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*Full Length Research Paper*

# The investigation of the ergonomic aspects of the noise caused by agricultural tractors used in Turkish forestry

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**Agricultural tractors in various types and dimensions are generally used in forest depots in Turkey for loading and stacking the forest products. In recent years, using machines for loading forest products has increased more and more due to the high productivity obtained from the machines and hardships in finding skilled workers. However, the risks accompanying these developments threaten the health of the operators working in loading machines. This study was applied on machines (145) working in loading and stacking operations in forest depots within the borders of the Western Black Sea Region. In the region, tractors on which loading equipment is mounted (85%) and original loading machines (15%) are used for loading and stacking operations. The average noise level that the operators were exposed to during the operations was above the hazard limit; for tractors without cabins on which the loading equipment is mounted, it was 93.5 dB (A) and with a noise level of 77.7 dB(A), it was below the warning limit for tractors with original cabins. In the operation, machines older than 20 years and/or machines with broken static and dynamic structures should be replaced. Instead of tractors with mounted loading equipment that are intensively used in the region and easily purchased due to their low cost, the use of original loading machines should be encouraged. In order to minimize the noise carried to the operators, the use of tractors with original cabins should be increased. While choosing places for forest depots, steeply sloped areas should be avoided, and the roughness of the ground should be reduced by covering the ground of existing depots with stabilized material.**

**Key words:** Ergonomics, forestry, loading tractors, noise.

## INTRODUCTION

Among the production stages of the raw wood material, loading and unloading are of great importance in terms of not only time and cost but also regular flow of transport works. Although a mechanized loading system has been largely adopted in today's forestry sector, no important study has been conducted on the issues of operator health and safety.

In ergonomic terms, a mechanized production system is composed of three components: human, machine, and medium. Physiological and psychological pressure exerted by the mechanization on humans should not be ignored when analyzing the mechanization process based on running costs and labor productivity. Occupational accidents and health damages can occur whenever the limits of human productivity are exceeded.

Exceeding these limits may also lead to failure to run the machines at full capacity, easy wearing of the machines, and in turn, accidents (Yildirim, 1988).

Noise is one of the important industrial and environmental problems of our time. Unless sufficient and effective measures are taken, the noises made by industrial machines may do serious harm to workers. Environmental noise affects humans both physically and psychologically (Durgut and Celen, 2004). The technical environment of the workplace should be adapted to humans' biological structure, natural tolerance limits and psychological as well as physiological reactions if the protection of employee health is desired as much as labor productivity (Gülcubuk, 1996).

The human ear tries to adapt any noise to a specific level. However, this adaptation is not enough to eliminate industrial noise. The studies conducted on this issue have shown that exposure to 85 dB(A) or a higher noise level for a long time results in hearing loss. Since the noises with a pressure level above 85 dB(A) have effects

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such as temporary and permanent hearing loss, the International Labor Organization (ILO) sets 85 dB(A) as the warning limit and 90 dB(A) as the hazard limit.

Arin and Çelen (1995) found that the noise measured at the ear level of drivers working with various tractor-mounted agricultural equipment stayed in the 92.47 - 100.14 dB(A) range. In the study conducted by Kamer (2005), the highest noise level was measured as 95.53 dB(A), on average, in plowing by open tractors and the lowest noise level was measured as 81.98 dB(A), on average, in drum moving by tractors that were originally open but were later mounted with cabs. A study carried out by Neitzel and Yost (2002) on forest workers in USA revealed that 46% of the workers were exposed to extremely high levels of noise. Among the machines the workers used, power saws, graders and loaders were found to produce the highest levels of noise.

The aim of this study was to perform an ergonomic analysis of the noise resulting from loading machines used in forestry activities in Turkey. In the study, the noise levels to which the operators were exposed while working with loading machines and the factors affecting these noise levels were determined via regression analysis. In conclusion, ergonomic suggestions are presented to decrease the noise level to which the operators are exposed while working with loading machines.

## MATERIALS AND METHODS

This study was conducted in the forest depots in the Western Black Sea Region, which is one of the regions of Turkey that is rich in forestry resources. The cluster sampling method was adopted in the selection of study fields, and the number of samples was kept high in the regions that have heavy forestry activities. On-site noise measurements were made during 2007 and 2008 when the operators were working with loading machines.

Measurements in the scope of the study were made when operators were working with International, Ford, John Deere and Massey Ferguson-brand agricultural tractors (on which loading equipment was mounted) and Komatsu and Hidromek-brand original loading machines (Figures 1, 2 and Table 1).

A TES 1353 noise measurement device was used in the study to measure the noise level to which the operator was exposed. The device is capable of recording measurements at 1.5 dB sensitivity level once every second and computerizing the data recorded by the RS232 outlet. Required evaluations can be made, and graphics can be drawn on the computer via the software belonging to the device. The noise measurement device was calibrated according to 104 dB(A) by using related equipment before the measurements.

The study tried to determine the noise levels to which the operators were exposed when working with the loading machines. Each time the noise measurement device was located in such a way as to ensure the noise measurement was as close to the operator's ear level as possible, and a minimum of 3 min measurements were made with 1 s recording intervals. Attention was paid to ensure that no other noise-making machine was working in the depot or the surrounding area during the measurements. With the help of the obtained data, descriptive statistical information of the noise measurements of all tractors (that is, cab-tractors and open-tractors) was provided. Then, it was determined whether the measured noise levels were above the 85 dB(A) warning limit or the 90 dB(A) hazard limit determined by the ILO for an 8 h working day. The difference between the mean noise levels of the cab-tractors and open-tractors was determined.

The study attempted to find important variables affecting the noise level to which the operators were exposed. In this scope, regression analysis was performed by designating the measured noise levels as the dependent variable and the variables listed below (thought to affect the noise level) as independent variables. Independent variables are listed as follows:

*Mt*: Machine type: Type of loading machine used (1: back shovel and 2: front loader).
*Md*: Machine use duration: The duration the loading machine has been used (year).
*Mc*: Machine-cab condition: Whether the tractor has a cab or not (1: no cab and 2: completely closed cab).
*Sd*: Seat use duration (year).
*Wf*: Front wheel pressure: Mean value of the front wheel pressure of the machines (psi).
*Wr*: Rear wheel pressure: Mean value of the rear wheel pressure of the machines (psi).
*Gt*: Ground type: Ground type of the study field (1: soil and 2: stabilized).
*Gr*: Ground roughness condition: 1: slightly rough, 2: mildly rough (There are 40 cm-roughs at 1.5 - 5 m intervals), and 3: quite rough (There are 60 cm or larger roughs at 1.5 - 5 m intervals).
*Gc*: Ground soil condition: Land condition according to soil characteristics (1: wet peat lands, 2: soft soil on a wet land, 3: soft soil on a dry land, 4: hard mineral soil, and 5: sandy-graveled soil on a dry land).
*Mv*: Machine's velocity: Velocity of the machine during measurements (km/hr)
*Ls*: Land slope: Mean slope of the study field (%).
*Oet*: Operator experience (year).
*Pt*: Professional training: Whether the operator was trained for the work he was performing (1: no training and 2: trained).
*Tp*: Temperature (°C).

## RESULTS

### Loading machines and their operating conditions

In the regions studied, the machines in the forest depots were used for 18 years, on average, with the seats being used for 5 years, on average. Front wheel pressure was calculated as 46.9 psi and rear wheel pressure as 29.7 psi. While the front wheel pressure value had to be 50 psi and rear wheel pressure had to be 20 psi, the rear wheel pressure was found to be 9.7 psi higher than the normal value. In the forest depots where the mean land slope was 3%, the mean machine feed rate was calculated as 5 km/h during work with the loading machines. Generally, the ground of the forest depots was soil, and the land was not covered with stabilized material. It was also found that loading was carried out on dry and soft soil, and the ground roughness was at mid-levels (40 cm-roughs at 1.5 - 5 m intervals).

### Noise measurements

The noise values to which the loading machine operators were exposed were recorded. Noise measurement

**Figure 1.** Loading equipment-mounted, open tractor.


**Figure 2.** Loading machine with original-cab.

information related to the noise that the operator of a 2007 model Massey Ferguson-brand tractor was exposed to during 11 min work is presented in Table 2.

As can be seen in Table 2, the operator of the loading machine was exposed to noise at the 85.4 - 104.7 dB(A) range for 11 min and 22 s. The equivalent noise level to which the operator was exposed was 92.9 dB(A). This value is above the 90 dB(A) hazard limit specified in the international standards.

The change every second in the noise level carried to the operator while working with the loading machine is presented in Figure 3. It is clearly shown in the figure that the operator was exposed to noise above the hazard limit during the majority of the working duration.

The general situation regarding noise levels is shown in Table 3. When all tractors were evaluated, it was seen that the mean equivalent noise levels were in the 76 - 105 dB (A) range, and the mean equivalent noise level was nearly 92 dB(A).

Table 3 shows that operators of loading-equipment-mounted, open tractors were exposed to higher noise levels than operators of the original cab-tractors. While the mean equivalent noise level of the original loading machines was 78 dB(A), it was found to be nearly 93 dB(A) for the loading-equipment-mounted, open tractors. The noise levels carried to the operators of the original cab-tractors were below the 85 dB(A) warning limit, and these noise levels were above the 90 dB(A) hazard

**Table 1.** Loading tractors using in the region.

| Machine type | Brand | Machine use ratio (%) | Average age |
|---|---|---|---|
| Loading equipment mounted | Massey Ferguson | 33 | 16 |
| | International | 29 | 26 |
| | Ford | 14 | 20 |
| | John Deere | 9 | 22 |
| Original | Komatsu | 5 | 5 |
| | Hidromek | 10 | 4 |

**Table 2.** Sample of noise measurement data.

| Measured data | Measurement values |
|---|---|
| Recording time (min: s) | 11:22 |
| Recording number (unit) | 681 |
| Equivalent noise (dB(A)) | 92.9 |
| Min value (dB(A)) | 85.3 |
| Max value (dB(A)) | 104.7 |

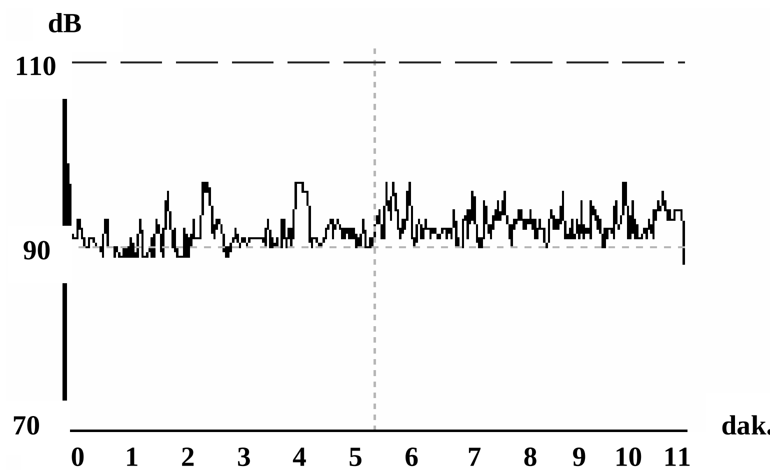


**Figure 3.** Noise levels of the operator is exposed to when working.

level for loading-equipment-mounted, open tractors.

The rates by which the measured noise levels exceeded the 85 dB(A) warning limit and the 90 dB(A) hazard limit are listed in Table 4. The rate of operators exposed to noises exceeding the 90 dB(A) hazard limit was found to be 45%. Only 15% of the operators were exposed to noise levels below the 85 dB(A) warning limit.

## Factors affecting noise level

Regression analysis was performed to determine the factors affecting the noise levels to which the operators were exposed. Noise level was classified as a dependent variable, and the variables related to the noise level were labeled as independent variables for the scope of the analysis.

The coefficient of determination ($r^2$) of the obtained model was calculated as 0.823 and its standard error as 2.63. The regression equation obtained at the end of the analysis by using eight variables is as follows:

$$Y = -215.265 + 8.999\,Mc - 6.761\,Mt + 0.398\,Sd + 1.278\,Gr + 0.151\,Md - 0.125\,Wr - 0.259\,Ls$$

The dependent variable of the “equivalent noise level” carried to the operators while working with loading machines ($Y$) was explained at an 82% rate and with a

**Table 3.** Average noise levels of loading machines (dB(A)).

| Loading machine | Mean | SD | Min | Max |
|---|---|---|---|---|
| All tractors | 91.80 | 6.10 | 75.60 | 105.00 |
| Loading equipment-mounted, open tractor | 93.45 | 3.88 | 83.50 | 105.00 |
| Original-cab tractor | 77.53 | 1.45 | 75.60 | 78.90 |

**Table 4.** Ratios in excess of noise warning and hazard limits.

| Noise level dB(A) | Rate (%) |
|---|---|
| < 85 | 15 |
| 85 - 90 | 40 |
| 90 - 100 | 30 |
| 100 < | 15 |

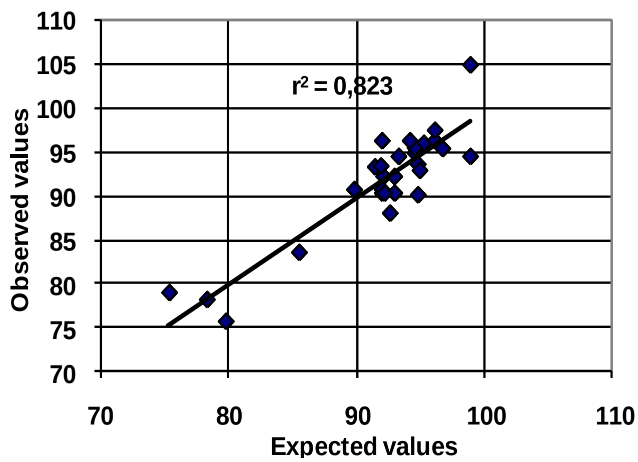


**Figure 4.** Regression analysis diagram of noise levels.

2.6 error margin by using the independent variables of machine-cab condition (*Mc*), machine type (*Mt*), seat use duration (*Sd*), ground roughness condition (*Gr*), machine use duration (*Md*), rear wheel pressure (*Wr*) and land slope (*Ls*).

An examination of the obtained model showed that the variable most affecting the noise level was whether the loading machine had an original cab (*Mk*). The regression analysis graphic for the obtained model is portrayed in Figure 4.

## DISCUSSION

While working with the loading machines, the lowest equivalent noise level was calculated as 76 dB(A) and the highest equivalent noise level as 105 dB(A) for all tractors. In a study conducted with forest workers in the USA, the source of the highest noise level was found to be power saws, road graders and loaders (Neitzel and Yost, 2002). The noise level varied but stayed in the 85 - 117 dB(A) range for tractors used in agriculture (Durgut and Celen, 2004). In a study on agricultural machines, Arin and Celen (1995) found that the noise level measured at the ear level of the driver while working with agricultural machines was in the 92.47 - 100.14 dB(A) range. As can be understood from these findings, loading machine operators are exposed to lower noise levels than the drivers of agricultural tractors.

The most ergonomic method to control the noise level in the tractors is to use an appropriate cab (Aybek and Sabanci, 1998). Cabs can decrease noise levels in tractors by 2 - 10 dB(A) (Tezer and Sabanci, 2005). The mean noise levels to which the operators of loading-equipment-mounted, open tractors were exposed were considerably higher (93.5 dB(A)) in comparison to the mean noise levels of operators of loading machines with original cabs (77.7 dB(A)). In the study conducted by Kamer (2005) on mechanized agricultural works, the highest noise level detected in open tractors was 95.53

dB(A) and the lowest noise level was 81.98 dB(A) in originally open tractors that were later mounted with cabs. Since noises with a pressure level above 85 dB(A) have effects such as temporary and permanent hearing loss, the International Labor Organization (ILO) set 85 dB(A) as the warning limit and 90 dB(A) as the hazard limit (Sümer et al., 1998). Operators of original cab-tractors were exposed to noises below the warning level and operators of loading-equipment-mounted, open tractors were exposed to noises above the hazard limit.

The hearing loss for tractor drivers is 12 dB (A) higher than for the average person, and hearing loss speed is higher (17.36 dB (A)) at younger ages (Sabanci et al., 1985). In India, an examination of the hearing loss of 100 people; 50 of whom drove tractors while the remaining 50 did not show that the tractor drivers who were exposed to noise levels of 90 - 110 dB(A) suffered hearing loss 2 times greater than those who did not drive tractors (Kumar et al., 2005). The loading machine operators, most of whom are generally young or middle-aged people, considerably suffer from the negative effects of the noise.

After determining the effects of the noise on hearing, the studies focused on the other physiological effects created by the noise (Ekerbicer, 1997). Long-term exposure to noise affects heart rate, blood pressure, respiration and the level of uric acid in blood (Orhun, 1991). Heart rate increases with the increase in the noise level. This is also an indicator of people’s energy consumption. Therefore, fatigue increases and labor productivity decreases as the noise increases (Sabanci, 1999).

The results of an audiology study conducted on the hearing loss of agricultural workers in New Zealand showed that the most important factors affecting hearing loss were the age of the operator and the use of an open tractor (McBride et al., 2003). When cabs are produced without consideration for noise insulation, the noise level carried to the driver increases (Saral and Avcioğlu, 2002). The noise to which the tractor driver is exposed can also be decreased via the use of personal protective earplugs and/or shortening the duration of the driver’s exposure to the noise. However, since the noise level can be decreased via the use of simple earplugs, it would not be appropriate to apply methods such as reduction of the study duration (Tunay and Melemez, 2003).

## Conclusion

The factors that most affected the noise level to which the operators of the loading machines were exposed were machine-cab condition, machine type, seat use duration, ground roughness condition, machine use duration, rear wheel pressure and land slope. By evaluating these factors, it can be stated that machine type and ground conditions generally affect noise level.

Characteristics, such as original cabs, front loaders, appropriate wheel pressure, and low duration for the use of the machine and the seat are related to the machines’ technology. The more developed these features become the lower the noise levels carried to the operator will be (Melemez, 2008). Therefore, high-tech machines with original cabs should be used for loading operations.

Land slope and the ground roughness condition of the forest depots are related to the grounds’ characteristics. The more appropriate these characteristics are, the lower the noise levels carried to the operator will be. In this framework, the forest depots should not be inclined above 8 - 10% grading, and ground roughness should be minimized by covering the depot ground with stabilized material.

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