

Estimation of the water table based on NDVI and NDWI Landsat, in the South Citrus Aquifer: a case study

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ABSTRACT

Objective: to assess the spatiotemporal changes of the vegetation of the Southern Citrus Aquifer and their possible association with the depth of the water table, through the analysis of the vegetation cover and the piezometric level with geomatics on Landsat images and the NDVI and NDWI spectral indices.

Design/Methodology/Approach: groundwater depth level data were collected from 63 monitoring wells distributed in the Southern Citrus Aquifer (DR-1914). And representative Landsat images corresponding to the years 2003, 2013 and 2022 (Landsat TM for 2003 and 2013, and Landsat OLI for 2022) were processed and analyzed with geomatics. The spatial distribution of the water table for each year was estimated by means of geostatistical interpolation techniques and the information was processed with QGIS[®] 3.28 and Google Earth Engine[®].

Results: our results showed a general trend of increase in NDVI values between 2003 and 2013; which changed towards signs of water stress in 2022. This means that there are changes in vegetation cover and vigor in relation to water availability and local anthropogenic pressure. The depth of the water table in 2022 differs significantly ($p \leq 0.001$) from the same value in 2003. This supports the existence of a progressive aquifer depletion process that spectral indices can detect, to assess the underground dynamics of the plant systems associated with the aquifer.

Limitations/Implications of the study: discontinuity was identified in the piezometric records, due to the absence of measurements in some years. This limitation was mitigated by interpolation estimation of average values from earlier and later records.

Findings/Conclusions: NDVI and NDWI indices proved to be effective tools for analyzing the relationship between vegetation dynamics, soil moisture availability, and water table depth. Remote sensing offers a methodological alternative for monitoring the hydrological and environmental dynamics of the aquifer. This methodology is efficient, spatially continuous, and temporally consistent.

Keywords: water table, Landsat, spatial distribution, vegetation health, geomatics.

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INTRODUCTION

The Southern Citrus Aquifer is a groundwater system that plays a vital role in supplying the agricultural, social, and ecological sectors, according to Mexico's Secretariat of Environment, and Natural Resources (SEMARNAT, 2020). This aquifer, identified as DR-1914, with an area of 4172 km², sustain agricultural cover (>20%), forest and

secondary vegetation (19%), shrubland (18%) and thorny vegetation [*Prosopis* as dominant] (1%), supplied by underground flows according to Mexico's National Commission for the Knowledge and Use of Biodiversity (CONABIO, 2021). It is recharged from the Sierra Madre Oriental with 75.1 hm^3 per year; extractions for agriculture, urban and industrial use are the main discharges according to Mexico's National Water Commission (CONAGUA, 2024). Climate change has reduced the average annual recharge by 10-15% in two decades, which has caused an imbalance that has caused the water table to drop from 1.5 to 2 m per year (30 m accumulated since 1980). This has affected dependent ecosystems according to Mexico's National Institute of Ecology and Climate Change (CONABIO, 2018; INECC, 2019).

In Linares and Hualahuises (Nuevo Leon, Mexico) irrigated agriculture covers 14 650 ha and demands 96.8% of the water in the aquifer according to data from the Secretariat of Agriculture (SAGARPA, 2019). The study of vegetation by means of remote sensing allows the aquifer condition to be evaluated through spectral indices. The reflectance of healthy vegetation is characterized by low reflectance in the visible spectrum, and high in the near-infrared (NIR). Changes in this pattern indicate stress or damage (Chuvieco, 2002; Fiallos & Alexander, 2024). The NDVI (Normalized Difference Vegetation Index) is a key indicator that estimates plant vigor and water stress associated with the depth of the water table. Whereas the NDWI (Normalized Water Difference Index) estimates the moisture content in the vegetation cover from green and near-infrared (NIR) reflectance, which allows identifying variations in the humidity of the vegetation.

The objective of this study was to measure the spatiotemporal changes of the vegetation of the Southern Citrus Aquifer (DR-1914) and its possible association with the depth of the water table, by analyzing the vegetation cover and the piezometric level with geomatics based on Landsat images and the NDVI and NDWI spectral indices.

MATERIALS AND METHODS

The Southern Citrus Aquifer (DR-1914) belongs to the hydrological-administrative region of the Rio Grande Basin Organization. It is located in the southeastern portion of the state of Nuevo León (Mexico) and includes the municipality of Hualahuises, most area of the municipality of Linares and smaller proportions of the municipalities of Galeana, Montemorelos and Iturbide, plus a few areas of Rayones and General Terán (Figure 1). The area has a variability of BSoh(x') semi-warm arid climates, (A) C(w1) semi-warm sub-humid, (A)C(wo) semi-warm sub-humid, C(wo)x' temperate sub-humid, and BS1(H') W warm semi-arid. Temperatures range from 18 °C to 22 °C, with rainfall distributed throughout the year and winter rainfall percentages of 5% to 10.2% according to the modified Köppen climate classification (García, 2004).

Depth of the water table

Information available on the depth of the water table of 63 measuring wells, distributed over the Southern Citrus Aquifer, with records in 2003, 2013 and 2022 was documented. In each of these years, an average of the total available records was obtained. Then, for

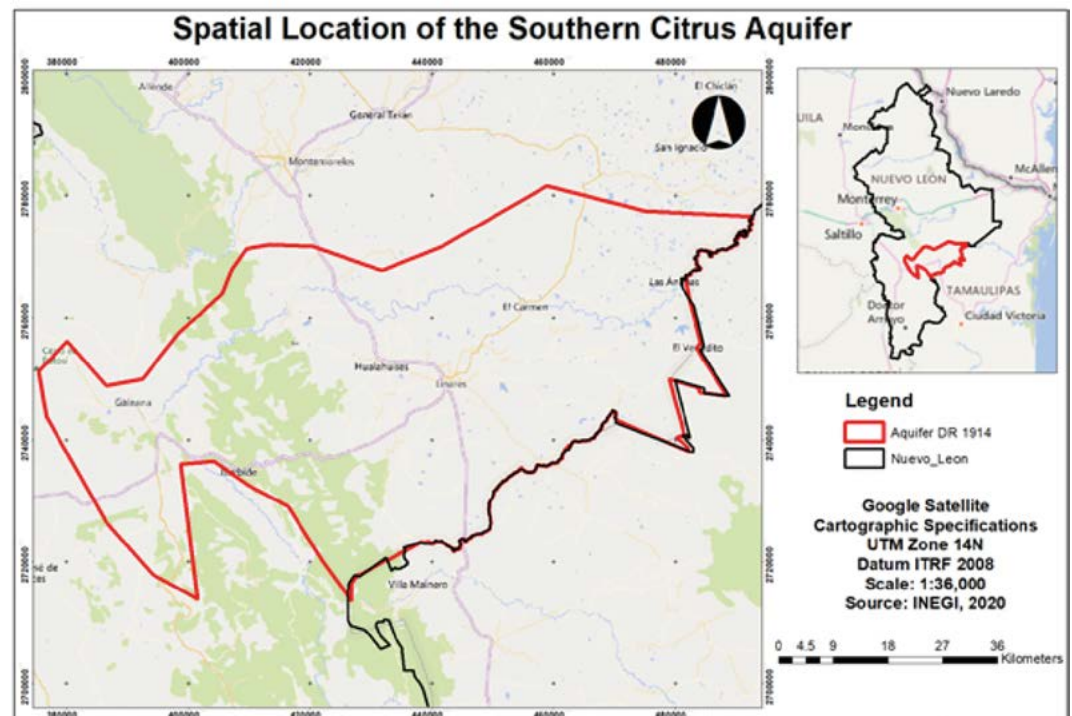


Figure 1. Location of the study area: the Southern Citrus Aquifer [DR-1914] in Nuevo León, Mexico.

each year, the spatial distribution of the depth of the wells was estimated by geostatistical interpolation in a 100×100 m mesh for a global variogram model, an exponential model, and kriging with the use of QGIS[®] 3.28 (QGIS[®] Development Team, 2023). Following this methodology, the values of the wells without data were estimated by spatial and temporal interpolation, and the trends were determined.

Afterward, statistical tests were performed to compare the periods with the Shapiro-Wilk normality test to verify compliance with the normality assumption. Then, the non-parametric Mann-Whitney test was performed to compare the distributions of water tables between different years, without assuming normality.

Remote sensing

Three Landsat Thematic Mapper satellite images dated November 22, 2003, May 11, 2013, and June 3, 2022, were analyzed, which were obtained from the Google Earth Engine[®] server. The information processing was done in QGIS[®] 3.28 and Google Earth Engine[®] to generate the scripts. The images were geometrically corrected with the methodology (GCPs) called the methodology of terrestrial control points and as a backup tool, we used the network of topographic map paths, scale 1:50000, of Mexico's National Institute of Statistics and Geography (INEGI, 2022).

In order to determine the water status of the vegetation, a spectral indicator was used throughout the area of interest. This indicator is widely used to assess plant health and vegetation density from spectral images. The Normalized Difference Vegetation Index (NDVI) is an index that identifies abnormal changes in plants and distinguishes vegetation

from other types of land cover (Rouse *et al.*, 1974). In the case of Landsat imagery, it is calculated according to the following equation:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

where, *NIR*: the reflectivities calculated from the near-infrared bands; *RED*: the spectral reflectance in the red.

To extract points in the satellite image, a systematic non-aligned sampling was done, to interpolate the data of depths of the piezometric level. The number of sampling points (*n*) was determined with the following equation:

$$n = \frac{z^2 \sigma^2}{L^2 + \frac{z^2 \sigma^2}{N}}$$

where, z^2 (95%): the abscissa of the normal curve for a given value of probability; σ^2 : the sample variance; *N*: is the size of the population; *L*: the margin of error allowed ($\alpha=5\%$).

The following equation was used to calculate the Normalized Water Difference Index:

$$NDWI = \frac{VIR - NIR}{VIR + NIR}$$

where, *NIR*: the spectral reflectance of the near-infrared; *VIR*: the spectral reflectance in the green.

RESULTS AND DISCUSSION

The statistical analysis of the depth of the water table of the Southern Citrus Aquifer allowed obtaining a record for each well in the years 2003, 2013 and 2022. The Shapiro-Wilk test showed that NDVI in 2003-2013 had a normal distribution ($W=0.9726$; $p=0.277 > \alpha=0.05$), while NDVI in 2003-2022 did not meet the normal assumption ($W=0.9357$; $p=0.00096 < \alpha=0.05$). Similarly, the NDWI in 2003-2013 maintained a normal distribution ($W=0.9823$; $p=0.3862 > \alpha=0.05$), in contrast to the NDWI in 2003-2022 which showed absence of normality ($W=0.9418$; $p=0.00196 < \alpha=0.05$). These values are evidence of greater variability in the periods of long-term analysis.

Considering the aforementioned results, the Mann-Whitney test was performed, which allowed comparing the distributions of the water tables between different years without assuming normality, to guarantee the robustness and statistical validity of the results obtained. The results showed that for the NDVI there were no statistical differences between 2003 and 2013 ($U=2324.0$; $p=0.0981$), while there were significant differences between

2003 and 2022 ($U=3285.0$; $p=2.25 \times 10^{-10}$); and between 2013 and 2022 ($U=2844.0$; $p=2.77 \times 10^{-5}$). In the case of the NDWI, the comparison between 2003 and 2013 did not show significant differences ($U=1606.0$; $p=0.0651$); while significant differences were identified between 2003 and 2022 ($U=849.0$; $p=3.06 \times 10^{-8}$), as well as between 2013 and 2022 ($U=1337.0$; $p=0.00159$).

The Mann-Whitney test provided evidence of significant changes in the distribution of water table depths (Figure 2). In 2003, the median was lower, and the distribution showed relatively shallow water tables, with less dispersion and few extreme values, indicating more homogeneous conditions. On the other hand, in 2013, a shift in the median towards greater depths and an increase in dispersion were observed, which suggests a general decrease in the water table and greater spatial heterogeneity. In 2022, this pattern intensified, the median reached the deepest values, variability increased, and more extreme outliers appeared, indicating areas with significant depletion of the water level.

In 2003, the NDVI showed high spatial variability, indicating patches of plant recovery, while the NDWI presented negative values associated with low surface-moisture. The NDVI-NDWI difference (Figure 3A) evidences the clear contrasts between areas with active vegetation and dry conditions. In 2013, NDVI remained stable or slightly lower than in 2003. The NDWI retained negative values with lower spatial dispersion, which suggests water homogenization. The NDVI-NDWI relation (Figure 3B) accentuates the differentiation between wells with different levels of plant vigor. On the other hand, in 2022 the NDVI recorded a generalized decrease and the NDWI reached more negative values, which reflects a more intense water deficit. The NDVI-NDWI (Figure 3C) amplifies the contrast and shows pronounced water stress in vegetation.

The comparisons (2003, 2013 and 2022) between the NDVI values per well showed temporal changes in plant vigor and its spatial variability. In 2003, NDVI values were concentrated in low to moderate ranges, with several wells close to zero or even negative.

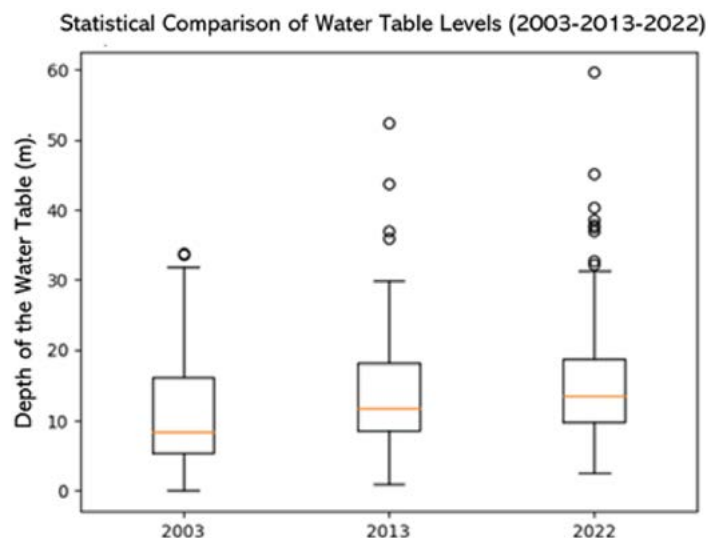


Figure 2. Distribution of the depth of the water table in the Southern Citrus Aquifer [DR-1914] in 2003, 2013 and 2022.

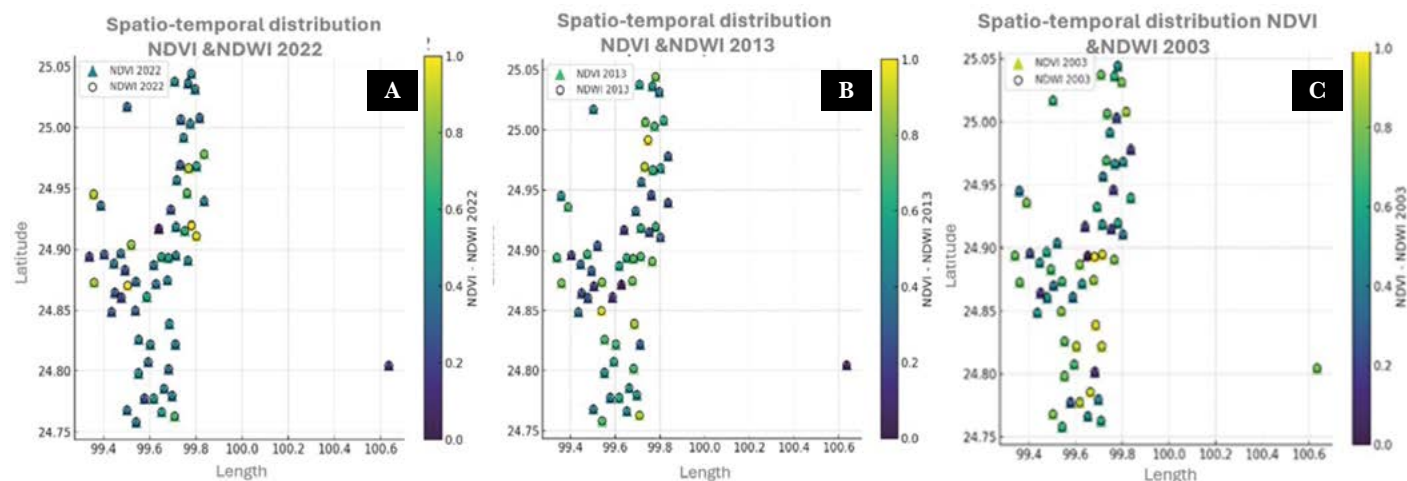


Figure 3. Spatio temporal evolution of vegetation and water table in the Southern Citrus Aquifer, through the NDVI-NDWI relation; 3A: 2003, 3B: 2013, 3C: 2022.

This indicates limited vegetation cover, consistent with water-stressed conditions. While in 2013 there was a general increase in NDVI in most wells, with predominantly positive values and less presence of negative extremes.

This suggests a better average vegetation condition and a more homogeneous system response, possibly associated with favorable climatic conditions. In 2022, although some wells reached higher maximum NDVI values than in previous years, spatial dispersion increased again, with coexistence of wells with high plant vigor and others with low or decreasing values. This pattern indicates a differential response of vegetation, compatible with localized water stress.

The correlation between the water table and the NDVI (Figure 4) shows a significant trend towards the margins of the Sierra Madre Oriental, where some wells showed an increase in their static levels. Vegetation, such as submontane scrub and the transition of pine and pine-oak forest areas, showed high NDVI values. This occurs because the Sierra acts as a hydrological regulator, and sustains high levels of plant vigor. To the north and south, NDVI values are medium to low, where vegetation cover is discontinuous and plant vigor is conditioned by water availability. Towards the northeast, the ranges are medium to high, due to agriculture and rural settlements, which generates less vigorous vegetation that is evidence of dry and anthropic conditions.

In an Eastern direction, low values are observed due to the fragmentation of the vegetation cover. In the center of the aquifer there are medium levels (0.2-0.05), where vegetation is moderate due to agricultural management practices and groundwater availability; in the Western portion, the highest values (>0.5) predominate, associated with mountainous topographic reliefs that reflect denser vegetation cover and continue to be favored by greater moisture uptake.

In the evaluation period (2003-2022), a decreasing relationship between NDVI and piezometric level variations was identified. In 2003, the trend showed a stable development between vegetation vigor and the availability of water tables (Figure 5). By 2013, an irregular

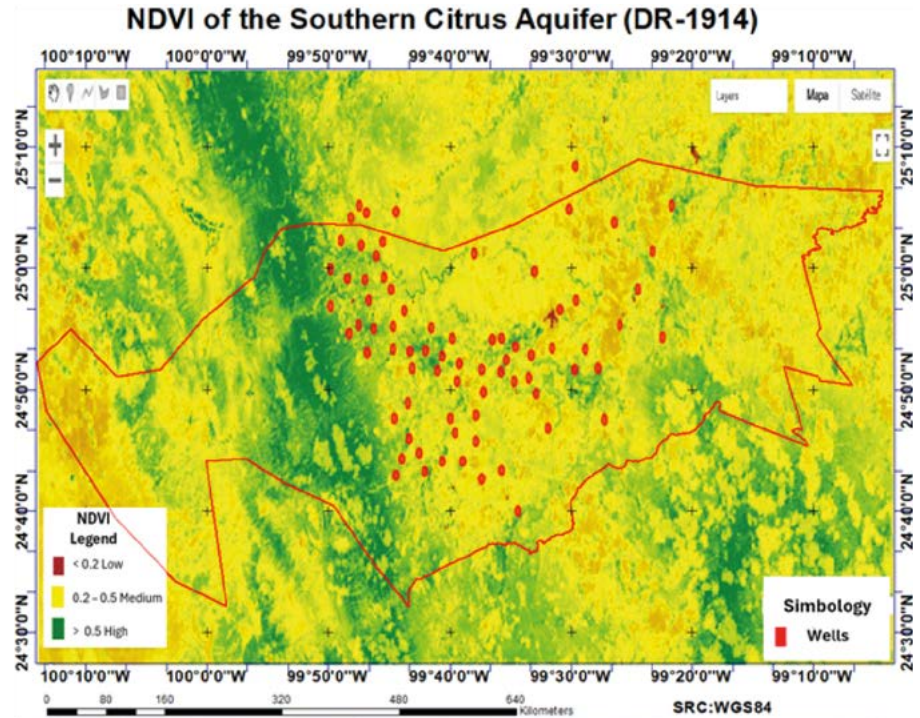


Figure 4. Correlation of NDVI with the water table in the Southern Citrus Aquifer [DR-1914].

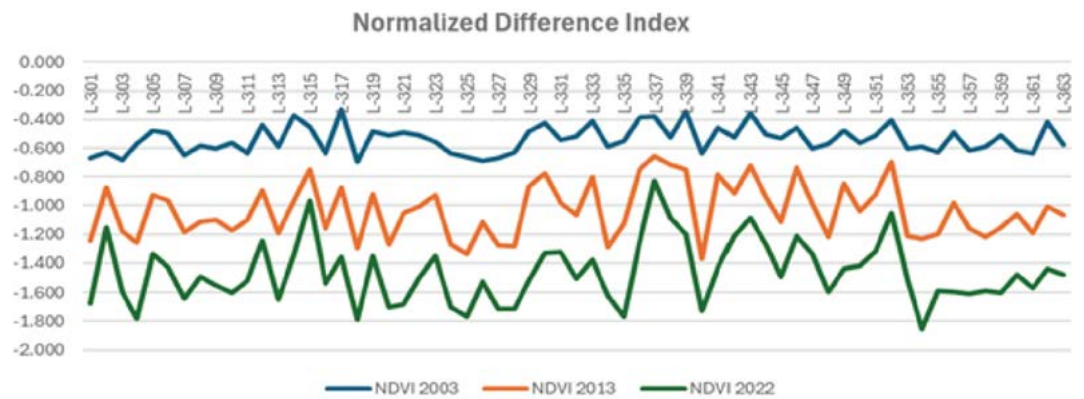


Figure 5. Relationship of depth records of the piezometric level in the South Citrus Aquifer [DR-1914] with the NDVI index.

behavior was observed, where the NDVI was maintained despite greater abatements. And in 2022, the most severe piezometric declines coexisted with high NDVI dispersion, indicating advanced groundwater stress and a clear loss of geological control over the water status of vegetation.

In the NDVI analysis, a consistent temporal evolution towards the reduction of surface water content in the sampled wells was observed. In 2003, the values reflected a relatively stable condition, with moderate variations and a balanced response between wells. By 2013, greater variability and a shift towards lower values were observed, indicating a perceptible decrease in humidity and a trend towards hydrological imbalance of ecosystems. And in

2022, the lowest and most dispersed values of NDWI predominated, which evidenced a generalized loss of surface moisture and confirmed the occurrence of advanced water stress, consistent with the progressive depletion of the Southern Citrus Aquifer.

The research presented an analysis of the average behavior and sustained trend of NDVI and NDWI for the 2003-2022 time series, associated with the piezometric levels of the Southern Citrus Aquifer. Overall, the statistical results and temporal trends showed that between 2003 and 2013 there were no statistically significant changes in either NDVI ($U=2324.0$; $p=0.0981$) or NDWI ($U=1606.0$; $p=0.0651$), indicating relative stability in both indices during this period.

In contrast, long-term analyses show statistically robust changes, with significant differences between 2003 and 2022 for both NDVI ($U=3285.0$; $p=2.25 \times 10^{-10}$) and NDWI ($U=849.0$; $p=3.06 \times 10^{-8}$), as well as significant differences between 2013 and 2022 in NDVI ($U=2844.0$; $p=2.77 \times 10^{-5}$) and NDWI ($U=1337.0$; $p=0.00159$). These comparative numerical trends confirmed that the variations of both indices intensified in the recent period and maintained temporal coherence. This is evidence that the response of vegetation, represented by the NDVI, is closely linked to the variations in surface water availability reflected by the NDWI, especially in the long-term multiple temporal analysis. The results identified that the 2003 period presented low NDVI values (<0.6) that coincide with Ceballos-Tavares & Ortega-Gaucin (2021), when determining that in that time interval the longest meteorological drought in the basin occurred. In 2013, a trend of NDVI continued with values similar to those of 2003, due to the fact that between 2011-2013 there was the greatest rainfall deficit in the basin (Palacios-Chapa, 2023). The NDVI and NDWI indices showed annual variations in their trends that did not exactly coincide with the climatic seasons, but decreased at the beginning of the year and tended to increase during the rainy season. These results are consistent with those reported by Ávila *et al.* (2020) and Carbajal & Paredes (2024), who in their research determined that in the dry season there were lower values in the spectral indices, while in the rainy season the health of the vegetation increased.

The values of the normalized water difference index ranged between -2 and -6 , which suggests that the vegetation maintained good vigor between 2013 and 2022. These data are similar to those determined by Longanezi *et al.* (2025), when using this index in the evaluation of land use in a basin in Brazil. The areas with the highest values of NDVI and NDWI are those belonging to mountains, slopes, and valleys where the dense and healthy natural vegetation cover was influenced by moisture capture due to the orography. These data contrast favorably with those reported by Xavier & Fortes (2023), who identified that native vegetation influences the results of high spectral indices and water availability.

Torrez (2024) used Sentinel 2 and Landsat-8 remote sensors for the evaluation of water tables and presented different correlations of each spectral band; the Landsat-8 sensor did not comply with the standards for the development of a methodology. Meanwhile, Sentinel-2 presented a moderate or high significance when evaluating pH and electrical conductivity. This allowed that author to generate mathematical models of water quality and predictive maps through a multivariate regression equation. On

the other hand, Castillo-Treminio (2022) mentioned that the methodology used to assess the state of the vegetation provides an effective tool to correlate the evolution of water levels in the aquifer; however, success depends on the quantity and quality of the data measured.

Likewise, Quiroz-Londoño *et al.* (2012) showed variations in frequency, applications and attenuations in the different parameters of ground movement. In that study, they determined with an analysis of piezometric levels and groundwater catchment patterns that the vegetation responds favorably to static surface levels. Finally, Uribe (2022) determined that, in the use of remote sensing and geographic information systems, 81.2% of the analyses are supported by the use of images from Landsat 7, 8, Sentinel 2A, unmanned aerial vehicles (UAVs) or drones, and new technological developments such as machine learning, neural networks and the use of smartphone cameras. Meanwhile, 18.8% use *in situ* sample collection to generate spatial distribution maps in geographic information systems with an inverse distance weighting (IDW).

This study demonstrates that the integrated use of remote sensing coupled with vegetation and humidity indices (NDVI and NDWI) is an effective and scientifically valid tool to analyze the relationship between vegetation and water tables of the Southern Citrus Aquifer (DR-1914). In contexts where traditional piezometric monitoring is limited by operational and spatial factors, remote sensing offers an efficient, spatially continuous, and temporally consistent alternative for monitoring hydrological and environmental dynamics.

The results confirm that NDVI is a reliable indicator of groundwater availability, particularly in arid and semi-arid regions where vegetation depends on the proximity of the water table. The temporal evolution of the index reveals a relative improvement in plant vigor in 2013, followed by greater heterogeneity and clear signs of water stress in 2022. This means vegetation that is increasingly conditioned by the decrease in water availability and by local anthropic pressure. Statistically, the Mann–Whitney test showed that the depth of the water table in 2022 differs significantly from the same value in 2003. This supports the existence of a process of progressive aquifer depletion, and this result reinforces the validity of the indirect approach based on spectral indices to detect substantial changes in the underground dynamics of the aquifer system.

CONCLUSIONS

The NDVI and NDWI vegetation and water indices proved to be adequate for the characterization of vegetation cover status; also, to differentiate vegetation status and recognize conditions associated with degradation, loss of cover and increased susceptibility to terrain instability processes, such as landslides.

The reduction of plant vigor emerges as a key factor in the identification of areas with greater environmental vulnerability. The use of Landsat imagery is confirmed as a reliable, accessible, and high-resolution source for the analysis of vegetation status and its relationship to groundwater.

The integration of these data with climate, land use, and water extraction information strengthens the comprehensive understanding of the factors that control the dynamics

of the aquifer. This methodology proved to be a strategic instrument for sustainable management, monitoring and planning of groundwater resources in regard to agriculture management.

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REFERENCES

- Ávila, D. D., E. A. Curbelo, L. J. Madrigal-Roca & R. D. Pérez-Lanyau. (2020). Variación espacio-temporal de la respuesta espectral en manglares de La Habana, Cuba, evaluada con sensores remotos. *Revista de Biología Tropical*, 68(1), 321-335. <https://doi.org/10.15517/RBT.V68I1.39134>
- Carbajal, L. & T. Paredes Palacios. (2024). Análisis de los índices de vegetación y variabilidad climática en la cuenca alta del río Guayllabamba para el periodo 1990-2023. *Revista Ciencia UNEMI*. 17(46) 80-87.
- Castillo-Treminio, B. G. (2022). Aplicación de métodos geoestadísticos en el modelado espacio-temporal de los niveles de agua subterránea del acuífero Valle de Sébaco, Nicaragua. *Revista de Ciencias Ambientales*. 56(2) 196-212. <http://dx.doi.org/10.15359/rca.56/2.10>
- Ceballos-Tavares, J. A. & D. Ortega-Gaucin (2021). Análisis regional de frecuencia de sequías basado en L-momentos para la cuenca del río Bravo, México. *Tecnología y ciencias del agua*, 12(5), 142-207. Epub June 26, 2025. <https://doi.org/10.24850/j-tyca-2021-05-04>
- Chuvieco, E. (2002). Teledetección ambiental: la observación de la tierra desde el espacio, Editorial Ariel, Barcelona. ISBN: 84-344-8047-6 586p
- CONABIO (2018). Biodiversidad y Recursos Hídricos en Nuevo León. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad.
- CONABIO (2021). Mapa de Uso de Suelo y Vegetación escala 1:250000, serie VII (continuo nacional).
- CONAGUA (2024). Actualización de la disponibilidad media anual de agua en el acuífero citrícola sur (1914), estado de Nuevo León, 2024. Subdirección General Técnica Gerencia de Aguas Subterráneas.
- Fiallos, Z. & E. Alexander. (2024). Aplicación de análisis espectral y principios físicos específicos de la reflectancia de la luz en la caracterización de las plantaciones forestales en la zona Palmira-Chimborazo, Ecuador. Escuela Superior Politécnica de Chimborazo.
- García, E. (2004). Modificaciones al sistema de clasificación climática de Köppen (para adaptarlo a las condiciones de la República Mexicana). Instituto de Geografía, Universidad Nacional Autónoma de México.
- INECC (2019). Impactos del cambio climático en los recursos hídricos de México. Instituto Nacional de Ecología y Cambio Climático.
- INEGI (2022). Mapa Topográfico de Linares escala 1:50000, serie VII (continuo nacional).
- Longanezi Bento L., H. J. Ribeiro, & K. K. Alcione. (2025). Análise de Uso e Cobertura da Terra e Índices de Diferença Normalizada de Vegetação e Água em Terras Indígenas e Entorno na Região Hidrográfica da Amazônia. Universidade Federal de Goiás- UFG, Goiânia, GO, Brasil. <https://doi.org/10.14393/SN-v37-2025-74902>
- Palacios-Chapa J. (2023). Enfrentando el reto del agua en Nuevo León 2021-2023. Reflexiones sobre una crisis y las respuestas institucionales. Servicio de Agua y Drenaje de Monterrey, I.P.D. Servicios Gráficos, S.A. de C.V. Noviembre, 2023. Monterrey, Nuevo León, MÉXICO. 195p.
- QGIS Development Team. (2023). QGIS Geographic Information System (Versión 3.28). Open Source Geospatial Foundation. <https://www.qgis.org>
- Rouse, J. W., R. H. Haas, J. A. Schell & D. W. Deering. (1974). Monitoring vegetation systems in the Great Plains with ERTS. NASA SP-35.
- SAGARPA (2019). Programa de fomento a la agricultura 2019.
- SEMARNAT (2020). Programa de Manejo Sustentable del Agua en Nuevo León. Secretaría de Medio Ambiente y Recursos Naturales
- Quiroz-Londoño O. M., D. Martínez & H. Massone (2012). Estimación de recarga de acuíferos en ambientes de llanura con base en variaciones de nivel freático. *Tecnología y Ciencias del Agua*. 3(2) 123-130.
- Torrez Aguilera, J. A. (2024). Evaluación de la utilidad de los sensores remotos Landsat- 8 y Sentinel-2 para el monitoreo de calidad de agua en la Laguna de Apoyo, 2021. Tesis profesional. Universidad Nacional Agraria. <https://repositorio.una.edu.ni/id/eprint/4726>

- Uribe, D. (2022). Revisión de métodos de monitoreo de calidad de agua con herramientas de percepción remota y sistemas de información geográfica (SIG) para Colombia. Universidad de Antioquia.
- Xavier, P. A. A. & Fortes, M. (2023). Aplicação do índice de vegetação por diferença normalizada (NDVI) na bacia hidrográfica dos educandos na cidade de Manaus-Amazonas. *Revista Verde Grande: Geografia e Interdisciplinaridade*, 5(02). 174-192. <https://doi.org/10.46551/rvg2675239520232174192>

