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# Prediction of the Working Time Requirement and Field Capacity of Laser Controlled Land Leveling Machines

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**Abstract:** The purposes of this study were, to determine the working time and field capacity of the laser controlled land leveling machine, manufactured by a local manufacturer in Turkey. The percentage of ground surface covered by tractor tire in field due to field traffic was also investigated. Mathematical model that allows predicting the working time by the value of 81.8% coefficient of determination was obtained. If total effective working time and hourly cost of tractor and laser machine combination are known, then prediction of total land leveling cost of any laser controlled land leveling machine could be possible with developed mathematical model.
**Key words**: Laser controlled land leveling machine, working time, field capacity, mathematical modeling

## Lazer Kontrollü Tesviye Makinelerinin Çalışma Sürelerinin ve İş Başarılarının Tahminlenmesi

**Özet:** Bu çalışma, yurdumuzda da geniş ölçüde imal edilen ve kullanılmaya başlanan lazer kontrollü tesviye makinalarının çalışma sürelerini, makine iş başarılarını tahminlemek ve traktör tekerlek trafiğinin tarla yüzeyini kaplama yüzdelerini bulmak amacıyla yürütülmüştür. Çalışma sonunda, çeşitli iş genişliğine sahip lazer kontrollü tesviye makinalarının çalışma sürelerini, %81.8 tahminleme katsayısı ile tahminleyebilen bir model elde edilmiştir. Tesviye için gerekli efektif çalışma süresinin ve lazer kontrollü tesviye makinesi ve traktör kombinasyonunun saatlik maliyetinin bilinmesi halinde, tarla tesviyesinin toplam maliyetini tahmin etmek mümkün olacaktır.
**Anahtar Kelimeler**: Lazer kontrollü tesviye makinesi, çalışma süresi, makine iş başarısı, matematik modelleme

## INTRODUCTION

Irrigation and drainage is one of the most important factors of agricultural production influencing the success. The best way to ensure control of irrigation is the land leveling. Land leveling is to give slope in accordance with the present land surface of topographic condition in order to give water to the depth of the root zone of plant with uniform water distribution, without water loosing and soil erosion (Figure 1). In accordance with the appropriate land leveling; irrigation efficiency increases, plants grows uniform all over the field, products matures at the same time, provides saving irrigation water and labor: The value of land increases, yield increases, at a rate of 30-50% reduction in irrigation costs are provided.

**Figure 1. Laser controlled land leveling machine provides water uniformity for surface irrigation (Anonymous c)**

By preventing soil erosion, soil fertility is maintained, chemicals and fertilizers can be used more effectively and agricultural mechanization can be easier. (Önal ve Yürdem, 1998; Önal, 2010). The research results shows that, for the same rice varieties and the same fertilizer input, the average increase in crop yield was 24% or 530 kg ha-1. In two experiments conducted at different localities, a strong correlation was found between the levelness of the land and crop yield (Rickman, 2002). Experience has shown that most forming jobs pay for themselves within three years (Anonimous d, -)

**Land leveling types:**

Land leveling types, in general, can be analyzed in two groups:

- Shallow grading: Unproper tillage and farming techniques such as plowing, ridge till, harvesting operations etc. destroy the leveling. In this case, lands should be smoothed by shallow grading machines such as scraper-float, laser controlled leveling machine etc. Shallow grading is also essential for the finishing work of land leveling.
- Medium, heavy or too heavy leveling can be solution for topographic or flood defects, rills and depressions.

Classification of land leveling according to degree of excavation (cut/fill) is given table 1.

**Table 1. Classification of land leveling according to degree of excavation (cut/fill) (Sonmez and Balaban, 1966)**

| Leveling type | Excavation (cut/fill) (cm) | Excavation ($m^3$ $da^{-1}$) |
|---|---|---|
| Shallow (light) leveling | 0 – 7.5 | 0- 50 |
| Medium leveling | 7.5 – 15 | 50 – 100 |
| Heavy leveling | 15 – 25 | 100 – 150 |
| Too heavy leveling | > 25 | > 150 |

In shallow (light) leveling, skreyper-float, land plane, Eversman leveling shovel etc. are used. In recent years, laser-controlled land leveling machine, has been used for shallow and medium leveling operations. Carrier-type scraper, motor scraper, dozer and grader are used for heavy and too heavy leveling operations. Application style of laser control sloping system can be seen in Figure 2.

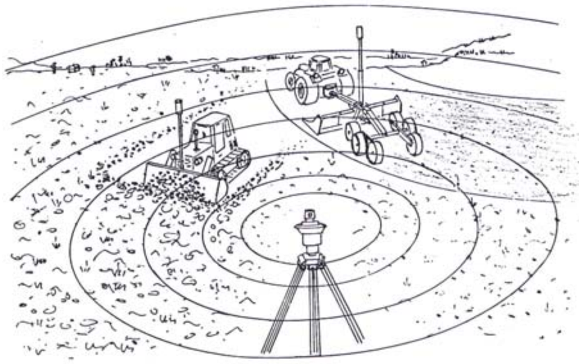


**Figure 2. Laser-controlled dozer and skreyper (Anonymous b)**

Agricultural grade control systems increase job quality and labor productivity of earthmoving machines such as skreyper, dozer, leveler, excavator, subsurface drainage machines and motor graders. Thus, land leveling for irrigation and drainage/ terracing / pond could be constructed precisely.

Laser system which is used for slope control at earthmoving machines consists of five major parts:

- 360° rotating laser transmitter,
- laser receiver,
- Control box,
- Electric installation: Feeding cable, receiving cable, electriv valve,
- Hydraulic components.

Laser transmitter spreads red laser beam which can be detected with an high accuracy (0.8 mm error at 100 m distance; 5 mm at 250 m; 20 mm at 500 m; 45 mm at 750 m; 80 mm at 1000m). It can even work at night. Laser beam can penetrate in dust and fog. It is possible to work in the unsufficient weather conditions. Multiple machines can be controlled simultaneously by one laser transmitter. The kinds of laser beam emitted by the laser transmitter are listed below;

- Parallel to the plane of water (zero slope for horizontal leveling),
- Single-axis slope (0-10%) or,
- Dual slope laser for slopes up to 10% (Fig. 3).

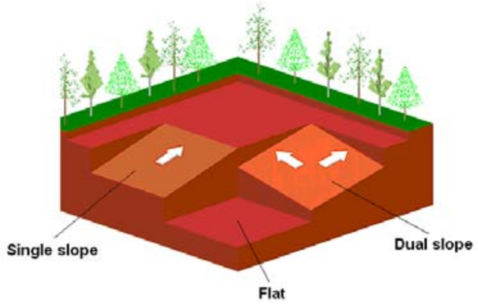



**Figure 3. Type of defined laser beam emitted by the transmitter**

The cheapest laser transmitter type is flat type that emits laser beam horizontaly. For an economical choice, single axis laser beam is preferred for excavator to dug the subsurface drainage channels. Dual slope is prefered working with scraper or laser controlled land leveling machines (Figure 4).

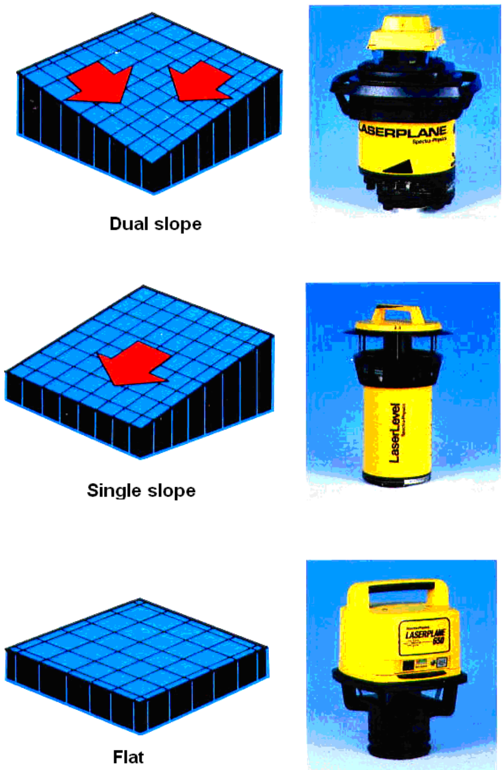



**Figure 4 Three type of laser transmitters (Anonymous c)**

Laser controlled system brings proven precision, productivity and reliability to the land leveling operation. Land leveling must be done with minimal traffic on the field. This achieves both the reduction of fuel consumption, as well as the minimum level of land compaction. In this sense, tractor operator's experience is very important to enhancing the success of the land leveling.

This study was conducted to predict the working hour requirement, machine capacity and the proportion of ground surface covered by tractor tire traffic (PGSCT) working with laser controlled land leveling machines.

## MATERIAL and METHOD

### Material

3, 4, 5 and 6 m width of laser controlled land leveling machines are used in the experiments and calculations. Some important technical features used laser controlled land leveling machines are given in Figure 5. The Laser controlled land levelling machines which have 5 and 6 meters of bucket width are equipped with paralelogramm linkage system to enlarge the whell distance. On the contrary, 4 m laser controlled land levelling machine has telescopic opening wheel system. Paralelogramm linkage system improves the stability of land leveling machine. In field experiments, 5 m width laser controlled land leveling machine was used. Field experiments were conducted on various sizes of field at 23 different locations. New Holland TM 175 power-shift tractor and 5m laser controlled land leveling machine combination were used in field experiments. Tractor operator had 20 years of experience in land leveling. Before leveling, elevations were taken from electrically operated mast mounted on the laser controlled land leveler on the corner of 25 x 25 m grid to determine the value of mean absolute deviation (MAD), standard deviation and coefficient of variation.

| | | |
|---|---|---|
| a) |  | Working width (B): 3 m<br>Fixed working width<br>Fixed wheel distance<br>Overall width: 3020 mm<br>Overall Length: 5225 mm<br>Overall height: 1260 mm<br>Weight: 1092 kg |
| b) |  | Working width (B): 4 m<br>Foldable bucket for easy of transportation<br>Variable tire range<br>Telescopic opening wheel system<br>(Picture shows open position)<br>Overall width (at transport position): 2600 mm<br>(at working condition): 4040 mm<br>Overall Length: 5520 mm<br>Overall height: 3180 mm<br>Weight: 2280 kg |
| c) |  | Working width (B): 5 m<br>Foldable bucket for easy of transportation<br>Variable tire range<br>Parallelogram wheel system (Picture shows closed position)<br>Overall width (at transport position): 2600 mm<br>(at working condition): 5040 mm<br>Overall Length: 5570 mm<br>Overall height: 3180 mm<br>Weight: 2470 kg |
| d) |  | Working width (B): 6 m<br>Foldable bucket for easy of transportation<br>Variable tire range<br>Parallelogram wheel system (Picture shows open position)<br>Overall width (at transport position): 2600 mm<br>(at working condition): 6040 mm<br>Overall Length: 5570 mm<br>Overall height: 3180 mm<br>Weight: 2620 kg |

**Figure 5. Some important technical features of Laser controlled land leveling machines used in field trials (c) , and in the modeling work (a, b, d)**

## Method

### Calculation of Working Time and Field Capacity of Laser Controlled Land Leveling Machines Using the Standard Parcel Method

Working times ($MWh_{SP}$) of 3, 4, 5 and 6 m width laser controlled land leveling machines were calculated for standard parcel (150 m x 66.67 m = 1 ha) (Figure 6a) (Uçucu, 1976). In calculations,

- The tractor travel speed for loading process (loaded pass) 2.0 m s-1 (7.2 km h-1), and for empty pass (return pass) 2.5 m s-1 (9 km h-1) was taken.
- Slope was 0.25% in one direction on the length of the field gradient for irrigation,
- Calculation was based on working four passes longitudinally, and two passes transversally on the field (Figure 6b).
- Field efficiency was taken as 0.85 for working with laser controlled land leveling machines.

Using the value of working hours per hectare for standard parcel ($MWh_{SP}$), the field capacity of laser controlled land leveling machine (FC) was calculated by the following equation (Uçucu, 1976; Anonim a, 1976).

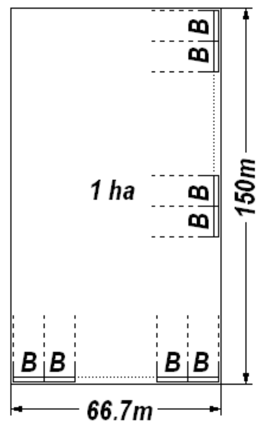



**Figure 6a. Standard parcel size**

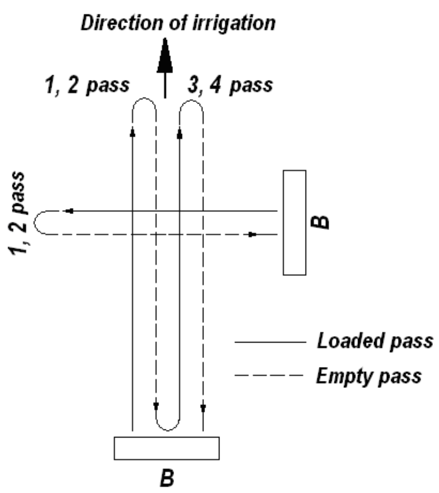



**Figure 6b. The number of longitudinal and transversal passes on standard parcel. (Bucket moves upward sloping without excavation (emty pass; bucket excavates down hill (loaded pass))**

$$FC = 1 / MWh_{SP} \quad (ha/h) \qquad (1)$$

**Determination of Working Time During the Experiment**

In order to estimate the working time with sufficient accuracy for various working bucket width, 5 m width laser controlled land leveling machine was used to level the 23 different farmers' fields. The total 82.65 hectares of land was leveled in 140 hours. Each one of the 23 fields was marked with stakes in a corner of the 25 x 25 m grid system and elevations were measured on the grid corners by using the elevation measurement system of laser controlled land leveling machine. In order to create a general mathematical-statistical model for estimating field capacity of machine, theoretical working hours per hectare for standard parcel of four different laser controlled land leveling machines ($MWh_{sp}$ ) and the mean absolute deviation of leveled fields (MAD) (total 23 fields) were combined.

The easy way to expose the degree of roughness of the land, the mean absolute deviation (MAD), standard deviation (SD) or coefficient of variation (CV) of the average elevation values which were measured from the corner of grids in the field could be used. Preliminary evaluations showed that the more accurate estimation of machine capacity of the laser-controlled land leveling machine could be made via the mean absolute deviation (MAD).

At first, a mathematical model was tried to achieve for revealing the relationship between the working time and mean absolute deviation (MAD) obtained from 23 different fields. Then, the model obtained by Minitab (v13.20) program combined with calculation result for the standard parcel and general model was created. General model is predicted the working time for the different width of the laser-controlled land leveling machine depending on MAD values (degree of roughness) and different field size. 95% significance level was chosen. To see how developed mathematical model fits the data obtained, the sensitivity analysis is used.

**Determination of the Proportion of Ground Surface Covered by Tractor Tire Traffic (Percentage of Field Traffic)**

The standard parcel sizes were used to determine percentage of field traffic. Percentage of field traffic during the land leveling was calculated for four models of New Holland tractors and John Deere tractors. The technical specifications belonging to the tractors used in the calculations are given in Table 2.

**Table 2. Specifications of the tractors combined with the laser-controlled leveling machines at different width.**

| | | | | |
|---|---|---|---|---|
| Working width of laser controlled leveling machines (B, m) | 3 | 4 | 5 | 6 |
| Power requirement (kW) | 60-75 | 75-104 | 90-135 | 120-157 |
| John Deere Tractors : Models | | | | |
| Serial No. | JD-6230 | JD-6630 | JD-7430 | JD-7530 |
| Tractor power (kW) | 74 | 96 | 131 | 143 |
| Rear-wheel-type of tractor | 420/85R38 | 460/85R38 | 620/70R42 | 620/70R42 |
| Rear-wheel tractor sidewalls height (mm) | 420 | 460 | 620 | 620 |
| Empty tractor weight (kgf) | 4390 | 5230 | 6620 | 6620 |
| Rear tractor wheel track width (cm) | 183 | 183 | 183 | 183 |
| New Holland Tractors: Models | | | | |
| Serial No. | TM 120 | TM 130 | TM 175 | TM 190 |
| Tractor power (kW) | 82 | 89 | 123 | 134 |
| Rear wheel- type of tractor | 18.4R38 | 18.4R38 | 20.8R38 | 20.8R38 |
| Rear-wheel tractor sidewalls height (mm) | 467 | 467 | 528 | 528 |
| Empty tractor weight (kgf) | 5960 | 5960 | 7310 | 7310 |
| Rear tractor wheel track width (cm) | 183 | 183 | 183 | 183 |

The proportion of ground surface covered by tractor tire traffic (PGSCT) was found in standard parcel (150 m $\times$ 66.67 m) using the following critera:

- Slope was 0.25% in one direction on the length of the field gradient for furrow irrigation,
- Calculation was based on four passes longitudinally; and two passes (loaded and empty) transversal moving (Figure 6a,b). One pass means that the bucket of laser controlled land leveling machine will go only in one direction, loaded or empty. One loaded or one empty travel in a field is called as a one pass. Two passes indicate one "circle" or "trip". It means that the bucket of laser controlled land leveling machine will travel longitudinal (150 m) four times (4 passes) (two passes loaded/two passes empty). At transverse work, the bucket of leveler will travel along the 66.67 m of length two times (one pass loaded/one pass empty) (Figure 6a,b).

## RESEARCH RESULTS

### Working Time at Standard Parcels

The calculated working times for different width of laser controlled land leveling machines for standard parcel (150 m x 66.67 m=1 ha) were given in Table 3. As shown in Table 3, longitudinal and transverse movements on the land were considered (Figure 6a, b). As a result, working times for standard parcel ($MWh_{SP}$) and machine field capacities (FC) for 3, 4, 5 and 6 m width of laser-controlled land leveling machines were calculated as 2.941, 2.206, 1.765, 1.471 h $ha^{-1}$ and 0.340, 0.453, 0.567, 0.680 ha $h^{-1}$, respectively.

By using the values given in Table 3, relationship between width of laser controlled land leveling machine and working time for standard parcel can be expressed by equation 2 (Figure 7).

$$MWh_{sp}=8.824 \times B^{-1} \quad (2)$$

In this equation, $MWh_{sp}$ is machine working time for standard parcel in h $ha^{-1}$ and B is bucket width of laser controlled land leveling machine in m

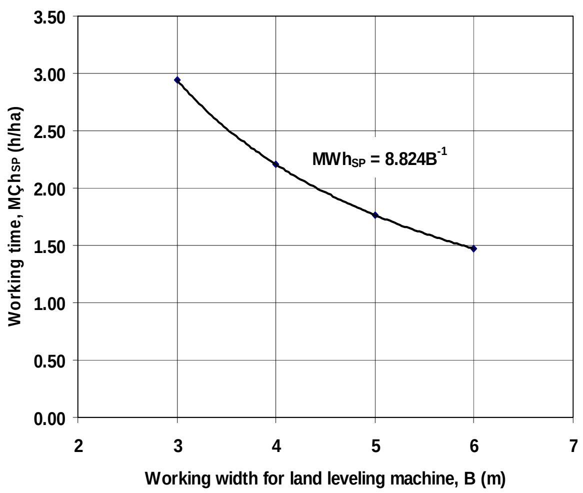
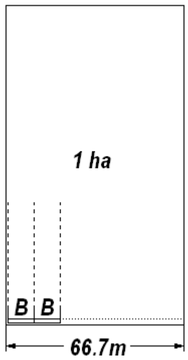
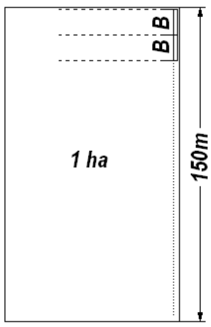



**Figure 7. The effect of width of laser-controlled land leveling machines upon working time on standard parcel (h/ha).**

**Table 3. The calculation results for working time on standard parcel**

| Work trips | Working width land leveling machine (m) | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| **Longitudinal movement** | The number of loaded or empty pass in one direction | 22.22 | 16.67 | 13.33 | 11.11 |
| | The required trip number included loaded and empty pass in longitudinal direction | 2 | 2 | 2 | 2 |
|   | The total loaded and empty pass number in longitudinal direction. | 44.45 | 33.34 | 26.67 | 22.22 |
| | Travel speed during loading (excavating) | 2 | 2 | 2 | 2 |
| | (m $s^{-1}$) | 2.5 | 2.5 | 2.5 | 2.5 |
| | | 75 | 75 | 75 | 75 |
| | | 60 | 60 | 60 | 60 |
| | | 3334 | 2500 | 2000 | 1667 |
| | | 2666.8 | 2000.1 | 1600.08 | 1333.4 |
| | Total loaded and empty time (s) | 6000 | 4500 | 3600 | 3000 |
| | **Total loaded and empty time (h)** | 1.667 | 1.250 | 1.000 | 0.833 |
| **Transverse movement** | The number of loaded or empty pass in one direction | 50.0 | 37.5 | 30.0 | 25.0 |
| | The required trip number included loaded and empty pass in transverse direction | 1 | 1 | 1 | 1 |
| | The total loaded and empty pass number in transverse direction | 50.0 | 37.5 | 30.0 | 25.0 |
| | Travel speed during loading (excavating) | 2 | 2 | 2 | 2 |
|   | (m $s^{-1}$) | 2.5 | 2.5 | 2.5 | 2.5 |
| | | 33.335 | 33.335 | 33.335 | 33.335 |
| | | 26.668 | 26.668 | 26.668 | 26.668 |
| | Total loaded and empty time (s) | 1666.8 | 1250.1 | 1000.1 | 833.4 |
| | | 1333.4 | 1000.05 | 800.04 | 666.7 |
| | Total loaded and empty time (s) | 3000.2 | 2250.1 | 1800.1 | 1500.1 |
| | **Total loaded and empty time (h)** | 0.833 | 0.625 | 0.500 | 0.417 |
| **Leveling** | **Total working time (h $ha^{-1}$)** | **2.500** | **1.875** | **1.500** | **1.250** |
| | **Field efficiency** | 0.85 | 0.85 | 0.85 | 0.85 |
| | **Adjusted total working time (h $ha^{-1}$)** | **2.941** | **2.206** | **1.765** | **1.471** |
| | **Effective field capacity of laser controlled land leveling machine (ha $h^{-1}$)** | **0.340** | **0.453** | **0.567** | **0.680** |

**Working Time Experiments for 5 m Width of Laser Controlled Land Leveling Machine**

To develop a mathematics-statistics model for various width of laser controlled land leveling machines, 5 m width of laser controlled land leveling machine was used for land leveling on the total area of 82.65 ha. The total time requirement for land leveling of 23 different farmers' fields was recorded as 140 hours.

The area of leveled fields, the calculation results of mean absolute deviation, standard deviations and the values of variation coefficient are given in Table 4. In process of land leveling, it is obvious that the amount of excavation will affect the working time of land leveling machine. To estimate work performance of laser-controlled land leveling machine with higher coefficient of determination ($R^2$) value, mean absolute deviations (MAD) are used. According to the multiple regression results, the following prediction model equation was developed from the measured data for working time of 5 m width of laser controlled land leveling machine:

$$MWh_5 = 0.562 \times MAD^{0.7846} \times A^{1.0057} \quad (3)$$

In this equation, $MWh_5$ is predicted machine working time for 5 m width lazer controlled land leveling machine in h and A is leveled area in (ha) for laser controlled land leveling machine , MAD is mean absolute deviation in cm. Results of multiple regression analysis for developed model was given at Table 5.

As seen from Table 5, the area (A) term, entered into the model, explained 59.79% of the variation in working time alone. After addition of mean absolute deviation (MAD) term into the model, the coefficient of determination ($R^2$) for the full model as given in Eq. (3) was found to be 81.8%. The contribution of the terms was found to be significant at the selected probability level of 95%.

The limit values of this developed model are given as follows:

- 0.85-10 ha for the area and,
- 2.041-8.858 cm for the mean absolute deviation (MAD) of the field surface roughness.

The working time prediction model described by Equation (3) was compared with the data obtained in the experiment and the comparison is shown in Figure 8. As seen from Figure 8, good agreement between the model and the measured data was achieved with a correlation coefficient (r) of 92%. However, especially in the case of working time exceeds 15 hours, estimation percentage falls.

**Table 4. Result of measured and calculated values taken from 23 farmer's fields.**

| Field Nr. | Leveled area A (ha) | Measured working time (h) | Mean absolute deviation (MAD) (cm) | Standard deviation SD (cm) | Coefficient of variation CV (%) |
|---|---|---|---|---|---|
| 1 | 5.4 | 4 | 2.685 | 3.120 | 7.370 |
| 2 | 2.4 | 2.5 | 3.556 | 4.650 | 14.092 |
| 3 | 3.0 | 6 | 3.837 | 5.050 | 2.921 |
| 4 | 5.0 | 8 | 2.593 | 3.090 | 6.786 |
| 5 | 5.0 | 11 | 5.740 | 4.545 | 18.375 |
| 6 | 0.85 | 1.8 | 7.260 | 4.707 | 21.114 |
| 7 | 3.0 | 7 | 7.000 | 4.286 | 38.274 |
| 8 | 10.0 | 21 | 6.659 | 4.762 | 18.201 |
| 9 | 4.5 | 16 | 6.450 | 2.813 | 19.993 |
| 10 | 1.2 | 2 | 2.708 | 3.480 | 8.775 |
| 11 | 1.5 | 4.5 | 8.858 | 3.333 | 25.705 |
| 12 | 2.0 | 1 | 2.245 | 2.860 | 8.123 |
| 13 | 3.4 | 4 | 2.661 | 3.290 | 8.594 |
| 14 | 2.0 | 2 | 2.041 | 2.660 | 7.407 |
| 15 | 2.3 | 3.5 | 3.387 | 6.571 | 11.602 |
| 16 | 6.6 | 5 | 2.545 | 3.270 | 9.351 |
| 17 | 2.5 | 3.5 | 2.507 | 7.143 | 9.914 |
| 18 | 3.8 | 4 | 2.598 | 3.080 | 10.334 |
| 19 | 3.0 | 5.5 | 2.464 | 5.455 | 9.157 |
| 20 | 1.9 | 3 | 2.929 | 6.333 | 9.615 |
| 21 | 3.3 | 5 | 2.818 | 4.068 | 10.054 |
| 22 | 4.0 | 7 | 3.003 | 3.938 | 10.876 |
| 23 | 6.0 | 13 | 3.605 | 4.621 | 11.096 |

**Table 5. Results of regression analysis**

| Terminology | Exponential term | Standard error | $R^2$ Change (%) |
|---|---|---|---|
| Log (sabit) | -0.2501 | 0.1118 | - |
| A | 1.0057 | 0.1212 | 59.79 |
| MAD | 0.7846 | 0.1595 | 81.80 |

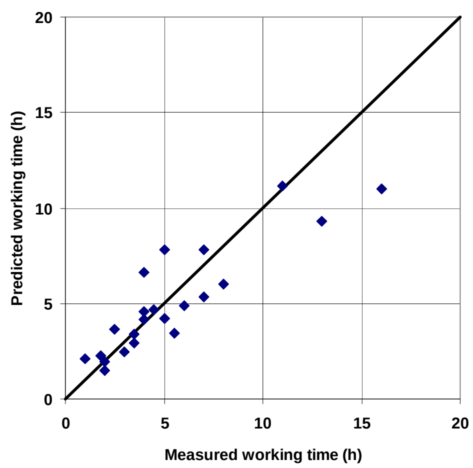



**Figure 8. Comparison between measured and predicted working time for 5 m working width of laser-controlled leveling machine**

**General Model Equation for the Prediction of Field Capacity of Laser Controlled Land Leveling Machine**

At first, a mathematical model was tried to achieve for revealing the relationship between the working time and mean absolute deviation (MAD) obtained from 23 different fields (Equation 3). Then, obtained model with the Minitab (v13.20) program combined with calculation result for the standard parcel (Equation 1) and general semi-empirical model equation was created (Equation 4). General model is predicted the working time for the different width of the laser-controlled land leveling machine depending on MAD values (degree of roughness) and different field sizes.

$$\mathrm{MWh} = 0.3175 \times \mathrm{MAD}^{0.7846} \times (\mathrm{A} \times 8.824 \times \mathrm{B}^{-1})^{1.0057} \qquad (4)$$

Where, MWh is the working time of laser controlled land leveling machine in h; MAD is mean absolute deviation in cm; A is area in ha; B is working width of laser controlled land leveling machine in m. If field area, field surface roughness (MAD) and working width of laser controlled land leveling machine are known, Equation 4 can be used to estimate the complete time of land leveling. Indeed, if the working width of laser-controlled leveling machine (B) is taken as 5m in the general model Equations 4, Equations 3 will be achieved.

**Percentage of Field Traffic Working with Laser Controlled Land Leveling Machine**

The standard parcel sizes were used to determine percentage of field traffic as mentioned before. Percentage of field traffic during the land leveling was calculated for four models of New Holland tractors and John Deere tractors (Figure 6 a,b). The results of calculations for percentage of field traffic on standart parcel with different width of laser controlled land leveling machine – tractor combinations are given in Table 6.

As can be seen from Table 6, using smaller working width of laser controlled land leveling machine increases the field traffic. As a result, soil is more compressed. Therefore, as described in general model equation 4, the width of bucket should be greater as possible. Sommer et al (2001) indicated that repeated compaction on the same tract width increases the strength of soil and soil compaction hazards.

**Table 6. Percentage of field traffic (PGSCT) values on standart parcel with different width of laser controlled land leveling machine and tractor combinations.**

| **Laser controlled land leveling machine width, B (m)** | **3** | **4** | **5** | **6** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|---|---|
| Tractor power (kW) | 74 | 96 | 131 | 143 | 82 | 89 | 123 | 134 |
| Tractor type | JD-6230 | JD-6630 | JD-7430 | JD-7530 | TM120 | TM130 | TM175 | TM190 |
| Rear wheel type of tractor | 420/85R38 | 460/85R38 | 620/70R42 | 620/70R42 | 18.4R38 | 18.4R38 | 20.8R38 | 20.8R38 |
| Tractor rear wheel sidewall widths (mm) | 420 | 460 | 620 | 620 | 467 | 467 | 528 | 528 |
| Tractor empty weight (kgf) | 4390 | 5230 | 6620 | 6620 | 5960 | 5960 | 7310 | 7310 |
| Tractor rear track widths (cm) | 183 | 183 | 183 | 183 | 183 | 183 | 183 | 183 |
| (cm) | 84 | 92 | 124 | 124 | 93.4 | 93.4 | 105.7 | 105.7 |
| longitudinal motion | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | 44.45 | 33.34 | 26.67 | 22.22 | 44.45 | 33.34 | 26.67 | 22.22 |
| Standard parcel length (m) | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |
| Standard parcel width (m) | 66.67 | 66.67 | 66.67 | 66.67 | 66.67 | 66.67 | 66.67 | 66.67 |
| Total compacted width for one trip (m) | 37.34 | 30.67 | 33.07 | 27.56 | 41.51 | 31.13 | 28.19 | 23.49 |
| Total compacted width for two longitudinal trips (m) | 74.67 | 61.34 | 66.14 | 55.11 | 83.03 | 62.27 | 56.38 | 46.98 |
| Total compacted area for two longitudinal trips ($m^2$) | 11201 | 9200 | 9920 | 8267 | 12454 | 9340 | 8456 | 7047 |
| motion | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | 50.00 | 37.50 | 30.00 | 25.00 | 50.00 | 37.50 | 30.00 | 25.00 |
| Standard parcel width (m) | 66.67 | 66.67 | 66.67 | 66.67 | 66.67 | 66.67 | 66.67 | 66.67 |
| Total compacted width for one transverse pass (m) | 42.00 | 34.50 | 37.20 | 31.00 | 46.70 | 35.03 | 31.71 | 26.43 |
| Total compacted width for one transverse trip (m) | 84 | 69 | 74.4 | 62 | 93.4 | 70.05 | 63.42 | 52.85 |
| Total compacted area for one transverse trips ($m^2$) | 5600.28 | 4600.23 | 4960.248 | 4133.54 | 6226.98 | 4670.23 | 4228.21 | 3523.51 |
| longitudinal | 16801 | 13801 | 14881 | 12401 | 18681 | 14011 | 12685 | 10571 |
| **The percentage of field traffic (PGSCT, %)** | **168** | **138** | **149** | **124** | **187** | **140** | **127** | **106** |

**DISCUSSION**

In this study, the working time requirement and field capacity of the laser controlled land leveling machine manifactured in Turkey were investigated. At the end of study, working time prediction model was developed for different working width of laser controlled land leveling machine with 81.8% determination coefficient

Field surface roughness values which expresses the mean absolute deviation (MAD) could be successfully used for modeling the working hour requirement equation of laser controlled land leveling machine. By using the model equation, the hourly cost of leveling operation could be predicted if the variable and fixed costs of tractor and land leveling machine are known.

It is clear that increases the field surface roughness increases the field working time requirement and thus increases the cost of land leveling.

Conditions in March 2010, hourly cost of tractor-laser controlled land leveling machine combination is 150 TL $ha^{-1}$. Approximately half of this cost (75 TL) is the cost of diesel fuel consumption of big tractor (25 L fuel per hour). Research findings showed that if land leveling machine with a small working width is used, especially wet soil conditions, the wheel tracks and soil engaging tools create the mechanical impedance, which limit the root growth. Therefore, as shown by the general model equations, the working width of land leveling machine could be taken as wide as possible. It is well known that the repeated compaction on the same track width by tractor wheel increases the strength of soil and thus soil compaction hazards.

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