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Effects of Varied Soil Leveling Methods on Physical Properties: A Comparative Analysis

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Abstract

The total cultivated land area in this context is 8,664,000 square meters, which constitutes about 4% of Egypt's territory. The cultivation relies on old land dams, lines, and furrow surface irrigation systems. A significant portion (76%) of the cultivated land is irrigated with high-density leveled soil instead of unlevelled soil. Leveled soil has very low clay and organic matter content. Land leveling is a preparation or modification process that provides a suitable surface for seeding production. It involves reducing high areas and raising low or deep spots to create a more even surface. Laser-controlled land leveling is a technique that helps create a more even surface by reducing high areas and raising low spots. This process aims to eliminate surface irregularities and create a level plane, which can significantly impact crop germination, uniformity, and, ultimately, the yield of field crops. Laser technology allows for precision in land leveling, ensuring a more consistent seed depth, better water distribution, and improved crop-growing conditions. By creating a more uniform surface, the potential for more consistent crop growth, better water retention, and improved distribution of nutrients is increased. The study's main objective appears to be to determine the most appropriate types of land leveling that can be implemented and to analyze how land leveling treatments affect the physical properties of the soil during different seasons. The data shows that the leaser treatment decreased soil porosity in both seasons, dropping values from 57.36% to 54.34% in the first season and from 55.47% to 51.32% in the second season. In contrast, the "rotary treatment" had the opposite effect, increasing soil porosity in both seasons. The values rose from 57.34% to 59.62% in the first season and from 57.74% to 59.25% in the second. Observing how these treatments had different impacts on the soil over time is intriguing.

Keywords: Land leveling; Soil Properties; Bulk Density; Crops.

1. Introduction

The overwhelming majority of the desert land covers Egypt. Much of the fertile land lies near the Nile banks, branches, and central canals. Egypt's agricultural sector absorbs approximately 86% of the water [1]. The application of laser land leveling resulted in an increase of 11.73% in wheat grain yield and 6.50 kg/fed-1 in N-uptake compared to conventional leveling [2]. Laser land leveling can help achieve a more uniform and level field surface, which is essential for efficient water distribution and plant nutrient absorption. The 11.73% increase in wheat grain yield suggests that laser land leveling contributed to more favorable growing conditions, resulting in higher wheat production. This is a significant advantage for farmers seeking to enhance crop yields [3]. The 6.50 kg/fed-1 increase in N-uptake (nitrogen uptake) indicates that laser land leveling improves water distribution and contributes to better nutrient absorption by the wheat plants. Level fields provide more consistent access to nutrients throughout the field, which is essential for plant growth and yield [4].

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It has also been shown that Manning n improves over time by irrigation as the flowing water smoothes the soil. This calculation of Manning n is based on the forward curve that essentially differs from those based on measured water depths. Unfitting equations or parameter values for one (roughness or infiltration) will lead to infeasible values of parameters for the other [5]. Laser land leveling plays a crucial role in optimizing water management in agriculture. It ensures that water is distributed evenly across the field, reducing the risk of waterlogging in low-lying areas and preventing drought stress in high spots. This even water distribution likely contributed to the increased yield in wheat production [6]. The use of knives, chisels, and certain tools seemed to result in lower roughness, while others created a moderate level. The roughness of the surface can significantly influence a range of environmental processes, such as depression formation, absorption rates, solar radiation distribution, runoff patterns, deposition locations, and the overall sediment yield in an area [7]. Smooth soil surfaces resulting from these methods may influence water absorption, solar radiation absorption, runoff, and sediment yield. For instance, smoother surfaces might reduce runoff by allowing water to infiltrate more easily into the soil, potentially decreasing erosion and sediment yield [8]. The N roughness coefficient typically measures the roughness of a surface, particularly in hydraulics and fluid mechanics. In this context, you're referring to a study or observations on the roughness of a surface being treated by hydraulic scraping along a slope. The N roughness coefficient average values were 0.0271, 0.0322, and 0.0287 with a zero-degree slope, hydraulic scraper, and rotary treatment [9]. The ground leveling would squander an estimated 30 percent of irrigation water with low precision and roughness. Leveling agricultural land is done with computer or scrubber leveling [10].

The contrast between laser-leveling land and beam-free land leveling shows significant improvements in irrigation efficiency and water usage [11, 12]. The effects of tillage operations on soil bulk density and resistance to soil penetration can vary depending on several factors, including the type of tillage, soil type, and the timing of the tillage. The statement you provided describes the specific effects observed in a particular context, with NT having the highest mean bulk density of 1.04, 0.95, and 1.03 g/cm³, while TT has the least, 0.84, 0.83, and 0.72 g/cm³ for the 1st, 2nd, and 3rd seasons, respectively [13]. With laser leveling, the highly significant effects were on both the water applied and the cotton yield. At laser leveling with a slope of 0.05%, the highest percentage value of cotton yield was around 17%. While the highest saving percentage of water applied at laser leveling was around 33%, with a 0.05-degree slope compared with conventional leveling [14]. Using precision land-leveling equipment and techniques allows for more uniform water distribution during irrigation, which results in water savings by reducing runoff and improving water penetration into the soil. Moreover, reducing water wastage and better control over irrigation can positively affect crop yield and quality, ultimately leading to higher agricultural productivity [15].

Using laser land leveling technology in agriculture saves water and resources by 24%, decreases irrigation costs by 44% compared to conventional land leveling, and increases water production by 39% [16]. It's important to note that laser land leveling is a well-established technology widely recognized for its ability to enhance water management and improve overall agricultural practices. By creating a more uniform field surface, laser land leveling can contribute to better water distribution, reduced water waste, and potentially increased crop yields [17]. The difference in the bulk density of the leveled and unlevelled soils clearly shows the effect of leveling on the bulk density, which is small in the unlevelled profile due to high organic matter, improved structure, and small ripple and erosion losses [18]. In land leveling treatments, the highest percentage of a shift in soil bulk density was observed during rotational treatment. The lowest shift in hydraulic scraper treatment was observed at 8.82, 5.25, and 4.26% at 0-15 cm depth and 6.56, 6.00, and 5.54% at 15-30 cm depth for rotary, laser zero, and hydraulic scraper treatments. This also noted that the highest average percent of change in soil porosity was identified during land leveling treatments under hydraulic scraper operation, and the lowest differences under rotating treatment, recorded -14.78, -8.31, and -6.64% at 0-15 cm depth, and -13.00, -11.78, and -10.77% at 15-30 cm depth for rotary, laser zero level slope, and hydraulic scraper treatments, respectively [9]. On historically leveled fields, average crop productivity in rice, wheat, sugarcane, and mustard increased by 14.35, 10.83, 16.07, and 15.8%, respectively. The total annual net revenue from the laser field was higher than Rs. 90380, 72649, 69440, and 195275 ha-1 in rice, wheat, mustard, and sugarcane compared to (unlevelled) control fields [17].

2. Material and Methods

2.1. Field Experiments

Field experiments were conducted during two seasons, winter 2018/2019 and summer 2019, at the Agricultural Research Station in El-Gemmeiza, El-Gharbia Governorate, Egypt, under the Ministry of Agriculture. The experiments aimed to study the effect of land leveling on soil properties. Figure 1 likely provides a visual representation or illustration of the experiments. The mechanical analysis of the soil revealed that the experimental land has a textural class of clay. The textural class of soil refers to the relative proportions of sand, silt, and clay particles in the soil, which influences its physical properties and behavior.

The experimental area of 1.2 fed (5040 m^2) ploughed by a chisel plough twice, then used disk harrow in all area. It was divided into three main plots, each plot divided into three subplots, each 7 m wide and 80 m length Figure 1. Three treatments leveling used in this study:

- Leveling by Laser equipment of 0.00% level slope (L1).
- Leveling by hydraulic scriber manual (L2).
- Treatment by Rotary tiller (L3)

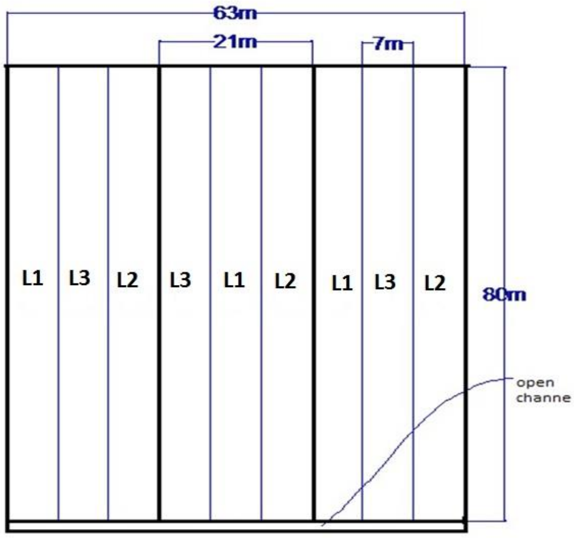

Figure 1. the schematic shape the experiment

Unfortunately, the specific details and results of the experiments and the information provided in Tables 1 and 2 explaining the soil properties and mechanical analysis are not available. Therefore, providing further insights or analysis based on the given information is impossible

Table 1. Soil mechanical analysis

Depth (cm)	Percentages soil particles %				
	Sand	Silt	Clay	Textural Class	$CaCO_3$
0-15	15.93	40.41	43.66	Clay	3.02
15-30	12.17	37.9	49.93	Clay	4.40
30-45	10.74	40.22	49.78	Clay	4.31
45-60	10.53	39.69	49.78	Clay	4.08

Table 2. Some soil physical properties

Soil physical properties	Depth's cm			
	0-15	15-30	30-45	45-60
Bulk Density (g/ cm^3)	1.13	1.14	1.165	1.161
Field capacity % wt.	42.3	38.9	36.9	34.7
Wilting point, % wt.	22.12	21.1	20.4	19.4

The experiments were carried out through two seasons. The first one was planted Wheat in the winter of 2018/2019, and the second was planted Maize in the summer of 2019 Table 3. All crops were planted in flat soil.

Table 3. Crops duration

Season	Crops
Winter 2018/2019	Wheat (Gemmeiza 11)
Summer 2019	Maize (Giza 352)

2.2. Devices and Equipment

One tractor was used in all agricultural operations in the experiment. The type of this tractor is New Holland TM 150 (Figures 2 and 3); Table 4 and Figure 4 explain the devices and equipment used in the experiment.

Table 4. Equipment and devices

Equipment	Mass (kg)	Working width (cm)	Remarks
Chisel plough (CH)	225	225	Source El-Behera co. Egypt, 9 Tines
Disk harrow	1000	330	The disc harrow you're referencing seems to have specific features: ***Layout***: It consists of 36 discs arranged in four groups, with two groups in the front and two in the rear. ***Disc Sizes***: The front groups have discs with a diameter of 57.5 cm, while the rear groups have slightly larger discs with a diameter of 59 cm. ***Adjustable Depth***: The hydraulic system allows for depth adjustments, enabling the discs to penetrate the soil to different depths as needed. ***Spacing and Angle***: The spacing between each pair of discs within the same group is 25 cm. The discs are positioned upright at an angle of 45°.
Scraper	770	3.6	Trailed scraper with pneumatic 4 tires, Capacity 1.275 m^3, And depth changed by the hydraulic cylinder.
Rotary tiller	846		35 Tines, Working depth Max 15 cm, Required P.T.O shaft speed 540 R.P.M.
Seed drill	450	250	Row spacing 12.5 cm, 20 rows, and Hydraulic control.
Cylinder bulk density	0	0	Type steel, Internal diameter 5cm, Height 5 cm, Content 100 cm^3
Double ring infiltrometer	0	0	No. of ring 2, Diameter of the inside ring 30 cm, Height of the inside ring is 50 cm, Diameter of the outer ring is 50 cm, and the Height of the outer ring is 50 cm.
Electronic balance	0	0	Maximum weight 500 g, sensitivity 0.01 g
Sieve	16	-	Max. batch/feed capacity 3 kg Max. number of sieves 8 full height / 16 half height (200 mm sieves), Suitable for dry sieving Power connection 1-phase

Figure 2. Tractor TM 150 New Holland

Figure 3. Land leveling by laser scriber

Figure 4. The Sieve test for different samples

2.3. Methods

Tillage

The experiment used two different tillage methods to observe changes in soil properties. The first method involved using a chisel plough to create two perpendicular paths, presumably for control purposes. The second method used a rear-trailed disk harrow to pulverize the soil. The chisel plough and disk harrow are traditional tillage methods, each with its way of impacting the soil. The chisel plough typically creates furrows without fully inverting the soil, which can help with aeration and water infiltration. On the other hand, the disk harrow grinds and breaks up soil more finely, which can aid in seedbed preparation but might also affect soil structure differently.

Description of Land Leveling and Field Procedures

Land leveling used two pieces of equipment: laser, hydraulic scriber, and rotary tillage.

Leveling by Laser: The laser system you described is used for laser leveling applications in construction and agriculture, among other fields. Here's a breakdown of its components and how it works:

- Laser-Transmitting Unit: This unit emits an infrared (IR) light beam. The laser beam must travel in a perfectly straight line in laser leveling. The laser transmitter is responsible for producing this high-intensity laser beam.
- Receiver: The receiver is designed to sense the infrared light beam. It captures the laser signal and converts it into an electrical signal. This signal is used to determine the elevation or grade of the receiver concerning the laser beam.
- Control Box: The control box is central to the laser leveling system. It receives the electrical signal from the receiver and processes it. It directs the signal to an electric hydraulic valve.
- Electric Hydraulic Valve: The control box activates the electric hydraulic valve. Its primary function is to control the raising and lowering of the blade of a scriber or land leveler. This control ensures that the blade follows the infrared beam accurately.
- Scriber or Land Leveler: The blade of the scriber or land leveler is responsible for shaping the ground to achieve the desired grade or slope.
- Dual Slope Laser: This is a specific type of laser level that allows for both horizontal and vertical slope control. It automatically adjusts the grade or slope of the land leveler's blade to match the desired specifications, ensuring the surface is free from irregularities or ripples that could lead to water pooling.
- Laser Rotation: To create a reference plane over the work area, the laser transmitter is often mounted on a rotating base, allowing the laser beam to rotate 360 degrees.

2.4. Soil Parameter

2.4.1. Soil Mean Weight Diameter

The collection and analysis of soil samples from different treatments. Here's a breakdown of the process:

Sampling**:** Soil samples were collected from each treatment after a leveling operation.

Depth and Collection**:** All samples were taken from the plowing depth to assess the size of clods in the soil.

Processing**:** The collected soil samples were leveled and dried in the air.

Sieve Analysis**:** The dried samples were sieved through various mesh sizes (25, 19, 12.5, 9.5, 3.5, 1.4, and 0.69 mm). Each size fraction was separated and weighed.

Proportion Calculation**:** The weight of each size fraction was compared to the total weight of the samples to determine the proportion of each fraction in the soil.

Diameter Determination**:** The mean diameters of each fraction were calculated. This likely involves analyzing the particle size distribution within the soil to understand the distribution of different-sized particles or clods.

To determine the soil, mean weight diameter was used the Equation (1) [19].

$$MWD = \sum_i^n (X_i - W_i) / W \tag{1}$$

where MWD is mean weight diameter (cm), W_i is Weight of the soil retained on (i^{th} $sieve$) (kg), W is total weight of soil sample, Δ is sieve mesh, mm.

The mean weight diameter was determined after each treatment.

2.4.2. Soil Bulk Density

The soil bulk density is measured with a cylindrical prop. The soil samples are taken at four depths (0-15, 15-30, 30-45, and 45-60) and laid in the drying oven at 105 C° for 24 hours. All samples are removed and weighted. The calculation of soil density follows the Equation:

$$Ds = \frac{Wsd}{Vt} \tag{2}$$

where Ds is Soil bulk density g/cm^3, Wsd is Dry soil weight, g – Vt is Total soil volume, cm^3.

2.4.3. Soil Pore Volume (Total)

The soil pore volume (Vp) is obtained from the soil bulk density with the aid of the Equation 3:

$$Vp = \left(1 - \frac{Ds}{Dss}\right) \times 100 \quad (3)$$

where Vp is pore volume (total) %, Ds is Soil bulk density g/cm^3, Dss is soil real density g/cm^3.

3. Results and Discussion

3.1. Effect of Land Leveling on the Soil's Physical Properties

The physical properties of the soil have been the increase in load can indeed lead to soil compaction, squishing the spaces between particles. As the pore space decreases, the soil's ability to hold water, facilitate root growth, and allow air movement is affected. Compacted soil can also hinder drainage, potentially leading to runoff issues and reduced fertility. Techniques like aeration or using specialized equipment can help manage this compaction and maintain soil health [20, 21].

3.2. Soil Bulk Density

The study investigated the impact of land leveling equipment traffic on soil surface properties up to a depth of 30 cm using laser equipment for accurate leveling. The results showed that the soil bulk density increased with the land leveling treatments. In the first season, the soil bulk density increased from 1.13 to 1.21 g/cm^3 under laser treatments L1 and L2. The soil bulk density increased from 1.18 to 1.29 g/cm^3 for the second season under the same treatments. Conversely, treatment L3 decreased soil bulk density for both seasons, with values of 1.13 to 1.07 g/cm^3 and 1.12 to 1.08 g/cm^3, respectively. The highest increase in bulk density was observed under the laser treatment L1, with values of 1.13 to 1.21 g/cm^3 and 1.18 to 1.29 g/cm^3 for the first and second seasons, respectively. On the other hand, the rotary treatment (L3) decreased soil bulk density for both seasons. These findings highlight the influence of land leveling equipment traffic and the specific treatments on soil bulk density, indicating the importance of accurate leveling techniques in managing soil properties.

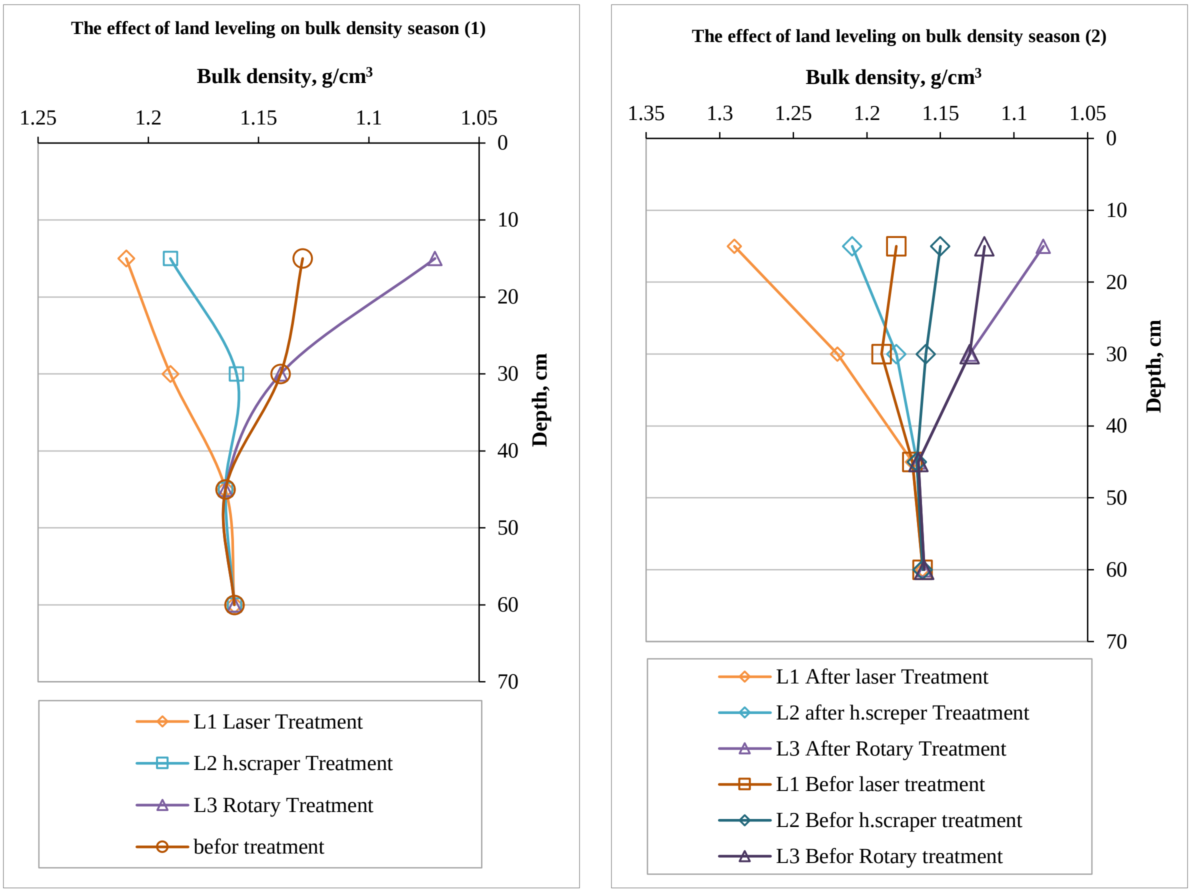

Figure 5. Effect of land leveling treatments on soil bulk density at two experimental seasons

3.3. Soil Porosity

The obtained results indicate that the traffic of land leveling equipment, specifically using laser equipment for accurate leveling, affects soil porosity at the soil surface up to a depth of 30 cm. Here are the key findings:

Laser Equipment (L1 and L2):

- The use of laser equipment for land leveling resulted in a decrease in soil porosity. In the first season, the soil porosity decreased from 57.36% to 54.34% for both L1 and L2 treatments.
- In the second season, the soil porosity decreased from 55.47% to 51.32% for L1 and from 57.36% to 55.09% for L2.

Laser Equipment (L3):

- In contrast, the use of laser equipment (L3) resulted in an increase in soil porosity at both seasons. In the first season, the soil porosity increased from 57.34% to 59.62%. In the second season, it increased from 57.74% to 59.25%.

These findings are supported by the information provided in Figure 6, which illustrates the effect of land leveling treatments on soil porosity at the soil surface up to a depth of 30 cm. It shows that L1 and L2 treatments decreased soil porosity in both seasons, while L3 treatment increased soil porosity.

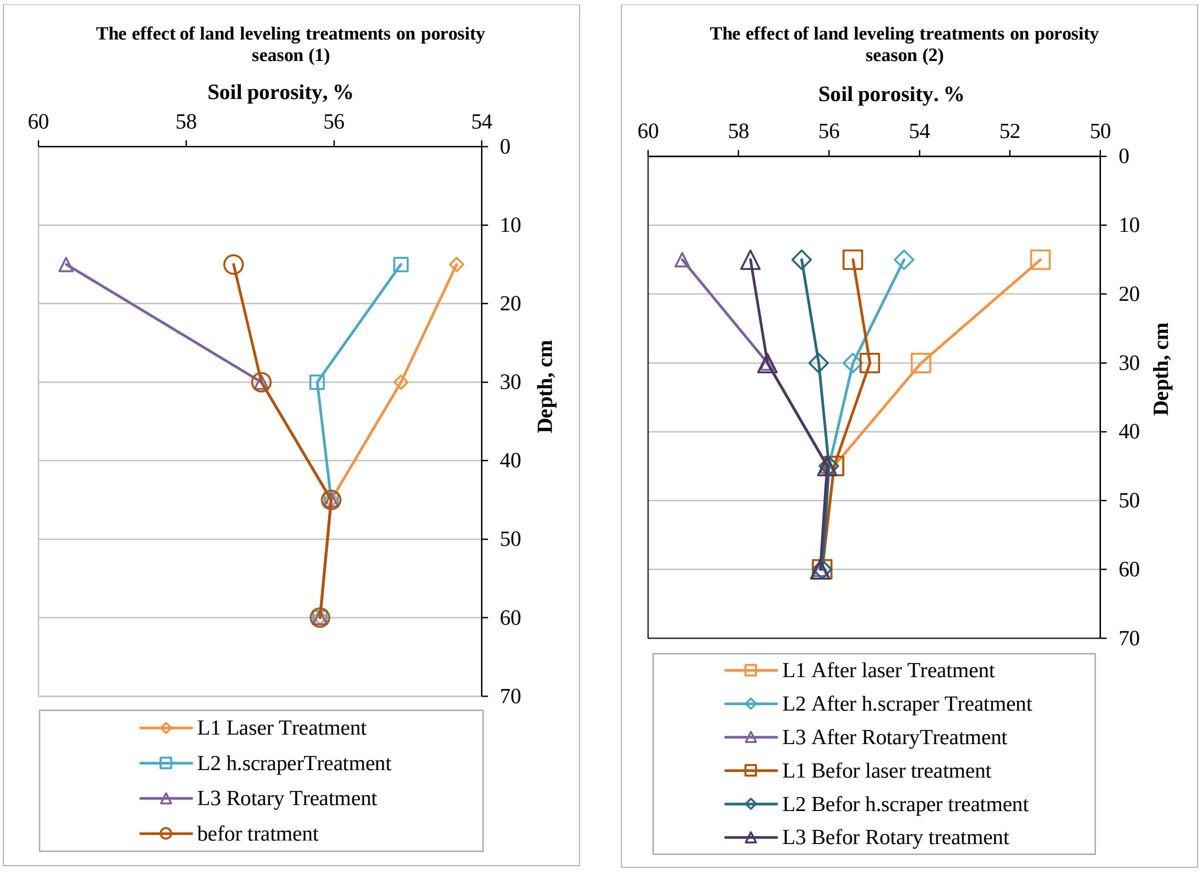

Figure 6. Effect of land leveling treatments on soil porosity at two experimental seasons

The obtained results from a study involving laser leveling, hydraulic scraper, and rotary treatments over two seasons showed changes in soil bulk density and porosity at the soil surface up to a depth of 30 cm. Here are the key findings:

Soil Bulk Density:

- Using laser leveling and hydraulic scraper treatments during the first season increased soil bulk density at the soil surface up to 30 cm depth. The rate of change of soil bulk density was recorded as 7.07% at L1 and 5.30% at L2.
- However, the rotary treatment during the first season decreased the soil bulk density at the soil surface up to 30 cm depth. The rate of change of soil bulk density at the end of the experiment was recorded as 3.30%.
- In the second season, the use of laser leveling and hydraulic scraper treatments again led to an increase in soil bulk density at the soil surface up to 30 cm depth. The rate of change of soil bulk density was recorded as 9.32% at L1 and 5.21% at L2.

- Similarly, the rotary treatment during the second season decreased the soil bulk density at the soil surface up to 30 cm depth. The rate of change of soil bulk density at the end of the experiment was recorded as 3.57%.

Soil Porosity:

- The obtained results also showed a decrease in soil porosity at the soil surface up to 30 cm depth when using laser leveling, hydraulic scraper, and rotary treatments during both seasons.
- During the first season, the rate of change of soil porosity was recorded as 5.26% at L1 and 3.94% at L2 for laser leveling and hydraulic scraper treatments. The rotary treatment during the first season resulted in a rate of change of soil porosity of 3.94%.
- In the second season, the rate of change of soil porosity was recorded as 9.32% at L1 and 5.21% at L2 for laser leveling and hydraulic scraper treatments. The rotary treatment during the second season resulted in a rate of change of soil porosity of 3.57%.

The study's results showed changes in soil porosity under different treatments across two seasons. Here are the key findings:

Laser Treatment (L1):

- The soil porosity decreased under the laser treatment (L1) in both seasons. In the first season, the soil porosity decreased from 57.36% to 54.34%. In the second season, it decreased from 55.47% to 51.32%.

Rotary Treatment (L3):

- In contrast, the soil porosity increased under the rotary treatment (L3) in both seasons. In the first season, the soil porosity increased from 57.34% to 59.62%. In the second season, it increased from 57.74% to 59.25%.

Different treatments and their effects on soil bulk density, porosity, and the breakdown of soil particles. Let me clarify and summarize the information you provided:

- Treatment L1 and L2: Tractor, scraper, and traffic were applied to the same area, this treatment aimed to increase soil bulk density and decrease soil porosity, The breakdown of soil particles occurred after the traffic scraper was used.
- Treatment L3: Soil bulk density decreased, and soil porosity increased in this treatment, the breakdown of soil particles occurred without any traffic or machinery.

It appears that L1 and L2 treatments involved mechanical compaction and traffic, resulting in denser soil with reduced porosity. In contrast, L3 treatment achieved lower soil bulk density and higher porosity by allowing soil particles to break down naturally without additional compaction from machinery or traffic. These treatments demonstrate how different management practices can influence soil properties.

3.4. Effect of Land Leveling Treatments on Mean Weight Diameter (M.W.D)

The results presented in Figures 7 and 8 demonstrate the effect of land leveling on the mean weight diameter of the soil during two seasons. Here are the key findings:

First Season:

- The average soil mean weight diameter for the laser land leveling treatment (L1) was recorded as 12.7 mm.
- The average soil mean weight diameter for the hydraulic scraper treatment (L2) was 14.58 mm.
- The rotary treatment (L3) showed the highest average soil mean weight diameter of 28.06 mm.

Second Season:

- In the second season, the average soil mean weight diameter for the laser land leveling treatment (L1) increased to 13.09 mm.
- The hydraulic scraper treatment (L2) resulted in an average soil mean weight diameter of 19.72 mm.
- The rotary treatment (L3) showed the highest average soil mean weight diameter of 29.19 mm.

The results indicate that the lowest average soil mean weight diameter was observed under the laser land leveling treatment for both the first and second seasons. On the other hand, the highest average soil mean weight diameter was observed under the rotary treatment for both seasons.

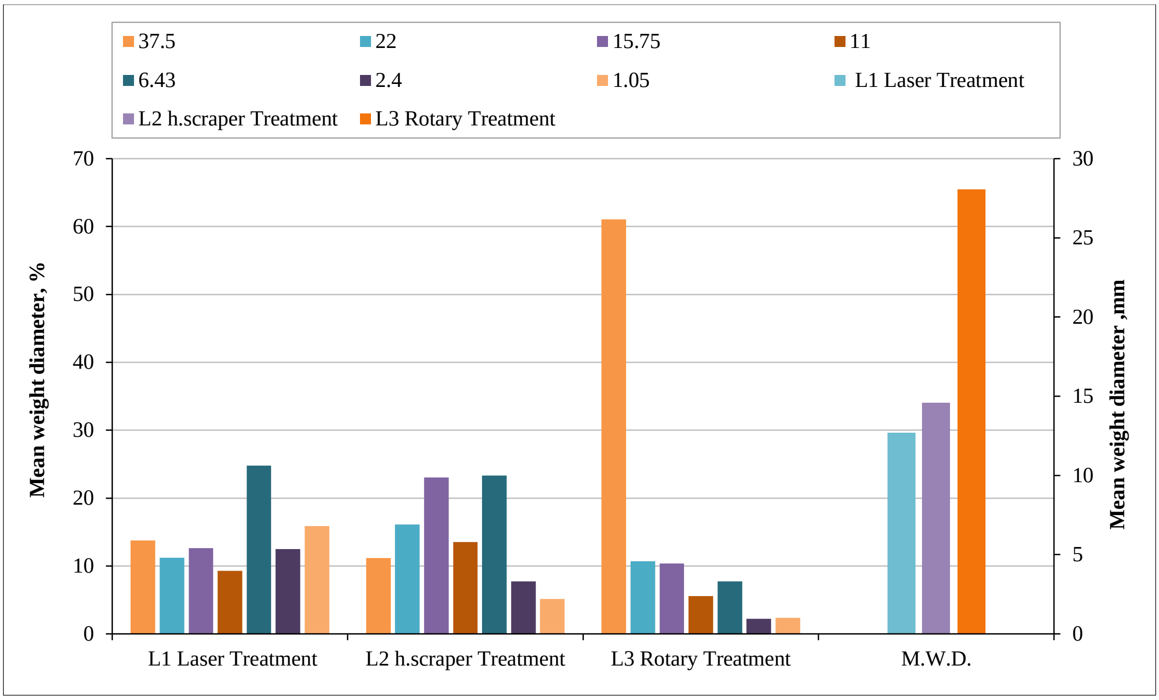

Figure 7. Effect of land leveling treatments on mean weight diameter at first season

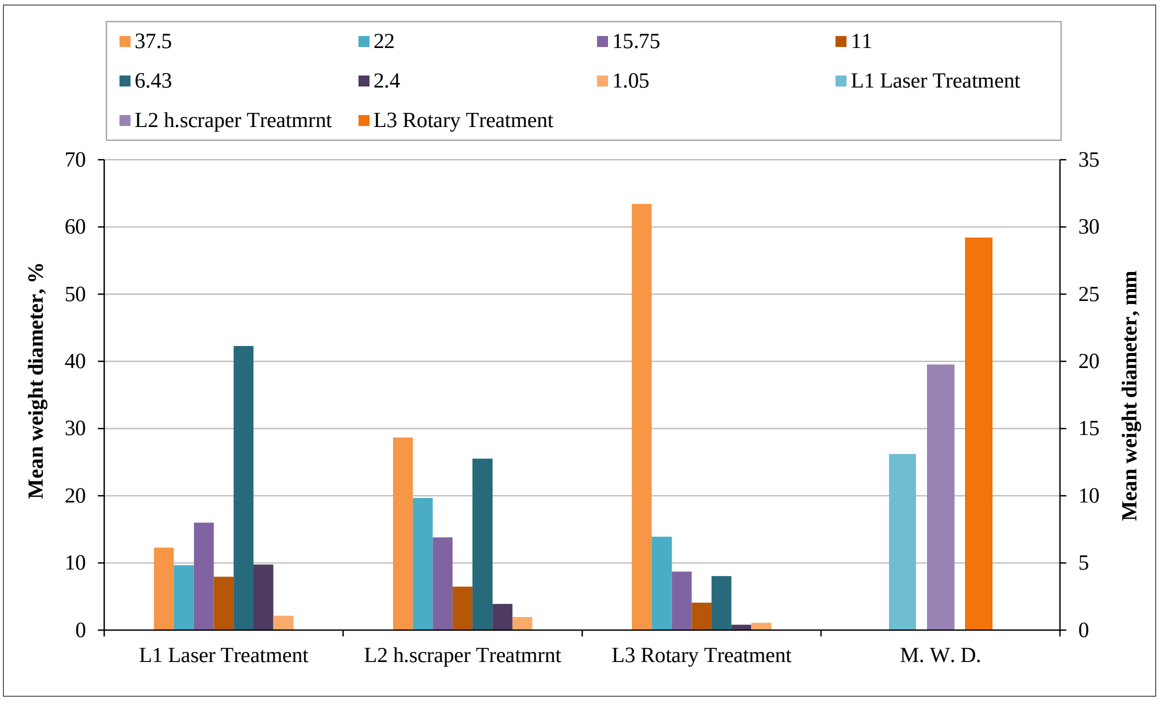

Figure 8. Effect of land leveling treatments on mean weight diameter at the second season

4. Conclusions

These results indicate that the rotary treatment (L3) generally led to a decrease in bulk density, an increase in soil porosity, and a higher mean weight diameter compared to the laser treatment (L1) over the two seasons. Laser treatment (L1) resulted in the opposite trends, with increased bulk density, decreased soil porosity, and lower mean weight diameter.

The data related to changes in bulk density, soil porosity, and mean weight diameter under different treatments (L1 and L3) in two seasons:

Bulk Density:

- Under laser treatment (L1), there was an increase in bulk density from 1.13 to 1.21 g/cm^3 in the first season and from 1.18 to 1.29 g/cm^3 in the second season.

- Under rotary treatment (L3), there was a decrease in bulk density from 1.13 to 1.07 g/cm^3 in the first season and from 1.12 to 1.08 g/cm^3 in the second season.

Soil Porosity:

- Under laser treatment (L1), there was a decrease in soil porosity from 57.36% to 54.34% in the first season and from 55.47% to 51.32% in the second season.
- Under rotary treatment (L3), there was an increase in soil porosity from 57.34% to 59.62% in the first season and from 57.74% to 59.25% in the second season.

Mean Weight Diameter:

- Under rotary treatment (L3), the mean weight diameter was highest, with values of 28.06 mm and 29.19 mm in the first and second seasons, respectively.
- Under laser land leveling treatment (L1), the mean weight diameter was lowest, with values of 12.70 mm in the first and 13.09 mm in the second seasons.

5. Declarations

5.1. Author Contributions

Conceptualization, A.E. and A.S.; methodology, A.E.; software, A.E.; validation, A.S., E.E., and M.M.E.; formal analysis, A.E.; investigation, E.E.; resources, A.S.; data curation, A.E.; writing—original draft preparation, A.E.; writing—review and editing, M.E.; visualization, M.M.E. and E.E.; supervision, A.S.; project administration, M.M.E.; funding acquisition, M.E. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available in the article.

5.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

5.4. Conflicts of Interest

The authors declare no conflict of interest.

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