SOIL TILTH: AN APPROACH FOR SOIL HEALTH MANAGEMENT

Abstract

Soil is one of the most essential natural resources to produce food for all living creature. The production capacity of soil depends upon the health of the soil. It is being damaged by erosion and intensive agricultural practices. Soil management must be improved to sustain a productive and profitable agriculture. Tilth has been used to describe the physical state of the soil. It denotes the ease with which tillage, preparation of seedbed, germination and root development can be accomplished. Tilth, in fact, is a composite of physical properties such as texture, structure, strength, organic matter, and consistency. The management practises to achieve desired soil conditions is difficult because the processes that influence tilth are poorly understood by the farmers. Tillage is one of the main activities that leads to the long-term deterioration of tilth because it accelerates the rate of oxidation of organic substance. Tillage facilitates the access of soil, air, and water to the plant and often increases soil tilth over the short period. Plant growth incorporates the influences of crop, soil, and microclimate, making it a useful predictor of soil tilth. The evaluation of soil tilth levels in agriculture is a difficult task, requiring a lot of time and knowledge. This chapter aims to give an insight about the available soil tilth assessment techniques.

Keywords: soil tilth; clod mean weight diameter; mechanical transducer; digital sieving

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I. INTRODUCTION

Soil is one of the most valuable natural resources and it is being damaged by agricultural practises and erosion **[19].** One of the most significant agricultural activities is tillage, which is the physical disturbance of soil with implements and tools to create an adequate seedbed that produces good tilth for improved germination and better crop growth. Tilth is a subjective term that indicates the physical status of the soil, showing how easily tillage operations can be carried out, seedlings may emerge and roots can grow **[23,7].** In reality, tilth is a composite of various physical characteristics, such as consistency, organic matter content, texture, structure and strength. It is a dynamic property, making it susceptible to both natural change and artificial manipulation, like cultivation and tillage **[20].** Implementing the strategies to maintain the physical, chemical, and biological characteristics can increase soil productivity. The health of the soil is greatly influenced by its tilth **[18].** Plant growth incorporates the influences of the crop, soil, and microclimate, making it a useful predictor of soil tilth **[6].** The variety of plants can influence soil tilth since certain species can penetrate hard soil layers while others favour aggregate and macropore integrity **[2]**.

Better tillage and crop rotation strategies in agricultural production, fertiliser management, and yield targets can be made by identifying the optimal soil tilth conditions for different crops and by knowing how tillage alters soil tilth. The biological, chemical and physical characteristics of the soil play a role in determination of soil health. Bulk density, infiltration, soil structure, porosity, and compaction are among the biological properties that depend on soil tilth. Tillage is one of the main activities that leads to tilth deterioration over the long run because it accelerates the rate of oxidation of organic substance. Tillage often enhances tilth over the short term because it strengthens plant soil-air-water relationships. Because of the dynamic interplay between the physical, chemical, and biological processes causing or maintaining tilth, time has an impact on soil tilth **[6].** If management techniques like long-term use of conservation tillage is adopted, creates new equilibriums in the soil matrix and frequently results in a new soil tilth state **[1,17,26,25].**

In order to maximise production and profitability, it is critical to measure soil tilth. However, assessment of soil tilth in a farm level is a difficult task that require a lot of effort and knowledge. Soil tilth assessment is necessary because a good soil tilth avoids erosion, floods, stream siltation, and improve the soil-air-water relationship for plants, strong soil tilth resists compaction, rapidly absorbs water and stores it for later plant use. Poor tilth soils, on the other hand, are readily compacted, restrict water absorption, cause runoff and erosion, diminish crop yields, and inhibit plants from utilising nutrients and soil moisture **[3].** An expert can determine the tilth of a soil by sight and touch. In current practice, tilth levels are frequently determined by applying subjective logic or judgement. Once the condition of the soil tilth is known, certain actions may be performed to preserve or enhance the tilth. With the use of this knowledge, farmers are able to predict how long-term farming techniques will affect soil resources and, in turn, identify the best management strategies that will encourage the ongoing management of soil and water resources.

In these circumstances, using an expert system to solve the soil tilth assessment problem is suitable. Computer programmes or expert systems may be created to simulate the information and thought processes that real experts would apply to a problem in their area of competence. The invention of an image processing method, a mechanical transducer-based approach, and decision support system can help to address site-specific soil tilth issues and be very beneficial to both farmers and extension professionals. The objective of this chapter is to explain the techniques available for soil tilth assessment and soil health management. There are very few methods available for soil tilth assessment involving different principles. Only three methods which are important from subject point of view have been discussed in this chapter.

II. SOIL TILTH QUANTIFIACTION BY TILTH INDEX

As tilth is a qualitative term to describe the physical status of the soil, assessing the tilth Scientists, engineers, and farmers would all be benefited for a quantitative knowledge of soil tilth. **Reference [18]** developed a tilth index to measure the soil tilth. Tilth was measured using a tilth index. The tilth index, which ranges from 0 (for soil conditions unsuitable by plants) to 1 (highly useful for cultivation), was calculated using five soil physical parameters, including bulk density, uniformity coefficient, cone index, plasticity index and organic matter content. The parameters were chosen in part because they could be quickly measured outside. Near Ames, Iowa; and Waseca, Minnesota, field trials were carried out to ascertain how the soil's tilth and crop output responded to various tillage systems, including the mouldboard plough, chisel plough, till plant, spring disc, and slot plant ridge. Both webster (a silty clay loam soil) and clarion (a loam soil) were used for the studies. The same tillage practices and crop rotation were followed for ten years at Ames and preceding four years at Waseca. This was the very first approach to quantify soil tilth.

The following polynomial relationship was developed to represent the tilth coefficient related to the five soil characteristics:

$$\mathrm{CF_x} = (\mathrm{A_0} + \mathrm{A_1} \times \mathrm{X} + \mathrm{A_2} \times \mathrm{X}^2 + \cdots + \mathrm{A_n} \times \mathrm{X}^n) \quad (1)$$

Where:

CF_x is Tilth coefficients for the soil properties (X)

A_0, A_1,... A_n are the constants

The tilth index was determined using the tilth coefficients using the following equation:

$$\mathrm{TI} = (\mathrm{CF_1} \times \mathrm{CF_2} \times \ldots \times \mathrm{CF_n}) \quad (2)$$

Where:

TI = Tilth Index

CF = Tilth coefficient

The tilth coefficients and tilth index both were normalized to lie in between 0 and 1.

1. **Bulk density:** Bulk density can be described as the dry soil mass per unit soil volume. A perfect soil has a volume ratio of roughly 50 percent solid particles and 50 percent pore space **[4,7].** Such a mineral soil has a bulk density of roughly 1.3 Mg/m^3. For the sake of all computations, the particle density of soil was taken to be 2.65 Mg/m^3, assuming that there are no pore spaces and only solid particles. Any soil that had a bulk density of 1.3

Mg/m^3 or less was regarded as nonlimiting based on the review of literature **[22].** Bulk density of 2.1 Mg/m^3 was taken to be suitable decision for maximum value of bulk density based on experience as there was no specific literature for the highest value of the bulk density that would be regarded useless by plants. Equation (4) used a regression analysis of those selected points. The generated curve was pressured to pass through the terminals in equations (3) and (5) in order to determine the number of significant digits. The bulk density of the fields used to evaluate this relationship was less than 1.7 Mg/m3. However, equations (3) to (5) represented the hypothesised relationship between the bulk density (BD) and the tilth coefficient (CF(BD)).

$\mathrm{CF(BD)} = 1$, [for BD ≤ 1.3 Mg/m^3] (3)

$\mathrm{CF(BD)} = -1.5 + 3.87\times \mathrm{BD} - 1.5\times \mathrm{BD}^2$

(4) [for 1.3 ≤ BD ≤ 2.1 Mg/m^3] $\mathrm{CF(BD)} = 0.0$

(5) [for BD ≥ 2.1 Mg/m^3]

2. **Cone index:** It is crucial to persuade the researchers that using the cone index to measure mechanical resistance to roots is a reliable technique **[5].** Cone index is a gauge of soil tensile strength and a predictor of plant development and crop yield due to how easily roots may penetrate the soil **[10,11,12].** Bulk density and water content significantly influence cone index so it was crucial to gather the data of these variables **[5].** Soil was regarded nonlimiting and unusable by plants if its cone index was less than or equal to 1 MPa and greater or equal to 10 MPa respectively. In the absence of specific values for the cone index corresponding to nonlimiting and plant-unusable the classification of cone index was made. It was formed based on years of personal experience and general trends observed in the literature. However, equations (6) to (8) described the hypothesised relationship between the tilth coefficient [CF(CI)] and the cone index (CI).

   $\mathrm{CF(CI)} = 1$ (6) [for CI ≤ 1.0 MPa]
   $\mathrm{CF(CI)} = 1.012 - 0.002\times \mathrm{CI} - 0.1\times \mathrm{CI}^2$
   (7) [for 1.0 ≤ CI ≤ 10.0 MPa] $\mathrm{CF(CI)} = 0.0$
   (8) [for CI ≥ 10 MPa]

3. **Organic matter:** The Potential agricultural soil productivity, tilth, and fertility are significantly associated with their organic matter content **[16].** Although the majority of semiarid dryland soils contain only a small quantity of soil organic matter; usually less than 1% and its impact on the soil's attributes is significant. Soil productivity is reduced by a decreasing soil organic matter levels in soil. According to **Reference [20],** organic matter is primarily found in the top few inches of soil and provides nutrients for plants and, helps the soil develop in ways that are good for plant growth. The soil can be considered as non-limiting for plant growth when mineral matter accounts for 45% of soil volume and organic matter accounts for 5% **[4,7].** According to **Reference [9],** the majority of mineral soil constituents have specific densities between 2.65 and 2.7 Mg/m^3, whereas residual humus materials, if any, have densities of about 1.4 Mg/m^3. Therefore, a nonlimiting soil will contain about 5.38% of its weight in organic matter. Any mineral soil that contains organic matter content higher or equal to 5% in weight basis was regarded as nonlimiting based on the research assessment. The smallest amount of organic matter that might be regarded as useless by plants was not specifically

documented in any literature that was available. Based on prior experience, it was determined that an organic matter level of less than or equal to 1% with the lowest tilth coefficient of 0.70 was the greatest option for reducing the impact of low organic matter. To generate equation (10), a regression analysis was used. The produced curve passed through equations (9) and (11) end points caused the number of significant digits to increase. Equations (9) to (11) depicted the suggested relationship between the organic matter (OM) and the tilth coefficient (CF(OM)).

$\mathrm{CF(OM)} = 1$

(9) [for OM $\geq$ 5%]

$\mathrm{CF(OM)} = 0.59 + 0.122\times \mathrm{OM} - 0.008\times \mathrm{OM}^2$

(10) [for 1% $\leq$ OM $\leq$ 5%] $\mathrm{CF(OM)} = 0.7$

(11) [for OM $\leq$ 1%]

4. **Uniformity coefficient:** Depending on how the grain size distribution curve is shaped representing a soil is either well-graded or poorly-graded. The curve represents the grading pattern and the aggregate diameter of the grains, whether the particle sizes are uniform or not and the array of sizes are continuous or not. Poorly graded soils display a step-like distribution curve. Well-graded soils have a smooth distribution curve that is flattened and devoid of obvious discontinuities. The uniformity coefficient, which refers to the D_{60} to D_{10} ratio and represents the diameter at which 60% of 33 the soil mass is finer, can be used to indicate this aspect of grain size distribution. D_{10} is the comparable diameter at which 10% is finer **[27].** In this investigation, a well-graded soil with a homogeneity coefficient more than or equal to 5 was chosen. According to the aforementioned discussion, soils with uniformity coefficients of 5 or more were regarded nonlimiting, whilst soils with uniformity coefficients of 2 or lower were considered unsuitable by plants. A value of 0.75 was considered to be the optimum option based on experience. A uniformity coefficient less than or equal to 2 tends to mitigate the effect of low uniformity coefficient because there was no particular literature for the lowest tilth coefficient. For obtaining equation (13), a regression analysis was used. The curve passed through equations (12) and (14) end points forced the number of significant digits to increase. However, equations (12) to (14) indicated the hypothesised relationship between the uniformity coefficient (UC) and the tilth coefficient (CF(UC)).

   $\mathrm{CF(UC)} = 1$

   (12) [for UC $\geq$ 5]

   $\mathrm{CF(UC)} = 0.384 + 0.245\times \mathrm{UC} - 0.023\times \mathrm{UC}^2$

   (13) [for 2 $\leq$ UC $\leq$ 5] $\mathrm{CF(UC)} = 0.75$

   (14) [for UC $\leq$ 2]

5. **Plasticity index:** The difference in moisture content between the soil's liquid and plastic limits is known as the plasticity index. It is a measurement of the soil's cohesive quality. High plasticity index materials typically soften and become slick in damp conditions. According to **Reference [8],** the particle size distribution of soils varies. The

characteristics of soils that impact soil-water relations are rarely uniform. Variations result from naturally existing variances in texture and structure as well as those caused by tillage, compaction, cropping pattern, and other management practices **[24].** Clay soils are difficult to manipulate because they are sticky when wet and hard when dry. Medium plastic soils were defined as having an average plasticity index of 15%, and very high plastic soils were defined as having an index of plasticity more than or equal to 40%. A value of 0.80 was deemed to be the optimum option, based on experience, for a plasticity index more than or equal to 40% to restrict the effect of a high plasticity index because there was no specific literature for the lowest tilth coefficient. Equation (16) was obtained by a regression analysis. However, the hypothesised relationship between the plasticity index (PI) and the tilth coefficient [CF(PI)] was represented by equations (15) to (17).

$\mathrm{CF(PI)} = 1$

(15) [for PI ≤ 15%]

$\mathrm{CF(PI)} = 1.02 + 0.0009 \times \mathrm{PI} - 0.00016 \times \mathrm{PI}^2$

(16) [for 15% ≤ PI ≤ 40%] $\mathrm{CF(PI)} = 0.8$

(17) [for PI ≥ 40%]

6. **Decision support system for soil tilth assessment: Reference [18]** developed a decision support system (DSS) for assessing the soil tilth. The system could generate a numerical tilth index whose value ranged from 0 to 1 as soil conditions unusable and desirable by plants respectively, using the values of five soil physical parameters. Additionally, it could make an estimation of crop yield, reports the soil's tilth status at a specific moment, and provides potential solutions for preserving and/or enhancing tilth and crop output. The technology gives the farmer the capacity to assess the effects of a future farm plan's overall strategy on the condition of the soil and to pinpoint potential fixes for site-specific soil tilth issues. The ideal tilth for crop development and higher yield was regarded to be tilth index value in between 0.8 and 1, and tilth index values below 0.5 was not acceptable for plant growth.

7. **Modified tilth index for rice-wheat system: Reference [21]** calculated tilth index by using tillage-induced changes in soil physical properties to optimise the tillage requirement in the rice-wheat cropping system. The experiment was carried out in a shallow water table that fluctuated between 0.02 and 0.96 m below the surface and was coupled with a silty clay loam. The tillage methods used for rice were: direct sowing without puddling (DSWP), reduced puddling (ReP), conventional puddling (CP), and four runs of a rotary puddler (PR). Over the plots of rice tillage treatments, wheat tillage treatments included zero tillage (ZT) and conventional tillage (CT). In the rice and wheat seasons, measurements were conducted of the different parameters such as bulk density, saturated hydraulic conductivity, infiltration rate, plasticity index, porosity, and organic carbon (only during the rice season). Wheat yield was highest in the DSWP plots under ZT condition and was statistically equivalent to that in the ReP plots, but rice yield was highest in the PR plots and statistically equal to that in the ReP plots.

Two methods were used to calculate the tilth index (TI): a proposed regression model and the model proposed by **Reference [18].** The physical characteristics of the soil that have a substantial impact on crop output are used in the suggested regression model. Rice yield dropped with increasing TI from 0.67 to 0.81, but wheat yield increased linearly with increasing TI from 0.75 to 0.89, according to the **Reference [18]** model. The following expressions for the tilth index were created for the rice and wheat cropping systems:

$TI = 0.75\ BD' + 0.25K'_S$ for rice (18)

$TI = 0.49\ IR' + 0.51f''$ for wheat (19)

Where:

BD'=normalised bulk density

K'_S= normalized saturated hydraulic conductivity

IR'= normalized infiltration rate

f'' = normalized porosity

III. MECHANICAL TRANSDUCER BASED SOIL TILTH ESTIMATION

With regard to precision farming, the invention of continuous and real-time soil tilth detection systems offers an invaluable tool for obtaining affordable and timely information on the soil's current condition and future management. **Reference [13]** developed a straightforward transducer for soil tilth measurement by investigating the dynamic strain behaviour of commonly available spring tines. Utilizing straightforward strain gauge circuits, the response from coarse, moderate, and fine tilths was examined in order to identify the dynamic properties of the tines. Utilizing digital signal processing techniques, the obtained signals were examined. Correlations between the results of the signal analysis and those of conventional sieving were found. The findings demonstrated that one useful factor for determining clod size was signal amplitude.

Three types of spring tines (S, Vibroflex, and double coil) were chosen to measure the clod sizes. The tines were affordable and easily accessible. Table 1 represents the geometry and natural frequencies of the tines. The tines' frequency and amplitude responses were studied in order to ascertain the dynamic response of tine transducers. A spectrum analyzer (Hewlett Packard 3582A, Agilent Inc., Palo Alto, CA, USA) was used to measure the three spring tine transducers' inherent frequencies. The tine tip was subjected to an impulse force in the horizontal plane, and the spectrum analyser provided the data.

Table 1: Specifications of the Tines

Type of tine	S	Vibroflex	Double coil
Width (mm)	30	35-155	25
Height (mm)	55	72	68
Thickness (mm)	20	30	25
Stiffness (N/mm)	2.5	6.1	6.6
Rake angle (º)	45	45	45
Natural frequency (Hz)	9	13	18
Sensitivity (mv/N)	0.79	0.15	0.44

S type spring tine was chosen for the further experiment due to its lowest natural frequency and highest sensitivity. The kind of sensor and where it would be installed were chosen to instrument the spring tine with a suitable measurement method. The most affordable and dependable option was a strain gauge system. Utilizing finite element analysis (FEA), the location of the highest potential strain on the tine body was determined in order to strategically place the strain gauges for optimal utilisation. The highest shear stress was determined when the horizontal force was applied. A system with full bridge gauge was established. Two dummy gauges were placed in an instrumentation box, and two gauges were fixed on the tine at the same ambient temperature. Tillage operations were carried out with: a mouldboard plough, a mouldboard plough + a chisel tine and a mouldboard plough + a power harrow to create three different soil tilths. Clay loam and sandy loam were the two types of soil chosen. The soil tilth conditions for sandy loam and clay loam soil were represented by their mean weight diameter.

According to the standard deviation vs clod size linear regression analysis results, it was clear that the standard deviation was an effective statistical tool to determine the soil tilths in terms of clod size variability. The S tine transducer was used to get the standard deviation findings (force) for the three soil tilths. The sensing speed was 1.39 m/s, and each application lasted for 10 seconds. The mean standard deviations and sieve-derived aggregate sizes (MWD) were 105, 36, and 21 N. and, 82, 58, and 22 mm respectively for the tilth created by a mouldboard plough, a mouldboard plough + tine, and a mouldboard plough + power harrow. The tine transducer was able to detect and discriminate the three different soil tilths with great clarity.

Figure 1 illustrates the assessment of the tine transducer prediction for the identification of the clod size distribution. There was a correlation between the sieve clod size results and the clod size prediction results from the tine transducer. The R^2 value of the relation between two clod sizes was 0.89, which showed the good corelation between these two methods. The findings of the error study showed an RMSE of 6.3 mm for both the sieve-derived and tine-predicted clod diameters. The evaluation results indicated that the S tine transducer can accurately predict clod size distribution in MWD with a maximum RMSE of 6.3 mm.

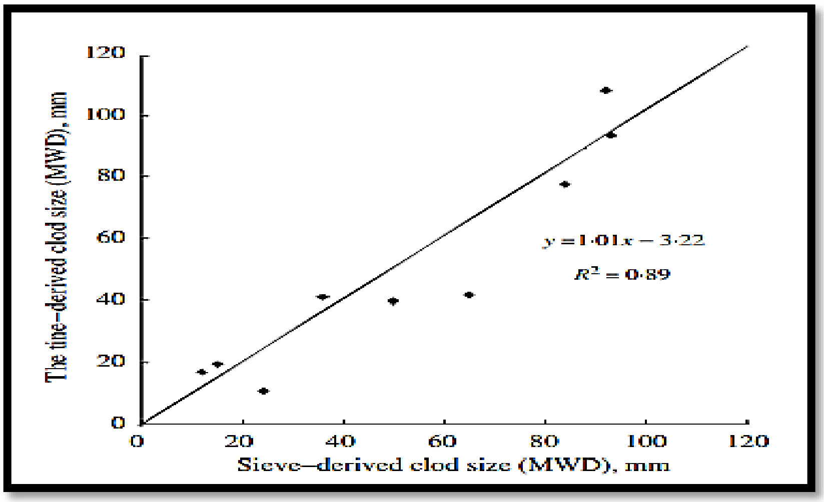

Figure 1: Tine and the Sieve Derived Clod Sizes Relationship (Source: Reference [13])

IV. IMAGE-PROCESSING BASED FOR SOIL TILTH ESTIMATION

It takes a lot of time and effort to collect, handle and sieve soil samples to determine the distribution of clod sizes. Therefore, computer vision technique was used by **Reference [14]** to determine the distribution of clod size in the field using a image processing based technique. For sandy loam soils, three different soil tilths: coarse, intermediate, and fine were digitally captured. The shape distortion and quality distortions in the photographs were rectified with digital filters, image enhancing methods, and geo-correction models. In order to assess the distribution of clod sizes, three digital image processing methods namely contrast detection, edge detection, and aggregate finding and classification (AFC) analysis were examined. Results of standard sieving were correlated with those of image processing.

The overall methodology to determine image processing soil tilth status is summarised below:

1. A sandy loam soil was created with three different soil tilths.
2. Digital image acquisition methods were used to capture the images.
3. Geo-correction techniques were used to fix geometric distortions in the photos.
4. In order to improve the quality of the photographs, image-enhancement techniques were utilised.
5. An image's visually derived mean weight diameter (MWD) was estimated, and the results were compared to those obtained using a traditional sieve technique.

1. **Image acquisition:** Both in the field and in a lab, the photographs were taken using sources of structure and ambient light. The frame was 500mm by 500mm without the grid, and 1000mm by 1000mm with the grid. Images were captured using a camcorder (Canon MV1, Canon Inc., Tokyo, Japan) with a progressive scan CDD image sensor and a lens that was able to zoom in and out by 14 times at a focal length of 5.2 to 72.8 mm. In this investigation, clods were initially collected, transported, and sieved before photographs were captured. The camera was perpendicular to the ground while taking images, mounted on a tripod at a height of 1.1m.

2. **Geometric correction and image enhancement:** Image geometric rectification/ correction is crucial when determining the clod size. Any geometrical inaccuracy in the photographs has a high likelihood of portraying and interpreting the real data incorrectly. Image-processing software (Erdas Imagine 8.3.1, Leica Geosystems Inc., St. Gallen, Switzerland) was used to create models to fix the geometric distortions because some of the photos of soil tilths had geometry and projection issues. The characteristics of the camera's optics also contribute to geometric distortion. For each image, a frame with known dimensions was chosen, and forty geometric correction points were chosen.

   The process image enhancement improving an image and making it easier to understand for a specific use. By making the best use of the colours present on the display or output device, contrast enhancement helps the visual features stand out more sharply. For each image, linear contrast stretching was done. The results showed the original pictures. Due to the nature of the process, some information was lost during linear contrast stretching. For instance, some lower grey values were zero, while others had maximum grey values. Making an image simpler to understand for a particular purpose is a part of the improvement process. Contrast enhancement makes the most of the colours that are available on the display or output device to make the visual characteristics stand out more strongly. Stretching of the linear contrast was done for each image. The outcomes displayed the original images. Due to the nature of the procedure, linear contrast stretching resulted in some information loss. As an illustration, while some grey values had minimum values, others had maximum values.

3. **Feature extraction:** A boundary between two disparate portions of an image is referred to as an edge. There are typically two phases in edge extraction procedures. (1) By looking for gradient discontinuities, pixels in the image where edges are likely to appear are located. Edge points, edge pixels, or edgels are common names for the points that define an image's edges. (2) By connecting the edge locations, lines and curves are used to describe the edges. Edge identification was accomplished using a Sobel filter (GLOBAL LAB Image, Data Translation Inc., USA).

Alternately, a line-scanning method was employed for edge and contrast detection, and an area scanning method was used for the AFC analysis. A virtual sieve was made specifically for these two techniques. The authors created a virtual sieve, which is a hypothetical computer sieve where the sieves number and sizes can be adjusted for a specific application to provide the grading curve and the MWD of the clods. The virtual sieve programme calculates the volume and mass of clods using the diameter of clod size from each image processing programme created by **Reference [15]**. The user chooses the quantity and dimensions of each virtual sieve, and the clods are fed through them. The clods' MWD is determined by the results of the virtual sieves, and the mass that passes through each sieve is utilised to calculate the percentage of clods that pass each sieve to produce the grading curve. To create frames with 1000 by 1000 pixels, the photographs were resized. The picture particles were discovered once the colour level was reduced to 16 grey (4 bits). A determination was made in the aggregate finding and classification procedure regarding whether or not a surrounding pixel was a component of the same particle, aggregate, or clod as the selected pixel.

The clod size distribution through mechanical sieving is a static method whereas, Visual sensing can be either static or dynamic. The general correlations between the MWD of aggregates as estimated by computer vision and mechanical sieving. In general, the clod/aggregate sizes for the three soil tilths are over-predicted by image-processing techniques. The fitted straight line (R^2 = 0.96) had a slope 21% higher than unity, yet it went through the y-axis at zero, according to regression analysis. The root-mean-square errors (RMSEs) for the contrast, edge, and AFC detection approaches for forecasting the clod size were 14, 21, and 37 mm, respectively. Since contrast detection technique had the lowest RMS error, it was advised for determining the distribution of clod sizes.

Comparisons were made between the outcomes of mechanical sieving and those of three different digital image-processing techniques, namely contrast recognition, edge detection, and AFC analysis. The horizontal axis compares the soil tilths used to determine the clod size distribution, while the vertical axis displays the MWD of clods and aggregates. The clod size distribution produced by the three image-processing methods was typically coarser than that of mechanical sieving. The breakage of clods during the sampling, transporting, air drying, and sieving processes as well as the huge clods on the surface disguising the smaller ones below where the reasons why optical approaches calculated the size of clods coarser than that of mechanical sieving. Although the standard deviation of clod sizes was lower than that of mechanical sieving, the results of the AFC analysis for the ploughed tilth were comparable to those of mechanical sieving. Contrarily, for the ploughed plus power-harrowed tilth, the discrepancies between the MWDs of the AFC analysis and mechanical analysis were substantially different from one another (P>0.05), whereas those for the other two tilths were within the range of the least-significant difference (LSD). Additionally, the results demonstrated that for all tilths, the edge and contrast recognition algorithms yield findings that are not statistically different from mechanically sieved data at the 95% confidence level. Even though its estimations were higher than those of mechanical sieving, edge detection technique produced good results for the ploughed plus tined and ploughed plus power-harrowed tilths.

V. CONCLUSION

The assessment of soil tilth is extremely needed in the farm level to optimize the input energy use in terms of tillage and the productivity of the soil. The methods discussed in this chapter are much accurate in assessing soil tilth as well as soil health but quite difficult in farmers point of view. Farmers need a simplified tool or method for soil tilth assessment so it may be recommended to conduct further research in this field to develop a compact and efficient device to assess the soil tilth.

The following conclusions can be drawn from the above discussion:

1. Knowing the status of soil tilth soil can be be managed appropriately for better crop production.
2. Based on a number of factors, including bulk density, cone index, uniformity coefficient, organic matter content, and plasticity index, tilth index, coupled with DSS, gives a quantitative measurement of soil tilth ranging from 0 to 1.
3. The mechanical transducer-based technique is tine specific and instrumentation is required to quantify soil tilth.
4. For determining the CMWD, the image processing-based technique (R^2=0.96) performed better than the mechanical transducer-based technique (R^2=0.89).

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