Quality labels for the quiet rural soundscape

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\section*{ABSTRACT}

A soundscape is not solely determined by its acoustic field but also by the context. In this paper the context is very specific: the area is rural, consisting of agriculture land, scattered farms, some bushes and woodland, small rivers and other water features, streets with little or no motorized traffic, an occasional rural village; the visitor is a person looking for quiet recreation and psychological restoration from the stress imposed by daily activities and a disturbed person-environment relationship. Because the benefits of having such an area within reach are clear, local governments may try providing such an area for all of their inhabitants. Because of the requirement that the restorative environment should be within reach, it is useful define quiet rural soundscapes of different quality. We propose a multi-criterion system for quality labeling. It includes a number of perception-based and a number of physical indicators. The physical indicators guarantee low background sound level, interesting and restoring dynamics, suitable spectral content and a limited number of intruding noise events. Literature review provided us with limiting values for these indicators for each quality level. Nevertheless a strong need for international standardization (of perception based assessment) and more extensive field studies is identified.

\section{INTRODUCTION}

The soundscape concept has been introduced for studying urban acoustic environments from an artistic angle \cite{1} \cite{2}. Since then it has been a source of inspiration for many researchers. Although soundscapes have been discussed in the context of noise annoyance, sleep disturbance and health effects, its main advantage lies in the study of the sonic environment of urban parks or squares and natural or rural environments \cite{3}. Much of this research agrees on at least one fact: the perceived quality of a sound environment strongly depends on the context in which it is experienced. In \cite{4} \cite{5} Job et al. introduced the notions of \textit{enviroscape} and \textit{psychscape} to refer to the effect of the non-acoustic environment and the personal factors affecting perceived soundscape quality. Using these notions, the narrowed scope of this paper can easily be described. The visual environment (part of the enviroscape) is a rural one: combined agriculture and woodland, bushes, scattered farms and an occasional village, a small stream or other water features, low level roads and paths without or with very limited motorised traffic. Occasionally some infrastructure for quiet recreation such as horseback riding, cycling, sailing, etc. The psychscape is the state of mind of people looking for quiet recreation, relaxation, quality time. This scope corresponds to the definition of \textit{quiet areas in open country} mentioned in the European Environmental Noise Directive \cite{6}.

Rural (and natural) soundscapes have been studied by several authors recently. In \cite{7} laboratory experiments are used to investigate the effect of relative levels of natural background noise and different intruding sound on quality perception. A physical indicator for noticebility is

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added to the overall level. The extensive overview report by Symonds [8] mentions several interesting approaches to quality assessment that were proposed and/or used in European countries but concludes on a single indicator based on overall level. In [9], it is argued that since the ambient noise level is low, intrusive noises are more audible and man-made sounds will more likely be intermittent and variable in level and duration. This makes the use of long term average sound levels such as $L_{den}$ less suitable. Event noise level (measured relative to the background level) and duration were found to be uncorrelated by Miller [10], when he quantified noise intrusions in National Parks in the US, which means that both add information about a location. Much the same approach was used in [11] to assess non-natural noise intrusions in Dutch quiet areas.

In [12], it is proposed to go beyond the use of quantitative approaches using average sound levels, when qualifying urban sound environments with a more complex temporal structure, or during quiet periods. Counting the number of noise events, using statistical levels or using psychoacoustic criteria is discussed. Brown [13] even proposes to depart from the classical level based approach and to adopt criteria based on the information content of sounds for outdoor soundscapes, e.g. “moving water should be the dominant sound”. In [14] urban and suburban green areas are investigated in an extensive study. The author nevertheless also concludes on a threshold for $L_{Aeq}$ as a physical criterion.

Overall, two lines can be discovered in current research on quiet area soundscapes. One line pursues the scientific goal of trying to understand the influence of the soundscape on its visitor’s state of mind. It consistently leads to the conclusion that long term average sound levels are poor indicators. A second line of research has started from classical noise mapping and suggests additional indicators, albeit mainly noise level based. In this work we propose to combine the best of both worlds in a multi-criterion assessment. Nevertheless the aim is to arrive at a set of indicators with strong focus on applicability.

This article starts by discussing an underlying model for perception of the quiet rural soundscape in Section 2. It proceeds by clarifying why a system of quality labeling is preferred over a crisp categorization. In Section 4 a possible set of indicators is related to the perception model discussed in Section 2.

2 AN UNDERLYING MODEL FOR PERCEPTION OF THE QUIET RURAL SOUNDSCAPE

Most of the research mentioned in the introduction uses a methodology strongly related to epidemiologic research to relate descriptors of the soundscape to perception. To structure ideas, it is nevertheless useful to draft a model for perception of the (sonic) environment. In [15] we presented such a model for noise annoyance based on notice events. This model assumed that noticing a sound is the trigger of a complex cognitive and emotional mechanism that can result in remembered noise annoyance at the time the person is interviewed in a retrospective way. Noticing a sound – in this model – depends on various factors: activity, personal factors, coping, focusing, etc. Together these factors constitute the context. For the perception of the sound climate in a quiet rural area, the context is totally different than the context of being at home minding daily activities and being exposed to intruding noise. In terms of the model in [15] this could be translated to a situation where the threshold of noticing a sound is particularly low. Indeed, attention of the recreant visiting this area is focused on maximal sensory experience of the environment. Following the recent overview on the physics of the mind in [16], this sensory experience of a noise event would trigger the cognitive system to activate low level models (a car, a bird, a plane, rustling leaves, ...). These in turn would activate higher level, more abstract models (nature, rural, ...). These abstract models are initially rather fuzzy, but could gradually
become crisper as an opinion is formed. The language system – again following [16] – works in parallel to this cognitive system. Language is thus an ideal tool to sample this cognitive process, as discussed in [17].

As children mature, additional abstract models are formed both by personal experience and through the coupling to the language system that makes humans different from any other species. In particular a model for the rural environment will be embedded. Based on the above description of how it is formed, it is clear that this model will depend on the culture and physical environment the individual has lived in. This model of the rural environment – and in particular the soundscape associated to it – can be related to expectation. According to [16], aesthetic emotions are related to knowledge instinct as other emotions are related to more basic instincts. The knowledge instinct is seen as the driving force that makes us want to match our model of the world to sensory inputs, the instinct that makes us want to learn, and the instinct that makes puppies want to play. We quote [16] “… we do not usually notice adequate performance of our breathing muscles and satisfaction of the breading instinct. However, if breathing is difficult, negative emotions immediately reach consciousness. The same is true about the knowledge instinct and aesthetic emotions: if we do not understand the surroundings, if objects around do not correspond to our expectations, negative emotions immediately reach consciousness.” Thus negative emotions could reach consciousness if the sound climate in the rural area does not fulfill our expectations. However, these emotions may also remain fuzzy and unconscious until the visitor of the rural area is questioned by the investigator. (This explains why retrospective evaluation could reach other conclusions than evaluation of the soundscape heard during questioning.) An influence of these emotions on further perception can be expected and it can be included in a mathematical model [18][15]. It is of no further use for the debate of this paper so we will not elaborate on it.

An important question remains to be answered: does a more direct path between the auditory sensory perception and emotion exist. It has been recognized that vocal expression and music are ideal channels to communicate emotion. An extensive literature review on the topic can be found in [19]. In their summary these authors mention acoustic quantities such as tempo, sound level, sound level variability, high frequency content, pitch level, pitch variability, etc. as primary clues. Thus it is reasonable to expect that sounds encountered in other context could also trigger emotions, emotions that may however to a large extend remain unconscious. When queried, the emotion may become crisper and more conscious. The 12 attribute tool presented by Berglund and Nilsson in [20] seems to focus more on this emotional evaluation of the soundscape. We base this conclusion on their choice of attributes: soothing, pleasant, light, dull, eventful, exciting, stressful, hard, intrusive, annoying, noisy, and loud. Although the choice of these attributes does not prove that the mechanism is a direct trigger of emotions by environmental sound, the richness in attributes provided indicates a richness of emotions that may go beyond the aesthetic emotion caused by mismatch of sensory perceptions and internal model of the rural area.

Figure 1 summarizes the model described above.

In [21] we discuss the quiet rural area as an environment that stimulates psychological restoration from the stress induced by work, family, a disturbed person environment relationship, etc. How does this fit in the above described model? It was found that a natural environment is preferred over an urban one for psychological restoration [22][23]. The difference between an urban and a natural environment is more specifically due to a difference in: presence of people, sound level, and aesthetic quality [23]. This would imply that the restorative capacity resides in
higher level cognitive model activation and correspondence to expectations. In [24] it is concluded that attentional capacity can be restored in an environment that evokes effect-less attention and allows directed attention to rest. This would imply that also the feedback paths to perception shown in Figure 1 are important. Literature is inconclusive when it comes to deciding whether the cognitive path or the direct emotional trigger by the soundscape is most important for restoration.

![Figure 1: Model for perception and cognitive / emotional effect of a soundscape.](image)

3 QUALITY LABELS
Each environment creates its own context and thus a different optimal soundscape is expected. In particular for quiet areas one usually distinguished between an urban quiet area and a quiet area in open country. On top of this differentiation, it is useful to identify areas of different quality, because of the requirement that a quiet area or an area with restorative potential should be within reach for all. In densely populated areas (e.g. Flanders) one may identify an outstanding quiet rural soundscape but assign to it a lesser quality label than the label assigned to an outstanding quiet rural soundscape in more remote places (e.g. Norway). We propose a labeling with stars that is easy to understand to the broad public. Three stars meaning that the soundscape is a prototypical soundscape matching to the “quiet rural setting”; it is close to the best thinkable soundscape for that context. One star meaning that the soundscape is still worth to be marked compared to the region around but the quality is low. On a scale from 0 to 10 (commonly understood by the population) one star could correspond to 6.5, two to 7.5, three to 8.5 and higher.

4 A POSSIBLE SET OF INDICATORS
Indicators are used in environmental monitoring, impact assessment and policy planning. They are proxies to the real effect of interest but at the same time are easy to measure or to calculate. Formal requirements for good indicators include: policy relevance and utility for users (provide a representative picture, be simple and easy to interpret, allow showing trends over time …), analytical soundness (theoretically well founded in scientific terms, lend itself to being linked to models …), measurability (available or made available at a reasonable cost/benefit).
Indicators can be defined at different levels in the model outlined in Section 2. If it involves questioning visitors concerning their cognitive evaluation and emotions with regard to the rural area they are visiting, it is guaranteed that the results are scientifically well founded and that the picture is representative. That is, provided that the sample is statistically relevant and the subjects are trustworthy. Typical expectations for the area at hand are automatically included.

Indicators based on querying visitors are less suited for modeling and prediction, (e.g. in the context of action planning) and their measurability is low for some applications. Consider for example mapping of a rural area of several tens of square kilometers. Thus more physical indicators are useful as well. To guaranty that these physical indicators are analytically sound, it is best to follow the paths in Figure 1 towards perception and assure scientific foundation. In particular, when constructing indicators that match cognitive evaluation, source recognition seems a key issue. The degree of mismatch between the sources heard and the environment could then be pre-coded by the scientist or extracted from surveys conducted with visitors of the area under study. The number of times a source is heard or the length of time that it is heard is more representative as an indicator than the level at which it is heard [10][21][25].

Following the direct path from perception to emotion, inspiration for defining physical indicators may be found in music research. Factors such as overall level, frequency content and pitch, and fluctuation of these quantities should be included. Single loud sound events can probably be excluded from this evaluation since they activate the cognitive path separately. Thus this group of indicators should focus more on the ambient noise. This analyses is in line with the hypothesis that we forwarded earlier [28][21]: ambient noise determines the overall feeling of quietness, sound events are perceived as disturbance of this quietness.

The discussion above makes clear that there is no single indicator that fits all. Thus assessing the quality of a quiet rural soundscape using an $L_{Aeq,day}$ or $L_{den}$ is not sufficient. Based on literature review and a small case study, we arrived at a multi-criteria system involving 6 acoustic indicators in [21]. These indicators are positioned in a plane (Figure 2) showing whether they sample cognition or emotion and whether they use physical measures or human observers. For readability we briefly repeat the definition of these 6 indicators:

- **SD – pleasing**: a semantic differential scale out of which 6 elements: silent(-loud), natural(-unnatural), relaxing(-stressing), soft(-rough), exciting(-boring), and open(-enveloping) are gathered in the first principle component that can be labeled pleasing-natural-silent. A semantic differential is preferred over open questions for easier interpretability by policy makers and because it allows to focus more on the emotion part of the evaluation.

- **Non-fitting sounds**: Visitors are asked about hearing and degree-of-fit of different sounds with 11-point answering scale. The indicator is a combination that represents: can be heard a lot AND is non-fitting in this context, where AND can be implemented as the minimum of both scores. A limited set of source categories is preferred over open questions because of transparency for policy makers, ease of post-processing and comparability.

- **$L_{A50}$**: The overall level of the ambient noise is measured by the median sound level because it is not influenced by the loudness of single events and because it was found to correspond better to an evaluation of quietness than $L_{Aeq}$ in previous work [26][27].

- **$N_{nc}$**: Counts the number of occurrences of non-natural sound events. It is a cheap ersatz to automatic source recognition and counting that is based on exceeding $L_{A50}$ by 3 dBA for more than 3 seconds.
- **ML1**: Measures the fluctuation of the sound level and is inspired by complexity theory and music [29]. Neither too much slow variation nor too much fast variation is appreciated.
- **Log(G)**: A physical indicator for sharpness based on the center of gravity of the spectrum [30].

In [21] we make a first proposal for limit values corresponding to the different qualities of quiet rural soundscapes for each of these indicators.

![Figure 2: Indicators position in a plane showing whether they sample cognition or emotion and whether they use physical or human observation.](image)

5 **CONCLUDING REMARKS**

Quality of life of the population benefits from the availability of high quality areas for recreation and psychological restoration. A policy aiming at providing such areas within reach of every member of society could benefit from a categorization method involving quality labeling of different areas. Many researchers have pointed out before that the quality of a soundscape cannot simply be assessed by studying a single noise level indicator. Hence we propose to use a multi-criterion assessment based on a set of well chosen indicators. The set should include physical indicators for mapping and action planning, but also indicators based on the real experience by people visiting the area. Care should be taken not only to “measure” the more cognitive evaluation of the soundscape but also the emotions it provokes. In this paper we made a first attempt in presenting such a set.

6 **REFERENCES**


The effects of noise on the hearing and vocalizations of birds

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The effects of anthropogenic noise on birds can fall into four potentially overlapping categories: annoyance, stress, auditory damage, and masking. The first two effects are best addressed in the field, while the second two are best addressed by laboratory experiments where precise control of stimulus and behavioral variables are obtained. Behavioral and anatomical laboratory experiments on acoustic over-exposure show there are considerable species differences in susceptibility auditory system damage and hearing loss. Laboratory studies also show that in spite of similar audiograms, there can be considerable species differences in how well birds can detect and discriminate both simple sounds and bird vocalizations against a background of noise. Generally, birds require a higher signal-to-noise ratio to discriminate between two vocalizations than to detect vocalizations. Comparing different noises, birds detect and discriminate vocalizations better in noises that resemble the spectrum of noise generated by highway traffic than in noise with a flat spectrum. Hearing loss affects the quality of vocal production. Masking noise has several effects including changes in the level of vocal output. These results aid in predicting effects of anthropogenic noise on bird acoustic communication.

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Preserving natural quiet areas and urban parks

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Nowadays the protection of natural quiet areas and parks inside cities is an issue of increasing importance, as also recognized in the European Directive 2002/49/EC, because in these places people can temporarily recover their health. In order to preserve these areas it is fundamental to characterize properly their soundscape, taking into account the several non-acoustic factors influencing the individual perception, such as the subject’s expectation of the environment and the sounds expected to be heard there. This paper describes the surveys carried out in urban parks in Naples and Milan, aimed at investigating their soundscape and the subjective evaluation on different aspects of the parks, including non-acoustic ones. The results show that mean overall L_{eq} levels are in the range 52÷62 dB(A). In all the parks, silence was ranked last as the most important factor for the pleasantness of the park. Voices and dogs barking are the sounds most expected to be heard in the park, whilst road traffic and aircraft fly-overs are the most annoying. The perceived quality of the soundscape was largely below the current threshold used to define quiet areas, whereas the perceived overall quality of the parks was rather satisfactory.