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Research Article

Spatial Noise Modeling in a Dairy Farm

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Abstract

A prototype sound monitoring and evaluation system was used to measure the noise level in a medium-sized dairy farm. In addition, the distribution of noise from the barn was also modeled in order to determine how much the barn, where only the animals, mechanical tools and working workers in the barn were the sound source, affect the neighboring farms in terms of sound intensity. Considering that the intensity of the sound fluctuates based on the activities during the day, the equal noise level (L_{eq}), which is a cumulative indicator, was used. The data recorded by 7 sensors placed inside the barn. The results were modeled for day and night conditions in CadnaA software, and the distribution of Leq values both inside and outside the barn was modeled numerically and visually. Since all sound sources were inside the barn, the sensors only recorded the inside conditions. As a result of the modeling study, L_{eq} levels in the barn were determined by averaging the values of 7 sensors. Accordingly, the L_{eq} values for day and night in the barn were calculated as 69.0 and 64.2 dB, respectively. It was determined that these values were considerably lower than the maximum allowable values for dairy cattle. In addition, the spatial distribution modeling of the sound emitted from this farm has shown that it is at levels that do not cause disturbance for the neighboring farms.

Key words: Dairy housing, noise monitoring, environmental quality, equivalent noise level

Bir Süt Sığırı İşletmesinde Mekansal Gürültü Modellemesi

Özet

Bir prototip ses izleme ve değerlendirme sistemi orta ölçekli bir süt sığırı ahırındaki gürültü seviyesini ölçmek için kullanıldı. Ayrıca ses kaynağı olarak sadece barınaktaki hayvanlar, mekanik aletler ve çalışan işçilerin söz konusu olduğu ortya konmuştur. Bu durumun ahırın komşu işletmeleri ses şiddeti anlamında ne derece etkilediğini belirlemek için gürültünün barınaktan yayılma durumu da modellenmiştir. Sesin şiddetinin gün içindeki aktivitelere göre dalgalanmalar gösterdiği dikkate alınarak kümülatif bir gösterge olan eşit gürültü seviyesi (L_{eq}) kullanıldı. Barınak içine yerleştirilmiş 7 adet sensörün kaydettiği veriler CadnaA yazılımında gündüz ve gece koşulları için ayrı ayrı modellenerek hem barınak içinde hem de barınak dışında L_{eq} değerlerinin dağılımı sayısal ve görsel olarak modellendi. Bütün ses kaynakları barınak içinde olduğu için sesnsörler sadece barınak içindeki sesleri kaydetmişlerdir. Yapılan modelleme çalışması sonucunda barınak içindeki L_{eq} seviyeleri 7 sensörün değerlerinin ortalaması alınarak belirlendi. Buna göre barınak içinde gündüz ve gece için Leq değerleri sırasıyla 69.0 ve 64.2 dB olarak hesaplandı. Söz konusu bu değerlerin süt sığırları için müsaade edilebilir maksimum değerlerden oldukça düşük olduğu belirlendi. Ayrıca, bu işletmeden yayılan sesin mekânsal dağılım modellemesi, komşu işletmeler için de rahatsızlık oluşturmayacak seviyelerde olduğunu göstermiştir.

Anahtar Kelimeler: Ahır, gürültü izleme, çevresel kalite, eşdeğer gürültü seviyesi

Introduction

There has been a great deal of study in detecting effects of environmental stress factors that may cause serious problems on livestock animals. If these effects are not detected correctly and in a timely manner, overall performance of the operation may be affected. Noise pollution, which is one of the environmental stress factors, negatively affects health of both workers and other livstock (Girgin and Kılıç, 2020). Noise is defined as unwanted sounds emitted from a source in our environment (Slabbekoorn , 2019). Sounds emitted by many sources such as highways, railways, construction machinery in different decibels mix and create noise (Goines and Hagler, 2007).

The monitoring of animal behavior also has an important role in determining the conditions that cause stress on the animal. It is known that adverse environmental conditions affect animal health and productivity. For this reason, in dairy cattle breeding, practices that will minimize the stress on the animal have gained priority and studies on animal behavior have been guiding (Bilgili, 2009).

Studies reported that livestock animals show different reactions against noise such as startle, freeze or move away from the sound source when sound intensities exceed 90 decibel (dB). It is also reported that farm animals are comfortable below 90 db (Bond et al., 1963; Ames and Arehart, 1972; Espmark et al., 1974; Ames, 1978). Even though the allowable sound intensity within the barn is reported to be 85 dB, it may be as high as 106.8 dB. Background noise level of 72 dB is reported caused by animal and/or labor activities within the barn (Anonymous, 2006).

With the development of technology, problems related to sound can be evaluated more realistically by using noise maps and three-dimensional models. In this way, it has now become possible to predict noise pollution by assessing different scenarios (Harris et al., 2000; Probst and Huber, 2000; Bayraktar and Mutlu, 2021). In noise mapping noise is distributed numerically over a map that allows visual demonstration depending on the noise sources (Probst and Huber, 2003).

In this study, it is aimed to use a software program to visualize the spatial sound distribution both inside and outside of a small-scale dairy farm.

Material and Method

Experimental barn and sensor setup

The prototype device was developed in the Digital Agricultural Laboratory in Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Agricultural Structures and Irrigation. The design and calibration procedure of the sound monitoring system is given by Kızıl et al. (2022). The prototype device employs 7 microphones collecting sound data and sending intensities to a web-based database for further analysis using the sound modelling software. The device uses a GSM module to communicate with the database. The database system was selected based on the bandwidth requirements and easiness of data transmission as far as the data format is concerned. Therefore, PHP open source data management system associated with MySQL was used.

The sound recording device was installed in the 80-head Simmental dairy barn located in Çanakkale Province, Biga District, Çınarköprü Village, Turkey (Figure 1). The study was carried out in 2021 and 8-month sound data was recorded. Since there was no major activities (heavy traffic, factory, school, etc.) around the farm, animals and labor activities within the barn were considered to be the only sound source in the study.

Data recorded from 06:00 to 18:00 was considered as daytime data, and data from 18:00 to 24:00 was considered as night data. Since there was almost no activity between 24:00 and 06:00 data obtained during this time was not considered.

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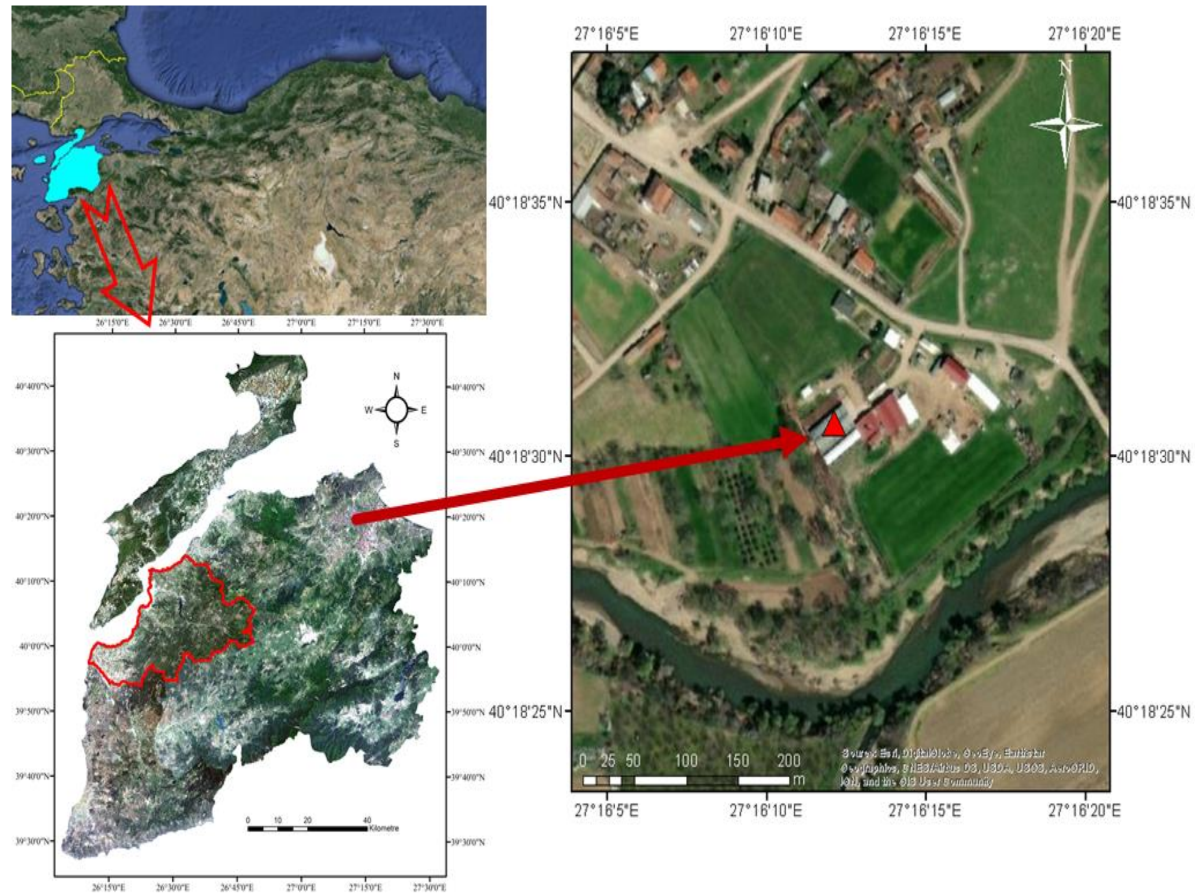

Figure 1. Study area

This farm was a good representation of the majorty of the dairy operations in the area with an average daily milk yield of 20 lt. The barn has dimensions of 15 × 30 m. The installation plan of the sensors is shown in Figure 2.

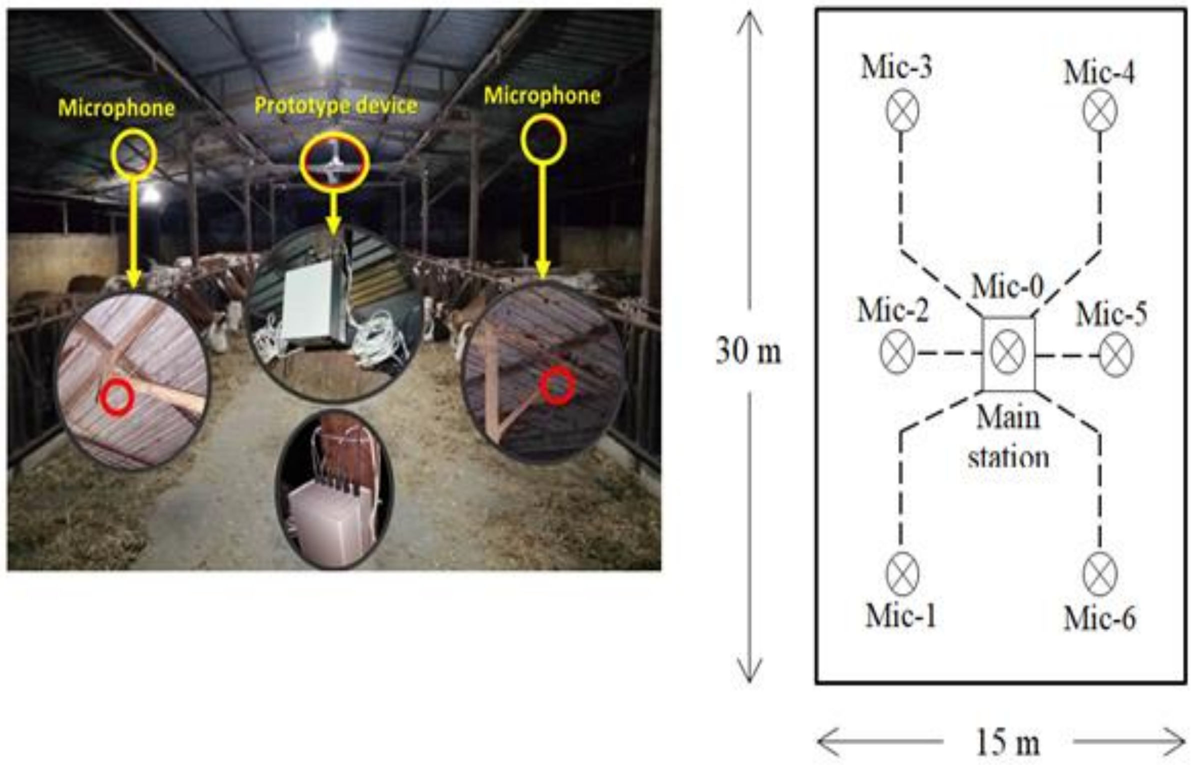

Figure 2. Microphone installation plan

Noise mapping

In order to visualize the spatial distribution and numerical changes over the project area CadnaA (Computer Aided Noise Abatement, DataKustik, 2010) software was used. CadnaA is a program that produces realistic prediction maps with two or three-dimensional models using different algorithms according to the type of data source (CadnaA, 2010). This software can calculate the equivalent noise level (L_{eq}) using the sound data obtained in a certain time period. Equivalent noise level is another noise scale in dB which explains the average energy value that is created by the sound pressures observed within a given period of time. In order to estimate the overall effect of sound energy this scale was preferred since the daily noise level varies during the measurement period (Behar, 1975). Another definition is that the L_{eq} is a noise scale in dB that gives the average value of sound energy or sound pressures over a given period of time (ISO, 1996).The software employs the following equation (1) to estimate the equivalent noise level (L_{eq}).

$$L_{eq} = 10 \times log\left[\frac{1}{T} \times \sum_i^n t_i \times 10^{\frac{L_i}{10}}\right] \qquad \text{(Eq. 1)}$$

where T: Total time in hours; Li: Sound intensity level in dB; t_i: part-time in hours.

Continuous sound intensity levels were calculated for each sensor separately. Also, calculated results were used to visualize the noise levels within the study area in CadnaA.

Results and Discussion

In order to demonstrate the environmental effect of the sound emitted from the barn the obtained data were modeled. The sources of recorded 8-month data consist of animals, work machines and the employees. There were no busy roads, settlements or other sources that may cause noise in the vicinity of the barn. Therefore, modeling was done using only recorded dataset in CadnaA software. In the L_{eq} modeling, the data was divided into day and night (Bayraktar and Mutlu, 2021).

Several researchers suggested the allowable sound intensity in dairy barns should be between 85 and 90 dB (Bond et al., 1963; Ames and Arehart,1972; Espmark et al., 1974; Ames, 1978). Kızıl et al. (2022) reported that even though recorded sound data in a dairy barn exceeds these suggested values it does not last for longer time periods. The major source of higher sound levels were animals, work machines or labor that last only for seconds. That means instead of considering instant higher values it is better to observe cumulative sound level value which is L_{eq}. When the L_{eq} values were considered, it was seen that these values for day and night in the barn are considerably lower than these suggested values of 85-90 dB. The L_{eq} values of each sensor inside the barn are given in Figure 3.

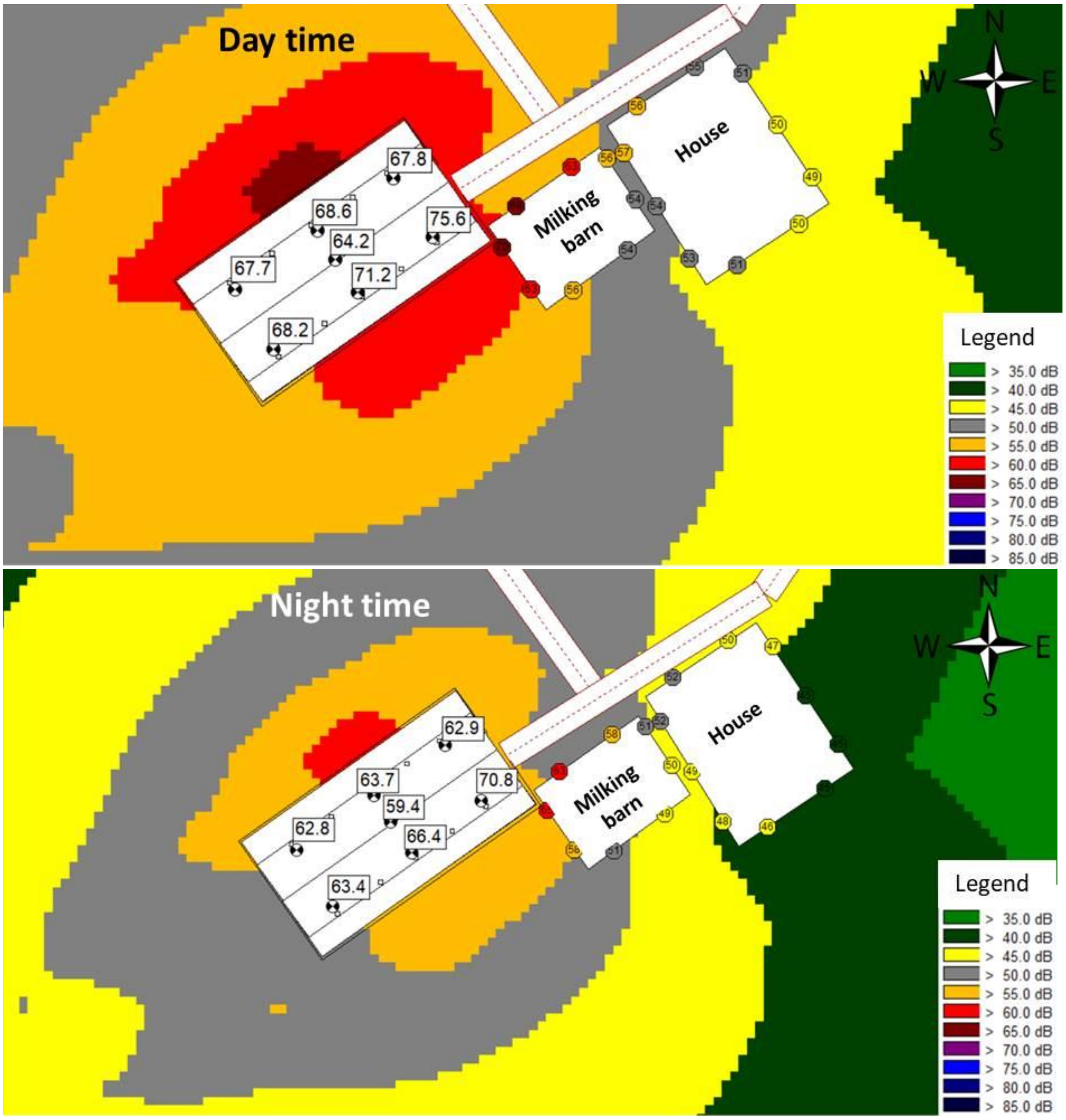

Figure 3. Equivalent noise levels for day and night within the barn

Anonymous (2006) stated that the background and highest sound intensities in dairy barns could be 72 and 106 dB, respectively. In this study average day and night L_{eq}s of seven sensors were found to be 69.0 and 64.2 dB, respectively (Table 1). These results are also compatible with the literature and also show that vocal environmental conditions within the barn are suitable for dairy cattles.

The CadnaA software was also used to model sound L_{eq}s around the operation. It was aimed to determine if continues L_{eq}s may affect the workers and/or neighboring operations. The safe level of L_{eq} for human is reported to be 70 dB (WHO, 2000). On the other hand the highest L_{eq} values obtained outside the barn modeled as 65 and 60 dB for day and night recordings, respectively. As the distance from the barn increases L_{eq}s decreases way below to acceptable limits (Figure 4).

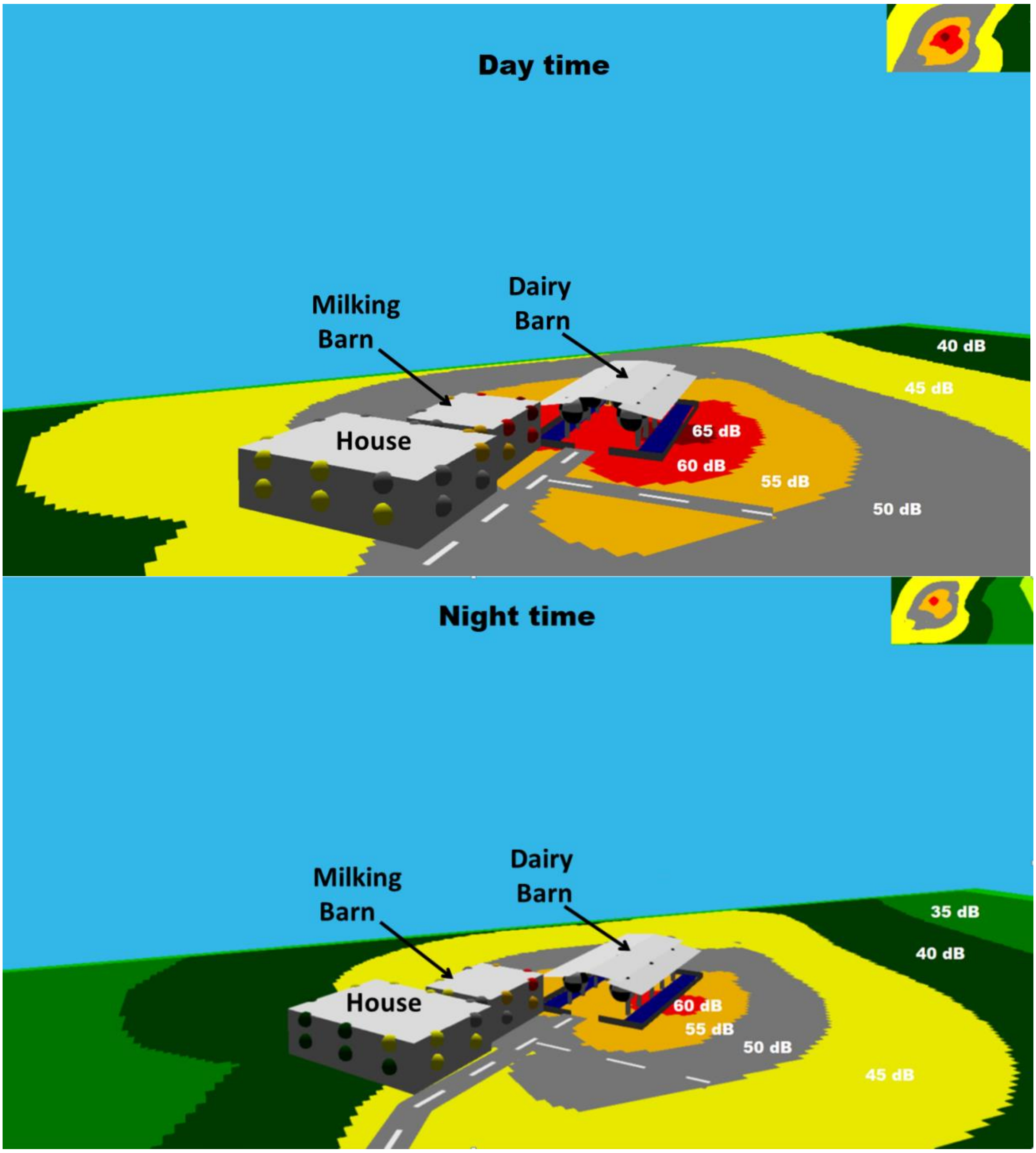

Figure 4. Equivalent noise levels for day and night around the barn

Conclusions

Continuous monitoring and evaluation of environmental conditions in livestock farms is highly critical to maintain a sustainable production. With the developments in sensor and data management technologies it has become more practical and economical to measure and evaluate the environmental stressors and take necessary actions. A ptototype sound data collection device along with data management unit not only provided a tool to monitor noise conditions it also a helped evaluate the overall noise levels within and outside the barn. The modeling results showed that this particular farm maintains the limits of noise exposure for both animals and labors. It is also modelled that this farm is not a disturbing source of noise for neighboring operations. The results indicated that such monitoring system works well on monitoring the noise in real time and for certain period of time. The future work includes integrating the system with a camera for visual monitoring as well.

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Contribution Rate Statement Summary: The authors declare that they have contributed equally to the article.

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