance level for all statistical tests was set to 95% ($p = 0.05$).

RESULTS AND DISCUSSION

Tree Cover

The vegetation was characterized by the presence of both invasive and native tree species. The trees were located per recording station; no overlapping of other tree species was observed, since there was only one tree species per recording station. Trees identified per site with the corresponding value for its covered area were shown in Table 2. The dominant trees were *Leucaena leucocephala*(ipil-ipil) and *Muntingia calabura* (manzanitas), which accounted for a third of the whole sampling stations. The canopy covers as estimated using Google Earth Pro ranged from 14 to 42 m^2. The highest cover of 41.7 m^2 was in Station 3, while the lowest cover, 13.9 m^2, was in Station 1. The highest tree height was 14.32 m in Station 4, while the lowest tree height was 2.87 m located in Station 6. The largest dbh was 450 cm in Station 3, and the smallest dbh was 79 cm located in Station 7. According to Pudjowati et al. (2013), factors such as plant height, plant species, and its corresponding leaves, branches and twigs play a big role in reducing levels of noise. This was evident in Station 3 as shown by the biggest difference (6.5dB) of recorded noise level, between an area with tree cover and an area without tree cover. The tree (*Ficus religiosa*) on Station 3 also had the biggest height. According to Huddart (1990), noise level could be greatly reduced with heavy vegetation; however, in this case, it was just one tree providing the canopy cover, which strongly suggests that if done properly with more trees planted, levels of sound will greatly decrease.

Peak Sound Intensity

Overall, the vegetation in the area was patched and very sparse. For every recording station,

Table 2. Sites and Their Vegetation, Corresponding Canopy Cover, and Tree Attributes

Station	Tree Species	Canopy Cover Area (m^2)	Tree Height (m)	dbh (cm)
1	*Leucaena leucocephala*	13.9	6.94	84
2	*Leucaenal eucocephala*	32.4	5.78	143
3	*Ficus religiosa*	41.7	12.5	245
4	*Swietenia macrophylla*	35.3	14.32	214
5	*Cocus nucifera*	26.3	2.87	97,118*
6	*Leucaena leucocephala*	15.6	8.43	124
7	*Muntingia calabura*	23.9	4.17	79
8	*Terminalia catappa*	28.6	12.61	102
9	*Muntingia calabura*	30.2	5.28	63,60**
10	*Muntingia calabura*	20.5	4.46	85

*Two trees standing side by side.
**Multitrunked tree.

a solitary tree canopy cover was present. A pattern was observed all throughout the sampling stations, showing that these solitary trees can abate noise. Although Stations 1 and 10 showed little noise abatement compared to the rest of the trees, they were still significant.

The mean peak sound intensity was consistently higher in the areas without tree cover than with tree cover. All stations showed significant difference between sublocations (i.e., tree cover and without tree cover). The highest peak sound intensity was at Station 9 for both with cover (87.4 ± 5.4) and without cover (92.1 ± 5.0). The lowest peak sound intensity was at Station 1 for both with cover (80.7 ± 4.3) and without cover (82.6 ± 5.8). The *p*-values for

Table 3. The Mean and Standard Deviation of Peak Sound Intensity (dB) in the 10 Recording Stations

Station	With Cover	Without Cover	*N*	*p*-Value
1	80.7 ± 4.3	82.6 ± 5.8	50	0.03*
2	81.5 ± 8.8	86.7 ± 9.2	50	0.00*
3	84.6 ± 5.3	91.1 ± 5.2	50	0.00*
4	84.4 ± 5.2	90.3 ± 8.6	50	0.00*
5	84.0 ± 5.2	87.7 ± 5.9	50	0.00*
6	82.6 ± 4.5	85.3 ± 7.7	50	0.00*
7	86.2 ± 5.0	89.8 ± 7.5	50	0.00*
8	86.3 ± 4.2	90.9 ± 4.2	50	0.00*
9	87.4 ± 5.4	92.1 ± 5.0	50	0.00*
10	81.7 ± 7.2	84.9 ± 6.1	50	0.01*

*Significant at $p = 0.05$.

Stations 1–10 showed significant difference with *p*-values ranging from 0.00 to 0.03 (Table 3).

The U.S. EPA has recognized 75-dB sound exposures for an 8-h period and 70-dB for a 24-h exposure as the standard average noise level to protect 96% of the population from acquiring a greater-than-5-dB permanent threshold shift (PTS; United States Environmental Protection Agency, 2015). Hearing loss is normally taken as the shifting of a higher sound level of the ear's sensitivity or acuity to perceive sound. These changes can be temporary, which is often called as temporary threshold shift (TTS), or even permanent, called a PTS (Berger, 1985). The results showed that the dB values for the two sublocations surpassed the EPA limit of sound exposure, greatly posing a risk in the surrounding neighborhood located near the airport runaway.

Effects of noise on performances, activities or tasks have also been a subject of many studies, and links that connect between continuous high noise levels and performance loss have been recognized. Studies showed that noise levels in excess of 85 dB have been correlated with noise-induced performance loss. The obtained peak value of 82.56 dB (without tree canopy) is close enough to the dreaded effects that noise annoyance may bring to local residents living near MCIA. The National Academy of Sciences Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) also identified 75 dB as the minimum level at which hearing loss may start to manifest (Pfander et al., 1980). In the case of Barangay Pajac, which is near the airport vicinity, residents living near these areas are subjected to constant exposure to noise all throughout the day, which may lead them to experience a mild to risky type of annoyances, considering aircraft noise is the greatest contributor of sound unpleasantness (Schreckenberg et al., 2010a). The World Health Organization in 2011 recently estimated that due to exposure of environmental noise (i.e., road traffic noise and aircraft noise) 1–1.6 million healthy life years are being taken away in high-income western European countries. Also long-term exposure to aircraft noise is known to pose negative health influences especially at exceeding levels (Basner et al., 2014).

The risk of having cardiovascular diseases such as heart attack, high blood pressure (hypertension), and stroke increased by 7% to 17% for a measured 10-dB increase in road traffic or aircraft noise exposure has been reviewed recently. It could be that the people in Barangay Pajac are at risk since they are exposed to both road and aircraft noise at the same time. In a study, exposure to aircraft noise of more than 50 dB was associated with a significant 20% increase in the chance of developing hypertension.

In areas of sleep disturbance, reviews also concluded an effect on night-time aircraft noise exposure in sleep patterns of people living in communities in which night-time aircraft noise ranging from 45–65 dB was associated with greater self-reported sleep disturbance than road traffic noise (Hume et al., 2012; Miedema & Vos, 1998). A follow-up study of this nature can be done in Barangay Pajac in the future.

Huddart (1990) found that greater noise reduction was achieved with vegetation, which also corroborated with our results suggesting that the presence of the vegetation cover can reduce noise intensity in the area. Trees reaching as high as 14.32 m and as low as 2.87 m supported a more or less 10-dB reduction from that of the nonvegetated areas. According to Windows et al.(2014), trees and shrubs that are effective for sound mitigation are those which have dense evergreen foliage and branches that extend to the ground with thick and waxy leaves. An example of a tree having waxy leaves is *Terminalia catappa* or *talisay* in the local dialect.

The benefit of considering the effects of trees in attenuating of aircraft noise can be significant to the residents of the nearby area. The results provided a positive prospect to plant more trees with considerable canopy cover in order to reduce aircraft noise in Barangay Pajac and other adjacent barangays (i.e., Basak and Bankal). The noise reduction capacity of trees with wide canopy cover provide additional benefits aside from the traditional uses of trees as shade, aesthetic values, its cultural value in the community, and its ecological importance to other organisms. Depending on the soil quality of the nonvegetated area of Barangay Pajac, there should be a preference for the planting of indigenous trees such asagoho (*Casuarina equisetifolia*) and molave (*Vitexparviflora*). Other species worth planting are smooth narra (*Pterocarpusindicus spp*.) and Manila palm (*Adonidiamerrilii*), which are considered to be vulnerable and near threatened,the plant species being listed under DENR DAO 2007-01 or the "National List of Philippine Plants." It is also noteworthy that these two species are included in the IUCN (2015) with their status being vulnerable and near threatened species. This idea not only helps in the mitigation of noise intensity in the area but also helps in the conservation of threatened or nearly extinct species of indigenous trees. By planting more trees, the impact of an urban heat island can also be minimized.

CONCLUSION

This study confirmed that tree cover can reduce noise based on the data that had been gathered. The sound meter application after calibration can be used to determine the level of aircraft noise intensity in the Barangay Pajac. The corresponding tree cover of each recording station was successfully assessed using Google Earth Pro. The comparison of noise intensity between areas with dense tree cover and areas without tree cover showed significant difference. Therefore, planting more trees with a dense canopy cover is suggested especially in places like Barangay Pajac, where residents are directly affected.

The study was limited to the effects of tree cover in aircraft noise attenuation, with paired samples (i.e., an area with tree canopy cover and open space). A separate study should be conducted on the attenuation of noise due to the type of building materials (i.e., wood, cement, metal sheets).It is also recommended that noise measurements be taken inside building structures and houses near MCIA and compared with the current measurements.

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