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STATISTICAL STUDY OF SOIL TILTH FOR SELECTED SOILS AT NORTHERN IRAQ

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Abstract

The concept of Soil is subject to great discussion due to soil interaction with the environment (soil, plant and atmosphere) and human intervention practices, which affects negatively or positively on soil quality and this is reflected in soil productivity. Therefore, the study was conducted to evaluate soil tilth for important agricultural areas of northern Iraq. The data required were collected from reliable sources, including soil texture, soil structure and soil consistency. The data were processed and converted into digital values for easier handling by using the division method and mathematical theorem, The results of the dry soil for A horizon showed that 13% of the samples were within the good class (C), 24% within the medium class (D), 35% within the weak class (E) and 28% within the very weak (F), Whereas in the wet case, the soil tilth of B horizon was 8% of the samples in the very good class (B), 21.5% within the good class (C), 38% within the medium class (D), 37% within the weak tilth (E) and 5.5% within the very weak class (F1).

Key words: Soil Tilth, Morphological characteristics, division method, mathematical theorem

Introduction

Soil management is the goal through which the efficiency of the soil is regulated to increase its ability to produce crops, which is positively affected by maintaining its physical, chemical, and fertile properties. Soil management is a regulatory process for the optimal exploitation of all field processes that increase soil productivity and fertility (Munkholm *et al*., 2019). The increased need for good management becomes necessary due to its importance in improving the physical and chemical soil properties (Stendberg *et al*., 1999; Kassam 2018). The American Soil Science Society (SSSA) used a new term for soil tilth (tilth-forming processes) whereby the relations between farming (Tilth) and many management problems of soil and water such as surface and ground water quality, soil erosion, productivity and long-term sustainability were discussed (Karlen *et al*., 1990). Soil tilth is a multifaceted and dynamic concept that refers to soil suitability for tillage, planting and crop growth. Soil tilth is related to soil physical properties such as porosity (Munkholm *et al*., 2019), soil structure and aggregate stability and its relationship with organic matter more than it is related to the soil quality and health (Jensen, et al., 2017, Ball, 2013, Obour, *et al.,* 2018). So, the well-Tilth soils are usually fragile and good structure (Rabot, *et al*., 2018), while soils with poorly tilth are usually had a hard consistency and blocky structure or structureless (Al-Khaffaf 2010; Khalid 2016), with high bulk density caused by machinery and animal's movement in the field or by the natural consolidation (Jensen *et al*., 2017; Schjonning and Lamandé, 2018; Kassam *et al*., 2018). Tilth and tillage conditions cannot measure directly; therefore, the soil status cannot be predicted during the tillage operations (Blanco-Canquio and Ruis 2018). To obtain predictions of soil tilth state some statistical methods are used and interface the soil physical properties with crops yield to determine the seedbed conditions and soil tilth. The soil bulk density index, cone index (penetration resistance), aggregation coefficient, organic matter content and plasticity index were used to predict crop (Gevao *et al*., 2006). Several statistical and mathematical methods are used to estimate the soil tilthincluding mathematical and division method (Al-Mashhadani 2000; Al-Ani 2009).

The aim of this study is to exploit the factors affecting the agricultural production process to its optimum level by quantifying the soil tilth in a quantitative manner using

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the division method and mathematical theorem.

Methods and Materials

Several locations for soil samples were selected from Nineveh, Salahuddin, Kirkuk, Dohuk and Erbil governorates from northern Iraq Fig. 1.

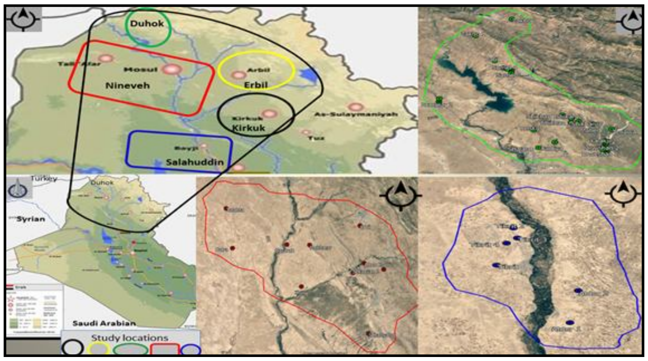


Fig. 1: Study locations.

Field work

Several soil pedons that were morphologically described and officially documented in published research, letters and thesis have been selected. A sum of 46 pedons was taken, 27 pedons of Vertisols and 19 pedons of Aridisols, from many Iraqi provinces as follows: 22 pedons were from Nineveh, 10 from Salahuddin, 7 from Kirkuk, 6 from Dohuk and 1 pedon from Erbil Fig. 1.

The required data, which includes the symbol of horizon, soil consistency were identified in their three cases (dry, wet and moist), soil structure (grade, class and type), and soil texture. The qualitative properties of consistency, structure and texture have been converted into quantitative percentages according to their agricultural importance, and arranged as follows:

1- The consistency arranged and divided into ten classes, only the division for the moiststate (6 divisions) was adopted due to the importance of the moisture content in determining the soil consistency. According to the significance of A horizon and superiority of the dry climate in Iraqi for most of the year, the classes (hard-slightly hard-soft) were added to a dry state and (extremely friable) has been added to consistency, which was developed along the lines of the class of cohesion (extremely firm). The soil which has this type of consistency is very fragile, but it does not reach the degree of loose, therefore, the number of classes became ten. This study did not adopt the state of wet consistency because it is not present in the soil of the study area, then each of these categories was given a numerical value (percentage) as shown in table 1.

2- Soil structure was divided into ten varieties as well and according to its agricultural importance, it depended only on the structure type because it is more suitable for distinguishing purposes and its importance for agricultural purposes. The size (class) and the types of structure were implicitly interfered, while the grade of the structure is automatically combined with the consistency. The 10 sections of the structure are divided into 100 degrees; the greater degree is given for the best structure and the lower for the structureless as shown in table 2.

Table 1: Consistency classes according to their agricultural importance.

No.	Consistency	Symbol	Quantitative value
1	extremely friable	ext.fr	91-100
2	very friable	V.fr	81-90
3	friable	fr	71-80
4	firm	fi	61-70
5	very firm	v.fi	51-60
6	extremely firm	ext.fi	41-50
7	loose	l	31-40
8	soft	s	21-30
9	slightly hard	sh	11-20
10	hard	h	0-10

Table 2: Structure varieties by agricultural importance.

No.	Structure	Symbol	Quantitative value
1	crumb st.	cru	91-100
2	granular st.	gru	81-90
3	subangular blocky st.	sbk	71-80
4	angular blocky st.	abk	61-70
5	columnar st.	col.	51-60
6	prismatic st.	pri.	41-50
7	week platy st.	w.pl	31-40
8	strong platy st.	s.pl	21-30
9	single grain	s.gr	11-20
10	Massive	mas	0-10

3- The soil texture was divided into 10 classes as well according to its agricultural importance; sandy clay and silt were excluded from the evaluation of the twelve textures varieties because they were not present in the study soils. The remaining 10 varieties are arranged according to the consistency of the percentages of their particles as shown in table 3.

Interaction between the three morphological characteristics

The three variables of 160 samples are plotted on the area of the triangle diagram and the distribution is shown in two ways:

First- Division method

The equilateral triangle sides is divided into equal units from 0 to 100, side is representing the three variables, and the values of these categories are distributed

Table 3: Textures according to their importance.

No.	Texture	Symbol	Quantitative value
1	Loam	L	91-100
2	Silt loam	SiL	81-90
3	Sandy clay loam	SCL	71-80
4	Silty clay loam	SiCL	61-70
5	Clay loam	CL	51-60
6	Silty clay	SiC	41-50
7	Sandy loam	SL	31-40
8	Clay	C	21-30
9	Loamy sand	LS	11-20
10	Sand	S	0-10

according to the percentages given in the previous divisions in tables 1, 2 and 3.

In this method, the value of each variable is converted to a percentage depending on the total values of the three variables, and for the final summation to become one hundred, each value also will be converted to a percentage, so the location of the sample within the triangle will be easier to determine as the method used for determining the types of texture.

Fig. 2-A shows the divisions of the values and ratios of the three variables, the eastern triangle will include soil samples in which has consistency value greater than the total value of the structure and texture (B>A+C) for each soil horizons in the study area, while the western triangle includes soil samples with good texture varieties, which have greater values than the total values of structure and texture (C>A+B) for each horizon. The northern triangle will represent soil samples has a good structure with a value higher than the total values of texture and consistency (A>B+C) for each horizon as well. While the small triangle with the light color includes soil samples in which the value of each of its three characteristics is not less than 20 and not more than 40 for each horizon. The rest of the soil samples, whose values are not included in the previous divisions, will be pointed within the large middle triangle, where these samples did not fall within the previous divisions, where the values of texture, structure and consistency were either less than 20 or more than 40 for each horizon.

Then, the density of the samples will be calculated according to the divisions mentioned above so that we can determine the types of soil tilth for each horizon.

Second-Mathematical theorem method

In this method, we will divide the sides of the graph triangle into equal parts from 0 to 100, where each side represents the values of the quantitative variables of one of the three variables mentioned as in Fig. 2-B, which we will adopt our calculations on without converting the values of adjectives to a percentage, as was done in the Dickenson method. In the same way, the side A will represent the structure, B will represent consistency, and side C represents texture varieties according to our quantitative division, where sample values will be pointed within this graph triangle.

In our calculations, we will rely on this theorem for ease of work in it, where this triangle and the values of its variables represent one point, and the center of the circle represents the values of all points inside and on its circumference, relying on that to the mathematical theorem that states (the average pieces of the triangle

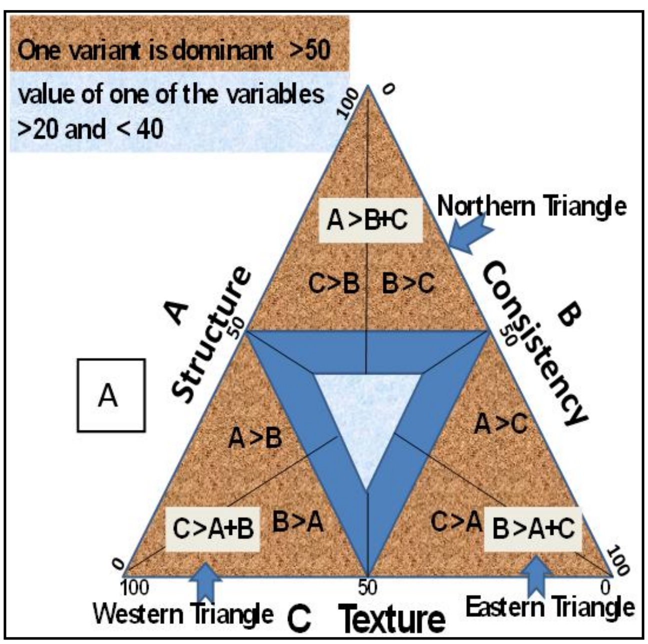


Fig. 2: A: Dickinson triangle and its subdivisions.

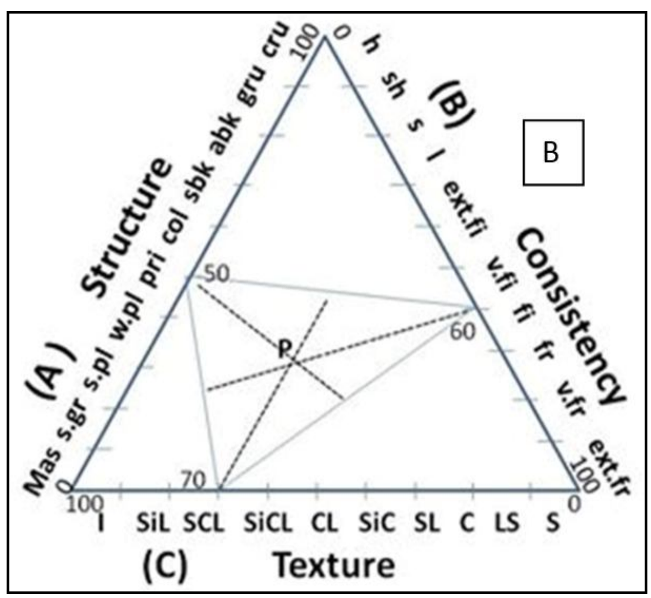
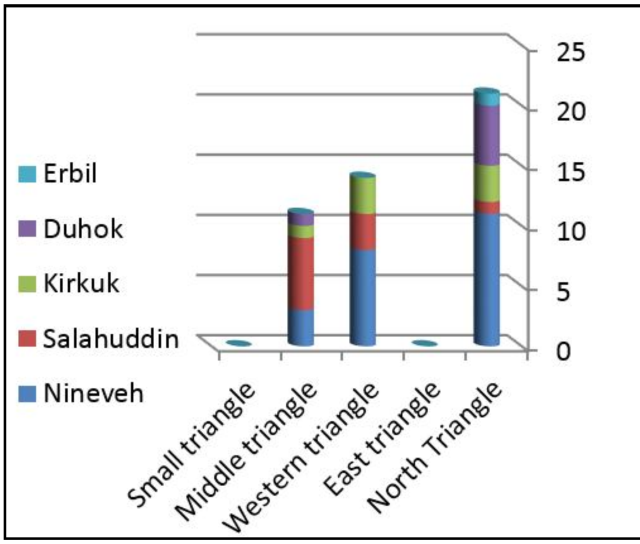


Fig. 2: B: Distribution of the three characters based on the mathematical theorem.



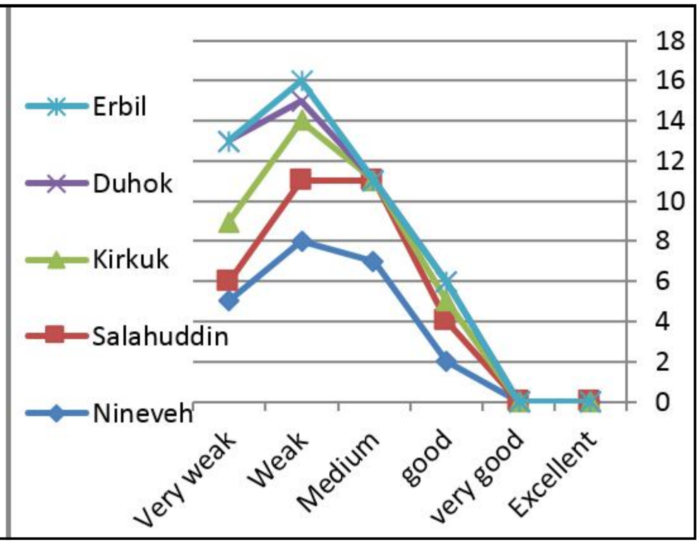


Fig. 3: The governorates location inthe, **Fig. 4:** Soils tilth classes in dry consistencystate Dickinson triangle.

converge at the point of dividing each of them by 2:1 from the side of the head).

The values of the three quantitative characteristics will be determined on the sides of the triangle each according to character it represents and the point where the straight segments descending on the opposite side (the point P) represents the sample with the variable values mentioned above as shown in Fig. 2-B. All 160 soil samples for each horizon will be pointed in this way.

Then we will be able to determine the density of the samples for each division and its distribution in each horizon, so that we can later identify the types of tilth in the study area.

Tilth description and measurement

The soil tilth gained six classes based on its three characteristics rates, and arranged according to its importance as shown in table 4 these classes are: excellent tilth (A), very good tilth (B), good tilth (C), medium or moderate tilth (E) and very weak tilth (F) the last latter divided into two parts: F1 and F2. Each of the tilth types can include multiple classes of the three characteristics provided that the rate of their values within the classes values ranges.

Table 4: The proposed tilth classes according to their preference and the numerical value of each class.

Tilth No.	Tilth class	Texture class	Structure class	Consistence class	Rate
A	Excellent tilth	L	cru.	ext. fri.	90-100
B	Very good tilth	SiL	gr.	v. fri.	80-90
C	good tilth	SCL	sbk	Fri.	70-80
D	Moderate tilth	SiCL	abk	Fi.	60-70
E	poor tilth	CLSiC	col.pri.	v. fi.	50-60
F	Very poor tilth (F1) (F2)	S, LS, SL, Cvariable classes	s.gr. –pl., mass variables	l, so. and s.h.ext. fi., H.	<50

For example, soil sample, with silty loam texture (SiL) has value (90), structure (bk) of value (70) and consistency (fi) of value (70), has a value rate of 76.66 and is thus graded among the good tilth (C).

Results and Discussions

Soil tilth characterization in dry stat

After pointing samples of A horizon on the tilth triangle Fig. 2-A and the graph triangle Fig. 2-B as shown in Fig. 3 it is noted that 45.5% of the samples were in the northern triangle of Dickinson triangle (A>B+C), which is characterized by good value for the structure which ranged between (gr and sbk), textures ranged between (L, CL, SiL and SL), while the consistency ranged was (soft and hard) which has the lowest values according to the quantitative estimate.

While samples that fell in the western triangle (C>A+B) reached 30.5% of the samples, which had a good texture values which ranged between (L and SL) and structure was (abk, sbk, pri and mass), while consistency was (soft and hard). The percentage of samples that fell in the middle was 24% and no values were dropped within the eastern or small triangle.

In the Fig. 4, depending on the table 4, noted that 13% of the samples were within the good class (C), 24% of the samples were signed in the medium class (D), 35% of the samples fell within weak tilth (E) and 28% of the samples fell into the very weak tilth (F).

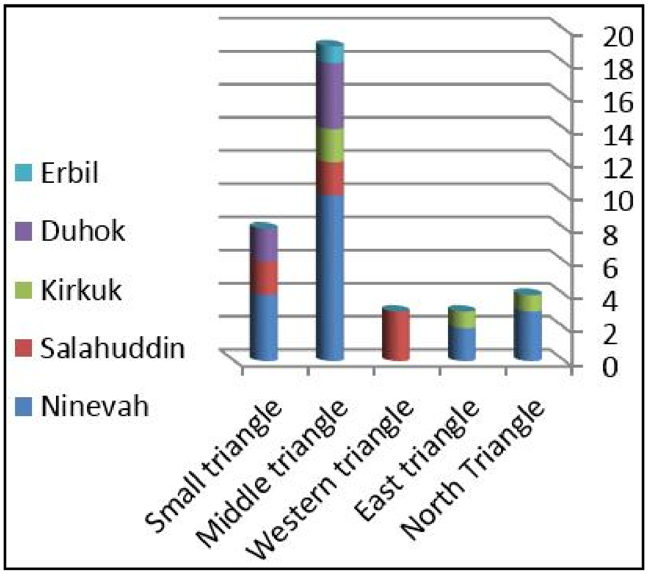


Fig. 5: B- horizon location for the study sites.

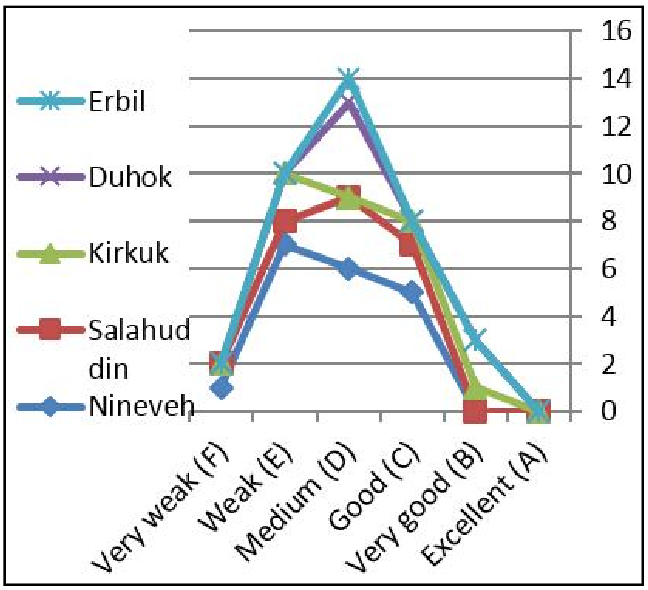


Fig. 6: Soil tilth for B horizons in moist in the Dickinson triangle consistency state.

From the above results, it should be noted that the majority of samples were good, medium or weak tilth in dry consistency, due to the low soil content of organic matter with its high content of calcium carbonate, which gives a weak soil structure, which adversely effects on soil tilth.

Soil tilth characterization in moist state of B horizon

The study showed that the soil tilth values of the moist state of B horizon as shown in the Fig. 5 were better than in the dry state of A horizon, where the largest percentage of samples fell in the middle triangle 51% of Dickinson triangle Fig. 2-A where the values of texture, structure and consistency were either less than 20 or more than 40 and were (abk or sbk), while consistency was (fi or fr), textures ranged from (C, CL, SL and SiL), 11.5% of the samples fell in the northern part of Dickinson triangle (A>B+C) by which is characterized by good values for the structure that ranged between (gr and sbk), while texture value was (C, CL and SL) al soils characterized by hard consistency, which have the lowest value, according to the quantitative evaluation.

The samples that fell in the eastern part of the Dickinson triangle, where the values of the consistency greater than values of texture and structure (B>A+ C) by 8% were characterized by (fr) consistency, blocky structure (abk) and texture (LC) and samples that fell in The western part of the Dickinson triangle (C>A+B) reached 8% of the samples with texture (SL) and by a hard consistency, while the rest of the soil where no dominance was recorded for any of the three characteristics. It fell in the small triangle 21.5%.

The Fig. 6, depending on table 5 showed that 8% of the samples were in the very good class (B), 21.5% of the samples were within the good class (C), 38% of the samples were signed within the medium class (D), 37% of the samples fell within the weak tilth (E), 5.5% of the samples fell within the very weak tilth (F1).

From the above results, it should be noted that the majority of the soils were of very good, good or medium tilth in moist consistency case of B horizon and only a small percentage (5.5%) fell in the very weak class. This is due to the low soil content of the organic matter with its high content of calcium carbonate, as well as there was a gypsic horizon which gives a weak soil consistency, and this is reflected in some soil tilth classes.

*some pedons doesn't have B horizon, so the number was less than the dry state

Soil tilth characterization in moist state of C horizon

The determination of soil tilth for C horizon was based on the moist state as shown in the fig. 7 in the same way as the B horizon, so there is a great convergence between the soil tilth for this two horizons from this side, so the largest percentage (59%) of samples fell in the middle part of the Dickinson triangle whereas the texture, structure and consistency values either less than 20 or more 40. All of them were (bk or sbk) and all had (fr) consistency with texture between (C, CL, SCL, SiL). 19.5 % of the samples fell in the eastern part of the Dickinson Triangle, where the consistency values greater than total values of structure and structure values (B>A+C), characterized by (fr) consistency and their textures ranged from (C, SiC, and SCl) and the structure was (massive).

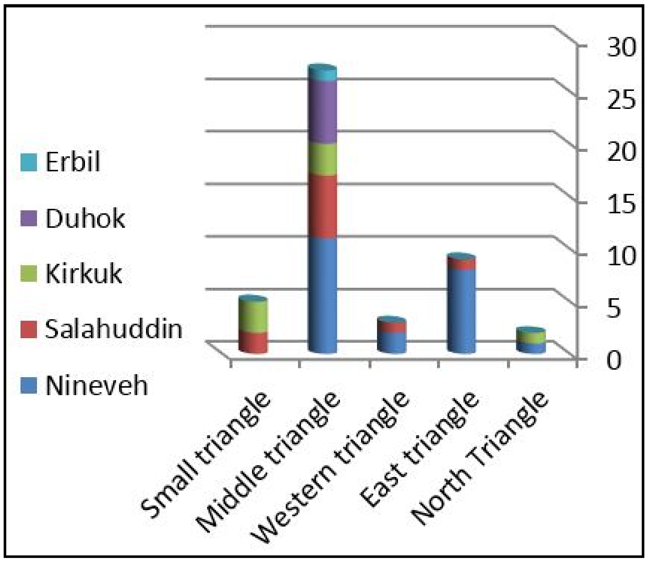


Fig. 7: B Horizon locations in Dickinson triangle.

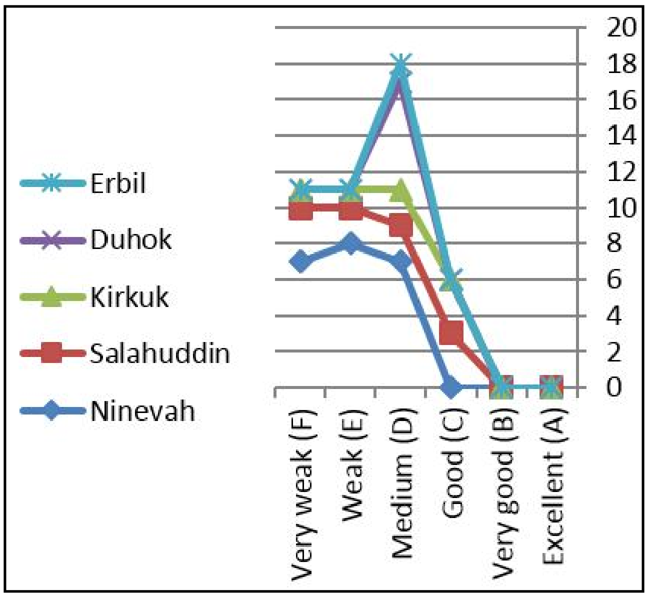


Fig. 8: Soil tilth for C horizon in moist state.

The samples that fell in the western part of the Dickinson triangle (C>A+B) were 6.5%, which had a good value for texture (L and SL), with structureless (massive) and the soil of this group had hard consistency. The samples that fell in the northern part of the Dickinson triangle (A>B+C) were 4% which had a good value for the structure (gr and sbk), the textures ranged from (CL and SL) and the soil of this group was characterized by hared consistency, which has the lowest values according to the quantitative evaluation. The remaining 11% of the samples fell in the small triangle, where no dominance was recorded for any of the three objects (texture, structure and consistency). The Fig. 8, depending on the table 4 showed that 13% of the samples were in the good class (C), 39% of the samples were in the medium class (D), 24% of the samples fell into the weak tilth (E) and 24% of the samples fell within the very weak tilth (F).

Conclusions

Soil cultivation is an old term and refers to the physical condition of the soil prepared for cultivation, and focuses on good tillage, proper seedbed, seedlings emergence and root penetration, thus covering the physical aspect of soil quality and health. This knowledge is used to improve soil management through agricultural rotations, crop coverage and plant residue management. From the present study, it was concluded that;

1- Most of the studied soils were of good, medium or weak tilth in the case dry consistency of A horizon and wet consistency of horizons B and C.

2- It is found 13% of A horizon in dry state was good tilth, 24% of medium tilth, 35% of weak tilth and 28% of very weak tilth.

3- It is found 8% of B horizon in the wet state was very good tilth, 21.5% of good tilth, 38% of medium tilth, 37% of weak tilth, and 5.5% of very weak tilth.

4- It is found 13% of C horizon in the wet state was good tilth, 39% of medium tilth, 24% of weak tilth and 24% of very weak tilth.

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