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# Effect of irrigation on physical properties of different soil types

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**Abstract**
Irrigation is an unavoidable operation, when growing of crops is required. Water is essential for the plants to carry out the metabolic activities, and is supplied to the plants through irrigation. The water supplied to the plants also reaches the soil around it, which is also an unavoidable phenomenon, especially in case of flood irrigation. The water present in the soil alters the soil physical properties, such as cone index and bulk density, in a different manner for different soil types. Therefore, the present study was done to find the effect of irrigation on two different soil types. The different soil types under the study were sandy loam and silty loam type. Irrigation was provided to both the soil types and bulk density and cone index, before and after the irrigation treatment, was recorded. It was found that the cone index of both the sandy loam soil and silty loam soil was found to be lower after irrigation was applied to the fields. The bulk density of sandy loam soil was found to be higher, after irrigation than that of before irrigation conditions, but in silty loam soil it was found to be lower after irrigation than that of before irrigation conditions.

**Keywords:** irrigation, sandy loam, silty loam, cone index, soil hardness, penetration resistance, bulk density, soil moisture

## Introduction
The physical, chemical and biological properties of soil varies from place to place and time to time. It may happen due to the addition and removal of certain materials to the soil continuously from the surrounding environment. The soil physical property (Bulk density, porosity, structure, temperature, soil resistance, etc.) is affected by the vehicle movement on the field. Many studies reported the significant effect of vehicle movement on the soil properties [1-7]. Soil physical properties affects plant growth because it does not allow the deep penetration of the plant root, when soil hardness is high. It leads to a decrease in the production of the crops. It also reduces the farm machinery's life due to more wear and tear in the case of hard soil. Irrigation also affects the soil physical properties, which needs to be quantified so that the farmers can plan the field operations accordingly. Cone index and bulk density gives us an idea of the soil strength and can be useful when farm tillage operations would be performed, to reduce wear and tear of the implements, thereby ensuring their long life, when run at optimum soil moisture conditions. Therefore, the measurement of the soil physical properties becomes important. In this study, the impact of irrigation on the soil physical properties (Bulk density & Cone index) was studied for the two different soils (Sandy loam & Silty loam).

## Materials and Methods
This section deals with the materials and methods employed for the experimental investigations. The tests were carried out on the fields of research farms of Department of Farm Machinery and Power Engineering, Punjab Agricultural University (PAU), Ludhiana. The effect of irrigation on soil hardness/compaction has been included in the present study. Soil compaction has been noted by taking cone index and bulk density samples, before irrigation. Soil compaction has also been recorded after applying irrigation to the fields by taking cone index readings and bulk density values, when the fields were at optimum moisture content, depending upon different soil types. Before irrigation condition has been denoted as BI and after irrigation condition has been denoted as AI.

### 1. Independent parameters of the study
Field plots at two different locations of varied soil texture described henceforth as S1 and S2 were selected.

The soil texture has been characterized by ascertaining the soil physical parameters. i.e. per cent sand, silt and clay. Soil samples were taken from at least four different locations of the selected plot i.e. from S1 and S2 separately. Samples taken from fields S1 and S2 were mixed separately and part of soil samples (S1 and S2) were taken to soil testing laboratory of the Department of Soil Science, Punjab Agricultural University, Ludhiana for analysis work.

## 2. Dependent parameters

### 2.1 Cone index (penetration resistance)

A hand-held digital cone penetrometer was used to measure soil hardness or penetration resistance as shown in Figure 1. The Cone index or penetration resistance, in kPa was measured as an indicator of soil hardness.

**Fig 1:** Soil hardness being measured using a digital cone penetrometer

A digital cone penetrometer used in the experiment was Rimik CP40II. It consists of a rigid, steel rod, with a cone tip attached to one end, fixed to a force transducer, through the other end. The force transducer has been fixed to the unit at lower portion and the force sensor has been connected to the microcomputer based circuitry of the unit with a display at upper portion, as shown in Figure 2.

**Fig 2:** A view of Cone penetrometer

The penetrometer can be used up to a depth of 75cm safely and has a maximum force limit of 75 kgf. Depth measurements were made by the unit with ultrasonic proximity sensor fixed at its lower portion. The cone tip of penetrometer has been exchangeable with other different sized tips.

Cone penetrometer was operated at a uniform speed range of 0.2 m/min to 2 m/min by placing the cone tip at the designated place of sampling with penetrometer rod held at near vertical orientation as possible. The cone index readings were automatically logged by the unit's data logger. An RS-232 interface connection has been provided with the unit along with software for downloading the logged data to a computer in an excel (.xls) file format for further analysis. The unit logs the cone index data for every 1 cm, 1.5 cm, 2 cm or 2.5 cm travel of penetrometer rod, as per customized requirements.

### 2.2. Soil Bulk Density

Soil compaction has also been characterized by recording the soil bulk density of the experimental plots. Bulk density of soils was recorded at three different depths 0-5 cm, 0-10 cm and 0-20 cm by using three different core samplers, shown in Figure 3.

The core samplers were hammered in the soil and samples were drawn without disturbing the soil, as shown in Figure 4. The samples were weighed using the platform type electronic weighing balance (Oras Tech, India). Bulk density values for 0-5 cm, 5-10 cm and 10-20 cm depth were calculated by using relative density separation method of corresponding depths, if needed for analysis. For calculating bulk density for depth 5-10 cm, relative weight and volume of 0-5 cm depth was subtracted from 0-10 cm depth values. Bulk density for 10-20 cm has also been calculated by using similar technique, when need arised.

The soil samples from the core were used for calculating out the wet bulk density. Standard core sampling technique was used to determine soil bulk density (wet basis) by using the relation given in equation 1.

$$D_w = W/V \quad \ldots 1$$

Where,

$D_w$ = Bulk density (wet basis) in g/cc,

W = weight of soil taken by sampler in g,

V = volume of specific sampler in cc.

**Fig 3:** Core samplers along with the hammer

**Fig 4:** Core samplers excavated out of the soil

The extent of soil moisture influences the soil bulk density at wet basis, so bulk density values have been determined at standard moisture i.e. at dry level. The dry bulk density of soil sample ($D_d$) has been calculated using the relation between the soil bulk density at wet basis and moisture content. A part of the soil sample has been collected in plastic envelops while recording wet bulk density of soil. The soil samples were then put for moisture determination at department laboratory using standard oven drying method. The soil samples were weighed on a weighing balance (Denver instrument, TP-3102) having precision of 0.01g. The soil moisture fraction has been calculated by using relation given in equation 2.

$$w = (W_w - W_d) / W_d \quad \ldots 2$$

Where,
w = soil moisture in fraction (dry basis) of given soil sample,
$W_w$ = wet weight of soil in g,
$W_d$ = dry weight of soil in g.

Then, the soil bulk density at dry basis ($D_d$) was calculated using the relation given in equation 3.

$$D_d = D_w/(1+w) \quad \ldots 3$$

Where,
$D_d$ = dry bulk density in g/cc,
$D_w$ = wet bulk density in g/cc,
w = soil moisture in fraction (dry basis) of given soil sample
Soil bulk density at dry basis for 0-5 cm, 0-10 cm and 0-20 cm has been used for comparing the results obtained in the present study.

## Results and discussion

The soil samples of two different sites, selected for the experimentation, were analysed for particle size distribution (soil texture). The S1 soil composed of 76% sand, 12% silt and 12% clay, hence termed as sandy loam texture whereas S2 soil composed of 20% sand, 55% silt and 25% clay, hence falls under silty loam texture category.

### Effect of irrigation on soil compaction

Cone index and bulk density values were taken before irrigation and after irrigation treatment for both types of soils.

### Values of cone index and bulk density before irrigation

#### 1. Cone index values for sandy loam soil type (S1) before irrigation

The field was divided into number of plots. Cone index values were recorded for sandy loam soil (S1) in kPa at 5, 10 and 15 cm sampling depths. The cone index values beyond 15 cm depth could not be recorded due to excessive hardness encountered at sub-soil level of the soil. A total number of cone insertions were 432 (24 plots x 6 insertions x 3 replications). The average cone index values were found to be 1816, 2059 and 2568 kPa at 5, 10 and 15 cm depths, respectively.

Coefficient of variation (CV) for cone index values for soil S1 were analysed for variation of data within the experimental plots and between the experimental plots. The CV for the cone index values at 5 cm depth was found to vary from 9.3 to 14.91 % among all values within the plots. The CV at 10 cm depth varied between 4.98 to 14.88% and at 15 cm depth it varied between 8.46 to 14.75% among all the sample values within the plots. The CV for the cone index between the plots for soil S1 at 5, 10 and 15 cm depths were found to be 4.34, 3.61 and 7.57 %, respectively. The maximum variation in the cone index value was 14.91 % within the plots and 7.57 % between the plots.

The T-test for the cone index values of soil S1 at sampling depths of 5, 10 and 15 cm is given in Table 1. No significant variation has been found, at 5 % level of significance ($p$>0.05), among cone index values at all the reported depths.

**Table 1:** The T-test for the cone index values, before the irrigation, for soil S1 at different sampling depths

| Sr. No. | Depth (cm) | Test value | t value | d.f. | Mean difference | p (2-tailed) |
|---|---|---|---|---|---|---|
| 1. | 5 | 1816 | 0.022 | 431 | 0.2399 | NS |
| 2. | 10 | 2059 | 0.089 | 431 | 0.9087 | NS |
| 3. | 15 | 2568 | 0.021 | 431 | 0.3546 | NS |

#### 2. Bulk density values for sandy loam soil type (S1) before irrigation

Bulk density values for 0-5 cm, 0-10 cm and 0-20 cm depth were calculated in g/cc for the soil. A total of 24 samples were taken. The reading value was the averaged value obtained over the three replications. The average bulk density values were found to be 1.69, 1.71 and 1.56 g/cc at 0-5 cm, 0-10 cm and 0-20 cm depths, respectively.

The CV for the bulk density values for 0-5, 0-10 and 0-20 cm depths were calculated between the plots and were found to be at 5.36, 7.05 and 4.20 %, respectively. The variation in the values may be due the heterogeneous nature & physical properties of the soil and due to manual operation of the sampling equipment. The T-test for the bulk density values at sampling depths for 0-5, 0-10 and 0-20 cm of soil S1 is given in Table 2. No significant variation has been found, at 5 % level of significance ($p$>0.05), among bulk density values at all the reported depths.

**Table 2:** The T-test for the bulk density values, before the irrigation, for soil S1 at different sampling depths

| Sr. No. | Depth (cm) | Test value | t value | d.f. | Mean difference | p (2-tailed) |
|---|---|---|---|---|---|---|
| 1. | 0-5 | 1.69 | 0.028 | 23 | 0.0005 | NS |
| 2. | 0-10 | 1.71 | 0.141 | 23 | 0.0034 | NS |
| 3. | 0-20 | 1.56 | 0.447 | 23 | 0.0059 | NS |

### 3. Cone index values for silty loam soil type (S2) before irrigation

Cone index values were recorded at initial compacted condition for silty loam soil (S2) in kPa at 5, 10 and 15 cm sampling depths.

The cone index values beyond 15 cm depth could not be recorded due to excessive hardness encountered at the sub-soil level of this soil, also as in case of soil S1. A total number of cone insertions were 432 (24 plots x 6 insertions x 3 replications). The average cone index values were found to be 2071, 1557 and 1968 kPa at 5, 10 and 15 cm depths, respectively.

CV for cone index values for S2 soil were also analysed for variation of data within the experimental plots and between the experimental plots. The CV for the cone index values at 5 cm depth was found to vary from 8.46 to 14.82 % among all samples within the plots.

The CV at 10 cm depth varied between 8.78 to 14.86 % and at 15 cm depth it varied between 7.09 to 14.59 % among all the sample values within the plots. The CV for the cone index between the plots for soil S2 at 5, 10 and 15 cm depths were found to be 4.00, 4.91 and 2.39 %, respectively. The maximum variation in the cone index value was 14.86 % within the plots and 4.91 % between the plots.

The T-test for the cone index values of soil S2 at sampling depths of 5, 10 and 15 cm is given in Table 3. No significant variation has been found, at 5 % level of significance ($p$>0.05), among cone index values at all the reported depths.

**Table 3:** The T-test for the cone index values, before the irrigation, for soil S2 at different sampling depths

| Sr. No. | Depth (cm) | Test value | t value | d.f. | Mean difference | p (2-tailed) |
|---|---|---|---|---|---|---|
| 1. | 5 | 2071 | 0.065 | 431 | 0.8352 | NS |
| 2. | 10 | 1557 | 0.06 | 431 | 0.6326 | NS |
| 3. | 15 | 1968 | 0.065 | 431 | 0.8958 | NS |

### 4. Bulk density values for silty loam soil type (S2) before irrigation

Bulk density values for 0-5 cm, 0-10 cm and 0-20 cm depths were also calculated in g/cc for the S2 soil. A total of 24 samples were taken. The reading value was the averaged value obtained over the three replications. The average bulk density values were found to be 1.82, 1.83 and 1.50 g/cc at 0-5 cm, 0-10 cm and 0-20 cm depth, respectively.

The CV for the bulk density values for 0-5, 0-10 and 0-20 cm depths were calculated between the plots and were found to be at 4.1, 6.33 and 6.84 %, respectively. The variation in the values may be due the heterogeneous nature & physical properties of the soil and due to the manual operation of the sampling equipment.

The T-test for the bulk density values at sampling depths for 0-5, 0-10 and 0-20 cm of soil S2 is given in Table 4. No significant variation has been found, at 5 % level of significance ($p$>0.05), among bulk density values at all the reported depths.

**Table 4:** The T-test for the bulk density values, before the irrigation, for soil S2 at different sampling depths

| Sr. No. | Depth (cm) | Test value | t value | d.f. | Mean difference | p (2-tailed) |
|---|---|---|---|---|---|---|
| 1. | 0-5 | 1.82 | 0.429 | 23 | 0.0064 | NS |
| 2. | 0-10 | 1.83 | 0.244 | 23 | 0.0057 | NS |
| 3. | 0-20 | 1.5 | 0 | 23 | 0.0001 | NS |

## Values of cone index and bulk density after irrigation

### 5. Cone index values for sandy loam soil type (S1) after irrigation

Cone index values were recorded for sandy loam soil (S1) in kPa at 5, 10 and 15 cm sampling depths. The cone index values beyond 15 cm depth could not be recorded, even after the irrigation treatment, due to excessive hardness still being maintained at sub-soil level of the soil. A total number of cone insertions were 432 (24 plots x 6 insertions x 3 replications). The average cone index values were found to be 398, 973 and 2081 kPa at 5, 10 and 15 cm depths, respectively.

CV for cone index values for soil S1 were analysed for variation of data within the experimental plots and between the experimental plots, after the irrigation. The CV for the cone index values at 5 cm depth was found to vary from 8.76 to 14.77 % among all samples within the plots. The CV at 10 cm depth varied between 7.96 to 14.93 % and at 15 cm depth it varied between 6.79 to 14.75% among all samples within the plots. The CV for the cone index between the plots for soil S1 at 5, 10 and 15 cm depths were found to be 8.87, 13.82 and 6.02 %, respectively. The maximum variation in the cone index value was 14.93 % within the plots and 13.82 % between the plots. The T-test for the cone index values of soil S1 at sampling depths of 5, 10 and 15 cm, after the irrigation, is given in Table 5. No significant variation has been found, at 5 % level of significance ($p$>0.05), among cone index values at all the reported depths.

**Table 5:** The T-test for the cone index values, after the irrigation, for soil S1 at different sampling depths

| Sr. No. | Depth (cm) | Test value | t value | d.f. | Mean difference | p (2-tailed) |
|---|---|---|---|---|---|---|
| 1. | 5 | 393 | 0.182 | 431 | 0.5298 | NS |
| 2. | 10 | 973 | 0.092 | 431 | 0.7805 | NS |
| 3. | 15 | 2220 | 0.034 | 431 | 0.5141 | NS |

### 6. Bulk density values for sandy loam soil type (S1) after irrigation

Bulk density values for 0-5 cm, 0-10 cm and 0-20 cm depth were also recorded in g/cc for the soil, after the irrigation. A total of 24 samples were taken. The reading value was the averaged value obtained over the three replications. The average bulk density values were found to be 1.79, 1.80 and 1.67 g/cc at 0-5 cm, 0-10 cm and 0-20 cm depths, respectively. The CV for the bulk density values for 0-5, 0-10 and 0-20 cm depths were calculated between the plots and were found to be at 4.31, 3.94 and 4.91 %, respectively. The variation in the values may be due to the heterogeneous nature & physical properties of the soil and due to the manual operation of the sampling equipment. The T-test for the bulk density values at sampling depths for 0-5, 0-10 and 0-20 cm of soil S1 after the irrigation is given in Table 6. No significant variation has been found, at 5 % level of significance ($p$>0.05), among bulk density values at all the reported depths.

**Table 6:** The T-test for the bulk density values, after the irrigation, for soil S1 at different sampling depths

| Sr. No. | Depth (cm) | Test value | t value | d.f. | Mean difference | p (2-tailed) |
|---|---|---|---|---|---|---|
| 1. | 0-5 | 1.79 | 0.512 | 23 | 0.008 | NS |
| 2. | 0-10 | 1.80 | 0.122 | 23 | 0.0017 | NS |
| 3. | 0-20 | 1.67 | 0.025 | 23 | 0.0004 | NS |

### 7. Cone index values for silty loam soil type (S2) after irrigation

Cone index values were recorded for silty loam soil (S2) in kPa at 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 cm sampling depths, after the irrigation. The cone index values were recorded beyond 15 cm depth after the irrigation due to influence of irrigation moisture at sub-soil level of the soil. A total number of cone insertions were 432 (24 plots x 6 insertions x 3 replications). The average cone index values were found to be 740, 1010, 1698, 1841, 1732, 1857, 2137, 2417, 2755 and 3021 kPa at 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 cm depths, respectively.

CV for cone index values for soil S2 were analysed for variation of data within the experimental plots and between the experimental plots, after the irrigation. The CV for the cone index values at different sampling depths were found to vary from 3.94 to 14.80 % among all samples within the plots.

The T-test for the cone index values of soil S2 at sampling depths of 5, 10 and 15 cm is given in Table 7. No significant variation has been found, at 5 % level of significance ($p$>0.05), among cone index values at all the reported depths.

**Table 7:** The T-test for the cone index values, after the irrigation, for soil S2 at different sampling depths

| Sr. No. | Depth (cm) | Test value | t value | d.f. | Mean difference | p (2-tailed) |
|---|---|---|---|---|---|---|
| 1. | 5 | 740 | 0.75 | 431 | 0.3411 | NS |
| 2. | 10 | 1010 | 0.187 | 431 | 0.6499 | NS |
| 3. | 15 | 1698 | 0.039 | 431 | 0.2048 | NS |

### 8. Bulk density values for silty loam soil type (S2) after irrigation

Bulk density values for 0-5 cm, 0-10 cm and 0-20 cm depth were also recorded in g/cc for the soil, after the irrigation. A total of 24 samples were taken. The reading value was the averaged value obtained over the three replications. The average bulk density values were found to be 1.71, 1.71 and 1.45 g/cc at 0-5 cm, 0-10 cm and 0-20 cm depths, respectively.

The CV for the bulk density values for 0-5, 0-10 and 0-20 cm depths were calculated between the plots and were found to be at 3.86, 5.89 and 6.32 %, respectively. The variation in the values may be due to the heterogeneous nature & physical properties of the soil and due to the manual operation of the sampling equipment.

The T-test for the bulk density values at sampling depths for 0-5, 0-10 and 0-20 cm of soil S2 is given in Table 8. No significant variation has been found, at 5 % level of significance ($p$>0.05), among bulk density values at all the reported depths.

**Table 8:** The T-test for the bulk density values, after the irrigation, for soil S2 at different sampling depths

| Sr. No. | Depth (cm) | Test value | t value | d.f. | Mean difference | p (2-tailed) |
|---|---|---|---|---|---|---|
| 1. | 0-5 | 1.71 | 0.216 | 23 | 0.0029 | NS |
| 2. | 0-10 | 1.71 | 0.238 | 23 | 0.0048 | NS |
| 3. | 0-20 | 1.45 | 0.261 | 23 | 0.0048 | NS |

### 9. Cone index for sandy loam soil type (S1) for before and after irrigation conditions

The cone index values were plotted across the sampling depth for the soil S1, before and after the irrigation, shown in Figure 5. The cone index values of the soil were found to be lower after irrigation than that of before irrigation conditions. This was due to the presence of moisture in the soil, which allowed the easy penetration of the cone, and thus lower cone index values.

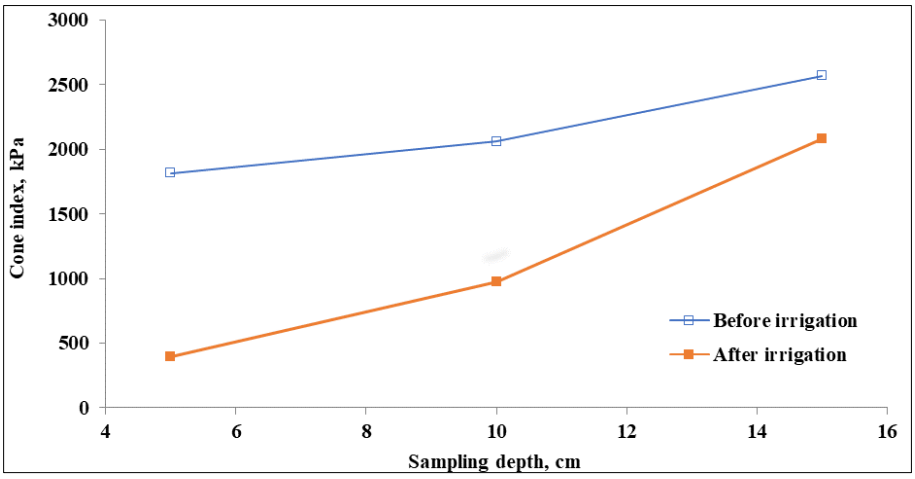


**Fig 5:** Cone index values of soil S1 before and after irrigation

### 10. Cone index for silty loam soil type (S2) for before and after irrigation conditions

The cone index values were plotted across the sampling depth for the soil S2, before and after the irrigation and shown in Figure 6. The cone index values of the soil were found to be lower after irrigation than that of before irrigation conditions. This was due to the presence of moisture in the soil, which allowed the easy penetration of the cone, and thus lower cone index values were obtained after irrigation.

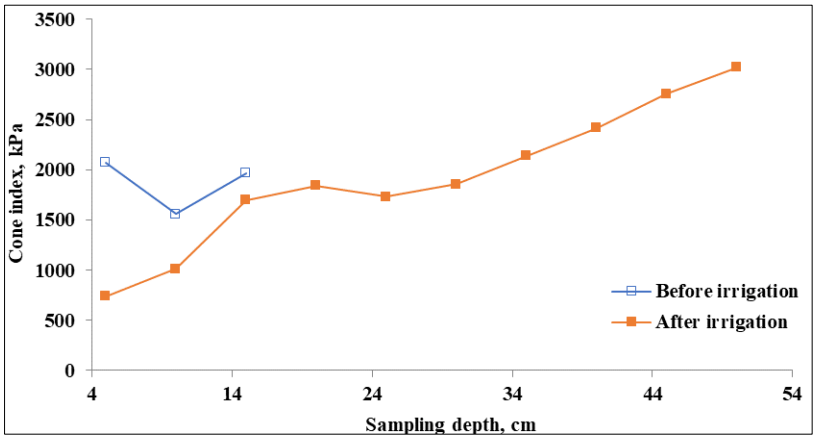


**Fig 6:** Cone index values of soil S2 before and after irrigation

**11. Bulk density for sandy loam soil type (S1) for before and after irrigation conditions**

The bulk density values were plotted across the sampling depth for the soil S1, before and after irrigation, shown in Figure 7. The bulk density values of the soil were found to be higher after irrigation than that of before irrigation conditions. This was due to the presence of moisture in the soil. The average moisture fractions of the soil samples, before and after the irrigation, were 7.5 % and 15.0 %, respectively. More moisture fraction may be attributed to more weight gain by same volume of the soil, leading to higher bulk density.

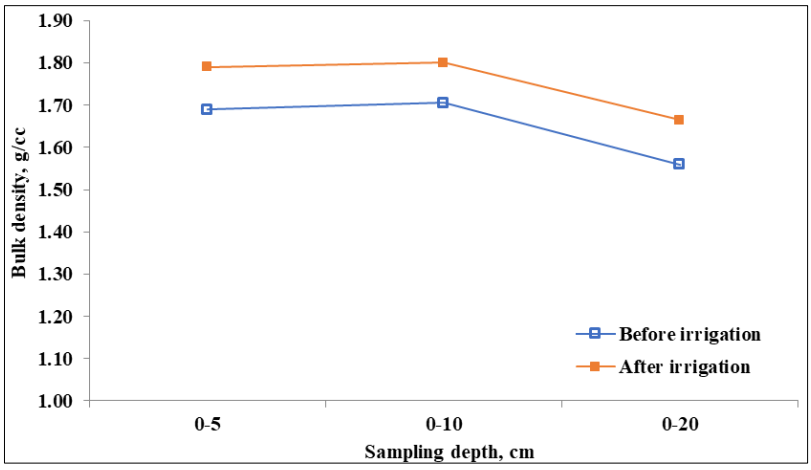


**Fig 7:** Bulk density values of soil S1 before and after irrigation

**12. Bulk density for silty loam soil type (S2) for before and after irrigation conditions**

The bulk density values were plotted across the sampling depth for the soil S2, before and after irrigation and shown in Figure 8. The bulk density values of the soil were found to be lower after irrigation than that of before irrigation conditions. The reason may be due to presence of large number of micro pores in the soil which leads to more sample volume gain as compared to weight gain, after the irrigation conditions (moisture fractions were 17.0 % and 21.0 %, before and after irrigation, respectively). This may be due to shrinking/swelling behaviour of the fine textured soils.

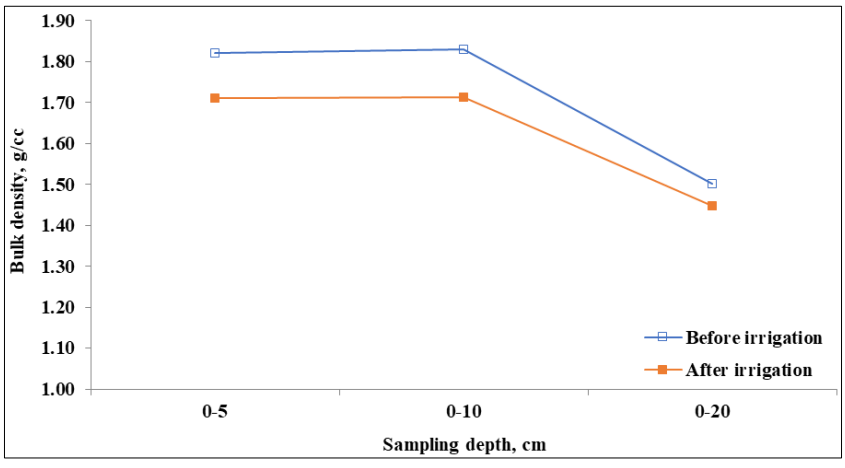


**Fig 8:** Bulk density values of soil S2 before and after irrigation

## Conclusions

The water present in the soil alters the soil physical properties, such as cone index and bulk density, in a different manner for different soil types. Therefore, the present study aimed to find the effect of irrigation on two different soil types. The different soil types under the study were sandy loam and silty loam type. Irrigation was provided to both the soil types. Bulk density and cone index, before and after the irrigation treatment, was recorded. The cone index of sandy loam soil and silty loam soil was found to be lower after irrigation was applied to the fields. The bulk density of sandy loam soil was found to be higher after irrigation than that of before irrigation conditions, but in silty loam soil it was found to be lower after irrigation than that of before irrigation conditions.

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