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Noise Level Assessment of Tractors in Operation: A Smart Approach to Tillage Activities

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Abstract- Tractor operations during tillage are a major source of occupational noise exposure in agriculture, posing significant risks to operators' hearing health and wellbeing. This study uses smart monitoring system in analyzing tractor noise levels during tillage operations. Real-time noise measurements were collected from an experimental field measuring 160 m × 38 m (4,480 m²), divided into three blocks with nine subplots at the implement-soil interaction zones. Noise data was acquired using a wireless sound level meter and an iPhone 15 Pro Max. High-resolution noise maps were generated using ArcGIS 10.3.1 (ESRI, USA) with the Inverse Distance Weighting (IDW) interpolation method, providing detailed spatial noise distribution. During tillage operations (ploughing, harrowing, and ridging), the tractor operator maintained forward speeds of 5, 7, and 9 km/h to assess noise variations. The results indicate that engine speed and implement dynamics are the dominant noise contributors with levels 71.30 dB, 79.00 dB, and 81.70 dB at a speed of 5, 7 and 9 km/h, were within the Global standard for safe noise exposure limits to protect workers, but higher than NESREA (2009) recommended noise limits. At setback distances of 5 m, 10 m, and 15 m, the noise levels decreased from 71.30 dB to 70.9 dB and finally to 54.00 dB. This indicates that the noise on farm personnel becomes harmless at a distance of 15 m and beyond. The noise maps developed for the different tillage operations illustrate how noise levels vary with setback distance. As the distance increases, noise levels decline across all tractor speeds, supported by high coefficients of determination (R^2) ranging from 0.77 for ploughing to 0.93 for both harrowing and ridging operations. This study demonstrates that smart noise monitoring systems can improve safety, reduce hearing risks, and ensure compliance with noise regulations in mechanized agriculture.

Index Terms- Tillage Operation, Noise Assessment, Setback Distance, Noise Mapping, Smart Monitoring

I. INTRODUCTION

Noise pollution in man-machine systems is a growing concern, particularly in agricultural mechanization, where the demand for increased food production has intensified the use of farm machinery [1]. Tractors, as the cornerstone of mechanized farming, generate significant noise during tillage operations, posing health risks to operators and nearby personnel. Prolonged exposure to such noise can lead to hearing impairment, cardiovascular diseases, sleep disturbances, and behavioral changes [2]. Additionally, noise pollution disrupts social interactions, reduces productivity, and diminishes overall quality of life [3][4]. Studies indicate that occupational noise exposure elevates physiological stress markers, including blood pressure, lipid levels, and cortisol secretion, mirroring the effects of chronic stress [5]. Despite regulatory efforts, noise control remains a challenge, particularly in agricultural settings. In Nigeria, the permissible noise restrictions for residential and industrial zones are 55–60 dBA during the day and 45–50 dBA at night, according to the National Environmental Standards and Regulations Enforcement Agency [6] aligning with WHO guidelines. During field operations tractor drivers often exceed these thresholds, necessitating measures to mitigate noise exposure. The tractor stands as the cornerstone of modern agriculture, driving efficiency, productivity, and scalability in farming operations. As the primary workhorse of mechanized farming, the performance indices are enormous ranging from ploughing and planting to hauling and powering implements that enable farmers cultivate larger areas seamlessly. However, along with its indispensable utility comes the challenge of noise which affects operator comfort, environmental impact, and compliance with regulatory standards. Notably, the sources of noise emanated from the mechanical movement of piston and valves under high load or high-speed operations with gear whine from transmission and pump system, hydraulic system, and implement hitched to the tractor contribute significantly to the overall noise levels. Tractor noise levels vary depending on the model, age of tractor, engine speed, and operational conditions which can significantly impact agricultural workers [7]. Studies on noise emissions from tractor exhaust outlet position with and without implement hitched has been conducted on three different agricultural tractors with results indicating high noise level exceeding the regulatory threshold with intense discomfort to operators amount to 91.7 dBA, whereas the bystanders experience minimal noise level of 67.7 dBA due to dense vegetation in an open space [8] [9].

The excessive tractor noise during tillage operations on the farm has turned into an environmental issue resulting to the possible health effects on staff. In order to establish safe setback distances for staff, this study sought to evaluate the propagation of noise during tillage activities (ploughing, and harrowing, ridging) and to develop noise maps. The smart assessment of tractor noise levels during tillage operations leverages on advanced devices like the iPhone 15 Pro Max and a professional-grade noise meter to deliver precise, real-time acoustic monitoring with computational capabilities. The iPhone's high-fidelity microphones array, combined with AI-powered noise filtering, GPS tagging maps and data logging indicates noise hotspots to specific field zones with precise sound measurements. The Type 2 sound level meter provide industrial-grade precision with real-time visualization and threshold alerts which comply with occupational safety standard (OSHA, ISO). Together, these devices enable dual-sensor validation, automated reporting, and predictive maintenance insights by detecting abnormal noise patterns that may indicate mechanical wear. This integrated smart approach may not only enhance operator safety but also optimizes tractor performance through IoT-enabled precision farming protocols, surpassing traditional manual logging in speed, reliability, and actionable insights.

The specific objective is to evaluate noise levels at varying tractor speeds (5, 7, and 9 km/h) and distances (5, 10, and 15 m) to establish operational safety guidelines. The choice of specific interval for variations in speed (s) and distances (d) is based on real-world operational considerations which provides a balance range (low, medium, high) with tractor operating speeds of 5 km/h represent slow-speed, 7 km/h represent medium-range speed, and 9 km/h represent high speed used to analyze the trends. Meanwhile, the worker exposure zones of 5 m represent close proximity, 10 m represent intermediate distance and 15 m represent farther away to bystanders or workers at the edge of the field.

II. MATERIALS AND METHODS

2.1 Experimental Setup

The experimental plot of 160 m × 32.5 m (5,200 m²) using a Swaraj 978 FE tractor equipped with a disc plough, harrow, and ridger Tables 1 and 2. Noise levels were measured by placing an iPhone at different setback distances with a calibrated sound level meter (IEC 61672-1:2013 compliant) and a Garmin 76 CX GPS for geospatial data collection.

Table 1: Tractor Specifications

Parameter	Description
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
Rear tyres	16.9 - 28,12 - ply
Width	2030 mm
Weight	3050 kg
Manufacturer	Swaraj, India.

Table 2: Implement Specifications

Parameter	Plough	Harrow	Ridge
Number of Disc	3	14	4
Working Depth (330)	300	160	330
Frame Width (mm)	1180	1390	2525
Width of Cut (mm)	1120	1150	1320
Disc Diameter (mm)	660	600	660
Manufacturer	Swaraj	Swaraj	Baldan Implementos Agricolas

2.1.2 Experimental Procedures and Noise Meter Sampling

The sampling points' geo-coordinates (north and east directions), were obtained using a Garmin 76 CX global positioning system (GPS). Sound levels during ploughing, harrowing, and ridging operations were measured using an iPhone equipped with a sound level meter compliant with the International Electrotechnical Commission (IEC) 61672-1:2013 standards. Prior to and after each use, the device was calibrated to ensure accuracy and minimize interference. Measurements were taken at varying tractor speeds and setback distances (5, 10, and 15 m). The iPhone was held at arm's length (4 cm from the tractor) with the bottom microphone directed toward the sound source away from the tractor.

2.1.3 Experimental Design

A 3 X 3 factorial design was employed by evaluating three speeds (5, 7, 9 km/h) and three setback distances (5, 10, 15 m) in randomized complete block design (RCBD) with three replicates (27 treatments) to evaluate the noise levels during ploughing, harrowing and ridging operations Table 3. Randomization was achieved using draw lots approach on three blocks of nine subplots, totaling 160 m x 32.5 m (5200 m^2) of experimental land. To offer several treatment possibilities, each subplot was marked 50 m x 2.5 m with a dimension of 1 m between each plot.

Table 3: Layout of the 3 X 3 Factorial Treatment Combinations of Three Speeds and Three Setback Distances

	Factorial Treatment Combinations								
Treatment		S_1		S_2			S_3		
d_1	S_1d_1	S_1d_1	S_1d_1	S_2d_1	S_2d_1	S_2d_1	S_3d_1	S_3d_1	S_2d_1
d_2	S_1d_2	S_1d_2	S_1d_2	S_2d_2	S_2d_2	S_2d_2	S_3d_2	S_3d_2	S_2d_2
d_3	S_1d_3	S_1d_3	S_1d_3	S_2d_3	S_2d_3	S_2d_3	S_3d_3	S_3d_3	S_2d_3

Note: Three replications of 27 treatments (S_1d_1, S_2d_1, S_3d_1, S_1d_2, S_2d_2, S_2d_2, S_1d_3, S_2d_3 and S_3d_3), S = speed, d = distance

S_1d_1: 5 m setback at speed of 5 km/h for ploughing, harrowing and ridging

S_1d_2: 10 m setback at speed of 5 km/h for ploughing, harrowing and ridging

S_1d_3: 15 m setback at speed of 5 km/h for ploughing, harrowing and ridging

S_2d_1: 5 m setback at speed of 7 km/h for ploughing, harrowing and ridging

S_2d_2: 10 m setback at speed of 7 km/h for ploughing, harrowing and ridging

S_2d_3: 15 m setback at speed of 7 km/h for ploughing, harrowing and ridging

S_3d_1: 5 m setback at speed of 9 km/h for ploughing, harrowing and ridging

S_3d_2: 10 m setback at speed of 9 km/h for ploughing, harrowing and ridging

S_3d_3: 15 m setback at speed of 9 km/h for ploughing, harrowing and ridging

2.3 Assessment of Noise Level

The tractor was warmed to normal operating temperature prior to the measurements. The noise meter and the iPhone with the noise app installed were placed 5, 10, and 15 meters away, respectively, while the tractor was operating. The readings were taken during the tillage operations at different speeds with varying distances from the tractor.

2.3.1 Setbacks Distance

During ploughing, harrowing and ridging operations, the operating setbacks were determined by setting the measuring instrument at specific level corresponding to the desired setback distance. The setbacks were fixed as 5, 10, and 15 m, respectively using the metre placed from tillage point to the setbacks distance.

2.3.2 Tractor Speed

In order to achieve the necessary tractor forward speed at a specific operating tillage depth that corresponded to the necessary parameters. The gear that was most suited for the desired operational speed of 5, 7, and 9 km/h during ploughing, harrowing, and ridging was accomplished either at full throttle or reduced throttle setting.

2.4 Noise Mapping
Nosie data were interpolated using inverse distance weighting (IDW) in ArcGIS 10.3.1 (ESRI Inc., USA) to generate spatial noise maps. The IDW methods was selected for its efficiency in handling unevenly distributed sampling points. From Literature, the reliability of experimental variograms, geo-statistical estimations of sampling location distributed in the regions of interest [10]. The geographic coordinates of the data points in decimal decrees were converted from geographic coordinate system to universal transverse Mercator UTM of Nigeria Mina Mid Belt national grid using ArcGIS software (pocket survey version 10.3.1). This software helps in converting from geographical coordinate system vice versa. The data was saved in, comma delimited format in Excel v 2016. The coordinates were imported into the ArcGIS 10.3.1 version environment. Shape files were created for digitization of road and important features. The Ikonos Imagery was deployed into the ArcGIS environment, which has a 0.2 m resolution. The rows were digitized and named by the help of the Ikonos Imagery.

2.5 Statistical Analysis
The linearized equations was used for tillage operations to determine the coefficient of determination among the different farming operations at different speed of travel expressed in equation 1-3

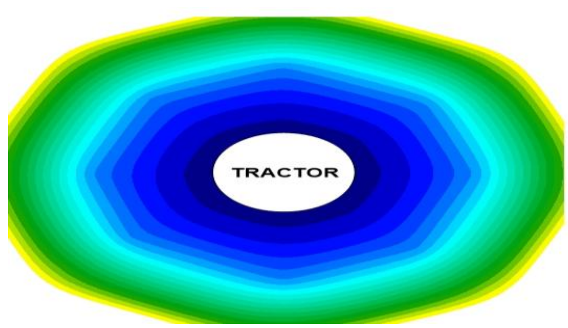
$Y = - 1.73x + 82.7$ (5 km/h, speed) (1)
$Y = - 1.15x + 85.03$ (7 km/h, speed)
$Y = - 0.49x + 83.80$ (9 km/h, speed)

For Harrowing
$Y = - 1.3x + 85.90$ (5 km/h, speed) (2)
$Y = - 1.43x + 87.76$ (7 km/h, speed)
$Y = - 1.3x + 87.97$ (9 km/h, speed)

For Riging
$Y = - 1.63x + 88.93$ (5 km/h, speed) (3)
$Y = - 1.63x + 89.80$ (7 km/h, speed)
$Y = - 1.54x + 87.97$ (9 km/h, speed)

III. RESULTS AND DISCUSSION

3.1 The Developed Noise Maps for the different Scenarios
The tractor speed was controlled and maintained at a constant 5 km/h during ploughing, harrowing, and ridging operations to ensure consistent noise measurements. Noise levels were recorded at setback distances of 5, 10, and 15 meters, revealing higher noise at closer proximity. This standardized speed allowed for accurate noise mapping, showing variations across operations while keeping engine and implement noise generation consistent for comparison. Noise map was developed on the experimental plot using different setback distance to measure noise levels based on the tractor forward speed. Three different operations ploughing, harrowing and ridging with their respective noise mapping were carried out in this study. Twenty classes were used for the map with identical class intervals to delineate the noise levels into distances. During ploughing the generated noise pollution level 78.20 and 76.80 dBA at 10 and 15 m distance measured rank the highest among harrowing and ridging operations. Fig 1 shows the tractor forward speed of 5 km/h with setbacks distances of 5, 10, and 15 m, noise mapping on the contour lines during ploughing operation range from 52 – 71 dBA which implies that noise level decreases as setback distances decreases from 15 to 5 m. These distances have different colour ramps which states the intensity of the different noise levels with 71 dB indicating darkest blue as the highest noise level and 52 dBA yellow with least noise level. Fig 2 shows eighteen classes used to delineate the noise levels into distances using tractor forward speed of 5 km/h during harrowing. These distances have different colour ramps of white to blue with noise levels 62 to 78 dBA as the setback's distances decreases from 15 to 5 m.



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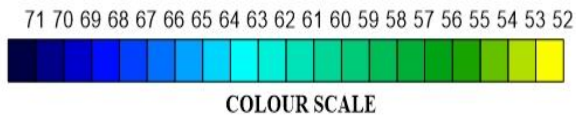

Fig 1: Noise Map Showing Contour Lines at Setbacks of 5, 10, and 15 Meters using 5 km Tractor Forward Speed during Ploughing

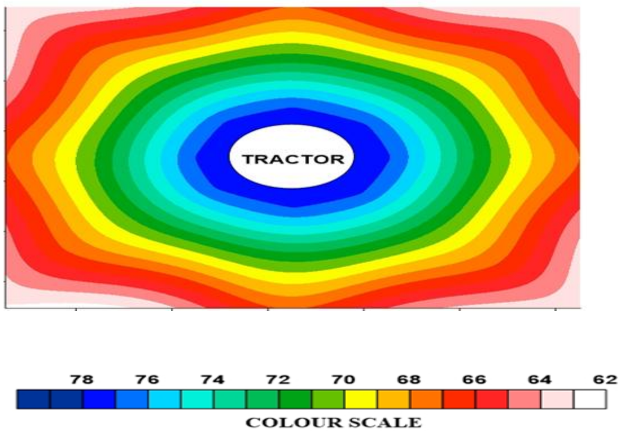

Fig 2 Noise Map Showing Contour Lines at Setbacks of 5, 10, and 15 Meters using 5 km Tractor Speed during Harrowing

Fig 3 illustrates the full-data point IDW noise map during ridging operation at setbacks of 5, 10, and 15 m using tractor forward speed of 5 km/h. The noise levels range between 61 – 79 dB which implies that the noise values increase from 61 to 79 dBA as the setback's distances decrease from 15 to 5 m. This can be inferred that the closer the personnel to the tractor the higher the noise effect from light green to the darkest blue of 79 dBA on the map posing high-risk point. This is above the exposure limits as contained in [6] for industrial area. However, the noise impact was within the acceptable threshold for field operation as documented [11]. The recommendations and guidelines [12]. The noise generated during harrowing and ridging were higher than ploughing. This could be connected to the width of operation, age, non-regular maintenance, loosed and wobbling parts contributing to noise generation during operation. This study aligns with [13] report on implements attached to tractors during tillage operations which generate high noise level of 80 to 150 dBA depending on the activity of the equipment engaged. The primary functions of ploughing and harrowing are to break compacted layers of soil for crop productivity and sustainable land management. A greater pull is required during ploughing than harrowing and ridging when the soil is already loosened [14]. [1] investigated twenty classes used to delineate the noise levels into distances with different colour gradient visually represents noise decay with increasing setback distance.

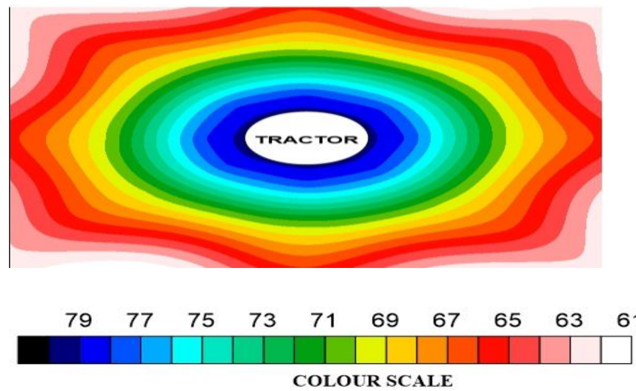

Fig 3. Noise Map Showing Contour Lines at Setbacks of 5, 10, and 15 Meters using 5 km Tractor Speed during Ridging

3.1.2 Tractor Forward of 7 km/h

Fig 4 shows the full-data point IDW noise map during ploughing operation at setbacks of 5, 10, and 15 m using tractor forward speed of 7 km/h. The noise levels increase from 60 – 78 dB as the setback's distances decrease from 15 to 5 m, the noise decreases. The nineteen classes were used to delineate the noise levels into distances with different colour ramps demonstrating the intensity of noise level with ploughing implement. Tractor forward speed of 7 km had the noise level 78 dB with the darkest blue highlighting high-risk point and light green the least noise level. Even with the least noise level with setback distances of 5 m is above the permissible limit according [6] for industrial area. Fig 5 shows the eighteen classes used to delineate the noise levels into setback distances 5, 10, and 15 m using tractor forward speed of 7 km/h. These distances have different colour ramps that range between 63 – 79 dB where the darkest blue is the least noise level and light purple is highest noise level 79 dB with high-risk point. Fig 6 shows twenty-one classes used to delineate the noise levels into distances with different colour ramps where light blue is the highest noise level 81 dB on the map is the high-risk point above the guidelines of [12] the light

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green is least noise level 61 dB. Tractor noise level decreases as the setback's distances decrease from 15 to 5 m

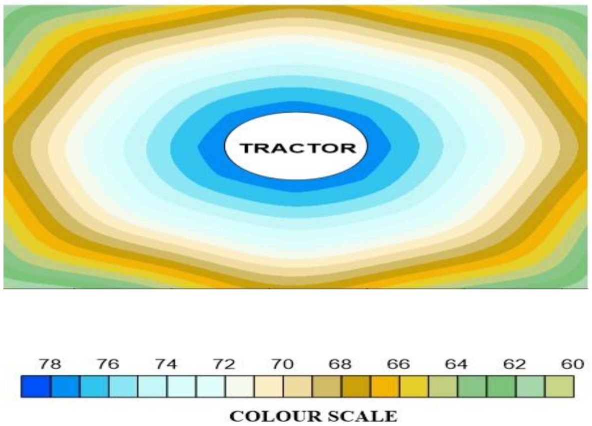

Fig 4: Noise Map Showing Contour Lines at Setbacks of 5, 10, and 15 Meters using 7 km Tractor Speed during Ploughing

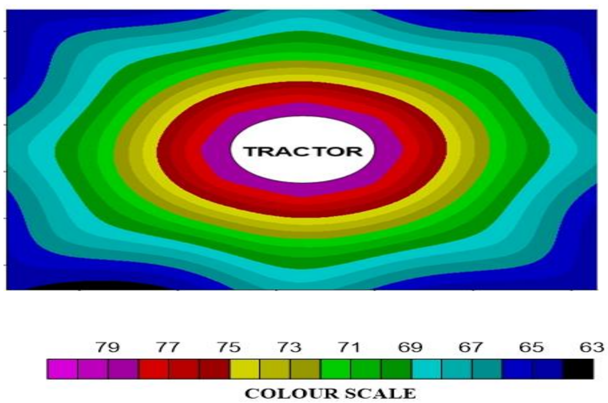

Fig 5: Noise Map Showing Contour Lines at Setbacks of 5, 10, and 15 Meters using 7 km Tractor Speed during Harrowing

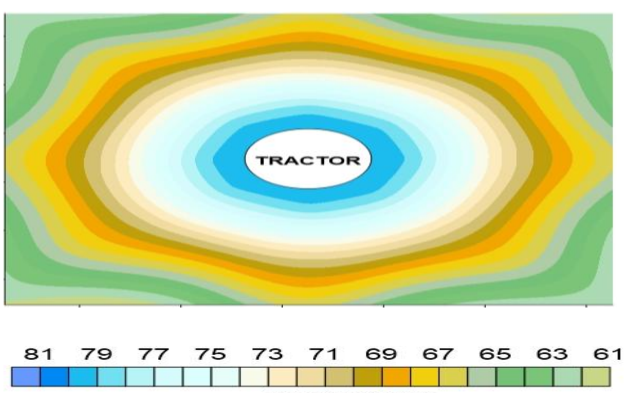

Fig 6: Noise Map Showing Contour Lines at Setbacks of 5, 10, and 15 Meters using 7 km Tractor Speed during Ridging

3.1.3 Tractor Forward of 9 km/h

Fig 7 shows different noise levels and setback distances range between 75 – 81 dB with thirteen classes in different colour ramps. These thirteen classes were used to delineate the noise levels into distances during ploughing at tractor forward speed of 9 km. The light blue with 75 dB indicates low noise level compare to the red colour with 81 dB with high risk above the permissible limit of [6] for industrial area. Fig 8 shows the noise levels with sixteen classes of different colour ramps which range between 66 – 80 dB at tractor forward speed of 9 km during harrowing operation. The tractor noise levels decreases as the setback's distances decrease from 15 to 5 m. This can be inferred that the closer the tractor the higher the noise and the range from light purple to red with 80 dB on the map pose high-risk. This is above the permissible limit according [6][12] for industrial area. Similarly, ridging operation with twenty classes demonstrated the noise levels between 62 – 80 dB with different colour ramps which implies that the noise values increase with tractor forward speed and decreases as the setback's distances from 15 to 5 m Fig 9. The closer the tractor the higher the noise (light purple colour ramps) with high-risk point and at setback distances of 5 m the less noise generated (dark blue) colour ramps.

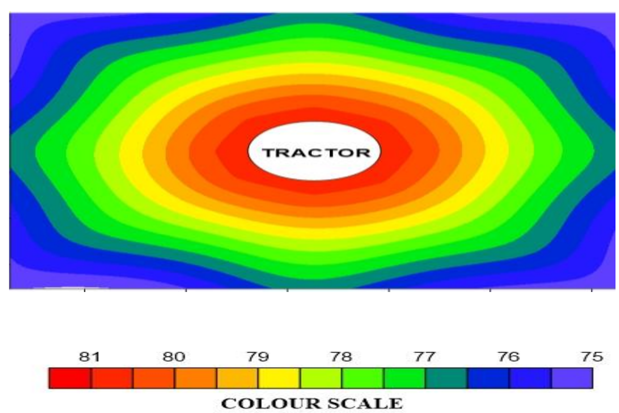

Fig 7: Noise Map Showing Contour Lines at Setbacks of 5, 10, and 15 Meters using 9 km Tractor Speed during Ploughing

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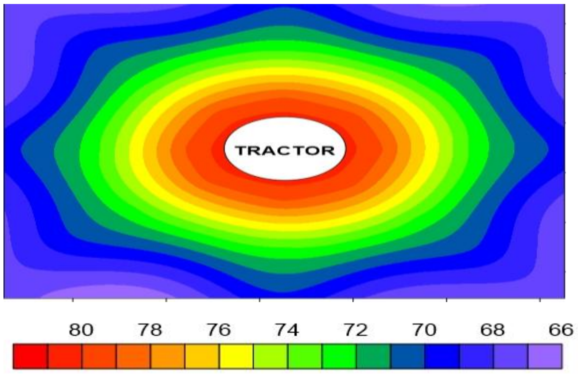

Fig 8: Noise Map Showing Contour Lines at Setbacks of 5, 10, and 15 Meters using 9 km Tractor Speed during Harrowing

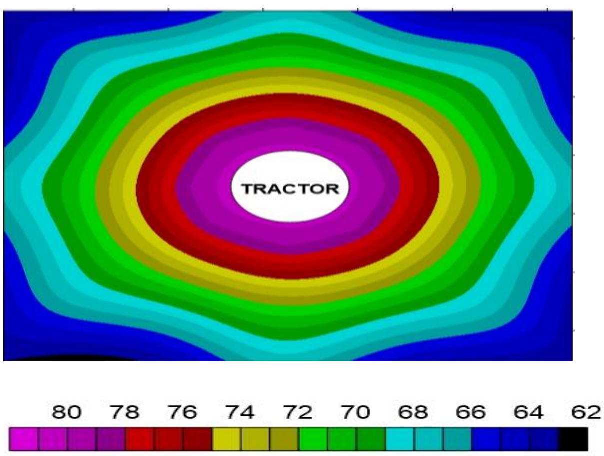

Fig 9: Noise Map Showing Contour Lines at Setbacks of 5, 10, and 15 Meters using 9km Tractor Speed during Ridging

3.2 Comparison of Setback Distance during Tillage Operations

The comparison between ploughing, harrowing and ridging with tractor forward speed of 5, 7, and 9 km/h with setback distance of 15 m using coefficient of determination (r^2) for ploughing 0.94, harrowing 0.81, and ridging 0.81 revealed that ploughing operations generate more noise as a result of greater pull on the implement while working on the compacted soil. The pulverized soil make harrowing and ridging operation seemless with less noise. The high r^2 value (0.94) for ploughing indicates noise levels decrease predictably with distance as the dominant factor in noise reduction for this high-resistance operation. The lower r^2 values (0.81) for harrowing and ridging showed noise reduction in less distance-dependent, suggesting implement dynamics and soil conditions play greater roles.

IV. CONCLUSION

This study evaluated the noise emissions from a Swaraj 978 FE tractor during three primary tillage operations (ploughing, harrowing, and ridging) on a 5,200 m^2 experimental plot using sound level meter and a smart device (iPhone 15 pro max) at varying distances (5, 10, and 15 m) and controlled tractor speeds (5, 7, and 9 km/h). The three different operations generate hazardous noise levels that exceed occupational safety thresholds, with ridging at maximum speed (9 km/h) and minimum distance (5 m) producing the most severe noise pollution at 81 dBA. Noise levels exhibited on experimental field showed inverse relationship with setback distance, decreasing significantly as distance increases, with ploughing showing the strongest correlation $r^2 = 0.94$. The operational characteristics significantly impact noise generation, with ploughing consistently producing higher noise levels 78 dBA than other operations due to greater soil resistance. Third, spatial analysis through IDW interpolation in ArcGIS clearly identifies high-risk zones within 10 m of operating machinery, particularly during high-speed operations. Currently, agricultural practices expose workers to dangerous noise levels that necessitate immediate intervention. These findings strongly support the development of specific noise regulations for agricultural operations to protect worker health and safety. These results prove ploughing requires strict distance-based noise control, while harrowing and ridging need additional mitigation measures like speed reduction and equipment maintenance.

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