Noise Exposure, Prevention, and Control in Agriculture

Subjects: Agricultural Engineering

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Noise is a major physical hazard in agricultural activities, and numerous research activities have managed to detect its effects, resulting in surveys and measurements which help to define exposure limits, prevention methods, and control strategies.

Keywords: noise ; agriculture ; forestry ; animal husbandry ; safety ; occupational health ; NIHL

1. Introduction

Noise exposure assessment is a key aspect in agricultural safety. Since most agricultural equipment used for heavy-duty activities generates high levels of sound, protecting agricultural workers against such hazards is vital, and monitoring for latent hearing loss issues must be carried out, even after retirement from these professions. Exposure levels to noise can even lead to severe damage, especially when workers do not wear any hearing protection during the most hazardous or prolongated jobs, indicating that often, they might be unaware of the consequences of such noise exposure.

2. Noise Exposure, Prevention, and Control in Agriculture

2.1. Noise Emission Levels in Agricultural and Forestry Activities

2.1.1. Noise Level Related to Agricultural Tractors

Agricultural tractors represent a significant source of noise that can be difficult to prevent given their power, and research activities often focus on a small number of variables that influence their noise emissions. Given the wide number of parameters that affect tractor noise emission levels, comparisons must consider working conditions that have been observed by all of the studies. Data regarding such observations is reported in **Table 1**, including important details for each one, along with their research findings.

Table 1. Noise levels associated with tractors.

Title	Year	Research Findings	Sample Data
Effects of noise and vibration on farm workers [1]	**1991**	**Exposure exceeded 85 dB(A) for 30 of 31 tractors at full throttle, while 6 produced levels at 95 dB(A).**	**A total of 31 tractors, effects evaluated with a 5 dB exchange factor**
Tractor noise exposure levels for bean-bar riders [2]	**1993**	**Noise exposure levels at the bean-bar position were, on average, 10 dB(A) higher (92 dB(A)) than those at the bystander position.**	**One bean-bar tractor**
Farm noise emissions during common agricultural activities [3]	**2005**	**Noise levels were 76 dB(A) for cabbed tractors, 92 dB(A) for tractors without cabs; 106 dB(A) for chainsaws, 73 dB(A) for dairies.**	**A total of 38 tractors with cabs, 26 tractors without cabs; exchange factor: 3 dB**
Safety and health of workers: Exposure to dust, noise, and vibrations [4]	**2009**	**Daily exposure between 86.9 and 95 dB(A) for tractors and self-propelled machines.**	**A total of 15 hazelnut harvesters**
Noise test of two manufactured power tillers during transport on different local road conditions [5]	**2010**	**The maximum overall noise measured at driver ear's position at different gear ratios were between 92 and 98.2 dB(A).**	**Two power tillers; effects evaluated with an exchange factor of 3 dB**
Exposure to audible and infrasonic noise by modern agricultural tractors operators [6]	**2013**	**Analysed tractors emit considerable infrasonic noise levels that tend to exceed the occupational exposure limits.**	**A total of 32 modern tractors**

Title	Year	Research Findings	Sample Data
Noise levels of a track-laying tractor during field operations in the vineyard [7]	**2013**	**Sound levels exceeded the limits, in almost all the test conditions, by up to 92.8 dB(A).**	**One tractor, tested in four different activities**
Harmful factors in the workplaces of tractor drivers [8][9]	**2016**	**The noise levels were 90 dB(A) for tractors manufactured in the 1980s, 73 dB(A) for newer tractors.**	**A total of 30 tractors**
Risk exposure to vibration and noise in the use of agricultural track-laying tractors [10]	**2016**	**The daily noise exposure levels always exceeded 87 dB(A).**	**A total of 6 track-laying tractors**
Tractor age effects on occupational noise level exposures inside agricultural tractor cabs [11]	**2016**	**The data showed a positive correlation of 0.308 between tractor hours and the increase in noise level; no tractors exceeded 85 dB(A).**	**A total of 19 tractors of different models, ages, and engine hours**
The hearing abilities of rural workers exposed to noise and pesticides [12]	**2018**	**The motor's noise ranged from 88.3 to 93.4 dB(A).**	**One tractor, with concurrent exposure to pesticides**
Assessment of tractor noise level during spraying operation while using a tractor-mounted aero blast sprayer [13]	**2018**	**Noise at a tractor operator's ear level during spraying operation can reach up to 93 dB(A) at 2000 rpm.**	**One tractor**
Noise exposure and its impact on psychological health of agricultural tractor operators [14]	**2021**	**Value of 81.9 dB(A) during operation of seed drill, 84.9 dB(A) with disk harrow, and 86.9 dB(A) with cultivator operation.**	**One tractor, tested in four different field activities**

In many of the articles listed in **Table 1**, the daily averaged noise emissions exceeded the 85 dB(A) threshold. Despite design improvements, which must have had a positive impact on reducing tractor emissions, it should also be noted that the type of farming activity also influenced their sound emissions by requiring the tractors to work at a wide range of engine speeds, torques, and terrain slopes [3]. It has been noted, for example, that an increase of 3 dB(A) was to be expected when passing from 1200 to 1500 rev/min or from 1500 to 2000 rev/min [2]. Data collection regarding tractor noise emissions has been performed on a large variety of samples, which differ in regards to:

- The number of vehicles in the sample, which range from just 1 tractor to 64 different models;
- The age of the vehicles, collected as the operational age or as year of manufacture;
- The design, which, in some cases, was simply divided into tractors with or without cabs;
- The power, ranging from power tillers to narrow-track tractors and large harvesters;
- The monitored activities, that have often been investigated singularly;
- The terrain and field conditions, including the slope.

The research often focused on just one or two of the previously listed variables, without considering any other of the aforementioned working conditions.

2.1.2. Noise Level Related to Farming Activities

Farming activities include a large number of different agricultural vehicles, and noise levels measured in research almost always resulted in values beyond the 85 dB(A) threshold, even up to 99 dB(A) for common farming activities and 102 dB(A) for certain specific tasks. A list of findings of noise levels related to farming activities is reported in **Table 2**.

Table 2. Noise level associated with farming activities.

Title	Sample Size	Year	Research Findings
Noise Exposure and Hearing Loss in Agriculture: A Survey of Farmers and Farm Workers in the Southland Region of New Zealand [15]	**28 farms**	**2003**	**Noise levels for the subsample of 60 farms lay between 84.8 to 86.8 dB(A).**

Title	Sample Size	Year	Research Findings
Noise Exposure and Hearing Conservation for Farmers of Rural Japanese Communities [16]	1538 farmers	2004	Daily noise exposure ranged from 81.5 to 99.1 dB(A) for tea harvesting, and from 83.2 to 97.6 for sugar cane harvesting.
Characteristics of Annual Exposure to Noise among Private Farmers on Family Farms of Mixed-Production Profile [17]	A total of 16 family farms.	2006	Noise levels equivalent to a mean exposure level equal to 91.3 dB(A).
Dust and Noise Exposures among Farmers in Southland, New Zealand [18]	A total of 60 farms.	2006	Total daily noise exposure levels were 86.8 dB(A) for sheep farmers, and 85.7 dB(A) for mixed farmers.
Occupational Noise Exposures among Three Farm Families in Northwest Ohio [19]	The family members of nine farmers.	2008	Occupational noise exposure for the children ranged from 15.4 to 81.2 dB(A), using the OSHA action level.
Task-Based Noise Exposures for Farmers Involved in Grain Production [20]	A total of 35 farmers or farm workers.	2013	Noise levels ranged from 78.6 to 99.9 dB(A) for 23 tasks and 18 pieces of equipment analysed.
Farmers' Work-Day Noise Exposure [21]	A total of 105 farmers.	2015	The average daily noise exposure was 85.3 dB(A).
Patterns and Trends in OSHA Occupational Noise Exposure Measurements from 1979 to 2013 [22]	A total of 493 samples between 1979 and 2013.	2019	Mean noise levels of 93.1 ± 6.8 dB(A) were found among the agriculture, forestry, and hunting industries.
Noise Exposure on Mixed Grain and Livestock Farms in Western Australia [23]	A total of 28 farm owners and workers.	2019	Up to 101 dB(A), mostly from seeding activities, but generally above 85 dB(A) for all farming activities.
Sound Power Determination for Centrifugal Pumps used for Local Agricultural Irrigation in Romania [24]	One farm, evaluating specific equipment.	2020	Noise level observed in all working conditions exceeded 85 dB(A), with a peak of 102 dB(A) at maximum pumping height.

Farm owners, farm workers, and family members are often affected by a large variety of noise sources, as shown in the research findings in **Table 4**. Apart from tractor noise emissions reported in the previous subsection, many other sources can produce additive effects and increase noise levels at any stage of involvement in farming activities, and as shown by Warwick et al. [21], several significant noise sources can be present at any time of the day—not just during work hours—on a farm. The same research noted a new trend in working models represented by a farming workload, often shared between male and female family members, on family-based farms, a key aspect that the authors highlighted for future research in NIHL among farm workers. In measurements performed by Miyakita et al. [17] in Japan, noise exposure was beyond 85 dB(A) for 8 h shifts in 82% of cases, while Firth et al. [18] assessed the incidence at 35% for New Zealand's farmers and indicated that 20% had a pattern of hearing loss; similar outcomes were also found in the United States of America by Sayler et al. [22], also indicating an apparent increase in occupational noise levels over time in agricultural industries. Despite several countries being included in studies focusing on agricultural noise levels, there is not enough information to state that similar outcomes could be generalised, but the research often indicated that technological progress in mechanisation in the past has led to a change in the agricultural working environment that occurred too quickly to be properly handled by occupational health and safety institutions.

2.1.3. Noise Level Related to Forestry and Animal Husbandry

Forestry and animal husbandry noise measurements have also been examined in relatively new research works. In **Table 3**, such levels are listed, along with the research findings. Some of the articles that cover forestry might also cover tractor or farming measurements, while most of the specific works on forestry cover chainsaw or logging work.

Table 3. Noise level associated with forestry and animal husbandry activities.

Title	Year	Research Findings	Sample Size
Farm Noise Emissions During Common Agricultural Activities [3]	2005	Levels of 106 dB(A) for chainsaws, 73 dB(A) for dairies.	A total of 32 agricultural activities
Occupational Noise Exposure Assessment in Intensive Swine Farrowing Systems: Dosimetry, Octave Band, and Specific Task Analysis [25]	2005	Exposures exceeded 90 dB(A), up to 96.6 dB(A) in farrowing areas.	A total of 11 activities in a swine confinement facility

Title	Year	Research Findings	Sample Size
A Task-Based Assessment of Noise Levels at a Swine Confinement [26]	2007	None of the workers' noise levels exceeded 85 dB(A), but HPDs are needed for snaring and power washing activities.	A farrow-to-finishswine confinement center
Exposure to Noise in Wood Chipping Operations under the Conditions of Agro-Forestry [27]	2015	Exposure did not exceed 80 dB(A) at low level utilizations. It may exceed the lower action values for utilization above 64%.	One agroforestry chipper
Operators' Exposure to Noise and Vibration in the Grass Cut Tasks: Comparison between Private and Public Yards [28]	2016	Exposures exceeded limit values within a range of 79.4 to 92.6 dB(A).	A total of 6 operators in public and private yards
Workload, Exposure to Noise, and Risk of Musculoskeletal Disorders: A Case Study of Motor-Manual Tree Felling and Processing in Poplar Clear Cuts [29]	2018	Exposure exceeding the acceptable limits, of 97.15 dB(A) and the daily exposure of 96.18 dB(A).	One feller
Noise Exposure on Mixed Grain and Livestock Farms in Western Australia [23]	2019	Up to 108 dB(A), with the highest values for the chaser bin, shearing, and seeding.	A total of 28 agricultural workers
Noise Exposures and Hearing Protector Use at Small Logging Operations [30]	2021	Use of PPE reduced exposure below 80.7 dB(A), excluding bulldozer operations (93.5 dB(A)).	A total of 31 loggers in 7 different sites
Evaluation of Occupational Noise Exposure among Forest Machine Operators: A Study on the Harvest of Pinus Taeda Trees [31]	2022	Operators were exposed to noise levels above the exposure limit of 85 dB(A) during timber extraction.	A total of 4 operators of self-propelled forestry machines

2.1.4. Evaluation of Noise Emissions in Agricultural and Forestry Activities

Exposures in dB(A) from papers cited in the previous subsections are reported in **Figure 1**, reported for the corresponding year of observation, showing sources separated by type of activity: tractors, farming activities, animal husbandry, and forestry. Most of the observations fall beyond the threshold level of 85 dB(A), and a change can be observed only for tractor activities as the only category showing a small decrease over time. It should be noted that technical advances in tractors, such as improved cabs and mufflers, have influenced this trend, given that tractors manufactured from the year 2000 on presented noise levels of73 dB(A), which are significantly lower than those of tractors built in previous decades [8].

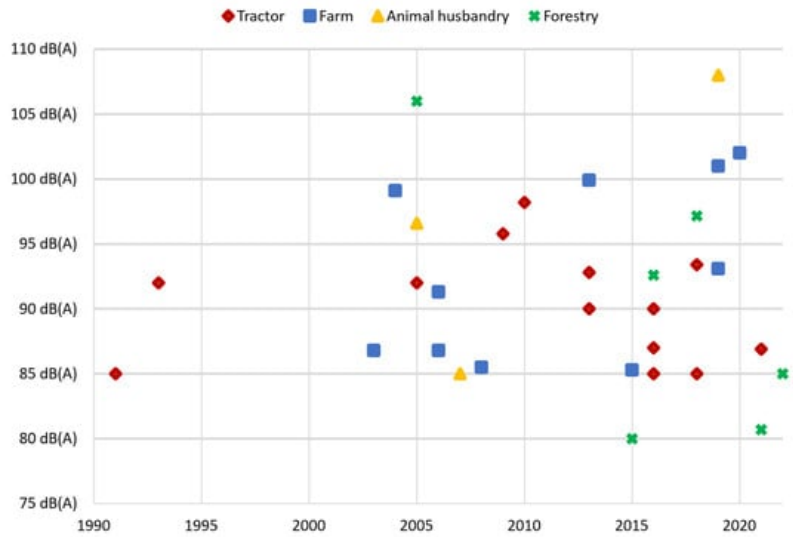

Figure 1. Distribution of noise emissions among agricultural, farming, and animal husbandry activities over time. Given the large number of parameters affecting noise measurements and the lack of protocols, the slight decrease in tractor noise emissions reported in various research findings cannot be taken as a function of time. Further studies are necessary to determine the impact of regulations and the effects of machinery electrification.

Regarding noise in forestry activities, it is clear that the duration of the activity can highly influence the effects of noise exposure. This can be seen as a possible area for improvement, if equipment is designed to perform faster, but might also cause concern under heavier working conditions confirmed by some of the measurements, which yielded noise levels at

106 dB(A) for chainsaws, indicating that the most effective margin for improvement would be obtained by best-practices that minimise the exposure.

2.2. Noise-Induced Hearing Loss (NIHL) in Agriculture and Forestry

The effects of excessive noise exposures have been analysed since the mid-1990s. A research article [32] from 1996, based on a large sample of two thousand interviews with farmers, found that field crop farm operators were exposed noisy jobs, which made up as much as 30% of their work, while the lowest exposure levels (median noise 1%) was found among nursery farmers. In addition, smaller farms reported higher exposure levels compared to larger farms, given that operators of the latter were more likely to wear hearing protection devices. These results, however, are based on national data and self-reported information provided by farmers.

2.2.1. NIHL in Tractor Drivers

Tractor drivers, given the higher levels of noise generated in their activities, are expected to show a higher prevalence of hearing loss after 30 years of employment in agriculture. A study including drivers of medium and high-power tractors, performed in 2001 [33], assessed the chance of hearing impairment after 30 years of occupational exposure to noise from medium and high-power tractors to be between 13% and 37.9%. The risk of hearing impairment due to occupational exposure to noise that may cause an acoustic trauma was 37.9% for medium-power tractors and 13.0% for high-power tractors.

2.2.2. Risk-Related Effects and Occupational Injuries

Hearing loss represents a health issue among farmers. Farmers also experience an increased risk of hearing asymmetry [34], and the rate of injuries was higher for those exhibiting occasional use of hearing protection devices compared to workers that did not use them at all, suggesting that an irregular use of hearing protections could negatively affect safety. It must be also noted that such effects might trigger stress and fatigue in workers, affecting their sensibility to detect any early onset issues related to hearing loss. Further evidence of the impact of NIHL in occupational health [35] shows that workers exposed to noise had a 52% increased risk of injury compared to unexposed workers, while these risks were far higher for workers with mild and moderate hearing loss, where chances increased by 7.87-fold and 4.48-fold, respectively. Such results indicate that a reduction in occupational noise exposure might improve safety in the workplace. Given the seasonal cadence of many agricultural activities, it has been found that summer and autumn posed higher noise risks among farmers [36].

3.2.3. Exposures by Groups and Activities

Farmers do not represent the only group exposed to NIHL in agriculture: family members and children are, in fact, often unrecognized exposed groups which should be included in prevention and protection programmes. Hearing loss in farmers may begin during childhood, where it can result from both noise, as well as ototoxic exposure that might be due to specific solvents and pesticides [37], and this hearing loss increases with age. A high prevalence of NIHL, as indicated by Ref. [38], is not the result of presbycusis, and this highlights the need to begin to prevent hearing loss among farmers at a young age. Another study [39] showed that for 25 adolescents from rural areas, 44% of the mean daily noise exposures were higher than the NIOSH recommended exposure levels (REL) of 85 dB(A), while 18% of the 71 daily noise exposure measurements exceeded 90 dB(A). Another study from Humann et al. [40], conducted separately for men and women in a large sample of more than 1500 participants, reported that short-term exposures from hunting and pneumatic tools should also be considered and assessed along with long-term common activities, given that exposure to noise from such activities was common between both farmers and rural residents; at the same time, the study showed the need for more precise analysis of NIHL in women, since performing the same activity might differ in duration. Specific research has also been performed on particular agricultural activities. For cotton gins, it has been estimated that 7 to 8 weeks of acute noise exposure with 10 months of respite from exposure can lead to NIHL during a working lifetime [41]. Another recent study [42] focused on the effects of both noise and pesticide exposure, finding that insecticides and noise exposure could separately affect hearing thresholds for high frequency sound bands or may have an additive effect, causing an increase in the risk of NIHL.

2.3. Noise Risk Prevention and Control

Analyses on noise exposures and effects provide a well-defined background for better risk prevention and control. Given the context, hazard elimination is not a viable solution: actions can aim to optimize vehicle engines and openings in cabs [43] or reduce noise emissions in cabins [44][45]. Regarding self-propelled harvesters [46] it should also be noted that noise issue related to pressurised air or vacuum systems also need to be tacked at design stage. In some cases, like in tasks

involving chainsaws, short breaks and better equipment that provide enough protection to the harvesting operators are required [47]. Better designs can also lead to an easier identification of noise sources and thus reduce workers' exposure, especially by models that allow the definition of noise source indices [48] or by studying suppression effects for workers exposed to noise [49] since transient Evoked Otoacoustic Emissions (EOAE) and Distortion Product Otoacoustic Emissions (DPOAE) examinations can be used as early identification of hearing damage.

Specific measures for mitigating noise risks also rely on HPDs and health programs or screenings. These aspects will be analysed in the following subsections.

2.3.1. HPD, Sensors and Other Detection Devices

Workers' behaviours are an important aspect in agricultural noise management, since proper education and training that aim to list the benefits provided by HPD can increase workers' willingness in wearing them: this approach can lead to better results, compared to mandatory requirements requested by laws or employers [50] and can also be promoted in schools or by adding training on farm noise for rural youth to other training courses that involve noise protections such as firearm training sessions. Randomized trials about the use of HPD and their effects [51] have also been proposed through the definition of test protocols, and the feasibility of hearing health education embedded in other already-existing and all-inclusive safety education programs has also been demonstrated to work out well as a booster intervention since it increased the chances of behaviour changes in wearing HPDs [52].

From medical point of view, sensors can be deployed to analyse in real time the difference in cardiovascular performances while workers are exposed to tractor noise at various engine speeds [53] or, for instance, evaluate how the operating conditions of different agricultural activities affect the main psychoacoustic parameters, namely loudness, sharpness, roughness, and fluctuation strength [54].

2.3.2. Screening and Health Programs

Another well-known approach is based on exposure levels, but healthcare institutions play a key role in that sector since rural areas often have limited access to hearing healthcare facilities. In addition, some categories have different perceptions related to noise effects and hearing loss since they might tend to consider it as a consequence of their job that cannot be avoided. Low-cost hearing screening [55] that could rely on community-based organizations, surveys regarding farmers' beliefs on hearing loss mixed with noise assessments and educational sessions [56] and methods to predict hearing loss by assessing the expected number of hours of hazardous noise exposure [57] can be a valuable resource especially if they lead to a better description of the effect of particular activities especially in older people and in workers with a family history of hearing loss [58].

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