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ESTIMATION OF SOIL SALINITY IN PLOT FOR AGRICULTURAL USE USING REMOTE SENSING IN THE DISTRICT OF FILADELFIA, CHACO

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Abstract: In the District of Philadelphia, Paraguay, soil salinization processes strongly threaten productive activity, increasing the need to use systems based on a precision agriculture approach, which allow the optimization of lands destined for production. Within this approach, Geographic Information Systems (GIS) play an important role, used to process data obtained through satellite images and field sampling. An agricultural plot of around 50 hectares covered by five types of crops (corn, sorghum, cotton, soybeans and mung) was presented as the study area, the distribution of which on the plot has varied from one year to the next. The electrical conductivity (EC) values were provided by the database of the Fernheim Cooperative of the city of Philadelphia, located in the Department of Boquerón of the Paraguayan Chaco, they are the result of the measurement with a Veris sensor in the entire plot of investigation in April 2019, with which a certain degree of salinity was observed. Geostatistics and remote sensing tools were used to achieve the general objective of the research, which consisted of evaluating the distribution of salinity in the soil in a plot of agricultural use in the Central Chaco, being carried out in the Philadelphia District of the Western region. The results obtained demonstrated that the relationship in terms of growth variability detected in the sorghum crop does not respond to the salinity variability of the plot, therefore, the EC values obtained are not significantly high to explain said variation. Factors such as texture, leveling and climatic conditions were considered to explain the variation in crop growth in the plot.

Keywords: Geographic Information Systems, remote sensing, geostatistics, satellite image, electrical conductivity.

INTRODUCTION

The soils of the Western Region of Paraguay are the result of transformation processes in which the accumulation and deposit of lacustrine, palustrine and deltaic sediments are generated in the Chaco Basin between the Tertiary and Quaternary ages. This process creates a confined environment influenced, in turn, by the presence of shallow seas at that time (Fulfaro et al. 1986). Given the geological conditions of formation, in addition to the natural processes of water evaporation, the presence of clay in the soil profile encourages the accumulation of salts from what was once a marine environment.

The District of Philadelphia, located in the central region of the Paraguayan Chaco, has saline soils, both due to natural causes and inadequate livestock management practices (poor management of irrigation systems, excessive loss of forest cover, among others). These salinization processes threaten productive activity, directly affecting the physiological functions of the crop. This problem was analyzed considering both natural and anthropogenic causes (Álvarez et al., cited by Lamz and González 2013), and this phenomenon is common in arid and semi-arid regions where evapotranspiration exceeds precipitation (García sf), characteristic of the locality under study.

In soils with a high water table, soluble salts can accumulate in the soil, reaching high concentrations and can be demonstrated with analysis of the soil profile, and even the surface layer. This situation affects the root system of the crop, causing stress to the plant, particularly in the initial stage of growth. This elevation of the water table resulting from irrigation practices and precipitation generates an accumulation of salts in the soil (Lázaro et al., cited by Mercado et al. 2011; Cihacek et al. 1990; Espinosa, cited by Mercado et al. 2011). Allbed and Kumar (2013) cite several authors asSchmid et al. (2008), Sing and Sirohi (1994), Metternicht and Zinck (2008), among others, who investigated the use of spectral bands for monitoring saline soils, corroborating a positive response of the visible red and near infrared bands. in observations of the behavior of electrical conductivity (EC). Therefore, the spectral index Normalized Difference Vegetation Index (NDVI), which combines both spectral bands, was used for this work.

The objectives of this research were a) to determine the spatial distribution of EC values by the Veris method and from the analysis of soil samples in the study area, b) to calculate the Normalized Difference Vegetation Index (NDVI) of the study area, c) relate the electrical conductivity estimated by the Veris sensor and laboratory analysis with the NDVI and d) compare the spatial distribution of CE with NDVI values from both sampling methods.

JUSTIFICATION

Over the course of recent years, new methodologies have been developed to be implemented in the field of monitoring saline soils through the interpretation of the calculation of the NDVI reflectance index (Normalized Difference Vegetation Index) in the software of an Information System. Geographic together with electrical conductivity data of the study area, mentioning that what is sought to be determined is the correspondence between the spectral reflectance of the plot and the electrical conductivity in it. Likewise, the basis of precision agriculture is the knowledge of the spatial variability of some soil factors and their relationship with production, a fundamental concept to establish production systems with greater sustainability and greater efficiency, since crop production is It is influenced by the spatial variation of some soil factors (Godwin & Miller 2003, Valbuena et al. 2008).

METHODOLOGY

Initially, the NDVI calculation was carried out with the bands of the satellite images in selected epochs divided into"with vegetation cover of commercial interest in development" (months of January 2020, March 2021 and March 2022) and "without vegetation cover of commercial interest in development" (months of November 2019, November 2020 and January 2022) of an experimental "larger plot" of 50 hectares, in which the species corn, soybeans, cotton, sorghum and mung (Zea mays, Glycine max, Gossypium sp. Sorghum sp. and Vigna radiata, respectively) are distributed.

After the interpretation of the NDVI results obtained, the plot corresponding to Sorghum (Sorghum sp.) was chosen, which was called "smaller plot". The latter was selected based on the interpretation of the lowest NDVI values of images provided by the Sentinel 2 sensor with a spatial resolution of 10 meters from 2019 to 2022, in times with vegetation cover of commercial interest and without vegetation cover of commercial interest, along with the analysis of electrical conductivity (EC) values of the Veris sensor provided from the database of the Fernheim Cooperative, considered one of the pioneers in developing the agricultural sector in the region. Both variables were taken into account to delimit the soil sampling area of 1.6 ha for determination of EC with a conductivity meter in the laboratory of the surface layer of 0 – 0.30 m. In turn, a 1.2 m pit was made in order to obtain samples of the soil profile and know the distribution of electrical conductivity in depth.

Considering studies carried out by Díaz (2015), on the application of Geographic Information Systems from aerial images in agriculture, who established a sampling of points on a 25x25 m mesh, and Doerge et al. (1999), who investigated soil EC mapping and suggested a spacing of no more than 8 m, a grid of points was established with an intermediate distance from both authors and a sampling density of 15x15 m was proposed with a total of 76 samples.

The base methodology implemented was the one proposed by Lau Quan et al. (2005), who studied "Estimation of soil salinity using a spectrozonal image and the Telemap geographic information system."

The EC estimated by the veris sensor and by laboratory analysis were correlated with the NDVI values corresponding geographically to the same sampled points, also analyzing indicators of descriptive statistics and the Shapiro - Wilks test.

To verify the assumption of spatial autocorrelation, the Moran Index was used to study the way in which a phenomenon is distributed across spatial units (Vilalta and Perdomo, cited by Celemin 2009). Then, interpolation maps of EC values were prepared in the QGIS 3.18 and ArcGIS 10.1 software and the subsequent interpretation of results and comparison of sampling methodologies.

RESULTS AND DISCUSSION

The descriptive statistics, the Moran autocorrelation test and the Shapiro – Wilks normality test indicated the lack of normality and a trend behavior of the CE data. As established by GIS Geography (2022), in order for data to be processed through kriging, normality and the absence of trend in the data must be met. Therefore, the IDW (Inverse Distance Weighting) interpolation method was chosen, the result of which is reflected in Figures 2 and 3 presented below, which illustrate the distribution of CE sampled by the Veris sensor in the study plot.

To present the IDW map of the Veris sensor data, no reclassification was performed. The complete 22,568 points with EC values at depths of 0 – 0.30 m and 0 – 0.90 m were taken. For the superficial layer, EC values of 0.1 dS/m to 3.24 dS/m were identified. For the depth of 0 – 0.90 m, values of 0.1 dS/m to 6.67 dS/m were found.

Figures 4 and 5 illustrate the results obtained through the IDW interpolation method of EC data collected with field sampling, subsequently processed in the laboratory, and EC values obtained by measurement with a Veris sensor for the smaller plot..

In Figure 2 it can be seen that the points that represent the highest EC values are in redder tones, with the highest value found in the superficial layer of 0 – 0.30 m being a maximum value of 3. 24 dS/m, entering within a slightly saline range according to Ibáñez (2008). However, in Figure 3 a more pronounced spatial distribution of high EC values can be observed in the 0 – 0.90 m layer of up to 6.67 dS/m, considering it within the category of saline soil according to the same. author. Furthermore, this value of 6.67 dS/m corresponds to the point at which the highest value found at a depth of 0.30 m, of 3.24 dS/m, is found.

Chen et al., cited by Badaracco (2012) mention that the range of values obtained from NDVI varies between (-1) and (+1). Only positive values correspond to vegetation zones. Negative values, generated by a greater reflectance in the visible than in the infrared, belong to clouds, snow, water, areas of bare soil and rocks. The NDVI value may vary depending on land use, phenological season, water situation of the territory and climatic environment of the area.

According to Díaz (2015), NDVI values greater than 0.2 correspond to areas in which there is vegetation. Likewise, Gama – Moreno et al. (2021), mentions that ranges between 0.2 and 0.3 the crop could be presenting a nutrient deficiency or some anomaly in its nutrients. Figure 6 and 7 closely observe the variability of the NDVI of the smaller plot selected for data processing, corresponding to

Figure 1. Grid of sampling points and pit location for soil sampling in the "larger plot" of 50 ha.

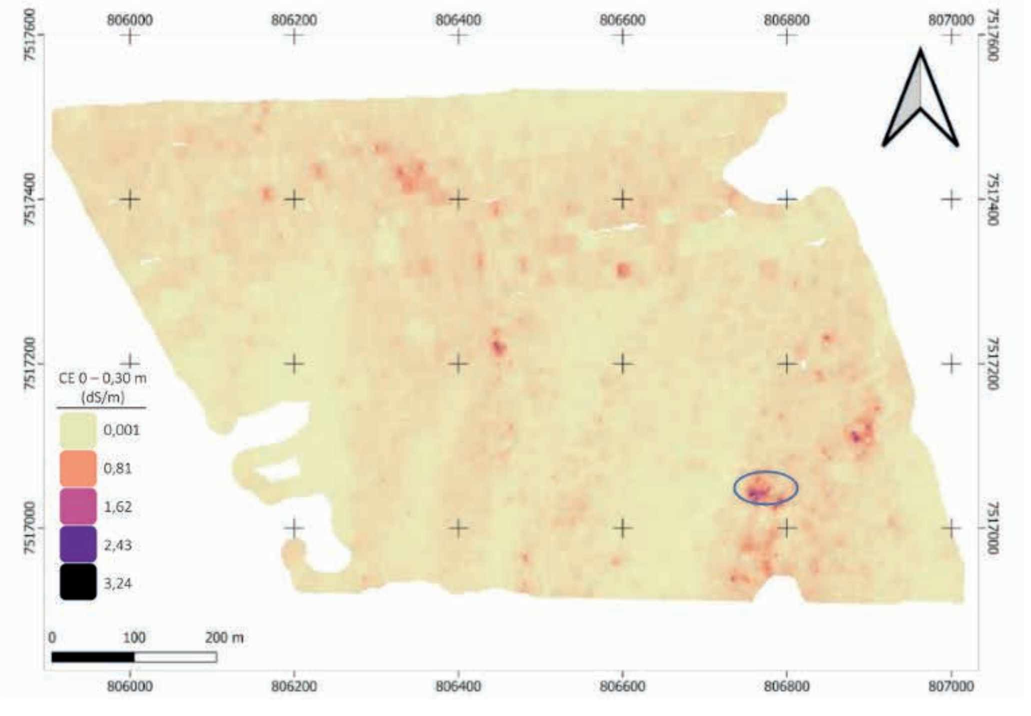

Figure 2. EC map sampled by Veris sensor from 0 - 0.30 m in dS/m of the plot larger than 50 ha. In black and stronger lilac shades they correspond to a higher EC value.

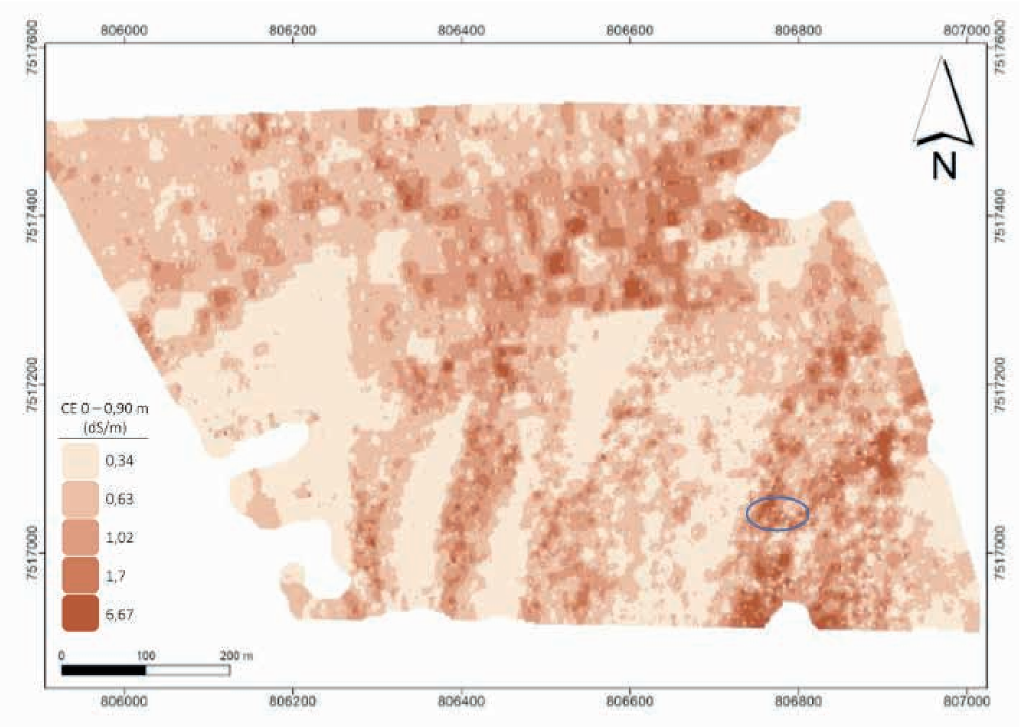

Figure 3. EC map sampled by Veris 0 - 0.90 m sensor in dS/m of the plot larger than 50 ha. Stronger red tones correspond to a higher EC value.

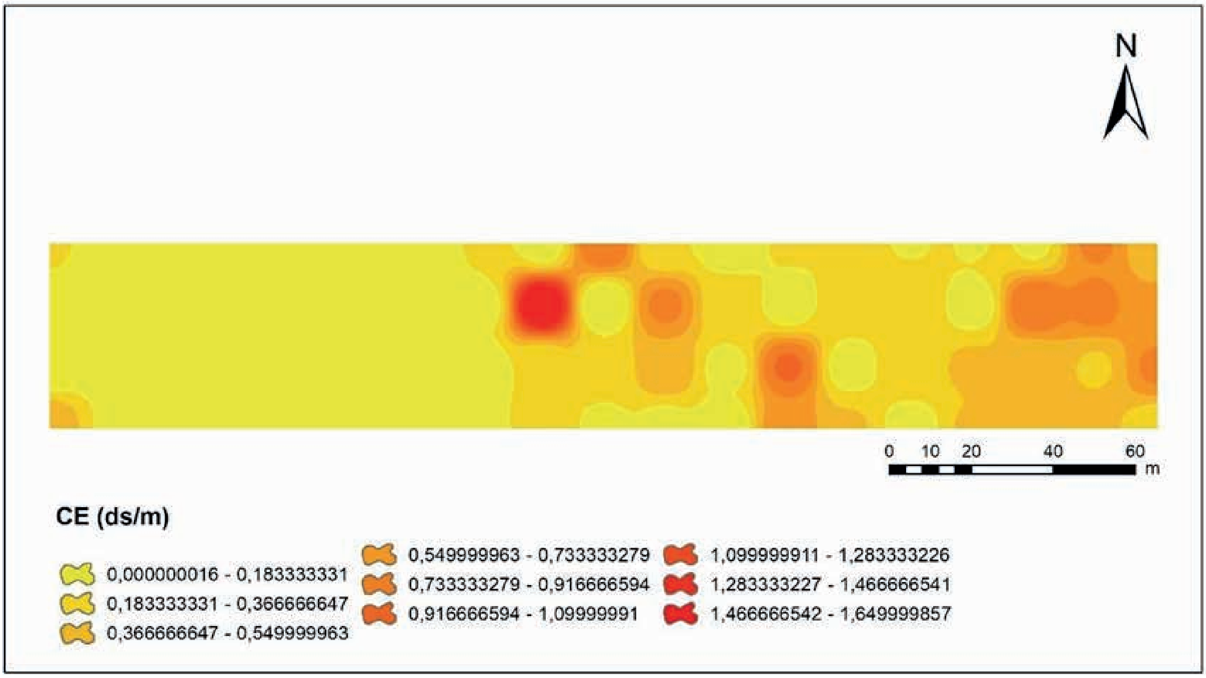

Figure 4. Estimation of the laboratory EC of the superficial layer of the smaller plot.

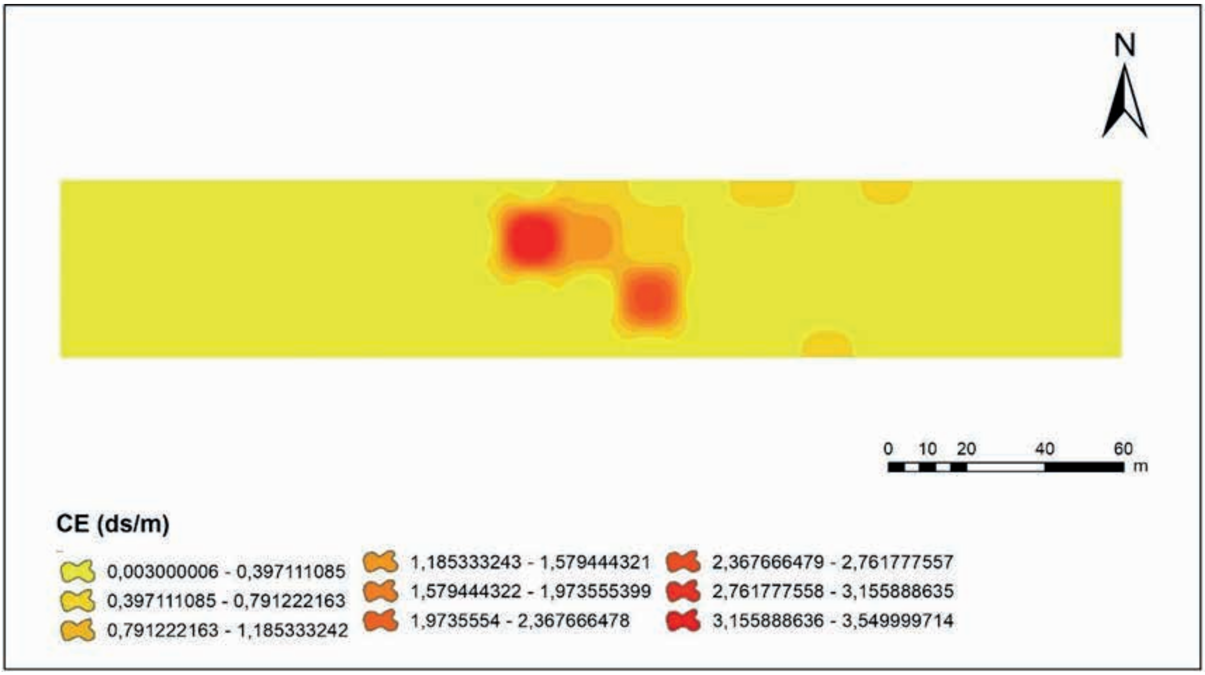

Figure 5. Estimation of the EC sampled with the Veris sensor of the surface layer of the smaller plot area.

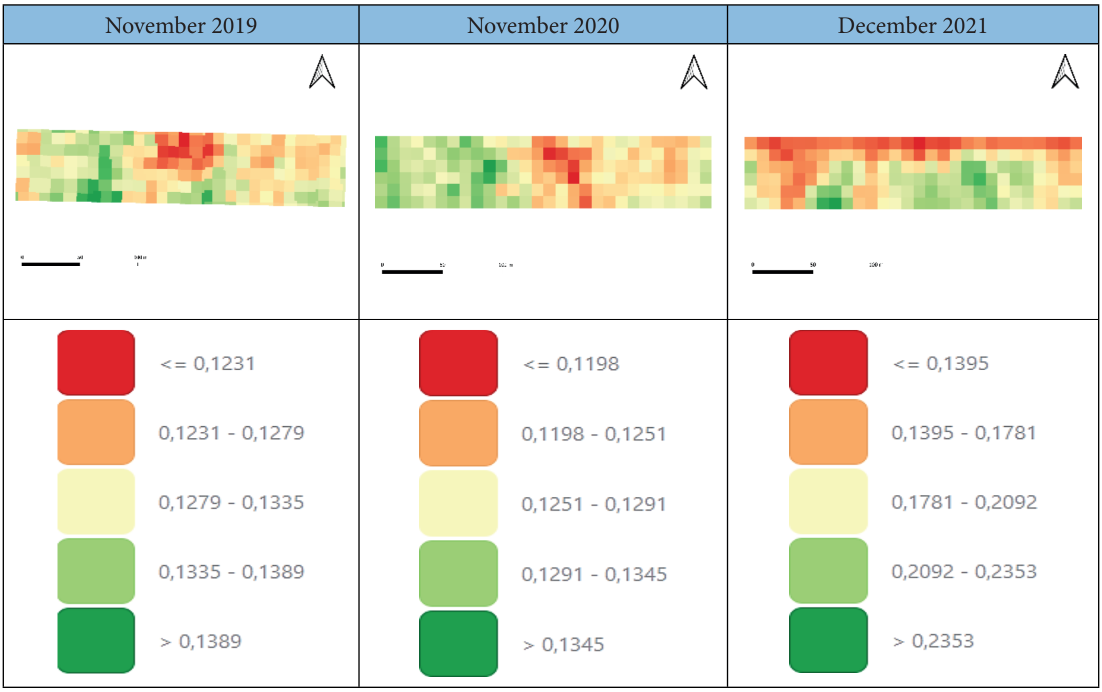

Figure 6. NDVI minor plot without cultivation of commercial interest in development in the months of November 2019, November 2020 and December 2021, respectively.

Figure 7. NDVI minor plot with crop of commercial interest in development in the months of January 2020, March 2021 and March 2022, respectively.

	Pearson ratio coefficient			
	EC laboratory(dS/m)	CE VERIS (dS/m)	NDVI without cultivation	NDVI with cultivation
Laboratory CE (dS/m)	1			
CE VERIS (dS/m)	0.533	1		
NDVI without Crop	0.009	-0.053	1	
NDVI with crop	-0.067	-0.082	0.562	1

Table 1. Pearson correlation coefficient between NDVI of the smaller plot with and without cultivation and the EC determined by two methods.

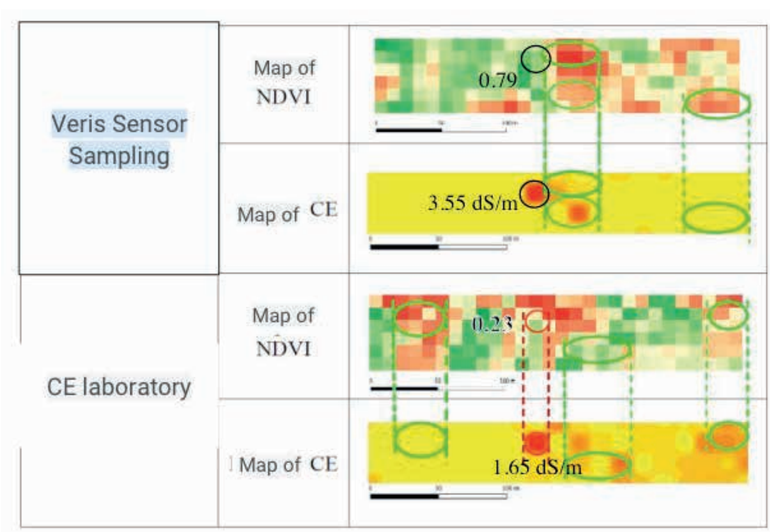

Figure 8. Comparison between EC 15 x 15 m vs NDVI of sampling by a conductivity meter in the laboratory and sampling by the Veris sensor of the depth 0 – 0.30 m of the 1.6 ha plot corresponding to sorghum.

the sorghum crop.

For the season without crops of commercial interest in development, values between 0.1 and 0.2 are again observed, indicating that there is soil with no more cover than stubble. Already for the time with a crop of commercial interest in development, values from 0.4 to even 0.8 are observed, demonstrating good quality in the crop in the years 2020 and 2021. However, for the year 2022, the values range from 0.1 to a maximum of 0.3, which indicates that for that year both the yield and quality of the crop has decreased compared to previous years.

According to the Pearson correlation coefficient (Table 1), there is a relationship of more than 53% between the EC sampled with the Veris sensor and the EC determined in the laboratory from soil sampling, between the NDVI of the date on which There was sorghum coverage in the plot and that obtained on the date that there was no crop in development, a relationship of 56% was detected. The correlation coefficients of the other pairs of variables were very low, not indicating a relationship in which the field samples were taken.

In Figure 8 below, mention can be made of the response of the reflectance in the NDVI with the EC values of the sampled sorghum plot. As already mentioned in previous paragraphs, the NDVI obtains values between -1 and + 1, with values closer to 0 indicating the absence of vegetation and NDVI values greater than 0.2 corresponding to areas in which there is vegetation, highlights again that, according to the literature, ranges between 0.2 and 0.3 the crop could be presenting a nutrient deficiency or some anomaly in its nutrients. Such is the case of sampling carried out by a conductivity meter in the laboratory, that the value of the NDVI pixel indicated with the red circle is 0.23, superimposing the EC map with a value of 1.65 dS/m, which corresponds to the highest value analyzed from said sampling. The other sectors colored in green do not indicate a correlation between the two variables, which could be due to other factors specific to the soil.

The case of sampling with the Veris sensor (May 2019) differs greatly from what was observed for field sampling (April 2022). If remote sensing is taken into account, with the naked eye the NDVI is observed with pixels in red showing lower values and, in green, higher values. The data indicates that the NDVI values obtained for the time of the Veris sensor passage are within a range of 0.73 (in red) to 0.87 (in green). According to Gama – Moreno et al. (2021), this shows that there is no condition in the crop at least to be considered as some indicator of nutrient deficiency, or that it is being affected by high concentration of salts.

CONCLUSION

The determination of the calculation of the Normalized Difference Vegetation Index made it possible to identify areas in which it coincided with observations both in the field and in satellite images of the areas in which variations in crop growth were detected.

The growth variability in sorghum detected by the NDVI and the EC determined by the veris sensor and by laboratory analysis with a conductivity meter is not responding to the salinity variability of the plot, therefore, the EC values obtained are not significantly high to explain this variation, considering that Sorghum presents resistance to salinity.

Although the time of the passage of the Veris sensor produced higher EC values than field sampling, greater variability in the distribution of values was observed in the second case.in addition to observing higher NDVI values for the time of the Veris sensor passage (between 0.73 and 0.87) and lower values (between 0.13 and 0.34) at the time in which the sampling was carried out. field. Since both samplings were carried out approximately at the same times, thirteen days apart, the existence of some more pronounced condition in the sorghum crop is evident in April 2022 compared to April 2019. The sowing times can be considered as an influence. which could vary and, consequently, demonstrate different phenological stages of development for both seasons in which the satellite images were analyzed to calculate the NDVI. Likewise, the influence of soil moisture in each season varies according to rainfall, which directly affects the rise of EC levels towards the surface from deeper areas of the profile. The percentage of soil moisture also influences the water stress that the crop could have experienced at the time of image taking for both sampling periods.

REFERENCES

Allbed, A; Kumar, L. 2013.**Soil Salinity Mapping and Monitoring in Arid and Semi Arid Regions Using Remote Sensing Technology: A Review**. Revista Scientific Reserch, 2:373 – 385. https://www.researchgate.net/publication/272656614_Soil_Salinity_Mapping_and_Monitoring_in_Arid_and_Semi-Arid_Regions_Using_Remote_Sensing_Technology_A_Review

Badaracco, R. 2012. **Detección de la Salinidad en los Suelos de Cultivos de Algodón usando Imágenes de Satélite en la Costa Norte del Perú**. Tesis Licenciatura en Física. Perú, Universidad Nacional Mayor de San Marcos, Facultad de Ciencias Físicas. 112 p

Celemin, J. 2009. **Autocorrelación espacial e indicadores locales de asociación espacial. Importancia, estructura y aplicación**. Scielo 18 (1): 84 – 106.

Cihacek, L; Swenson, L; Dahnke, W. 1990. **Soil sampling For Fertilizer Recommendations**. Dakota del Norte, US, North Dakota State Unversity. https://core.ac.uk/download/pdf/5051912.pdf

Díaz, J. 2015. **Estudio de Índices de vegetación a partir de imágenes aéreas tomadas desde UAS/RPAS y aplicaciones de estos a la agricultura de precisión**. Madrid, ES, Universidad Complutense de Madrid. https://eprints.ucm.es/id/eprint/31423/1/TFM_Juan_Diaz_Cervignon.pdf

Fúlfaro, V; Alvarenga, D; López, A; Benítez, J; Gutiérrez, M; Gómez, D. 1986. Texto explicativo: mapa geológico del Paraguay. Asunción, PY. https://www.geologiadelparaguay.com.py/Texto_explicativo_mapa_geologico_del_paraguay_1986.pdf

Gama – Moreno, L; Martínez, C; Ramírez, A; Torres, J; Torres, J. 2021. **Procesamiento de imágenes infrarrojas para detectar deficiencias de nitrógeno de cultivos en ambientes controlados usando dispositivos móviles**. Lomas de Tejeda, MX. https://www.rcs.cic.ipn.mx/rcs/2021_150_4/Procesamiento%20de%20imagenes%20infrarrojas%20para%20detectar%20deficiencias%20de%20nitrogeno%20de%20cultivos.pdf

García, A. s.f. **Manejo de suelos con acumulación de sales**. s.l. http://www.secsuelo.org/wp-content/uploadS/2015/06/2-Manejo-de-suelos-con-acumulacion-de-sales-Garcia-A.pdf

GISGeography. 2022. **geostatistics, Kriging interpolation**. s.l.https://gisgeography.com/kriging-interpolation-prediction/

Ibáñez, J. 2008. **Tipos de suelos salinos**. s.l https://www.madrimasd.org/blogs/universo/2008/01/04/81822

GODWIN, R.; MILLER, C. **Review of the technologies for mapping within-field variability.** Biosystems Engineering, Amsterdam, v.84, n.444 44, p.393-407, 2003.

Lau Quan, A; Garea, E; Ruíz, M. 2005. **Estimación de la salinidad de los suelos utilizando una imagen espectrozonal y el sistema de información geográfica Telemap**. Revista Ciencias Técnicas Agropecuarias. 14:47-54. http://www.redalyc.org/articulo.oa?id=93214111

Lamz, A; González, M. 2013. **La salinidad como problema en la agricultura: la mejora vegetal una solución inmediata**. Scielo 34(4): 31-42. http://scielo.sld.cu/pdf/ctr/v34n4/ctr05413.pdf

Mercado, T; Ortega, M; Arenas, A; Combatt, E. 2011.**Dinámica de sales en el distrito de riego La Doctrina, Colombia**. IDESIA 29(1): 83 – 90. https://scielo.conicyt.cl/pdf/idesia/v29n1/art11.pdf

Valbuena D, Verburg PH, Bregt AK (2008) **A method to definea typology for agent-based analysis in regional land-useresearch**. Agric Ecosyst Environ 128:27–36