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INFLUENCE OF DIFFERENT SYSTEMS OF SOIL USE ON ITS STRUCTURE

Influencia de diferentes sistemas de uso del suelo sobre su estructura

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ABSTRACT. Soil structure is defined as the ability of the soil mass to disintegrate itself into separations of different shapes and sizes, which can be assessed by the stability of the aggregates. The following work was carried out with the objective of determining the change influence of the agricultural use on the structural stability index (Ie) and its relation with the dispersion factor (Kd) in Red Ferralitic leachate soils (FRL) of the National Institute of Agricultural Sciences (INCA). The soils for this study were subject to different uses, a Forest system, a Fruit trees system and a Crop Various system. The samples were taken at a depth of 0-20 and 20-40 cm. Structural analyzes were performed every two months by the Savinov and the dispersion factor method by dividing the percentage of microaggregated clay between the clay percentage of the mechanical analysis multiplied by 100. The mean and the confidence interval of the means were determined for all variables evaluated. The comparison was performed by analyzing the confidence intervals (± Z1.Esx) for a significance of 0,05. The results showed that the Forest system presented the best coefficients and the highest index stability structure and the lowest value as factor the dispersion regards of the clay in the soil, but this is not the case in the Fruit trees and Crop Various systems where these indicators showed how intensive exploitation influences in soil degradation.

Key word: clay, fruit trees, organic matter, physicochemical properties

RESUMEN. La estructura del suelo se define como la capacidad que tiene la masa de suelo de disgregarse por sí misma en separaciones de distintas formas y tamaños, la cual se puede evaluar mediante la estabilidad de los agregados. El siguiente trabajo se realizó con el objetivo de determinar la influencia del cambio del uso agrícola sobre el índice de estabilidad estructural (Ie) y su relación con el factor de dispersión (Kd) en suelos Ferralíticos Rojos Lixiviados (FRL) del Instituto Nacional de Ciencias Agrícolas (INCA). Los suelos para este estudio se encontraban sometidos a diferentes usos, un sistema Bosque, un sistema Frutales y un sistema Cultivos Varios. Las muestras fueron tomadas a una profundidad de 0-20 y 20-40 cm. Los análisis estructurales se realizaron cada dos meses por el método de Savinov y el de factor de dispersión por la división del porcentaje de arcilla de microagregados entre el porcentaje de arcilla del análisis mecánico multiplicado por 100. A todas las variables evaluadas se les determinó la media y el intervalo de confianza de las medias. La comparación se realizó mediante el análisis de los intervalos de confianza (±Z1.Esx) para una significación de 0,05. Los resultados reflejaron que el sistema Bosque presentó los mejores coeficientes y mayor índice de estabilidad de la estructura y el menor valor en cuanto al factor de dispersión de la arcilla en el suelo, no siendo así en los sistemas Frutales y Cultivos Varios, donde estos indicadores manifestaron como la explotación intensiva influye en la degradación de los suelos.

Palabras clave: arcilla, frutales , materia orgánica, propiedades fisicoquímicas

INTRODUCTION

Soil structure is one of the most important characteristics within the soil resource, as it influences water movement and water retention, drainage, aeration, root penetration, nutrient cycling, and consequently over the yield of crops (1,2).

The soil during its formation acquires different types of structures depending on multiple factors such as the content and type of clay and the amount of organic matter (3,4).

The formation process of the structure is based on the capacity of the soil mass to disintegrate by itself into separations of different shapes, sizes and pores, related by the influence of natural forces and also the microbial activity (5-7).

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The physical, chemical and biological properties of the soil have their own characteristics under natural conditions; however, these characteristics change abruptly with anthropogenic action in a short period of time, giving rise to the Global Changes in Soils (CGS), mainly due to the destruction of microaggregates due to mineralization and loss of organic matter (8, 9).

The structuring of the soil is included as a physical property which is evaluated from two different points of view, indirectly through the coefficient or dispersion factor, which is understood as the amount of clay dispersed in the soil mass and directly through the soil structural stability analysis (3).

The structure stability is defined as the resistance of the lumps and aggregates of the soil to be disintegrated or dissolved in humid conditions, due to the effects of external factors, depending on the type and amount of clay; organic matter or another cementing agent that allows the structure to remain stable (10,11).

The stability of the structure determines the degradation state of soils and it is an important quality parameter of the same, which summarizes both the negative and positive effects in the systems of agricultural management (7,11,12). On the structural stability of the soils, the formation of microaggregates is very closely related, especially in Ferralitic soils, in which iron, clay content and organic matter participate actively to form aggregates with a certain degree of stability (4).

Based on the above, this work aims to evaluate the dynamics of the stability behavior of the aggregates and the dispersion factor in leachate Red Ferralitic soils (FRL) under different agricultural uses.

MATERIALS AND METHODS

The study was carried out in Ferralitic Red Leachate soils (13), belonging to the areas of the National Institute of Agricultural Sciences, subjected to different land uses:

- Ficus spruce (*Ficus* sp.) (Forest system)
- Plantation of mango (*Mangifera indica*) of 35 years (fruit system)
- Intensive cultivation (Various Crops system)

Table I shows the main physical-chemical characteristics and organic matter content of the genetic horizons of the soils under study (8).

Experimental procedure

In each land use system, the simple random sampling method (14) was used, taking ten samples for each system, at depths of 0-20 and 20-40 cm, using a shovel, without damaging the soil conformation. Each sample weighed 500 g and they were transported in plastic bottles with a wide lid. The samples were placed in the open air for drying and later they were analyzed in the laboratory of the Agrophysical Research Group (GIAF, according its acronyms in Spanish) of the Agrarian University of Havana (UNAH).

Table I. Content in organic matter and some physical-chemical characteristics of the Ferralitic Red Leachate soil profiles studied

Horizonte	Profundidad (cm)	pH (H_2O)	M.O. (%)	Cationes cambiables (cmol kg^{-1})				
				Calcio	Magnesio	Sodio	Potasio	CCB
Bosque								
A1h	6-16	7,27	9,19	27,0	2,4	0,5	0,9	30,8
AB	16-32	7,16	2,27	13,7	1,0	0,2	0,5	15,4
B11t	32-47	6,41	2,34	12,6	0,9	0,2	0,3	14,0
B12t	47-65	5,54	1,38	11,0	0,8	0,2	0,2	12,2
B2t	65-100	5,70	1,07	10,2	0,8	0,2	0,2	11,4
Frutales								
A11	0-8	6,99	3,55	19,7	2,8	0,5	0,5	23,5
A12	8-22	6,05	3,12	12,6	1,7	0,3	0,1	14,7
B11t	22-41	5,12	1,38	8,8	1,0	0,2	0,1	10,1
B12t	41-64	5,26	0,7	8,0	0,8	0,2	0,1	9,1
B2	64-100	5,34	0,5	7,3	0,7	0,2	0,1	8,3
Cultivos Varios								
A1	0-19	7,34	3,67	16,3	2,1	0,2	0,9	19,5
B11	19-44	6,85	-	13,4	2,8	0,2	0,5	16,9
B12	44-60	6,72	2,00	9,5	1,5	0,2	0,3	11,5
B2t	60-100	5,77	1,12	8,3	1,0	0,2	0,2	9,7

CCB: Base exchange capacity

Each sampling was carried out in five moments, every two months, during the period from September 2008 to May 2009, covering a period of ten months and two climatic periods. The dates in which the samplings were executed appear in Table II, as well as the soil condition of the Various Crops area.

The behavior of the meteorological variables during the period in which the evaluations were carried out, are described in Figure 1.

Evaluations carried out and methodology used

The state of the soil structure was evaluated through the determinations of the structural stability index by means of the Savinov method which includes the dry and wet sieve evaluations (15).

The aggregate contents of 0,25-10 mm of the fractions were compared with the interpretation table proposed by Kaurichev (16) (Table III).

Table II. Dates of the samplings made, climate season and soil condition of the area of various crops

Muestreo	Fecha	Época climática	Estado del suelo (sistema Cultivos Varios)
1	septiembre/2008	período lluvioso	barbecho
2	noviembre/2008	período lluvioso	surcado
3	enero/2009	período poco lluvioso	Sembrado (*Phaseolus vulgaris* L.)
4	marzo/2009	período poco lluvioso	barbecho
5	mayo/2009	período lluvioso	barbecho

The structural stability indexes were determined according to the following formulas (15):

$$Kes = \frac{\Sigma\,\%\,Ag\;10\;mm\;a\;0.25\;mm}{\%\,Ag > 10\;mm + < 0.25\;mm}$$

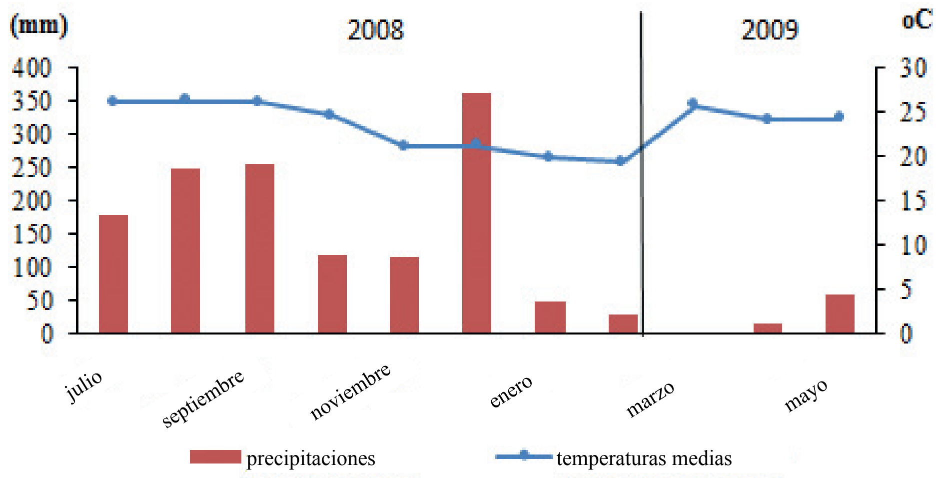
$$Keh = \frac{\%\,Ag < 0.25\;mm}{\Sigma\,\%\,Ag > 0.25\;mm}$$

$$Ie = \frac{\Sigma\%\,Ag > 0.25\;mm\;(Th)}{\Sigma\%Ag > 0.25\;mm\;(Ts)}$$

where:
Ag: aggregates
Keh: coefficient of structural stability in wet sieve
Kes: coefficient of structural stability in dry sieve
Th: wet sieve
Ts: dry sieve
Ie: structural stability index

Table III. Appreciation of the structural state of the soil

Contenido de agregados de 0,25-10 mm (% de la masa de suelo seco al aire)		Apreciación del estado estructural del suelo
Tamizado en seco	Tamizado en húmedo	
>80	>70	Excelente
80-60	70-55	Bueno
60-40	55-40	Satisfactorio
40-20	40-20	No satisfactorio
<20	<20	Malo



Meteorological Station “Tapaste”, (23º01’ North Latitude and 82º08’ West Longitude, 138 m a.s.l.)

Figure 1. Behaviors of meteorological variables mean temperature and rainfall during the analysis period

The determination of the dispersion factor was made by mechanical analysis of the soils, by the Bouyoucos method with sodium pyrophosphate and sodium hexametaphosphate (15). The calculation of the dispersion factor was made by dividing the percentage of clay of microaggregates by the percentage of clay in the mechanical analysis multiplied by 100. This analysis was performed at the depth of 0-20 and 20-40 cm in the three variants of land use only in sampling number three, corresponding to the month of January 2009, because this is an indicator that varies slowly over time.

Statistical analysis

To all the variables evaluated for each variant of soil use and at each sampling moment, the mean and the confidence interval of the means were determined. The comparison was made by analyzing the confidence intervals (± Z1.Esx) for a significance of 0,05, through the Excel data processor.

RESULTS AND DISCUSSION

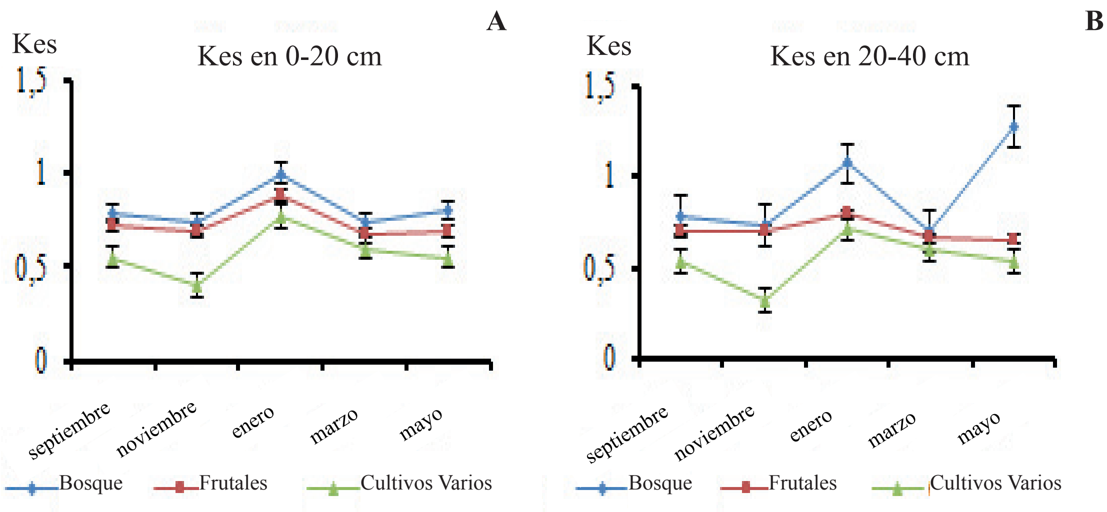
The structural state of the soil was evaluated as satisfactory in the Forest system, with 44,5 and 46,9 % of aggregates in the depths of 0-20 and 20-40 cm for dry sieving and wet sieving it was evaluated as excellent with 73,1 and 74,2 % of aggregates for each depth.

In the Fruits system the structural state was satisfactory with 40,3 and 41,1 % at 0-20 cm and at 20-40 cm respectively, with the dry sieving and in the wet sieving it was evaluated as good with a 62,2 % to 0-20 cm and 66,1 % of the aggregates for 20-40 cm.

The structural state of the soil in the system Various Crops with dry sieving was evaluated as unsatisfactory due to the presence of 36,2 % of the aggregates in the range of 0,25-10 mm for the depth of 0-20 cm and 32,5 % at 20-40 cm. With respect to the wet sieving, it was evaluated as satisfactory with 51,2 and 50,2 % of the aggregates respectively for each depth.

When the structural state is evaluated as satisfactory, there are good porosity conditions in the soil, air-water ratio, root penetration and moisture retention (17). In soils with a predominance of aggregates smaller than 0,25 mm, this is not the case, due to the effects that the predominance of these fractions can create in the structural characteristics due to the fact that they disfavor aeration porosity, filling the pores and favoring the compaction of the soil. Also, the predominance of aggregates larger than 10 mm in a degraded soil favors a low porosity, which contributes to increase the degree of soil compaction (18).

When analyzing the behavior of the dry structural stability coefficient, it was observed that for the depth of 0-20 cm the highest values were reached in the Forest and Fruit systems (Figure 2A) presenting differences between them only in the analysis carried out in the month of January, similarly for the depth of 20-40 cm similar results were achieved (Figure 2B), between the Forest and Fruit trees system there were significant differences in the months of January and March.



A: depth of 0-20 cm; B: depth of 20-40 cm. Vertical bars: Interval of confidence of the means

Figure 2. Coefficient of structural stability in dry

This behavior of the dry stability coefficient could be given by the action of the rootlets of the plants, which exude polysaccharides which adhere to the soil particles, helping the formation and conservation of the aggregates (19,20). In this case, although it was not quantified, a greater presence of roots was observed in the forest soil samples, followed by the soil with fruit trees and, to a lesser extent, the soil with various crops.

In addition, the organic matter contained in the soils positively influences the behavior of the structure, since it reduces the phenomenon of dilation and permeability and decreases the destructive forces due to the bursting of the aggregate (21,22). Likewise, since there is no movement of the soil by tillage in the Forest and Fruit systems, in these undisturbed ecosystems a favorable structure with a high concentration of organic carbon is maintained (23).

On the contrary, in soils where tillage is carried out, as is the case of the Multiple Crops system, in which there is an increase in the oxidation and decomposition of organic matter due to tillage, weathering and intensive use, reduces the ability to maintain the soil structure (24).

Regarding the wet coefficient, this is a parameter that the lower its value, the more stability the aggregates present due to the influence of water. During the wet sieving at both depths, higher values were observed in the Various Crops system (Figure 3), followed by the Fruits system and the Forest system, reflecting an increase in the Various Crops system in the months of January and March. The Forest and Fruit systems in the depth of 0-20 cm did not present differences in the months of September and November, at 20-40 cm in the months of September, November and May.

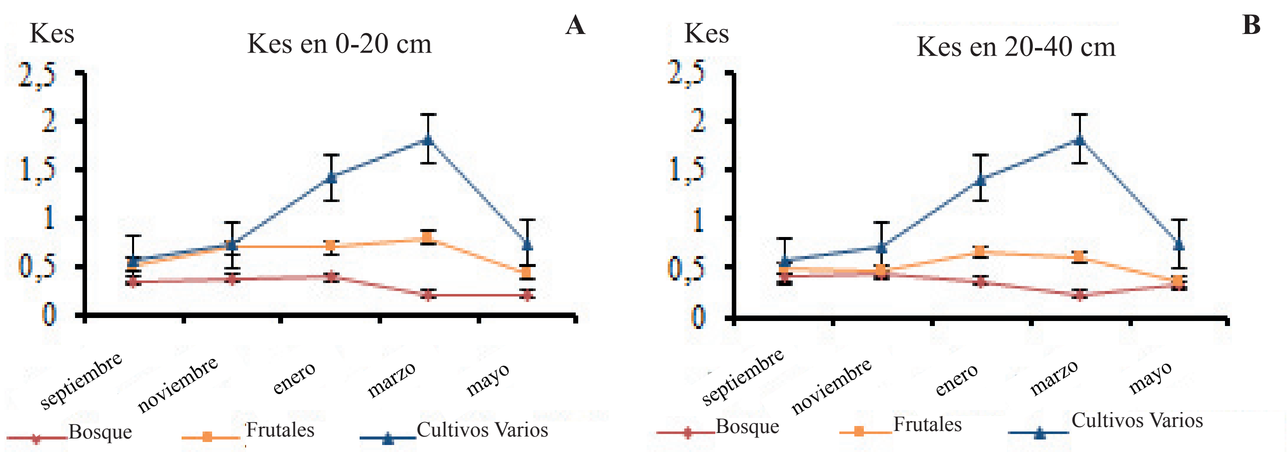
The results in the most degraded soil are due to the fact that the water influences the disintegration of the aggregates of intermediate diameters, leaving only the largest aggregates and the smallest fractions. However, in other soils, they maintain a large part of their structures before the action of water, due to the fact that they present a higher content of organic matter, which acts as a cementing agent for soil particles (4).

This behavior of higher values of the coefficient of wet stability at both depths in the Multiple Crops system was due to the fact that the soils most degraded by the effects of water mechanically disperse the particles, as the aggregates presented a weak internal cohesion (6) .

The results in the stability index showed for both depths that the Forest system behaved with higher values compared to the Fruits system and the Various Crops system, except at the depth of 0-20 cm where in the month of September the Forest system it reflected the lower values in relation to the other systems analyzed and at 20-40 cm there were no differences between the Forest and Fruit systems in the months of November and May.

This result shows that the Bosque system, due to its fertility conditions and its content of organic matter, shows some resistance to the effects of water in terms of destruction of its structural aggregates (Figure 4).

In the case of the Various Crops system in both depths is reflected as from January there is a slight decrease in the Ie, unlike the Forest system, which may be related to the influence of the lack of moisture in the soils in those months of little rain and the work of preparing the soil.



A: depth of 0-20 cm; B: depth of 20-40 cm. Vertical bars: Interval of confidence of the means

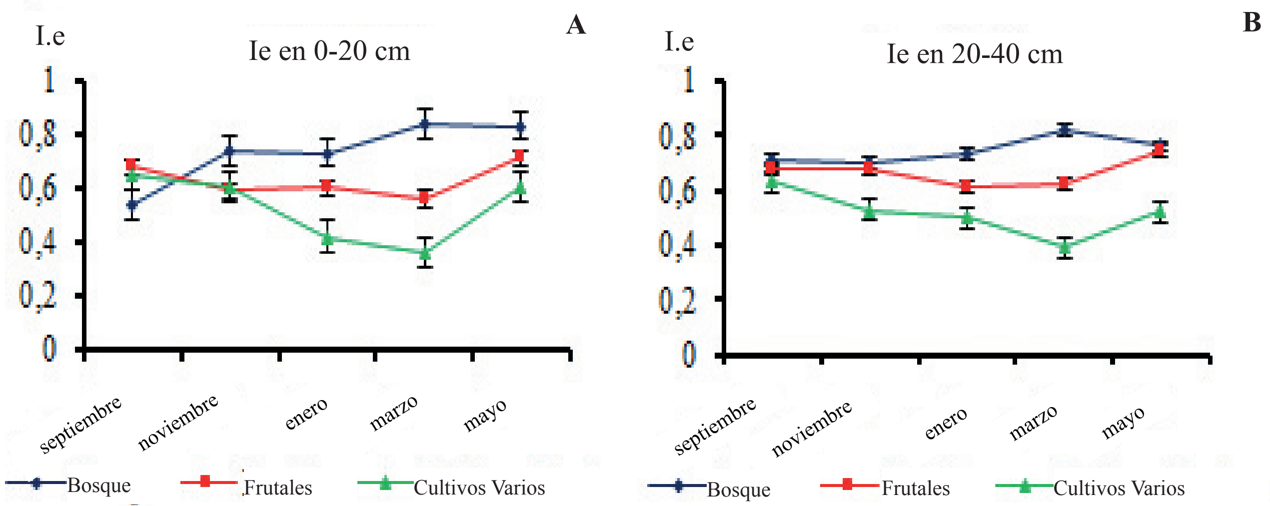
Figure 3. Coefficient of structural stability in wet

In soils that present a certain degree of degradation, the impact of raindrops confers a low stability and a high susceptibility to the separation of aggregates (19,21). This phenomenon occurs due to the fact that the water, when put in contact with the clods, facilitates the disintegration of these, product of the expansion and separation of their particles and to a displacement of the oxygen by the water in the porous fraction of the soil (18). However, this process does not occur in soils that have vegetation or vegetation cover which acts as a buffer, protecting the surface of the soil (6,25).

Table IV shows the results of the mechanical and microaggregated analyzes, with which the dispersion factor was determined. The lowest results in both depths were observed in the Forest and the Fruits systems, in contrast to the Various Crops system, which showed higher values, indicating that there is more dispersed clay at the studied depths (16), with values higher than the point critical 25 % (26).

The Various Crops system presented a higher Kd, since when the organic matter is oxidized, the microaggregates break up, increasing the dispersed clay in the soil, which fills the pores of the aggregates forming larger structures, forming a plow floor , favoring the lateral washing of the soil material and increasing the compaction (4).

By making a ratio of the stability index with the dispersion factor in these soils, it is shown how the stability index tends to decrease as the soil is more exploited (Figure 5); however, in the Forest and Fruits systems, the dispersion factor is maintained at similar values. On the other hand, the Various Crops system has a lower value in terms of the structure stability and the dispersion factor is higher compared to the other soils studied.

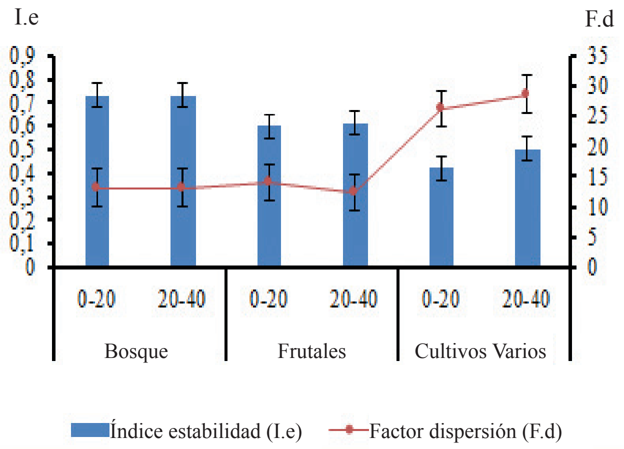


A: depth of 0-20 cm; B: depth of 20-40 cm. Vertical bars: Interval of confidence of the means

Figure 4. Structural stability index

Table IV. Mechanical and soil microstructure analysis

Profundidad (cm)	(%) tamaño de las fracciones en mm					<0,002 mm en microagregados	Factor de dispersión
	2,0-0,2	0,2-0,02	0,02-0,01	0,01-0,002	<0,002		
Bosque							
0-20	5,96	12,0	7,0	13,0	62,04	8,15	13,14
20-40	3,96	9,5	9,5	9,5	67,54	8,88	13,15
Frutales							
0-20	3,96	13,5	11,0	6,5	65,04	9,03	13,88
20-40	0,96	5,0	5,0	5,0	84,04	5,38	12,35
Cultivos Varios							
0-20	0,61	15,0	13,0	7,64	63,75	17,39	26,10
20-40	0,61	19,0	10,0	9,64	60,75	15,39	28,63



Vertical bars: Interval of confidence of the means

Figure 5. Structural stability index and dispersion factor

The results in terms of the stability of the aggregates in the soils are in agreement with the works carried out where this indicator is evaluated, from other methods of analysis and in different types of soils. An example of this, it has been found that when using systems of crops with continuous tillage for several years, compared with direct sowing systems, aggregates with a diameter greater than 0,25 mm are affected (27). Also the levels of tillage in the soils, conventional compared to the reduced, negatively influence the stability of the structure, affecting aggregates with sizes greater than 2 mm (28).

In works related to the change of the use of forest soils to cropping systems, it has been proven how the intensification of agricultural activity causes a gradual deterioration of the soil structure conditions for an adequate development of the crops (20, 23).

CONCLUSIONS

- The best values of the evaluated indicators were presented in the Forest System, followed by the Fruit System, indicating that in these systems, the soil structure has a certain degree of conservation.
- In the Various Crops system, subjected to intensive soil tillage, the worst values of the evaluated indicators are presented, which is the result of the degree of degradation due to the inadequate management that is carried out.

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