

## Incidence of rice (*Oryza sativa* L.) cultivation on soil hydrophysical properties

### Incidencia del cultivo de arroz (*Oryza sativa* L.) sobre las propiedades hidrofísicas del suelo

Yoansy García<sup>1</sup>  
Daniel Mancero<sup>2</sup>  
Daniel Ponce de León<sup>3</sup>  
Miguel Guaranda<sup>4</sup>

**Abstract:** Rice is one of the most important crops in Ecuador and also one of those that cause the greatest degradation of soil properties. In this sense, the effect of rice cultivation on soil hydrophysical properties was evaluated in the Bejuco Prieto area of Samborondón canton, Guayas province. A completely randomized design with two treatments and three replicates was used: treatment 1 corresponded to the use of soil for rice cultivation and treatment 2 was the control (virgin soil used to compare the degree of degradation). The results obtained for the first treatment indicate a clayey soil texture, apparent density of  $1.13 \text{ Mg m}^{-3}$ , real density of  $2.61 \text{ Mg m}^{-3}$ , total porosity of 55.33%, moisture content of 45%, structural index of 6.6%; suggesting that the soils are at risk of soil degradation. In addition, the structural factor was 69.9%, organic matter was 3.08%, sodium content in the soil was 104 ppm and sodium in the water sample was 14.08 ppm. The electrical conductivity in saturated paste was  $6.8 \text{ dS m}^{-1}$  and in water it ranged between 0.8 and  $1.7 \text{ dS m}^{-1}$  while pH was between 6.0 and 7.0. Of the hydrophysical parameters evaluated, electrical conductivity, sodium content, structural stability and organic matter loss were found to be the most sensitive to the deterioration of soil hydrophysical properties. Consequently, it can be affirmed that rice cultivation accelerates soil degradation, which reduces production, increases costs and decreases profitability.

**Keywords:** Stable aggregate, moisture content, real density, soil structure, hydrophysics.

#### Published

Instituto Tecnológico Superior Edwards  
Deming. Quito – Ecuador

#### Periodicity

April - June

#### Dates of receipt

Received: January 01, 2023

Approved: March 23, 2023

<http://centrosuragraria.com/index.php/revista>  
vol. 2. Num. 18. 2023.  
pp. 55-67

#### Correspondence author

[dmancero@uagraria.edu.ec](mailto:dmancero@uagraria.edu.ec)

#### Creative Commons License

Creative Commons License, Attribution-  
NonCommercial-ShareAlike 4.0  
International. <https://creativecommons.org/licenses/by-nc-sa/4.0/deed.es>

1 Jacobo Bucaram Ortiz, Ph.D, Agrarian University of Ecuador. [yogarcia@uagraria.edu.ec](mailto:yogarcia@uagraria.edu.ec), <https://orcid.org/0000-0002-2839-3956>

2 Msc. Instituto de Investigación Ing. Jacobo Bucaram Ortiz, Ph.D, Universidad Agraria del Ecuador. [dmancero@uagraria.edu.ec](mailto:dmancero@uagraria.edu.ec), <https://orcid.org/0000-0003-3917-1811>

3 Msc. Faculty of Agricultural Sciences, St. Helena Peninsula State University. [dponcel@upse.edu.ec](mailto:dponcel@upse.edu.ec), <https://orcid.org/0000-0002-7798-1551>

4 Student of Agronomy Engineering, Faculty of Agrarian Sciences, Agrarian University of Ecuador. [mguaranda@uagraria.edu.ec](mailto:mguaranda@uagraria.edu.ec), <https://orcid.org/0000-0003-1323-5290>

**Resumen:** El arroz es uno de los cultivos más importantes del Ecuador y también, uno de los que provocan mayor degradación de las propiedades edáficas. En este sentido, se evaluó el efecto del cultivo de arroz sobre las propiedades hidrofísicas del suelo en el recinto Bejuco Prieto del cantón Samborondón, provincia del Guayas. Se empleó un diseño completamente aleatorizado con dos tratamientos y tres repeticiones: el tratamiento 1 correspondió al uso de suelo para cultivo de arroz y el tratamiento 2 fue el testigo (suelo virgen utilizado para comparar el grado de degradación). Los resultados obtenidos para el primer tratamiento indican una textura del suelo arcillosa, densidad aparente de  $1,13 \text{ Mg m}^{-3}$ , densidad real de  $2,61 \text{ Mg m}^{-3}$ , porosidad total de 55,33%, contenido de humedad del 45%, índice estructural de 6,6%; lo que sugiere que los suelos están en riesgo de degradación edáfica. Además, el factor estructural fue del 69,9%, la materia orgánica del 3,08%, contenido de sodio en el suelo de 104 ppm y el sodio en la muestra de agua es de 14,08 ppm. La conductividad eléctrica en pasta saturada fue de  $6,8 \text{ dS m}^{-1}$  y en el agua osciló entre 0,8 y  $1,7 \text{ dS m}^{-1}$  mientras que el pH estuvo entre 6.0 y 7.0. De los parámetros hidrofísicos evaluados, se encontró que la conductividad eléctrica, el contenido de sodio, la estabilidad estructural y la pérdida de materia orgánica son los más sensibles al deterioro de las propiedades hidrofísicas del suelo. En consecuencia, se puede afirmar que el cultivo del arroz acelera la degradación del suelo, lo que reduce la producción, aumenta los costos y disminuye la rentabilidad.

**Palabras clave:** Agregado estable, contenido de humedad, densidad real, estructura de suelo, hidrofísicos.

## Introduction

Agriculture is a human activity that has evolved over thousands of years and has become one of the most important sources of food production for the world's population. However, it is important to note that it can also have negative effects on the environment, especially in relation to soil. In particular, agriculture can cause major soil contamination and degradation, which is largely attributable to inadequate land management and the use of agrochemicals on crops. In Ecuador, the expansion of the agricultural sector is constantly growing, and a wide variety of crops are grown, which has generated a wide range of negative impacts on the hydrophysical properties of the soil. Such a variety of crops implies different agricultural practices, and therefore, diverse forms of soil management and agrochemical use, which complicates the identification and evaluation of negative impacts on the soil (Delgado et al., 2020).

Land cultivation in Ecuador has increased considerably in recent years, and this has generated a high susceptibility to soil degradation in cultivated soils. Consequently, it is essential to deepen studies to evaluate the influence of agricultural operations on the quality of agricultural soils, particularly in those cases where there is a higher soil-water ratio, as in the case of rice cultivation. To address this problem of soil deterioration, it is essential to recognize the importance of studying hydrophysical parameters, which are determinant in soil degradation processes. Therefore, it is crucial to address the investigation of these parameters in order to advance in the search for solutions to the problem of soil deterioration in agricultural soils (Cobos Mora et al., 2021)..

In Ecuador, there is growing concern about the deterioration of agricultural soils, which affects their physical, chemical and biological properties, leading to a decrease in fertility, productivity and regenerative capacity of the soil. In particular, the decrease in their capacity to recover after long periods of cultivation is of concern, which has become a major challenge for the sustainability of agriculture in the country (García et al., 2022).

The causes of soil degradation are rooted in socioeconomic factors, overexploitation of land use capacity, and inadequate soil and inappropriate water management practices (Baude et al., 2019).

It is well known that rice farming is one of the most aggressive agricultural activities on the soil environment. According to studies carried out show that if conservation practices are not carried out on these soils, in a few years the agro-productive properties - together with the crops - will not be profitable (Sione et al., 2017).

The type and rate of soil degradation are determined by the use and management imposed on the soil, so it is important to identify the hydrophysical properties that are affected and the degrading processes caused by human action (Díaz et al., 2009). (Díaz et al., 2009)..

It is known that soil compaction increases bulk density (DA), causing in turn an increase in mechanical resistance, decreasing total porosity, favoring the risk of soil erosion by runoff. (Lima et al., 2009).

Soil aggregates in turn give rise to pore spaces of different designs and sizes. The frequency of agricultural activities greatly affects the binding agents of soil aggregates, among which we can mention: organic debris, fungal hyphae and rhizospheric organisms. It is in these pore spaces where air and water are available for the normal development of plants and their productivity (Qi et al., 20). (Qi et al., 2022).. The effective depth, texture, structure, total porosity and macroporosity, apparent density, real density, internal drainage, presence of water table, are parameters that are related to a greater or lesser degree and affect the

hydrophysical properties of the soil (Blanco-Canqui & Ruqui, 2022). (Blanco-Canqui & Ruis, 2020)..

Agricultural activity has negative effects on the physical, chemical and biological properties of the soil, where the importance of the first horizon of the soil and subsoil profile stands out in order to understand the impact of this phenomenon. Alteration of porosity, compaction and water retention capacity are changes associated with the first horizons of degraded soils, which limit the growth and elongation of the crop root system. These factors, along with other processes, are essential for the intrinsic capacity of the soil to resist and recover from agricultural damage (Blum, 1997). (Blum, 1997). In this sense, the objective of this research was to evaluate the effect of rice cultivation on soil hydrophysical properties.

### Materials and methods

Three sectors of the Bejuco Prieto area in the canton of Samborondón dedicated to rice cultivation were selected (coordinates 642086m, 9784585m WGS84 UTM 17S). Each site had at least one hectare in production.

In this study, a completely randomized design was used to compare the two treatments: Commercial Rice Cultivation (T1) and Undisturbed Forest (T2). Three replicates of each treatment were carried out and three composite samples were collected per replicate, each composed of 10 subsamples. In total, 18 composite samples were obtained, consisting of 180 subsamples throughout the experiment.

At each research site, sampling locations were established using a zigzag pattern. A Riverside type auger was used for sampling, the sampling depth was 20 cm. The samples were then subjected to a mixing, quartering and labeling process and were sent to the laboratory; this procedure is recommended by MAGAP (2020).

**Table 1.** *Treatment evaluation variables and methodology*

<b>Indicators</b>	<b>Method</b>
Structural Stability	Pieri Index (1995)
Structure factor	Vageler and Alten (1931)
Soil texture	Bouyoucos method (Soil Survey Staff, 2022)
Bulk density	Gravimetric method (Soil Survey Staff, 2022)

Actual density	Pycnometric method in water (Soil Survey Staff, 2022)
Porosity	Calculation from bulk density and real density
Soil pH	pH in water (1:2.5) (Soil Survey Staff, 2022)
Total organic carbon	Wet digestion (Walkley & Black, 1934)
Soil electrical conductivity	Conductometry (Soil Survey Staff, 2022)
Na on the ground	Adapted HACH method for Na
pH of the water film	HACH potentiometric method
Electrical conductivity of the water film	HACH conductimetry method
Na of the sheet of water	HACH potentiometric method with sodium selective probe

Table 2 shows the interpretation of Pieri's index to establish the structural state of the soil.

**Table 2. PIERI Structural Index 1995**

<b>Structural condition of the soil</b>	<b>Value</b>	<b>Detail</b>
Degraded Soils	< 5	These soils are highly susceptible to erosion and physical degradation.
Highly Susceptible Soils	5 a 7	These soils are at high risk of physical degradation due to the formation of hard clay crusts on the surface, compaction and erosion.
Slightly Susceptible Soils	7 a 9	They are soils with slight physical degradation
Structurally Stable Floors	> 9	These soils are relatively stable and have an important organic carbon content.

Organic matter was determined by the Walkley-Black (Wet Combustion) method, which is the most widely used method. The determination consists of the oxidation of organic carbon by an

oxidizing mixture of potassium dichromate ( $K_2 Cr O_{27}$ ) and concentrated sulfuric acid ( $H_2 SO_4$ ). The supernatant is then taken from the samples and taken to the colorimeter for subsequent reading in carbon content, which is then converted to organic matter.

For pH, a soil preparation was made and allowed to stand for 2 hours for subsequent analysis, in the electrical conductivity and sodium values were measured from the preparation of the soil paste that rested for 24 hours, then filtered and saturation extract readings were made. For the water analysis, a direct analysis of the sample was made using the HACH multiparameter equipment.

It was determined by the gravimetric method, the wet samples were dried at  $105^0 C$  to stable weight and the calculation was made using the following equation

$$Humedad\ gravimétrica = \frac{(PC + SH) - (PC + SC)}{(PC + SC) + PC}$$

PC: Capsule Weight, SH: Soil Moist, SC: Soil Dry at  $105 C^0$

#### *Structure factor*

The structural stability of the soil was determined by the method of Vagaler and Alten, in this procedure the amount of clay that acts as a cementing agent of the soil structure is determined, using a dispersant (Sodium hexametaphosphate) and an undispersed soil (only water) are used and the Bouyoucos technique is followed. If the clays contained are involved in the formation of the structure, the factor is said to be 100%, and if they are the average, they are characterized with 50%. The following formula is applied:

$$Factor\ estructura = \left( \frac{a - b}{b} \right) \times 100$$

Soils are classified as having a good structure when they contain a percentage of 80 to 100% (humic and oxisols) and as poor when they contain 50 to 60% (vertisols and hydromorphic), the higher the value, the greater the soil's capacity for aggregation.

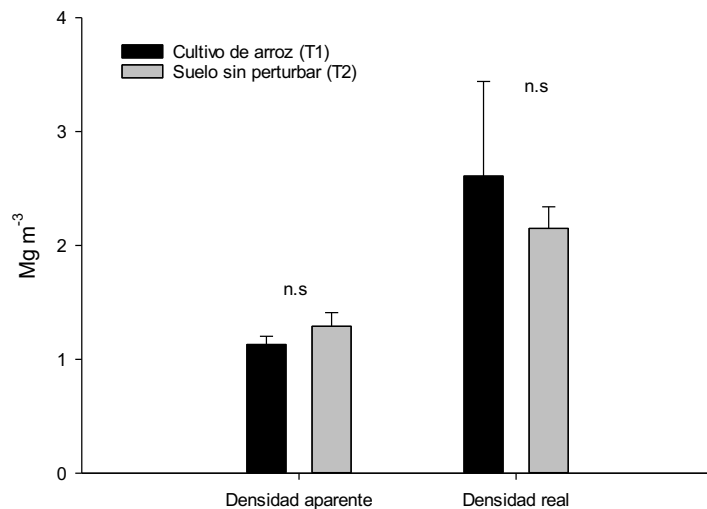
#### *Statistical analysis*

The normality of the data was evaluated using the Shapiro-Wilk test, and homogeneity of variance was tested using the Levene test. Comparison of means was performed using Student's t-test. A significance level of 5% was used for all statistical procedures. All analyses were performed in the R Studio program (version 2022.07.2) (RStudio Team, 2022).

### 3. Result

The soil texture for both treatments was clayey. Figure 1 shows the values obtained for the bulk density and real density properties for the different soil uses.

**Figure. 1** Effect of land uses Rice cultivation and Undisturbed soil on bulk density and true soil density.



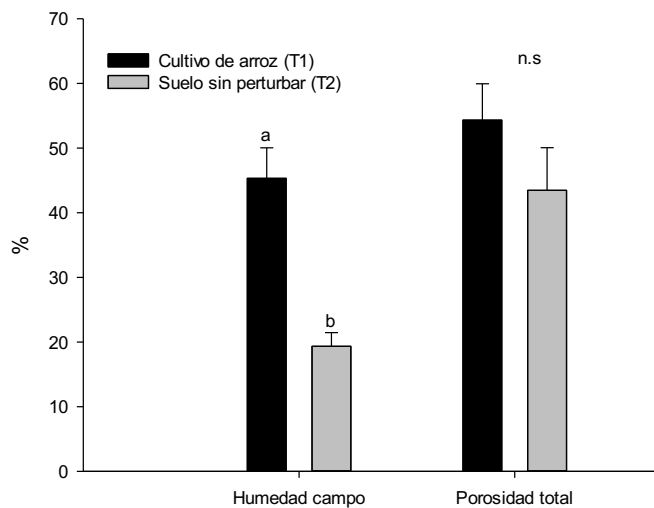
<sup>Z</sup>: Different letters indicate significant differences, according to the Student's t-test ( $p=0.05$ ).

The results show that the average bulk density for treatment T1 was  $1.13 \text{ Mg m}^{-3}$ , while for treatment T2 it was  $1.29 \text{ Mg m}^{-3}$ . However, no significant statistical difference was found between these two treatments. The real density had a similar behavior, in T1 it was  $2.61 \text{ g cm}^{-3}$  and in T2 it was  $2.15 \text{ g cm}^{-3}$  and no significant difference was found ( $p<0.05$ ). The apparent and real density determine the degree of soil compaction, this property is related to many aspects of the hydrophysical environment (Manrique & Jones, 1991). (Manrique & Jones, 1991). Both results remained in an acceptable range, and coincides with that reported by Kalita et al. (2020) who in their research observed a bulk density of  $1.30 \text{ Mg m}^{-3}$  in the rice crop.

The relationship between bulk density and actual density determines the total porosity of the soil; therefore, no significant difference ( $p<0.05$ ) was found in this variable (Figure 2). Porosity in T1 was 53.33% and in T2 43.7%; however, field moisture was 45.33% and 19.33% for T1 and

T2, respectively. This indicates that the soil cultivated with rice had a high level of water saturation at the time of sampling, in contrast to the undisturbed soil, which had lower moisture.

**Figure 2.** Effect of land uses Rice cultivation and Undisturbed soil on field moisture and total porosity.



<sup>Z</sup>: Different letters indicate significant differences, according to the Student's t-test ( $p= 0.05$ ).

Excess moisture in soils is a degrading factor, which causes the dispersion of clays and, therefore, a detriment to the structure and the rest of the physical properties (Amezqueta et al., 2003). (Amezqueta et al., 2003)..

This is intensified if there are elements that have dispersing power, such as Na. Table 3 shows the effect of the soil uses studied on the chemical properties evaluated. The Na content in the rice crop presented very high values with respect to the undisturbed soil (difference of 89.90%), which leads to a significant increase in the electrical conductivity of the soil (difference of 74.33%). In this sense, it can be seen that these two variables have a significant weight on the degrading processes of the rice soil; in addition, several authors state that from a conductivity of  $3.0 \text{ ds m}^{-1}$  a significant decrease in yields begins and increases by 12%

for each unit of electrical conductivity. Salinity is a component that must be properly managed since the detrimental effects vary according to the vegetative stage of the crop, being the most affected the initial stages, but the damage is maintained until harvest (Zeng & Shannon, 2000). (Zeng & Shannon, 2000). There were no significant differences in pH among the treatments under study.

**Table 3.** *Effect of land uses Rice cultivation and Undisturbed soil on Na, electrical conductivity and soil pH.*

Land use	Na soil (ppm)	Diff. ¥ (%)	C.E soil (dS m) <sup>-1</sup>	Diff. ¥ (%)	Soil pH	Diff. ¥ (%)
Rice cultivation	104.00±8.2 4 <sup>a</sup>	89.9	6.86±0.5 8 <sup>a</sup>	74.3	6.14±0.7 4 <sup>a</sup>	2.44
Undisturbed soil	10.45±2.15 b	0	1.76±0.2 8 <sup>b</sup>	3	6.29±0.8 7 <sup>a</sup>	

¥ Difference

Z: Different letters indicate significant differences, according to the Student's t-test (p= 0.05).

The sodium content in the soil can be increased by the use of irrigation water with high concentrations of this element; and poor management of the washing fraction of salts. Another factor is the use of fertilizers with high salt index, Das et al. (2015) state that the problem is exacerbated after fertilizer application, during droughts or arid conditions. If the soil is allowed to dry out too much for a few hours, it can also cause salinity damage. However, the greatest effect of high salt content in the soil is usually manifested in the roots.

*Effect of land uses Rice cultivation and undisturbed soil on soil organic matter, structural stability and structure factor.*

Land use	MOS* MOS*	MOS* MOS*	MOS* MOS*	MOS* MOS*	Di ff ¥	E.A* *	Di ff. ¥	F.E** *	Di ff. ¥
	MOS				%				
Rice cultivation					40	6.86	19		14
					.9	±0.5	.5	69.21	.8
	3.08±0.22 <sup>a</sup>				9	8 <sup>a</sup>	7	±8.74 <sup>a</sup>	7

Undisturbed soil	5.22±0.37 <sup>b</sup>	8.53 ±0.2	81.30 ±11.4
		8 <sup>b</sup>	8 <sup>a</sup>

\*Soil organic matter, \*\*Aggregate stability, \*\*\*Structure factor, ¥ Difference

z: Different letters indicate significant differences, according to the Student's t-test (p= 0.05).

The level of organic matter was lower in the rice crop by 40.99% (Table 4.), which indicates that the humification processes are affected by this type of soil use. Another relevant aspect is how the structural stability was affected in this type of crop, a decrease of 19.57% was evidenced with respect to undisturbed soil, also in Pieri's scale it corresponds to "Highly Susceptible Soils". This leads to an increase in erosive processes and severe degradation processes. Consequently, a detriment of the soil structure develops, which can be corroborated with the structure factor variable, which had a decrease of 14.87 %. The data obtained in the research coincide with those reported by Singh et al. (2023) These authors indicate that salt content significantly affects structural stability and MOS content in rice soils.

The pH of the irrigation water was 7.26, the electrical conductivity was 1.31 dS m<sup>-1</sup> and Na was 12.65 ppm. This shows that one of the factors that most affect the salinization of these soils and the deterioration of their physical properties is the use of hard water with a high saline level. Therefore, a management system should be considered to improve the efficiency of the use of water resources and reduce the effect on the environment - in this case, the soil.

#### 4. Conclusions

Rice cultivation favors soil degradation, as there was evidence of an increase in electrical conductivity, sodium content and a decrease in structural stability (stable aggregates) and organic matter content. Structural stability, salinity and organic matter content are the hydrophysical properties most sensitive to soil management in this study, and can be used as an indicator of the quality of the soil environment.

## References

- Amezqueta, E., Aragües, R., Carranza, R., & Urgel, B. (2003). Chemical, spontaneous and mechanical dispersion of clays in arid-zone soils. *Spanish Journal of Agricultural Research*, 1(4), Article 4. <https://doi.org/10.5424/sjar/2003014-51>
- Baude, M., Meyer, B. C., & Schindewolf, M. (2019). Land use change in an agricultural landscape causing degradation of soil based ecosystem services. *Science of The Total Environment*, 659, 1526-1536. <https://doi.org/10.1016/j.scitotenv.2018.12.455>
- Blanco-Canqui, H., & Ruis, S. J. (2020). Cover crop impacts on soil physical properties: A review. *Soil Science Society of America Journal*, 84(5), 1527-1576. <https://doi.org/10.1002/saj2.20129>
- Blum, W. E. H. (1997). Basic Concepts: Degradation, Resilience, and Rehabilitation. In *Methods for Assessment of Soil Degradation*. CRC Press.
- Cobos Mora, F. J., Gómez Pando, L. R., Reyes Borja, W. O., Medina Litardo, R. C., Cobos Mora, F. J., Gómez Pando, L. R., Reyes Borja, W. O., & Medina Litardo, R. C. (2021). Sustainability of two rice production systems, one under salinity conditions in the Yaguachi area and the other under normal conditions in the Babahoyo irrigation and drainage system, Ecuador. *Ecología Aplicada*, 20(1), 65-81. <https://doi.org/10.21704/rea.v20i1.1691>  
<https://doi.org/10.21704/rea.v20i1.1691>
- Das, P., Nutan, K., Singla-Pareek, S., & Pareek, A. (2015). Understanding salinity responses and adopting 'omics-based' approaches to generate salinity tolerant cultivars of rice. *Frontiers in Plant Science*, 6. <https://www.frontiersin.org/articles/10.3389/fpls.2015.00712>.  
<https://www.frontiersin.org/articles/10.3389/fpls.2015.00712>
- Delgado, I. R., Iglesias, H. I. P., Batista, R. M. G., & Mosquera, A. J. Q. (2020). Effect of agricultural management on soil physical and chemical properties in different agroecosystems. *University and Society*, 12(5), Article 5.
- Díaz, G. S., Ruiz, M., & Cabrera, J. A. (2009). Modifications to soil physical properties by the action of different productive practices to grow rice (*Oryza sativa* L.). *Cultivos Tropicales*, 30(3), 40-46.

- García, Y., León, D. P. de, Mancero, D., & Pancho, T. (2022). Incidence of commercial banana plantation management on soil quality, Balao, Guayas. *Polo del Conocimiento*, 7(10), 2011. <https://doi.org/10.23857/pc.v7i10.4827>.  
<https://doi.org/10.23857/pc.v7i10.4827>.
- Kalita, J., Ahmed, P., & Baruah, N. (2020). Puddling and its effect on soil physical properties and growth of rice and post rice crops: A review. *Journal of Pharmacognosy and Phytochemistry*, 9(4), 503-510.
- Lima, A. C. R. R., Hoogmoed, W. B., Pauletto, E. A., & Pinto, L. F. S. (2009). Management systems in irrigated rice affect physical and chemical soil properties. *Soil and Tillage Research*, 103(1), 92-97. <https://doi.org/10.1016/j.still.2008.09.011>.  
<https://doi.org/10.1016/j.still.2008.09.011>
- Manrique, L. A., & Jones, C. A. (1991). Bulk Density of Soils in Relation to Soil Physical and Chemical Properties. *Soil Science Society of America Journal*, 55(2), 476-481. <https://doi.org/10.2136/sssaj1991.03615995005500020030x>
- Pieri, C. (1995). *Long term soil management experiments in semiarid francophone Africa* (Afrique francophone) [Book section]. Soil Management. Experimental Basis for Sustainability and Environmental Quality = [Gestion Du Sol. Base Expérimentale Pour Une Durabilité et Une Qualité de l'environnement]; CRC Press. <https://agritrop.cirad.fr/387515/>
- Qi, J.-Y., Han, S.-W., Lin, B.-J., Xiao, X.-P., Jensen, J. L., Munkholm, L. J., & Zhang, H.-L. (2022). Improved soil structural stability under no-tillage is related to increased soil carbon in rice paddies: Evidence from literature review and field experiment. *Environmental Technology & Innovation*, 26, 102248. <https://doi.org/10.1016/j.eti.2021.102248>
- Singh, P., Sharma, S., Nisar, S., & Choudhary, O. P. (2023). Structural Stability and Organic Matter Stabilization in Soils: Differential Impacts of Soil Salinity and Sodicty. *Journal of Soil Science and Plant Nutrition*. <https://doi.org/10.1007/s42729-023-01136-3>.  
<https://doi.org/10.1007/s42729-023-01136-3>

- Sione, S. M. J., Wilson, M. G., Lado, M., & González, A. P. (2017). Evaluation of soil degradation produced by rice crop systems in a Vertisol, using a soil quality index. *CATENA*, *150*, 79-86. <https://doi.org/10.1016/j.catena.2016.11.011>.
- Soil Survey Staff (2022). *Kellogg Soil Survey Laboratory methods manual. Soil Survey Investigations Report No. 42, Version 6.0*. U.S. Department of Agriculture, Natural Resources Conservation Service. <https://nrcs.app.box.com/s/fgrv9vdiiwrymtemw3ns8ocsdz7n5q3q/file/998358972771>
- Vageler, P., & Alten, F. (1931). Böden des Nil und Gash. I. Ein Beitrag zur Kenntnis arider Irrigationsböden. *Zeitschrift für Pflanzenernährung, Düngung, Bodenkunde*, *21*(1), 47-57.
- Walkley, A., & Black, I. A. (1934). An examination of the degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, *37*(1), 29-38.
- Zeng, L., & Shannon, M. C. (2000). *Salinity Effects on Seedling Growth and Yield Components of Rice*. *40*(4), 996-1003. <https://doi.org/10.2135/cropsci2000.404996x>