

## Comparative evaluation of soil aggregate stability using classical and fractal methods<sup>1</sup>

**Shiva Mohammadian Khorasani**

Assistant Professor, Islamic Azad University, Science and Research Branch, Tehran, Iran.  
mohammadian.shiva@yahoo.com

### Abstract

**Introduction:** Improving water and soil productivity and its management by considering soil structure, soil textures and soil physics parameters are an important criterion for the suitable management of soil and water resources. One of the relatively new methods proposed to explain soil structure in a quantitative manner is the so-called fractal geometry concept. Soil particles are very different from each other in size and shape. As a result, there is not a certain shape for soil structure. Soil structure is very important, because it has a direct relation with the efficiency and operation of soil in agricultural industry in particular.

**Material and methods:** In this concept, by determining the fractal dimension of bulk soil, the stability of aggregates can be quantitatively analyzed at different scales. The objective of this study has been to quantify the soil structure stability using some classic indicators and also fractal approach in a large scale. Consequently, 41 intact soil samples were taken from an agricultural area and their particle size distribution, soil bulk density and aggregate bulk density, were measured. The weighted mean diameter and geometric mean diameter of both dry and wet aggregates were measured using the dry and wet sieving method. Forty-one intact soil samples (0-30 cm) were taken from Varamin area, Iran. Samples were kept in the plastic bags and when they were moved to laboratory, dry air and intended physical decomposition consist of particle size distribution (Via hydrometer method) and diameter size distribution (via wet and dry sieves methods) were applied. Soil bulk density was calculated via volumetric manner in the field. Then, two experimental models (classic) and four fractal cumulative distribution models were used for the determination models that were used for determination of the mass distribution, size and number, soil aggregates size in the dry and wet conditions.

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**Results:** The fractal dimensions of all dry and wet aggregates were obtained using the fractal models of Mandelbrot, Tyler-Wheatcraft and Rieu-Sposito. The results indicated that fractal dimensions of the number-size model of Mandelbrot for dry sieve series and the number-size model of Rieu-Sposito in the wet sieve series perform quite well ( $R^2=0.82$ ). These two models could have the suitable determination coefficient with classical geometric mean and weighted mean diameters of aggregates ( $R^2=0.69$ ). Stability indicators of soil aggregates in wet sieve with fractal dimension of Mandelbrot, Tyler-Wheatcraft, Rieu-Sposito ( $D_f$ )'s models in significant level is equaled to 1% and in wet sieve with the fractal dimensions of Mandelbrot, Rieu-Sposito ( $D_f$ )'s model and GMD indicator only with fractal dimension of Tyler-Wheatcraft's model have a negative correlation in one percent significant level and they don't have any significant relations with the fractal dimension of Rieu-Sposito's model ( $D_m$ ) in both wet and dry sieve. As a result, using of multi fractal methods is useful in such conditions, because soil would be a fractal-like material. Also, the calculated dimensions have an inverse relation with the geometric mean diameter, so humidity dues to increase of line slope for the decreasing relation. The amounts of experimental indicators are decreased by increasing of fractal dimension. In the other word, these two experimental and physical indicators have an inverse relation together.

**Conclusion:** The results of this study indicated that there is an acceptable relation between the experimental indicators and fractal models. So fractal dimensions of soil aggregate can be computed by having the experimental indicators without a need to determine the other parameters of fractal models. However, experimental models are as a simple instrumentation to express the soil aggregate stability, but the accuracy of their results needs to recognize the type of statistical distribution for the soil aggregates, because they don't have an experimental nature. So it is better that fractal physical models are used for expression of soil structure quantitatively. In this study, statistical assessments also showed that Mandelbrot and Rieu-Sposito's model of number and size for description and quantification of soil structure is the best model in comparison with the investigated models. The results of this study also showed the same soil aggregate that have the dimensions which were more than 3. This outcome shows that the soil aggregate should be evaluated with the multi-fractal models. As a result, more research should be done to evaluate and quantify these soil aggregates in the future.

**Keywords:** Fractal Methods, Soil Aggregate Stability, Soil Physics, Water and Soil Productivity.



## 1. Introduction

Soil is one of worthy natural resources in the world whose stability management is made possible only by protection from life cycle (Mohammadian Khorasani & et al., 2020; Lal & Pierce, 1991). Soil particles are very different from each other in size and shape. As a result, there is not a certain shape for soil structure. Soil structure is very important, because it has a direct relation with the efficiency and operation of soil in agricultural industry in particular. This issue results from many effects on physical, chemical and biological process, soil ability to the growth of plants, carbon cycle and availability of microelements, reception-saving-moving of water and also resistant against erosion. It is necessary to pay a special attention to soil structure and this should be evaluated quantitatively, because eco-systematic management by human activities cause the short and long term changes on soil and these intense changes may have the positive or negative influences on soil operation. The quantitative description of soil has many challenges for pedologists, because there is not the practical, scientific and universal method to measure it. In contrast to soil texture, soil structure is changed as a result of the biological activities, water, air and different managements. As a result, there is no certain method to measure soil structure. This statement shows that soil structure has not been described quantitatively up to now. On the other hand, soil structure needs a quantitative concept to be expressed as an evaluation characteristic. Size, shape and stability are 3 indicators to evaluate soil aggregate stability (Harris & et al., 1965).

Soil aggregate stability which is one of the soil operation indicators is used for determining soil quality. Classical methods (wet and dry sieving) are used for evaluation of soil stability. This method is acceptable for more coarse-grained soil, because they stick to each other. A better understanding of soil structure in particular and soil sciences in general with fractal geometry and its use in pedology and determination of soil structure stability and its comparison with the classical methods can be achieved (Mandelbrot, 1977). Fractal geometry was introduced by Mandelbrot in order to quantify and describe the nature of irregular shapes in 1982. Many researchers after him, for example Perfect & Kay (1991), Rieu & Sposito (1991a,b), Tyler-Wheatcraft used the concept of fractal geometry in the various fields of soil sciences. Fractal shapes like their fractal dimensions are not integer and are very complicated in microscopic scale. Fractal shapes in contrast to Euclidean geometry shapes are not regular, anyway. These shapes are all through irregular and their irregularities are the same in all scales, so that fractal object seems the same



from distance or close up. During the Analytic hierarchy process (AHP) of soil aggregate formation, the longer sizes of soil aggregates have got crushed and are changed to the shorter size of soil aggregate again. The smaller soil aggregate due to the larger size of soil aggregates are formed by gathering. As a result, the shape and size of longer soil aggregates are a function of the longer units, numbers and this crushing method is expressed via deduction of fractal dimension. In this way, soil Structure can be expressed by the functions that are based on fractal geometry quantitatively (Perfect & Blevins, 1997). In the recent years, the description for the distribution of particles size, pores size and soil aggregate size using fractal geometry has been considered as an appropriate instrumentation for quantifying of soil structure (Filgueira & et al., 2006; Miao & et al., 2007; Montero, 2005; Rieu & Sposito, 1991a,b).

Researchers have used the fractal approach successfully for studying of the soil structure (Ding & Ding, 2007), the distribution pattern of soil variables (Eghbal & et al., 1993), the modeling of particle size distribution and soil porosity (Perfect & Blevins, 1997), the modeling of water maintenance via soil (Perfect & et al., 2004). The modeling soil aggregates the distribution and impact of different usages on it based on the fractal geometry (Pirmoradian & et al., 2005) and evaluation of soil moisture curve using the PSF model (Zhou & et al., 2004). Some researchers have also used the fractal geometry for description of transferring water and salts porous perimeter and also for simulation of porous perimeter properties (Leao & Perfect, 2010).

Fractal dimension can be considered as an appropriate instrumentation for studying of the physical properties, erosion, hydrological process and quantitative explanation of soil structure that soil aggregates are considered as a fractal-like object (Zhao & et al., 2006). Fractal dimension of soil can be used for soil disturbance as an appropriate indicator. Because it shows the result of mechanical crushing well (Duhour & et al., 2009). The clear fractal property for soil aggregate only when is possible that extent of them are not double or more (Halley & et al., 2004). Three properties of soil structure what provide its modeling via fractal geometry contain the iterative formation, self-similarity and un-integer dimension. As a result, the estimation of parameters of experimental models (weighted mean diameter and geometric mean diameter) and fractal dimension about distribution of soil aggregate size, made of physical models (fractal models) and identification of the relation between the experimental and physical models are so important.

Because of this fact that using of the fractal geometry concept is a new issue in soil sciences, the researches which are not so wide have been done by some



researchers. In one of these studies, Dathe & et al., (2001) showed that the fractal dimension is not only used for the quantitative description of soil structure but also it can present an accurate understanding of the process what involve in formation of the soil structure. Ding & Ding (2007) reported more amounts of the fractal dimension that are indicative for more fragmentation. It means that the distribution of soil size almost attends with more amounts of tiny soil aggregates. Small amounts of fractal show that the distribution of soil aggregates size was composed more than the longer soil aggregates. Gülser (2006) found that there is a relation between the fractal dimension and structural parameters of soil. He noticed during an experiment that fractal dimension will increase when the amount of organic carbon decreases and his results showed the decrease of fractal maybe represents the improvement of structural properties of the clay soils.

Perfect & Kay (1991) assumed that the shape of soil aggregates are globular to fix the estimated amount of fractal dimension and they showed that numerical amount of fractal dimension is sensitive to the effects of agricultural activities on the soil properties. As a result, fractal dimension can explain the local and temporal variability well and it can be used as a quantitative and usable parameter in the stability management of soil. Whatever the amounts of fractal dimension are more; it shows the dispersion of soil particles that are more too. As a result, the amounts of short size particles are more.

Pirmoradian & et al. (2005) reported the nonlinear fractal dimension is more sensitive than the weighted and geometric mean diameter in surveying of the tillage effect on soil aggregate stability and they suggested using of fractal dimension is surveying of soil aggregate stability because of the stronger base.

Rieu & Sposito (1991) and Tyler & Wheatcraft (1992) showed that the amount of fractal dimension has to be less than three. Going from soil surface to the depth due to this fact that soil tissue has the smaller probability and the percent of clay and silt are more than the amount of dimension that is increased. Su & et al. (2004) reported that fractal dimension is sensitive to the soil processes and the fractal dimension of mass Rieu-Sposito size is decreased and there is a linear relation between the fractal dimension and soil properties. Soil has a high variability in large scales because it is a hetrogenous material and real quantitative explanation of soil needs to abundant the measurement. These measurements are usually time-consuming and costly, so acceptable parameters have been achieved the probability with a low accuracy by the method that was employed in this research. Thus the objective of this study was the determination of fractal parameters about soil aggregate stability and



comparing it with the classic evaluation indicator of soil aggregate and determination of a relation between these indicators with the fractal dimension of soil aggregates.

The most important limitation of this research is the relative small number of samples and as a result the lack of a community set somewhat overshadows the results. The purpose of this research has been to quantify the soil structure stability using some classic and fractal approaches in a large scale. Therefore, the main innovation of this research can be a comparative evaluation of traditional methods against a modern and practical method called fractal method for estimating soil stability parameters.

## 2. Material and methods

Forty-one intact soil samples (0-30 cm) were taken from Varamin area, Iran. Samples were kept in the plastic bags and when they were moved to laboratory, dry air and intended physical decomposition consist of particle size distribution (Via hydrometer method) and diameter size distribution (via wet and dry sieves methods) were applied. Soil bulk density was calculated via volumetric manner in the field. Then, two experimental models (classic) and four fractal cumulative distribution models were used for the determination models that were used for determination of the mass distribution, size and number, soil aggregates size in the dry and wet conditions.

Experimental models (classic) were consisting of the determination of weighted mean diameter and geometric mean diameter:

$$MWD = \sum_{i=1}^n \bar{X}_i w_i \quad (1)$$

**MWD:** Weighted mean diameter (mm).

$\bar{X}_i$ : Arithmetic mean of soil aggregate diameter in each size class.

$W_i$ : The ratio of weighted residual dry soil aggregates on every sieve per total weight of soil aggregates.

$n$ : Number of sieves that were used.

$$GMD = \exp \left[ \left( \sum_{i=1}^n w_i \log \bar{X}_i \right) / \sum_{i=1}^n w_i \right] \quad (2)$$

**GMD:** Geometric mean diameter (mm).

$W_i$ : Weight of soil aggregates in each class with the mean diameter ( $\bar{X}_i$ ).

$\Sigma w_i$ : Total weight of soil.



Fractal models were consisting of two number-size model and two mass-soil aggregate size models. The following formula was used for calculation of the fractal dimension of Mandelbrot's number-size model (1982) (Mandelbrot, 1982):

$$N(r > R) = KR^{-D} \quad (3)$$

**r:** Size of normalized diameter of soil aggregates in each metric part.

**N(r>R):** The cumulative number of soil aggregates with r size which they are higher than R measurement scale and determined by diameter of sieve.

**K:** Constant.

**D:** Fractal dimension.

Fractal dimension of Rieu-Sposito's model of number-size (Rieu & Sposito, 1991b) was calculated by the following formula:

$$N_k = Ad_k^{-Df} \quad (4)$$

**D:** Diagram slope  $N_k$  against  $d_k$ .

**$N_k$ :** The cumulative number of soil aggregates.

$$N_k = \sum_{i=0}^k N(di) \quad (5)$$

$$N(di) = \frac{M(di)}{di^3 \rho_i} \quad (6)$$

**M( $d_i$ ):** The mass of soil aggregates on sieve of class i (kg).

**$\rho_i$ :** The Aggregate bulk density of class with size i.

**$d_i$ :** The average of soil aggregate diameter for class with size i.

Fractal dimension of Rieu-Sposito's model of mass-size (Rieu and Sposito, 1991a) was calculated by the following formula:

$$\log(\rho_i/\rho_o) = (D_m - 3) \log(d_i/d_o) \quad (7)$$

**$\rho_i$ :** The Bulk density of the class with i size ( $\text{mg}/\text{m}^3$ ).

**$\rho_o$ :** The largest aggregate bulk density.

**$d_i$ :** The average of soil aggregate diameter for class with size i (mm).

**$d_o$ :** The average of largest soil aggregate.

**$D_m$ :** Fractal dimension (mass-size).

Fractal dimension of Tyler-Wheatcraft's model of mass-size (1992) was calculated by the following formula:



$$M(r < R) / MT = (R / RL)^{3-D} \quad (8)$$

**$M(r < R)$ :** The cumulative mass of soil aggregate with  $r$  size (smaller than  $R$  measurement scale and it is determined by perforated diameter of sieve).

**$M_T$ :** Total mass.

**$R_L$ :** The parameter which estimates the size of largest soil aggregate.

**$D$ :** Fractal dimension.

### 3. Results

Minimum and maximum amounts of the fractal and experimental models were presented in Table 1 for the conditions of wet and dry sieve. According to this table, minimum, maximum and average of MWD are 2.80, 8.90, and 5 respectively for dry sieve. Also minimum, maximum and average amounts of the GMD indicator are 1.03, 1.91, 1.35 respectively for this sieve and these amounts about the GMD indicator for wet sieves are 0.43, 1.01, 0.67 in respectively. The reason of this difference is because of the associated wet and dry conditions which applied the forces on soil aggregate that are different in these conditions and decrease of MWD and GMD represents the soil particles instability because of the immersion in water. The numerical amount of fractal dimension of soil aggregates will be decreased when the soil aggregates are crushed and fined and the numerical amounts of fractal dimension is poor in wet sieve compared with the dry one. As a result, the changes of physical indicators have an inverse relation with the changes of experimental indicators. So that, the stability of soil structure will be increased when the weighted mean diameter and geometric mean diameter are increased. But the stability of soil structure will be decreased when the fractal dimension is increased.

The numbers in Table 1 show for dry sieves that fractal dimensions of number and Mandelbrot's model of size which their minimum, maximum and average amounts are 2.76, 3.63 and 3.17 respectively have the largest average. Also fractal dimension of mass model, Tyler's model of size and Wheatcraft's model which their minimum, maximum and average amounts are 2.24, 2.76 and 2.51 respectively have the lowest average in wet sieves. Fractal dimensions of number model, Rieu-Sposito's model of size ( $D_f$ ) which the amount of average equal to 3.06 and mass model, Tyler-Wheatcraft's model of size and which the amounts of their average equal to 2.65 are between the largest and lowest group in order. On average, fractal dimensions of mass model, Rieu-Sposito's model of size ( $D_m$ ) which their averages equal to 2.89 and in wet





sieves and fractal dimension of mass model, Rieu-Sposito's model of size (their average equal to 2.95), Mandelbrot's model of number and size (its average equals to 2.95) and Rieu-Sposito's model (its average equal to 2.90) are in a limited area about the wet sieves. Fractal dimensions of mass model, Rieu-Sposito's model of size (its average equals to 2.95), Mandelbrot's model of number and size (its average equals to 2.95) and Rieu-Sposito's model (its average equals to 2.90) would not show a high difference when the significant level equals to 1 percent.

According to the estimation of soil aggregate stability and soil structure by the fractal models, fractal dimension is a stability representative of the soil aggregates so that whatever the amount of fractal dimension is less due to an increase of soil aggregate stability. Experimental indicators what are calculated by the experimental data do not exist to describe these data, because some of these data may have the same weighted and geometric mean. The using of experimental indicators for soil aggregates stability would be valid when the type of statistical distribution of soil aggregates size is the same, But this does not seem to be correct in this study, because the basic of comparison is completely different. As a result, the type of statistical distribution of soil aggregate size is the same in the fractal models because of using of the physical parameters (not experimental parameters). So the fractal geometry and fractal models are more appropriate instrumentation than the experimental models to quantity of the soil structure properties.

**Table- 1.** Maximum and minimum values  
of the empirical models (GMD, MWD) and fractal models

Parameters	Dry Sieve			Wet Sieve		
	Minimum	Maximum	Average	Minimum	Maximum	Average
MWD	2.80	8.90	5	0.30	1.85	1.01
GMD	1.03	1.91	1.35	0.43	1.01	0.67
Mandelbrot's D Model	2.76	3.63	3.17	2.54	3.55	2.95
Tyler-Wheatcraft's D Model	2.44	2.78	2.65	2.24	2.76	2.51
Rieu-Sposito's ( $D_m$ ) Model	2.86	2.91	2.89	2.91	2.99	2.95
Rieu-Sposito's ( $D_t$ ) Model	2.66	3.54	3.06	2.51	3.50	2.90

The amounts of maximum, minimum, standard deviation of the data and standard error of the coefficient of determination for fractal models were displayed in Table 2. According to this table , in wet sieve, Rieu-Sposito's model of number and size (its average equals to 0.93) and in wet sieve, Rieu-



Sposito's model of mass and size (its average equals to 0.62) and Mandelbrot's model of number and size (its average equals to 0.99) have the largest and lowest of standard error SE and standard deviation, respectively. Mandelbrot's model of average mass and size equals to 0.99 and Tyler-Wheatcraft's model of average mass and size (equals to 0.96) in dry sieve and Rieu-Sposito's model of number and size (its average equals to 0.99) and Tyler-Wheatcraft's model of average mass and size equals to 0.89 in dry sieves have the lowest amount of error and standard deviation. In both of the sieve series, Rieu-Sposito's model of mass and size has the higher amount of error and standard deviation. According to Table 2, the amount of calculated fractal dimension by some researchers for some samples was more than 3. This issue can be interpreted as follows. First of all, the intended model for particular distribution of soil aggregates is not appropriate. Other interpretation is that the sensitivity of the model is higher than that for the particulate distribution and so the intended samples should be evaluated by the another models (multi-dimensional model). As a result, using of multi fractal methods is useful in such conditions, because soil would be a fractal-like material.

The correlation coefficients of experimental stability indicator for soil aggregates with fractal dimensions of models were displayed in Tables 3, 4. Stability indicators of soil aggregates in wet sieve with fractal dimension of Mandelbrot, Tyler-Wheatcraft, Rieu-Sposito ( $D_f$ )'s models in significant level is equal to 1% and in wet sieve with the fractal dimensions of Mandelbrot, Rieu-Sposito ( $D_f$ )'s model and GMD indicator only with fractal dimension of Tyler-Wheatcraft's model have a negative correlation in one percent significant level and they don't have any significant relations with the fractal dimension of Rieu-Sposito's model ( $D_m$ ) in both wet and dry sieve. These results match with the results that were presented by Perfect & Kay (1991).

Figures 1 to 4 show the relations between two experimental models (mean weighted diameter and geometric mean diameter) and coefficient of determination for two fitted models. Figure 1 shows the investigation of the relation between the mean weighted diameters with fractal dimension model. Figure 1 shows this indicator has a linear and decreasing relation with all of the three models. In other words, whatever mean diameter of soil aggregate is high; soil aggregate stability will be increased because of the resistant against collapse.

Every time when the distribution of soil aggregate diameter is semi-logarithmic geometric mean diameter will be used instead of weighted mean



diameter. The studied area is exposed to high erosion because of locating in the dry and half-dry region. As a result, accessing to the best model and then finding a method for increasing of soil aggregate is necessary. So the relation between geometric mean diameters and dimension of models was investigated and shown in Figure 2. According to this figure, this indicator has an inverse relation with the fractal dimensions of the three models. This relation emphasizes decreasing of soil aggregate stability by increasing of the fractal dimension.

**Table- 2.** Maximum, minimum, and standard deviation error coefficient fractal models

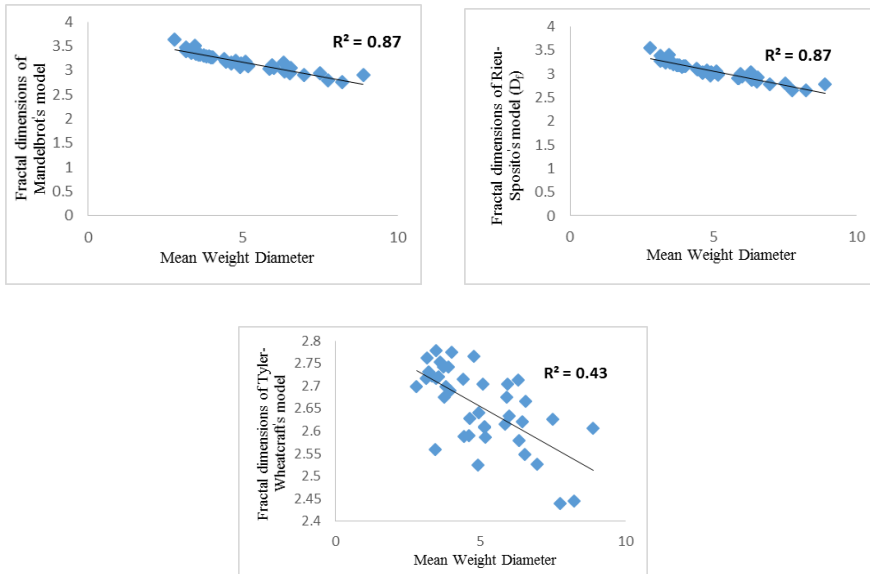
Model	Dry Sieve					Wet Sieve				
	Minimum	Maximum	Average	Standard Error	Standard Deviation	Minimum	Maximum	Average	Standard Error	Standard Deviation
Mandelbrot	0.96	1	0.99	0.001	0.007	0.98	1	0.99	0.001	0.005
Tyler-Wheatcraft	0.90	0.99	0.96	0.003	0.022	0.80	0.97	0.89	0.007	0.044
Rieu-Sposito (D <sub>m</sub> )	0.80	0.98	0.93	0.008	0.053	0.14	0.93	0.62	0.035	0.227
Rieu-Sposito (D <sub>f</sub> )	0.96	1	0.99	0.001	0.007	0.98	1	0.99	0.001	0.005

**Table 3-** Indicators of MWD and GMD solidarity with fractal dimensions of the models in the series of dry sieves

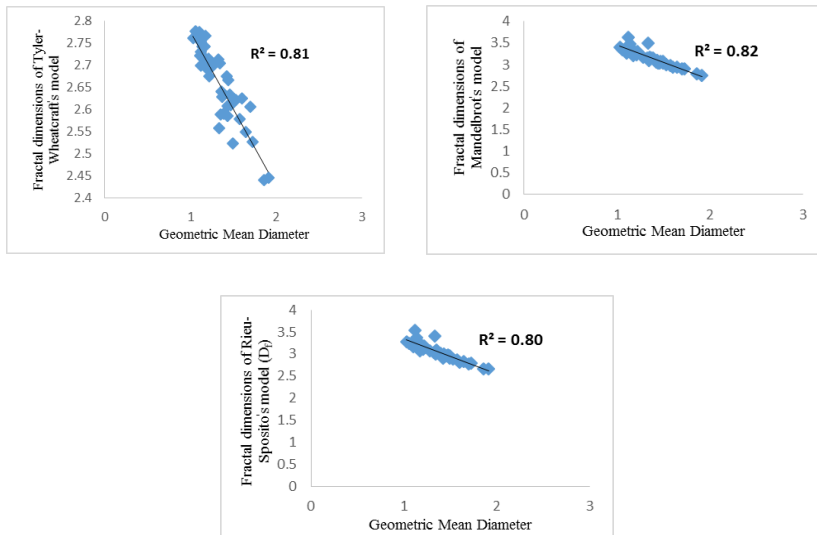
Fractal Models	Dry Sieve	
(Dry Sieve)	MWD	GMD
Mandelbrot	-0.94**	-0.91**
Tyler-Wheatcraft	-0.66**	-0.90**
Rieu-Sposito (D <sub>m</sub> )	-0.10	0.05
Rieu-Sposito (D <sub>f</sub> )	-0.94**	-0.90**

**Table 4-** Indicators of MWD and GMD solidarity with fractal dimensions of the models in the series of wet sieves

Fractal Models	Wet Sieve	
(Wet Sieve)	MWD	GMD
Mandelbrot	-0.80**	-0.94**
Tyler-Wheatcraft	-0.25	-0.61**
Rieu-Sposito (D <sub>m</sub> )	0.10	0.11
Rieu-Sposito (D <sub>f</sub> )	-0.80**	-0.94**



**Fig. 1-** Relation between fractal dimensions of models in dry conditions with weighted mean diameter



**Fig. 2-** The relation between dimensions of models with geometric mean diameter in dry sieve condition

The evaluation of soil aggregate stability about the dry sieve showed the resistance of soil aggregate is decreased against of the destruction and collapse



in effect of the suddenly increasing of primary wet. In other words, gradual moisturizing of the soil aggregates provides the possibility of exclusion for internal air of the soil aggregate and as a result is minimized and soil aggregates stability is increased. Figure 3 shows the relation between weighted mean diameter and dimension of the investigated models in the wet sieves series. According to figure 3, the gained dimensions have a linear and decreasing relation with the weighted mean diameter, so the humidity dues to increase of line slope for this decreasing relation.

Figure 4 shows the relation between geometric mean diameters with the dimension of models in dry sieves series. According to Figure 4, the calculated dimensions have an inverse relation with the geometric mean diameter, so humidity dues to increase of line slope for the decreasing relation. The amounts of experimental indicators are decreased by increasing of fractal dimension. In the other word, these two experimental and physical indicators have an inverse relation together.

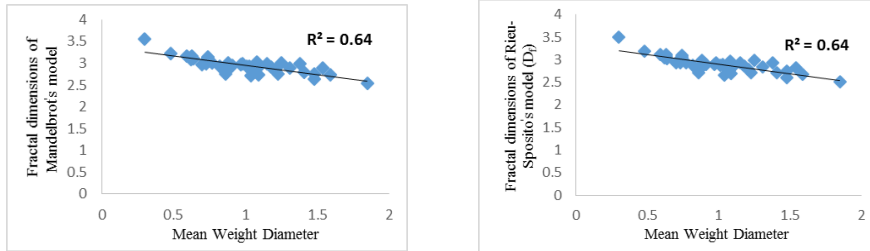
Estimation of fractal dimensions having of two experimental indicators (MWD and GMD) was shown in Tables 5 and 6. According to Table 5, the calculated line slope in both wet and dry condition is the same approximately for Mandelbrot's model of the number and size and Rieu-Sposito's model. As a result, the influence of decreasing of MWD on increasing of dimension of these two models is the same amount. According to the calculated coefficient of determination, there is the highest correlation between MWD with the fractal dimension for these two models. As a result, the fractal dimension of Rieu-Sposito's model for the number and size and Mandelbrot's model can be calculated by having MWD.

According to Table 6, the calculated line slope in wet and dry condition for Mandelbrot's model of number and size and Rieu-Sposito's model is approximately the same. According to the calculated high coefficient of determination, the highest correlation has been between GMD with the Mandelbrot's model of number and size and Rieu-Sposito's model and Tyler-Wheatcraft's model of mass and size. As a result, the fractal dimension of Rieu-Sposito's model of mass and size and Tyler-Wheatcraft's model can be calculated.

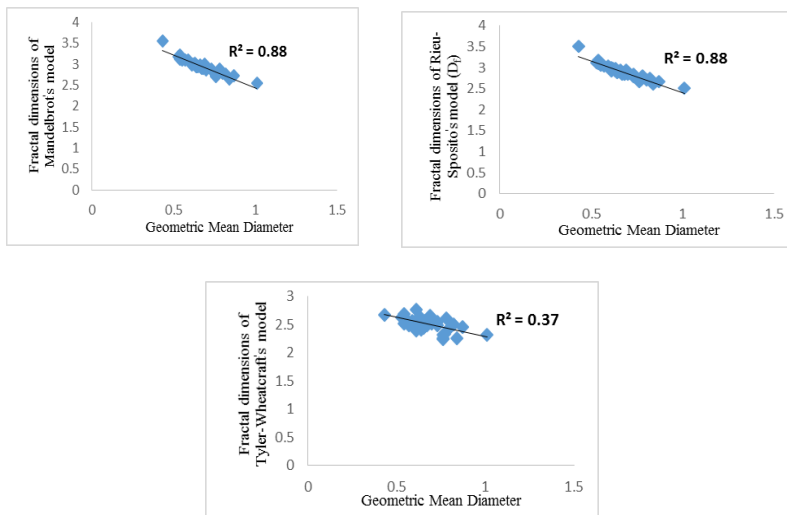
According to the calculated correlation between two experimental and physical indicators in dry sieve condition, the fractal dimension of Mandelbrot's model of number and size and in wet sieve, the fractal dimension of Rieu-Sposito's model have the highest correlation with two experimental



indicators of soil aggregate diameters. As a result, fractal dimension can be estimated with an acceptable accuracy by considering this correlation and having the experimental indicators.



**Fig. 3-** The relation of fractal dimensions of models in wet sieve condition with mean weighted diameter



**Fig. 4-** The relation of fractal dimensions of models in wet sieve condition with geometric mean diameter

**Table 5-** Estimation of fractal dimension with mean weighted diameter

Model	Fractal dimension of dry sieve	R <sup>2</sup>	Fractal dimension of wet sieve	R <sup>2</sup>
Mandelbrot	$-0.12\text{MWD}+3.76$	0.87	$-0.43\text{MWD}+3.38$	0.64
Rieu-Sposito ( $D_f$ )	$-0.12\text{MWD}+3.66$	0.87	$-0.43\text{MWD}+3.33$	0.64
Tyler-Wheatcraft	$-0.04\text{MWD}+2.84$	0.43		

**Table 6-** Estimation of fractal dimension with geometric mean diameter

Model	Fractal dimension of dry sieve	R <sup>2</sup>	Fractal dimension of wet sieve	R <sup>2</sup>
Mandelbrot	-0.80GMD+4.25	0.82	-1.55GMD+3.98	0.88
Rieu-Sposito (D <sub>f</sub> )	-0.80GMD+4.14	0.80	-1.53GMD+3.93	0.88
Tyler-Wheatcraft	-0.35GMD+3.13	0.81	-0.68GMD+2.97	0.37

## 4. Conclusions

The results of this study showed that there is an acceptable relation between the experimental indicators and fractal models. So fractal dimensions of soil aggregate can be computed by having the experimental indicators without a need to determine the other parameters of fractal models. However, experimental models are as a simple instrumentation to express the soil aggregate stability, but the accuracy of their results needs to recognize the type of statistical distribution for the soil aggregates, because they don't have an experimental nature. So it is better that fractal physical models are used for expression of soil structure quantitatively. In this study, statistical assessments also showed that Mandelbrot and Rieu-Sposito's model of number and size for description and quantification of soil structure is the best model in comparison with the investigated models. The results of this study also showed the same soil aggregate that have the dimensions which were more than 3. This outcome shows that the soil aggregate should be evaluated with the multi-fractal models. As a result, more research should be done to evaluate and quantify these soil aggregates in the future.

## 5. Acknowledgments

None declared.

## 6. Conflict of interest

None declared.



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