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Interaction of the physical properties of an agricultural soil: resistance to penetration and volumetric humidity

Interacción de las propiedades físicas de un suelo agrícola: resistencia a la penetración y humedad volumétrica

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Abstract

The spatial variability of the physical property resistance to penetration in a soil with agricultural vocation under a rice cultivation system was studied. For the design of spatial variability maps in a study area of 22.6 ha located in the town of San José de la Vega, Municipality of San José de Cúcuta, the different variables were classified and analyzed, achieving the representation of the information obtained in the field using the "QGIS" software for the classification and distribution of the study area. A quantitative experimental method was carried out for the study, which was divided into a systematic grid with 27 points located by means of coordinates. At each point, measurements corresponding to the physical properties were made, which were: resistance to penetration, where four measurements were taken for each depth level (0-5cm, 5-10cm, 10-15cm and 15-20cm) and averaging each measurement. In the 10 to 20 cm resistance, significant values were recorded in the ranges of 3.8 and 8.42MPa from the sampling points. The moisture retention measurement is made up of the ranges of 31.1% minimum and 50.2% maximum.

Keywords: soil physics, satellite mapping, Qgis, GIS, soil spatial variability

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Resumen

Se estudió la variabilidad espacial de la propiedad física resistencia a la penetración en un suelo con vocación agrícola bajo un sistema de cultivo de arroz. Para el diseño de los mapas de variabilidad espacial en un área de estudio de 22,6 ha ubicada en el corregimiento de San José de la Vega, Municipio de San José de Cúcuta, se clasificaron y analizaron las diferentes variables, logrando la representación de la información obtenida en campo utilizando el software "QGIS" para la clasificación y distribución del área de estudio. Para el estudio se realizó un método experimental cuantitativo, el cual se dividió en una malla sistemática con 27 puntos localizados mediante coordenadas. En cada punto se realizaron las mediciones correspondientes a las propiedades físicas, las cuales fueron: resistencia a la penetración, donde se realizaron cuatro mediciones para cada nivel de profundidad (0-5cm, 5-10cm, 10-15cm y 15-20cm) y promediando cada medición. En la resistencia de 10 a 20 cm se registraron valores significativos en los rangos de 3,8 y 8,42MPa de los puntos de muestreo. La medición de la retención de humedad está compuesta por los rangos de 31,1% mínimo y 50,2% máximo.

Palabras clave: física del suelo, mapeo satelital, Qgis, SIG, variabilidad espacial del suelo.

Introduction

The study of soil physics aims to evaluate the result of the interaction between its different phases (solid, liquid and gas), which is affected by the proportion in which each of these phases are found; It focuses mainly on the structure and its mediation by the adhesion and cohesion forces that each of its components present [1]. The physical degradation of the soil disables its proper functioning, due to the fact that it affects its capacity to transmit fluids, the volume of storage related to the balance of gases and water, necessary to dissolve the nutrients for plants [2]. The loss of the physical quality of a soil can also be evaluated by the alteration in the density, porosity, distribution of the pore size, structure and the rate of water infiltration in the soil [3].

In Colombia, the agribusiness sector accounts for about 6.2% of the GDP [4], and for almost 50% of the world population, rice (Oryza sativa L.) is one of the staples of the family basket [5]. In Latin America, Colombia contributes 6.67% of production in this ruble [6]. More than 215 municipalities depend on up to 90% of its production, generating approximately 500,000 direct and indirect jobs [7]. In 2016, national production reached 2,971,975 tons, the eastern plains are the area that occupies the first place in production with 45.8%, followed by the central area with a percentage of 34.0% [8].

In the Norte de Santander department (central area), the Río Zulia Irrigation District is characterized by the fact that the soil preparation systems in the last 40 years have led to transformations that affect its structure, more than 80% of these soils present an advanced state of degradation of physical properties due to excessive tillage and the monoculture of rice developed with flood irrigation [9]. Among the physical properties of the soil, one of the most important is resistance to penetration (RP), defined as the level of soil compaction that affects the growth of the roots [10] and the spaces of water and air [11]. Penetration resistance is measured with an instrument called a penetrometer that calculates the resistance of the soil to the entrance of a cone vertically downwards [12]. Compaction is a physical process in which its porosity is reduced as a consequence of the mechanical action of soil tillage, when pressure is applied to it [13].

The use of technologies such as geographic information systems (GIS) have become a real alternative to obtain quantitative data [14, 15], which helps us locate and characterize a soil to make the best decisions [16]. Fundamentally, GIS is a technique that gives us the possibility of mapping and analyzing the geographical distribution of all kinds of variables that we consider relevant [17]. The physical properties of soils have been studied geostatistically by different authors [18]. Those who affirm that the spatial variability of soil physics within agricultural fields is induced by tillage and the type of irrigation [19]. Likewise, ignorance of the physical properties of the soil and its relationship with compaction, makes it difficult to manage the exploitation of crops and the proper use of the soil resource [20] Consequently, in this work the physical variables resistance to penetration and volumetric humidity were characterized and related in a soil destined for rice cultivation in the Zulia river valley, Colombia.

Methodology

The work was carried out in a rural area of the municipality of Cúcuta (Norte de Santander - Colombia), in the Vereda San José de la Vega, located in the irrigation district of the Zulia river [21], on a plot of 4 lots, located between the coordinates geographic 8° 4' 37.8" north latitude, 72° 33' 59.8" west longitude and 8 ° 4' 50.4" north latitude, 72° 34' 11" west longitude Following the methodology proposed by [22], the study area was georeferenced using a WGSS84 coordinate system. The sampling network consisted of 27 points (3 transects separated by 100m and 9 intersections distributed every 60m), in a lot of 22.6 ha (Table I). To measure the physical property of resistance to penetration, the methodology reported by [23], the Delta-T Tevices brand spring penetrometer, the cone of the equipment of the caliber 3 was introduced into the profile of the ground, applying manual force and vertically downwards, taking directly the measurement thrown by the clock, whose value it was given in Newton (N) for the different established depths (5 cm, 10 cm, 15 cm and 20 cm), which was related to the volumetric moisture content later. To measure the volumetric humidity, a humidity sensor based on the HH2 dielectric resistance was implemented, according to Deagustini et al. [24].

Statistical analysis

The data were analyzed to obtain the average, maximums, minimums and the coefficient of variation (CV), indicators of the magnitude of the variability [25]. For descriptive statistics, the Statgraphics Centurion XVII software was used. To determine the degrees of spatial dependence, we took into account the theory of regionalized variables, which has different methods to analyze spatial variation [26, 27].

Results and discussion

Resistance to penetration

The values obtained in the field according to the scale of the penetrometer of N / mm2 were transformed to Megapascals (MPa) to facilitate their understanding. Penetration resistance is an appropriate indicator to measure the quality of soils because it allows us to determine the degree of compaction in it. For this case, the values taken at the sampling points for the depth of 0 to 5 cm (Table I) ranged from a range of 0 - 1.7 MPa obtaining an average of 0.352 MPa; likewise, for the depth of 5 to 10 cm, the values taken at the sampling points ranged in the range of 0 - 4.59 MPa, obtaining an average of 1.36 MPa. Similarly, for the depth of 10 to 15 cm, the values taken at the sampling points ranged between 0.63 - 8.36 MPa, obtaining an average of 3.88 MPa and finally, at the depth of 15 to 20 cm, the values taken at the sampling points. They ranged from 2.27 -

significant differences between the depths 0-5cm and 10-15cm, also, there are significant differences between the depths 0-5cm and 15-20cm, in the same way, there are significant differences between the depths 5-10cm and 15 -20 cm, no significant differences were obtained between depths 0-5 cm and 5-0 cm, since their values approximate each other [28].

Table I. Data taken in the field for resistance to penetration and volumetric humidity of the soil.

Resistance to the penetration of a soil in MPa and % humidity					
Points	Depth 5 CM	Depth 10 CM	Depth 15 CM	Depth 20 CM	% Humidity
1	0	3	7.93	12.95	34.9
2	0.39	4.59	8.17	9.76	34.9
3	0	0.44	1.64	4.93	33.5
4	0.24	1.89	7.15	8.8	31.1
5	0	2.56	8.36	9.57	40.2
6	0.48	1.45	2.61	6.48	40.5
7	0.12	3.09	5.27	10.56	35.8
8	0.23	1.16	3.19	14.02	35.8
9	0.07	1.55	4.54	8.41	36.2
10	1.74	3.18	5.75	13.82	40.8
11	0.73	1.98	5.13	13.53	34.3
12	0	0.19	2.25	2.76	31.6
13	0	0.48	6.09	14.11	44.1
14	1.33	3.67	5.05	9.57	41.6
15	0.77	2.71	7.06	7.64	33.3
16	0	0	1.81	10.34	40.5
17	0	0.48	3.05	8.17	47.6
18	0.97	1.21	3	8.51	50.2
19	0	0	2.9	8.41	46.4
20	0	0	2.13	5.32	38
21	0.19	0.44	4.21	6.89	45
22	0	0.19	1.64	5.73	43
23	0	0.39	2.13	14.5	46.8
24	1.11	1.26	0.87	3	43.9
25	0.48	0.48	0.63	2.27	42.4
26	0.1	0	1.35	4.25	45.9
27	0.56	0.58	0.95	3.17	40.9
Media	0.35	1.36	3.88	8.42	39.97
Standard deviation	0,21	1,64	5,60	13,67	27,35
Minimum	0	0	0.63	2.27	31.1
Maximum	1.74	4.59	8.3	14.4	50.2
Variation coefficient	0.61	1.20	1.44	1.62	0.684

According to Carter [29], in the depths of 5 to 20 cm there are restrictions for some crops, since it exceeds the values of 0.9 Mpa; Amézquita [30], classifies as critical the radical pressure exerted by most crops, between 0.9 and 1.5 MPa; similarly, the ranges (resistance to penetrability) and humidity found show a similar behavior in soils with low clay contents, in studies carried out by Kiliç et al. [31]. From the perspective of descriptive statistics, it can be considered that the greatest difference between the smallest and largest penetrability range with respect to the mean (Table I) was found at a depth of 15 to 20 cm, where the coefficient of variation was 1.62, the minimum value is 2.27 MPa and a maximum of 14.5MPa with respect to penetrability (Table I). Penetration at depths of 0 to 5 cm varied from 0 to 1.74 MPa with an average of 1.36 MPa and a moderate range at points 11, 14, 15, 18, 24 and 27 with a reading of 0.487MPa-1.32MPa. In the case of the depth of 5 to 10 cm, the values obtained at the points ranged from 0 to 4.59 MPa with a very low range at points 3, 12, 13, 16, 17, 19, 20, 21, 22, 23, 25, 26 and 27 with a reading between 0 MPa and 0.19 MPa. Similarly, the depth of penetration of 10 to 15 cm, the values obtained at the points ranged between 0.63 and 8.3 MPa, the average value being 3.88 MPa, presenting a very high range at points 1, 2, 4, 5, 6, 7, 8, 10, 12, 13, 15, 16, 17, 18, 19 and 20 with reading from 5.27 to 8.3 MPa. Regarding the penetration depth of 15 to 20 cm, the values obtained at the points ranged between 2.27 - 14.11 MPa, the average value being 8.42 MPa, presenting a high range at points 1, 2, 4, 5, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18 and 23 with a reading of 3.05 - 14.11 MPa.

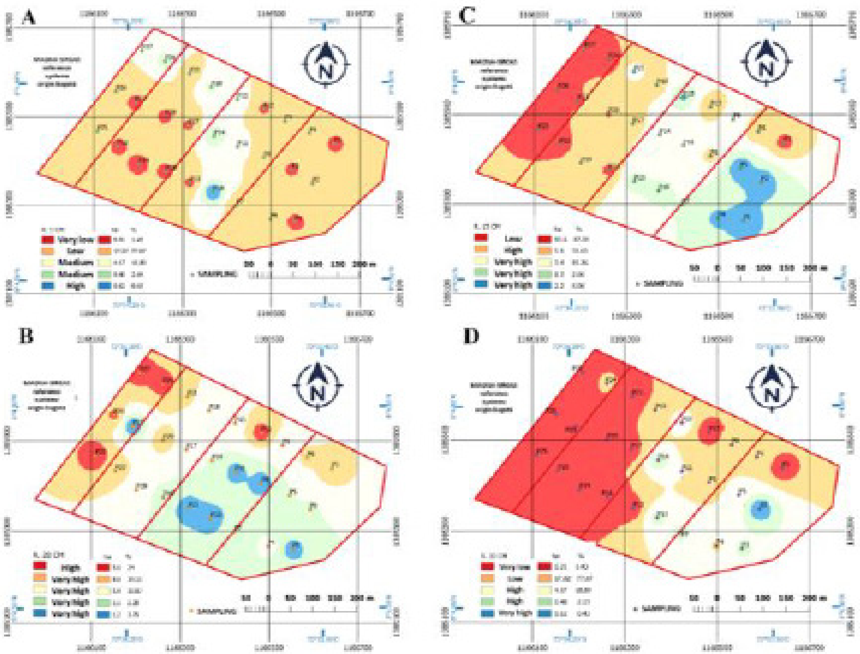

Figure 1. Penetrability resistance. A. Resistance to penetrability from 0 to 5 cm. B. Resistance to penetrability from 5 to 10 cm. C. Resistance to penetrability of 10 to 15 cm. D. Resistance to penetrability of 15 to 20 cm.

Moisture retention

According to the data obtained on moisture retention (Table I), it can be seen that its highest content was presented at points 17 to 19, exceeding the acceptable limits [17]. The area composed of 2.4% (0.32ha) had a greater presence than the others in terms of the incidence of corresponding volumetric humidity between the ranges of 46.4% and 50.2%. Similarly, in an area of 0.18ha (3.2%) ranges between 31.1% and 35.8% of volumetric humidity were observed, these areas being the driest between points 1 and 15 in the study area. Given that there is a great dominance with respect to clays, in addition to this, excess moisture presents a loss of consistency in the soil [18]. This flooding process produces varied biochemical changes in the soil, causing degradation, mineralization, immobilization and oxygen reduction phenomena. [8] Regarding resistance to penetration, it was observed that it presented in a moderate and high way, which is an indicator of soil compaction due to the type of preparation being implemented, managing ranges of 0 MPa and 14.11 MPa, which is considered harmful. for the good physiological development of the crop, taking into account critical levels between 10.34 MPa and 14.11 MPa. This leads to problems such as decreased development of plant roots, little pore space for aeration, and deterioration of soil structure. [16, 9].

Therefore, the use of tools such as GIS in irrigation application management decision making. As well as the analysis of rainfall recurrence and the incidence of the water table, which is affected by the characteristics of the watershed in the area [32]. Thus, the implementation of these technologies is as important for the success of agriculture as is the study of sciences such as seed physiology [33, 34], genetic improvement in plants [35] and the responsible use of agrochemicals [36].

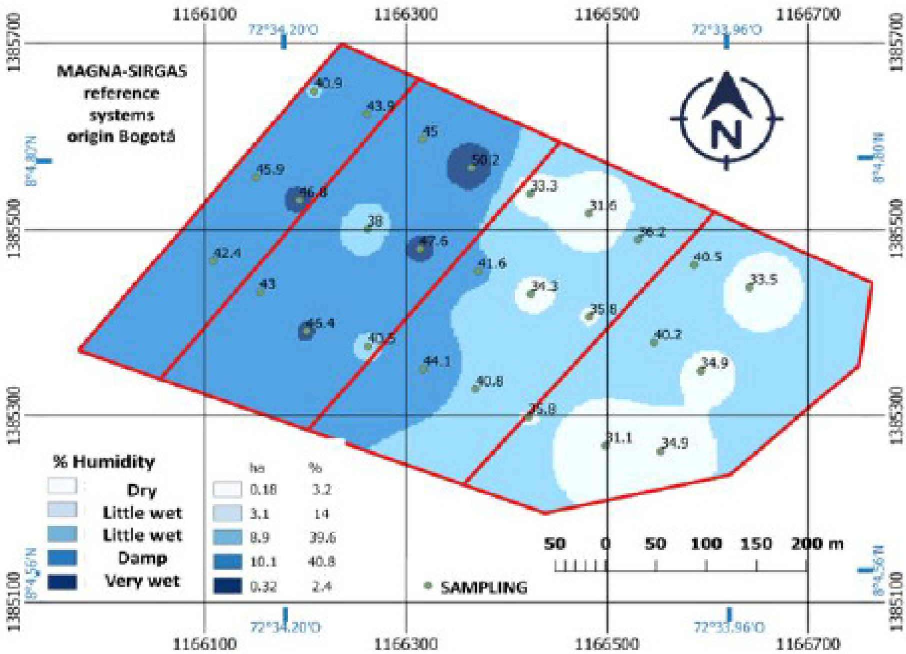

Figure 2. Volumetric humidity

Conclusions

A directly proportional relationship is observed between penetration resistance and volumetric moisture content at depths of 0 to 5 cm and 5 to 10 cm. The use of geostatistics allows the identification of compacted layers in the soil, as well as the location of densified areas that can restrict the radical development of different crops, making it an appropriate tool for making decisions and facilitating localized management of compacted layers. In the same way, as we know the method of soil preparation most used in rice cultivation (muddy), it produces severe damage to the soil structure, accelerating the degradation processes and, on the other hand, the use of floods also produces the soil loss. in the different layers.

References

[1] B. Tran, L. Le, K. Van, S. Van-Elsacker and M. Cornelis, *Land Degrad*. Develop. 2016

[2] I. Novillo-Espinoza, M. Carrillo-Zenteno, J. Cargua-Chavez, V. Nabel Moreiral, K. Albán Solarte, y F. Morales Intriago, “Propiedades físicas del suelo en diferentes sistemas agrícolas en la provincia de Los Ríos, Ecuador”, *RTA*, vol. 23, no. 2, pp. 177-187, 2018

[3] O. Ostos-Ortiz, O. Aparicio-Gómez, J. Gonzales Devia y S. Rosas Arango, Análisis de las temáticas y enfoques de

los artículos publicados en la Revista NOVA en el periodo comprendido entre 2014 y 2019. *NOVA*, vol. 19, no. 36, 2021. https://revistas.unicolmayor.edu.co/index.php/nova/article/view/1939

[4] K. Y. Sánchez-Mojica, J. E. Herrera-Rubio, M. Martínez-Parada, y L. A. Pérez-Domínguez, "Aplicación móvil como estrategia para la comercialización de productos agropecuarios", *Respuestas*, vol. 23, n.º 1, pp. 52–59, abr. 2018

[5] R. Charry, D. Pérez, E. Cabrales y V. Degiovanni, "Parámetros de crecimiento de nuevos genotipos de arroz (*Oryza sativa* L.) en tres ambientes de Córdoba", *RTA*, vol. 21, no. 1, pp. 18-27, 2016

[6] Departamento Administrativo Nacional de Estadística, "4o Censo Nacional arrocero", *DANE*, 2016

[7] FEDEARROZ, "Discurso instalación del XXXIV congreso nacional arrocero del doctor Rafael Hernández", 2014

[8] FEDEARROZ, "Fedearroz y la Universidad Nacional construyen las bases de la investigación en líneas transgénicas de arroz", vol. 58, no. 488 pp. 36-39, 2010

[9] R. García, L. Pérez y C. González, "Producción de semillas de arroz con alta calidad, obtenidas en Pinar del Río", *Revista Avance*, vol. 16, pp. 329-334, 2014

[10]J. Herrick and T. Jones, "A dynamic cone penetrometer for measuring soil penetration resistance", *Soil Sci. Soc. Am. J*, vol. 66, pp. 1320-1324. 2002

[11]R. Klvac, P. Vrana and R. Jirousek, "Possibilities of using the portable falling weight deflectometer to measure the bearing capacity and compaction of forest soils", *Journal forest Science*, vol. 56, no. 3, pp. 130-36 2010 doi: 10.17221 / 71/2009-JFS

[12]J. Lampurlanés and C. Cantero-Martínez, Soil Bulk Density and Penetration Resistance under Different Tillage and Crop Management Systems and Their Relationship with Barley Root Growth, *Agronomy Journal*, vol. 95, pp. 526-536, 2003

[13]SENA, "Manual de prácticas de campo y de laboratorio de suelos Centro agropecuario la Granja", *Regional Tolima*, 2013

[14]D. F. Flórez-Delgado, "Estimación de la capacidad de carga del sistema de producción lechero de la vereda Fontibón del municipio de Pamplona", *Mundo Fesc*, vol. 7, no. 13, pp. 15-21, 2017

[15]A. Ramirez, Implementación de un sistema de información geográfica con un perfil aplicable al sector arrocero, 2016. http://www.laccei.org/LACCEI2016-SanJose/RefereedPapers/RP94.pdf

[16]S. E. Fernández, J. P. Del Rio, "Sistema de información geográfica para el ordenamiento territorial", *Manual de series de gestión urbana*, pp. 9, 2011

[17]G. Zerpa, "Degradación de suelos en uso pastoril", *Universidad Nacional de / Rosario*. 2006

[18]F. A. Rodríguez-Garay, J. H. Camacho-Tamayo y Y. Rubiano-Sanabria "Variabilidad espacial de los atributos químicos del suelo en el rendimiento y calidad de café", Ciencia &Amp; *Tecnología Agropecuaria*, vol. 17, no. 2, pp. 237-54, 2016. doi:10.21930/rcta.vol17_num2_art:493

[19]R. Salas, I. Ordóñez, S. Valle, I. López, D. Dec, C. Descalzi y J. Dörner, Variación espacial de propiedades físicas de un suelo derivado de cenizas volcánicas sometido a distintas estrategias de mejoramiento de una pradera degradada", *Agro Sur*, vol. 44, no. 3, pp. 29-40, 2016

[20]J. Sánchez-Molina, D. Álvarez-Rozo, J.F. Gelves-Díaz and F.A. Corpas-Iglesias, "Coffee husk as substitute material for clay in the manufacturing of ceramic materials in construction in the Metropolitan Area of Cucuta", *Respuestas*, vol. 23, no. 1, pp. 27 - 31, 2018

[21]H. R. Paternina, A. C. Pérez and D. Vitola R. "Presencia De Bacterias rizosféricas Resistentes a Mercurio En Suelos Del Sur De Bolívar, Colombia", *Revista Colombiana De Ciencia Animal - RECIA*, vol. 9, no. 2, pp. 301-310, 2017. doi:10.24188/recia.v9.n2.2017.612.

[22]J. Flores, C. Valero, P. Osuna, B. Corral y M. Shukla, "Textura del suelo y tipo de agua de riego en la disponibilidad de fósforo de estiércol bovino", *Terra Latinoamericana*, vol. 31, no. 3, pp. 211-220, 2013

[23]E. Ramos y D. Zúñiga, "Efecto de la humedad, temperatura y ph del suelo en la microbiana a nivel de laboratorio", *Universidad Nacional Agraria La Molina Lima, Perú*, 2008

[24]L. Ramirez-Lopez, A. Reina-Sanchez and J. Camacho-Tamayo, "Spatial variability of physical attributes in a typic haplustox in the eastern planes of Colombia", *Engenharia Agrícola*, vol. 28, no. 1, pp. 55-63, 2008

[25]A. Rodriguez-Vasquez, A. Aristizabal-Castillo y J. Camacho-Tamayo, "Variabilidad espacial de los modelos de infiltración de Philip y Kostiakov en un suelo Ândico", *Engenharia Agrícola*, vol. 28, no. 1, pp. 64-75, 2008

[26]M. W. Roque, E. L. Silva y E. E. Matsura, "Análisis comparativo de la dependencia espacial de las propiedades físico-hídricas en suelos a lo largo de un transecto perperndicular a un drnaje natural", *In Estudios en la Zona no Saturada del Suelo*, vol VII, pp. 229- 333, 2005

[27]S. Vieira, V. Alvarez y C. Schaefer "Variabilidade espacial de propriedades físicas do solo em uma parcela experimental", *Ciência do Solo*, vol. 1, pp. 1-54, 2000

[28]IUPAC, "Harmonized guidelines for single- laboratory validation of methods of análisis", vol. 74, no. 5, pp. 835–855, 2002

[29]M. Carter, "Penetration resistance to characterize the depth and persistence of soil loosening tillage studies", *Canadian Journal of Soil Science, Ottawa*, vol. 68, no. 4, pp. 657-668, 1988

[30]E. Amezquita, "La fertilidad física del suelo", *En: Congreso Latinoamericano, XVI Congreso Colombiano de la Ciencia del Suelo sobre Suelo, ambiente y Seguridad Alimentaria*, Cartagena, Colombia, pp. 354, 2004

[31]K. Kiliç, E. Özgöz and F. Akbaş, "Assessment of spatial variability in penetration resistance as related to some soil physical properties of two fluvents in Turkey", *Soil and Tillage Research*, vol. 76, no. 1, pp. 1-11, 2004

[32]L. Vargas Garay, O. D. Torres Goyeneche y G. A. Carrillo Soto, "Evaluación del modelo de hidrograma unitario SCS en

la determinación de caudales máximos en cuencas de Norte de Santander", *Respuestas*, vol. 24, no. 1, pp. 6–15, ene. 2019

[33]S. A. Salazar-Mercado, EA. Botello-Delgado and Quintero-Caleño, JD. "Pre-treatments effect on the tetrazolium test on *Epidendrum barbaricum* Hágsater & Dodson seeds", Acta Agronómica, vol. 68, no. 4, pp. 306-311. 2019

[34]S. Salazar-Mercado, J. Quintero-Caleño, J. Rojas, "Determinación de la viabilidad de semillas de capsicum annuum L usando la prueba de tetrazolio.Determining the viability of capsicum annuum L seeds using the tetrazolium test", *Revista De Investigación, Administración E Ingeniería Aibi*, vol. 8, no. 3 pp. 7 - 12, 2020

[35]S. A. Salazar, GJ. Valderrama and JD. Quintero, "Effect of colchicine on <i>Kalanchoe daigremontiana</i> Raym.-Hamet & H.Perrier (Crassulaceae) leaf morphology and stomates", *Rev. Colomb. Cienc. Hortic.*, vol. 12, no. 1, pp. 212–222, 2018

[36]S. A. Salazar-Mercado, JD. Quintero-Caleño, "Use of Lens culinaris Med test as environmental bioindicator to identify the cytogenotoxic effect of paraquat pesticide", *Environ Sci Pollut Res Int*. vol. 28, no. 37, pp. 51321-51328, 2021