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Assessment of the Impact of Tractor Noise Exposure on Operators and Bystanders

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Abstract
Rising noise levels from agricultural machinery contributed to environmental and occupational health issues, adversely affecting machine operators. This study investigated the impact of noise on operators and bystanders during tillage operations. A field experiment covering 1.10703 acres of land was divided into three blocks, each with 9 subplots measuring 160 × 38 m, for a total of 27 treatments in a randomized complete block design (RCBD). The generated noise data were used to create noise distribution trends for different tractor speeds during ploughing, harrowing, and ridging operations. The findings showed that increasing tractor speed from 5 to 9 km/h raised noise levels from 54 to 83.3 dB, affecting individual performance and productivity. As recommended by NESREA in 2007, harrowing met the noise level of 70 dB, while ploughing and ridging were 83.3 dB. Regression analysis revealed strong correlations (r^2 = 0.8073–0.995) between setback distance and noise reduction. This study has shown that tractor operators may experience temporary hearing loss when leaving the work environment in addition to cognitive fatigue.

Keywords: *Agricultural machinery, noise exposure, setback distance, hearing impairment.*

1.0 Introduction

In the manufacturing industry, noise has a significant impact on human productivity due to prolonged exposure to high levels of noise, stimulating stress and fatigue. According to the National Institute for Occupational Safety and Health (NIOSH), continuous exposure to noise above the threshold of 85 dB can affect human performance, making it difficult to stay alert at work, where alertness is crucial to safety. Noise is a major environmental stressor that affects human comfort, health, and overall work performance. This stress can impair the function of key brain regions, such as the hippocampus, which is responsible for memory and learning [1]. [2] noted the negative impacts of noise on humans, which contribute to early signs of dementia and other cognitive disorders. The report from the World Health Organization (WHO) and the European Environmental Agency (EEA) states that noise exposure disrupts human mental health, posing a highly vulnerable risk of death [3, 4, 5].

In agricultural settings where machinery use is intensive, elevated noise levels increase the mental demands placed on operators and reduce operational efficiency, while long-term exposure poses significant health concerns [6]. Excessive noise can lead to mental fatigue, in which the brain becomes overwhelmed by associated tractor noise, delaying work. [7] The human auditory system is particularly sensitive to sounds in the higher-frequency range, in the sense that when above 20,000 Hz, and its vulnerability becomes more pronounced with age, especially among those aged 65 to 75. Extended high-frequency in early noise detection significantly damages the auditory system, particularly affecting outer hair cells, making hearing loss permanent [8, 9]. On the other hand, [10] explains that outer hair cells serve to boost sound signals in a way that depends on frequency and follows a compressive, nonlinear pattern, allowing a broad span of sound pressure levels to be represented by only slight movement of the inner hair cells. Once the hair cells are damaged, the healing process can be an age-long challenge or may never grow back. In addition to auditory deterioration, noise generated by tractors and other farm machinery disrupts task performance and negatively affects operators' well-being. Within tractor cabins, both airborne and structure-transmitted noise raises interior sound levels enough to compromise health and productivity, leading engineers to focus on improving cab soundproofing and noise-control designs [11].

Advances in agricultural machinery have helped lower the amount of noise operators perceive; however, the use of high-powered implements and engines operating at elevated speeds still makes hearing protection essential [12]. Factors such as gender and exposure duration also influence individuals' vulnerability to noise-related health problems [13]. To protect farm workers, ergonomic standards generally prescribe limits on exposure to risks such as noise, dust, vibration, and heat [14]. Farmers remain highly exposed because tractors, harvesters, grain dryers, and related equipment often generate sound levels that exceed recommended limits. [15] reported that roughly 360,000 agricultural workers in Japan suffered hearing losses greater than 40 dB at 4 kHz. Comparable trends have been documented in many other countries [16,17]. Although mitigating noise directly at the machine source is expensive, shielding operators through enclosed cabins or protective barriers has proven effective [18]. Operators working with tractors lacking factory-built cabins are typically exposed to prolonged hazardous noise, whereas

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properly installed cabins can lower sound levels by about 4–18 dB at higher frequencies [19]. In situations where noise cannot be adequately isolated, the use of personal protective equipment (PPE) is strongly advised. This study investigates the minimum safe setback distance needed to limit operators' exposure to the noise produced by tractors during tillage operations and its implications for worker health and efficiency.

2.0 Materials and Methods

2.1Experimental Site Description

The trial was carried out at the Rivers State University, Agricultural Research and Teaching Farm, Port Harcourt, Nigeria, within a geographical reference of latitude 4°54'32"N and longitude 7°2'20"E (Figure 1). The study site hosts a wide range of experimental agricultural activities, including crop and livestock production with an annual rainfall of 2,310.9 mm, a mean daily maximum temperature of 32 °C, a minimum of 23 °C, and an average relative humidity of 85% [20]. The Ambient noise levels at the site are typically 45–55 dB, though airplane movements occasionally raise levels significantly around the study area.

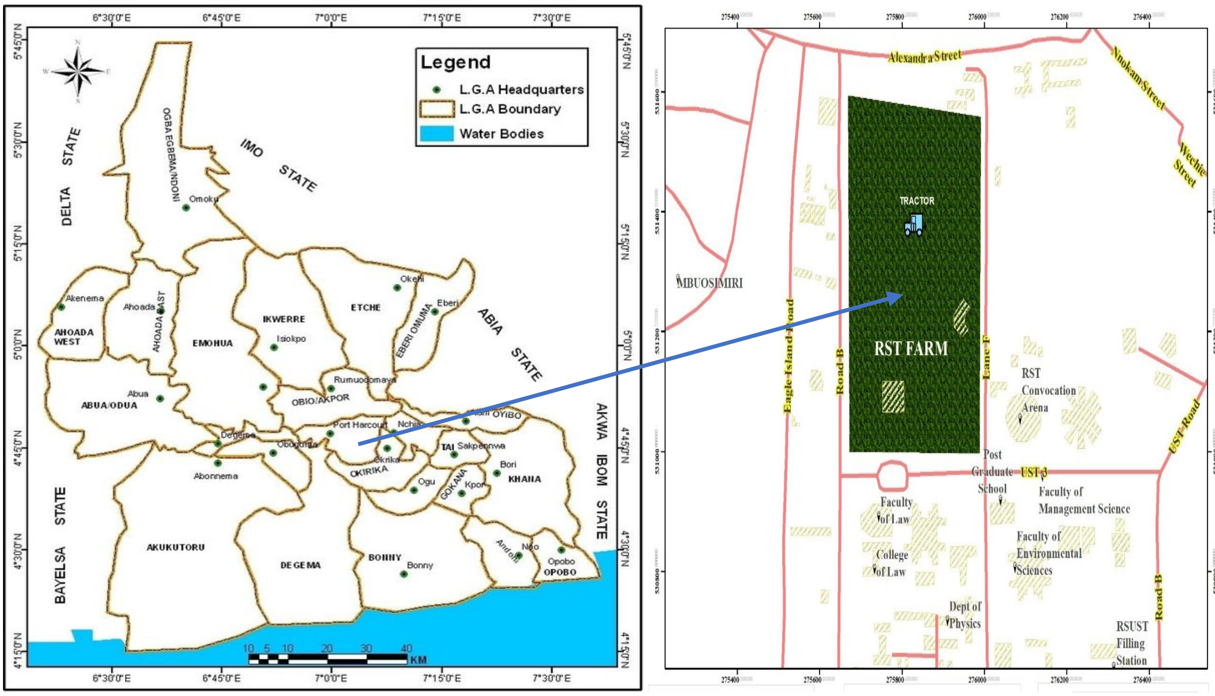

Figure 1: Map of the Experimental Site of Rivers State University Research Farm

2.1.2 Materials and Equipment used for the Experiment

A Swaraj 978 FE tractor, which has been in continuous service for over 15 years at the Agricultural Research and Teaching Farm, was used in the field experiment. The tractor was operated under standard working conditions and paired with the required implements. Detailed specifications of the tractor and associated equipment are provided in Tables 1 and 2.

Table 1: Equipment and its Specifications

Description	Implement Specifications		
	Plough	Harrow	Ridge
Number of Disc	3	14	4
Working Depth (mm)	300	160	330
Frame Width (mm)	1180	1390	2525
Width of Cut (mm)	1120	1150	1320
Disc Diameter (mm)	660	600	660

Table 2: Tractor Specifications

Model	Swaraj 978 FE
Drive	2 Wheel drive
Engine Horse Power	72 hp
Lifting Power	2200 kg
Hitch	3-point CAT III
Front Tyres	7.5 – 16, 8-ply

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Rear Tyres	16.9 – 28, 12-ply
Width	2030 mm
Weight	3050 kg
Manufacturer	Swaraj

2.1.3 Experimental Design and Noise Sampling Procedure

A 3 × 3 factorial arrangement in an RCBD was employed to assess noise levels across three tractor speeds (5, 7, and 9 km/h) and three setback distances (5, 10, and 15 m) of ploughing, harrowing, and ridging as discussed [21]. Each of the 27 treatments was replicated three times, and subplots were measured at 160 × 38 m separated by 1 m paths. Ambient levels were recorded before each session.

2. 1.4 Noise sampling

Noise measurements were carried out downwind from an uncontrolled sound source during field operations at specified speeds (5, 7, and 9 km/h) and setbacks (5, 10, and 15 m). The measurement location was selected on the south-north side of the sound source to measure the propagation effects in the downward refracting direction of the tractor, and readings were taken at arm's length using the device's microphone. The device conforms to the international electro technical commission IEC 61672-1: 2013. A calibration check was done on the sound level meter before and after use to avoid interference.

2.1.5 Statistical Analysis

Data were analyzed using ANOVA at 5% and 1% significance levels, and regression models were developed to quantify the relationship between tractor speed, setback, and noise intensity.

3.0 Results and Discussion

3.1 Tillage Operations and Noise Level

Figures 2 - 4 illustrates the relationship between tractor operational speed, setback distance, and induced noise levels during ploughing. In all measured distances, noise levels increased with the forward speed. At 5 km/h, the recorded noise levels were 71.3 dB at 5 m and 70.9 dB at 10 m, decreasing to 54.0 dB at 15 m. This trend is consistent with the findings of [21], who reported that tractor noise increases significantly with speed but attenuates with increasing distance due to acoustic dissipation in open-field conditions. With an increased speed of 7 km/h, the noise level rose to 79.0 dB at 5 m and 74.1 dB at 10 m, before declining to 67.5 dB at 15 m. The highest induced noise occurred at 9 km/h, reaching 81.7 dB at 5 m and 78.2 dB at 10 m. These results demonstrate that both tractor speed and proximity to the source are critical determinants of noise exposure. The observed reduction in noise with increasing setback distance revealed that spatial separation as a mitigation strategy in the report [22] emphasized the role of distance in maintaining safe exposure limits.

In comparison with other tillage operations, harrowing produced relatively lower noise levels, ranging from 70 – 71 dB at 10-15 m setback, whereas ridging generated the highest peak value of 83.3 dB at 5 m. Notwithstanding the general decline in noise levels with increased distance across all operations, several measurements at 15 m remained above the recommended limits of 70 dB as reported [23, 24]. These findings align with [25], which noted that tractor noise is strongly influenced by engine speed. However, prolonged exposure to elevated noise in agricultural environments may adversely affect workers' concentration, precision, and productivity, particularly during planting and seeding, which require sustained attention. The percentage error bars indicate increased engine vibration at higher speeds and measurable reductions in operational efficiency. This study revealed the implications for operator safety, regulatory compliance, and the need to implement effective noise control strategies in mechanized agricultural systems.

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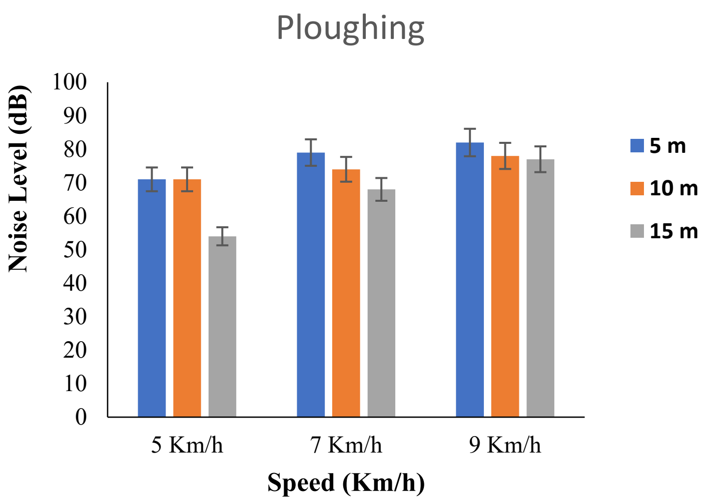

Figure 2: Tractor Speed and Noise Level during Ploughing

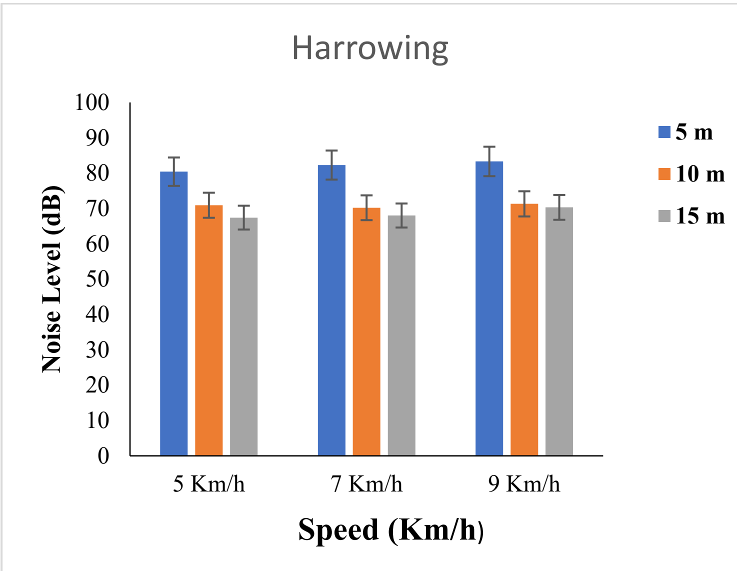

Figure 3: Tractor Speed and Noise Level during Harrowing

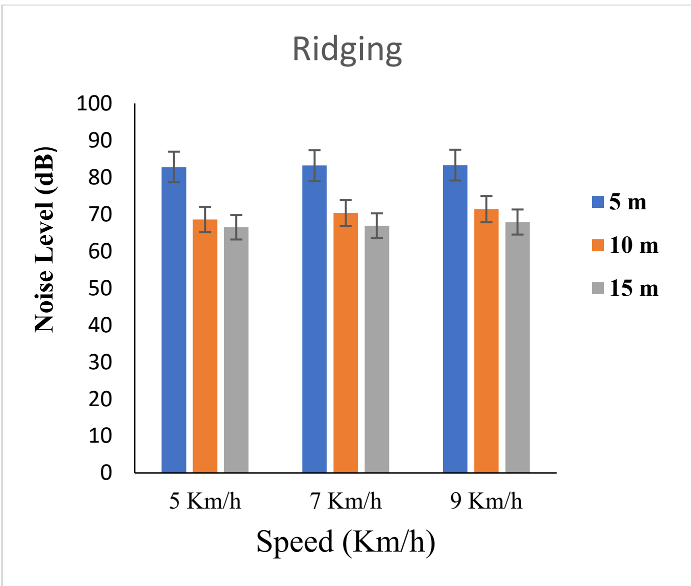

Figure 4: Tractor Speed and Noise Level during Ridging

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3.1.2 Setback Effects

Figures 5-7 showed the regression analysis with correlations between setback and noise levels (r^2 values: ploughing 0.9285 –0.995, harrowing 0.8073–0.9337, ridging 0.8929–0.9735). The strength of the relationship depends on speed, with high-speed operations producing persistent noise that attenuates less effectively. Tables 3 -5 show ANOVA results indicating that the combined effect of setback and speed does not significantly affect the noise level at both the 5% and 1% significance levels. Similarly, tractor noise and setback distance were below the thresholds, confirming the absence of a significant main effect on speed.

Table 3: Anova of 3 x 3 Factorial Experiment in RCBD during Ploughing

Sources of Variation	**Degree of Freedom (df)**	**Sum of Squares (SS)**	**Mean Squares (MS)**	**Computed F**	**Tabular F 5%**	**1%**
Setback, S	2	19693.99	9846.993	0.643331 ns	6.23	3.63
Speed, V	2	19473.43	9736.713	0.636126 ns	6.23	3.63
S x V	4	92713.96	23178.49	1.514313 ns	4.77	3.01
Error	8	244900.3496	15306.27			
Total	26	272152.4163				

ns= no significant

Table 4: Anova of 3 x 3 Factorial Experiment in RCBD during Harrowing

Sources of Variation	**Degree of Freedom (df)**	**Sum of Squares (SS)**	**Mean Squares (MS)**	**Computed F**	**Tabular F 5%**	**1%**
Setback, S	2	15574	7787.001	0.49457 ns	6.23	3.63
Speed, V	2	15353.44	7676.721	0.487566 ns	6.23	3.63
S x V	4	104698.3	26174.57	1.662406 ns	4.77	3.01
Error	8	251919.9	15744.99			
Total	26	279265.4485				

ns= no significant

Table 5: Anova of 3 x 3 Factorial Experiment in RCBD during Ridging

Sources of Variation	**Degree of Freedom (df)**	**Sum of Squares (SS)**	**Mean Squares (MS)**	**Computed F**	**Tabular F 5%**	**1%**
Setback, S	2	16385.32	8192.658	0.521616 ns	6.23	3.63
Speed, V	2	16164.76	8082.378	0.514595 ns	6.23	3.63
S x V	4	102520.4	25630.1	1.631837 ns	4.77	3.01
Error	8	251300.6142	15706.29			
Total	26	278411.0163				

ns= no significant

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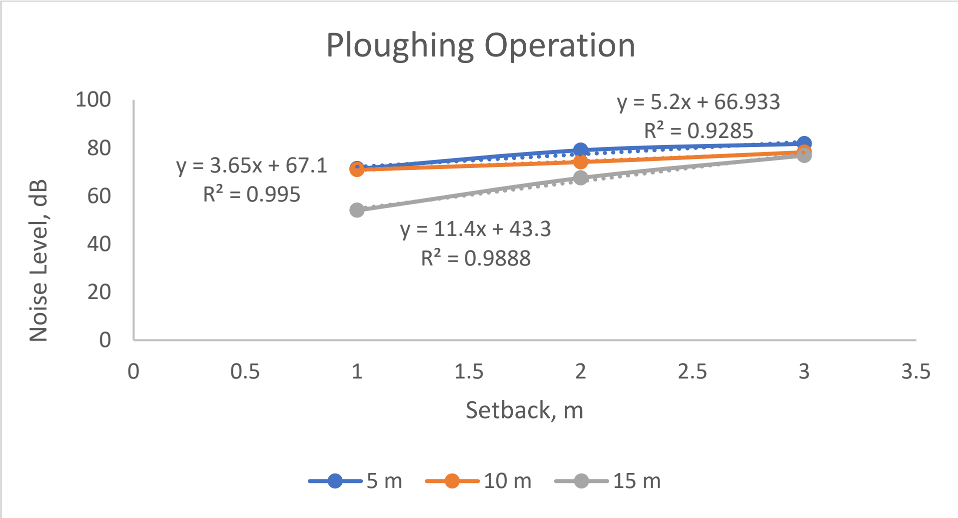

Figure 5: Setback Minimum Noise Level at Different Tractor Forward Speed during Ploughing

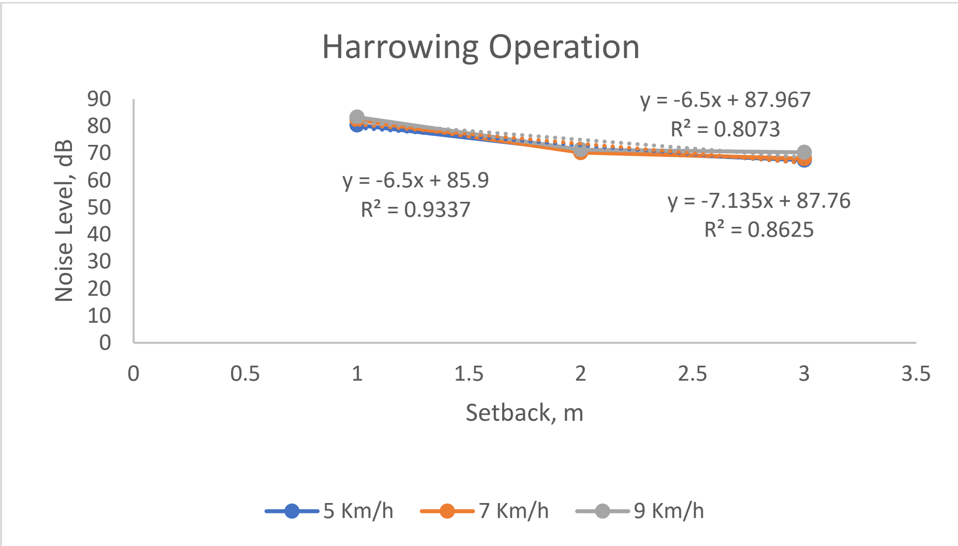

Figure 6: Setback Minimum Noise Level at Different Tractor Forward Speed during Harrowing

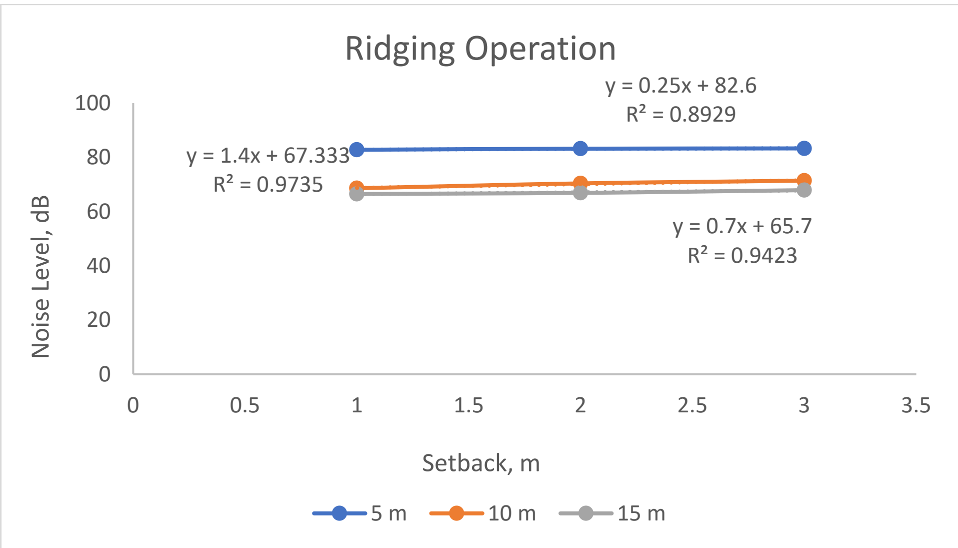

Figure 7: Setback Minimum Noise Level at Different Tractor Forward Speed during Ridging

4.0 Conclusion

This study highlights tractor speeds and the setback distances that significantly impaired humans during tillage operations. Tractor forward speed between 5–9 km/h raised noise levels to 83.3 dB, surpassing OSHA, NESREA, and WHO exposure thresholds. Noise intensity decreased with increasing setback, but safe exposure was not consistently achieved at distances below 20 m. Effective noise-management strategies and setback distances are crucial to protect workers from hearing impairment and mental fatigue.

The following recommendations were made:

i. Operators and assistants should maintain a minimum setback of 20 m.
ii. Tractors should be fitted with noise-reducing cabins where possible.
iii. PPE such as earmuffs should be used during prolonged exposure.
iv. Policy makers should enforce noise monitoring as part of occupational safety in agricultural operations.

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