ICASX
2026

Assessing Corn Stunt Disease through Remote Sensing: A Preliminary Analysis

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Abstract

Corn stunt disease is caused by a complex of pathogens, most notably the bacterium *Spiroplasma kunkelii*, whose insect vector is the corn leafhopper (*Dalbulus maidis*). It affects plants of the genus Zea. In Argentina, maize is the only host for this insect. The objective of this study is to use two vegetation indices—the Normalized Difference Vegetation Index (NDVI) and the Simple Ratio (SR)—to infer the health status of plants and monitor crops from satellite imagery. Given the symptoms of the analysed disease, these indices may be useful for assessing the condition of maize fields. The province of Santiago del Estero was selected as the study area due to data availability and the influence of the corn leafhopper in the region; polygons were selected based on information provided by the Random Segment Method. Results showed a statistically significant difference in NDVI decline between March and April of 2024 among fields reported with *Spiroplasma* and those without. Furthermore, based on a crop map developed for the Alberdi, Moreno and J. F. Ibarra departments, it was estimated that 41.7% of the maize polygons showed evident damage from corn stunt disease.

Keywords: Spiroplasma kunkelii; NDVI; satellite imagery; crop monitoring.

1. Introduction

Maize is one of the most globally significant cereals, alongside wheat and rice, due to its versatility and contribution to food security. In recent years, Argentina has positioned itself among the world's leading maize producers, together with the United States, China, and Brazil [1]. Furthermore, this cereal constitutes one of the country's main export complexes, with a high share within the grain sector and a significant weight in total national exports [2].

In Argentina, maize is distributed from the south of the province of Buenos Aires to the north of Salta. This broad geographic range, combined with advances in agricultural technology, has led to a diversification of sowing dates that allows the crop to be present throughout almost the entire year. This year-round availability of maize can favour the persistence of pathogens between seasons and facilitate their dispersal across time and space [3].

Corn stunt disease is caused by a complex of pathogens, most notably the bacterium *Spiroplasma kunkelii*, which invades the phloem and is transmitted by the corn leafhopper (*Dalbulus maidis*), which acts as a vector. Transmission occurs in a persistent propagative

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manner, meaning that once the leafhopper acquires the pathogen, it remains infective throughout its lifetime [4]. The insect is practically monophagous or specialist, feeding almost exclusively on plants of the genus *Zea*, including maize (*Z. mays L.)* and its wild ancestors (teosintes), and is only able to complete its development and reproduce on these plant species. In Argentina, there are no wild or cultivated teosintes, meaning the only host where *D. maidis* can complete its life cycle is maize [4].

In the Argentine context, *S. kunkelii* is regarded as the primary causal agent within this pathogen complex. For clarity, throughout this paper the terms "corn stunt" and "*Spiroplasma*" are used interchangeably to refer to fields reported as affected by this condition.

This is a disease typical of tropical and subtropical regions that can cause damage levels of up to 100% [5]. In Argentina, this species is frequent and abundant in the northern provinces (Jujuy, Salta, Tucumán, Catamarca, Chaco, Formosa and Santiago del Estero), typically north of the 30° S parallel [4].

Typical symptoms in maize plants include: leaf chlorosis, shortening of internodes, reddening of margins of adult leaves, and proliferation of ears. The typical symptomatology may be modified by the timing of infection, temperature, the hybrid sown, and the presence of other pathogens [4, 6]. The impact of corn stunt disease on maize is usually greater when infection occurs in the early stages of the crop, making vector control during these phases critical [5].

In tropical regions, reproduction is continuous, whereas in subtropical zones up to five annual generations may be completed, with population peaks in summer and winter survival in the adult stage. Even in the absence of the crop, a small proportion of individuals persists sheltered in grasses and volunteer maize plants, ensuring population continuity between seasons [4].

In addition to *Spiroplasma kunkelii, D. maidis* transmits a group of other diseases that contribute to the described symptomatology.

Vegetation indices can be calculated from satellite imagery and allow the health status and density of vegetation to be inferred. In the case of crops, their evolution can be observed throughout the growing cycle, enabling the monitoring of any deviation from normal trajectories.

The reflectance of green leaves is typically high at wavelengths of 700 to 1300 nm, which correspond to the near-infrared (NIR) region, and low in the visible spectrum (400 to 700 nm) due to the high absorption by photosynthetic pigments. The relationship between these two bands has been used to calculate various vegetation indices.

The first and most commonly used index is the Simple Ratio (SR), which is obtained by dividing the NIR reflectance by the RED reflectance [Formula 1] [7]. Low values indicate bare soil, water, or non-vegetated objects, while high values indicate green vegetation. The normalisation of this index gives rise to one of the most widely known: the Normalized Difference Vegetation Index (NDVI) [Formula 2].

$$[\text{Formula 1}] \quad SR = NIR / RED$$

$$[\text{Formula 2}] \quad NDVI = (NIR - RED) / (NIR + RED)$$

The NDVI ranges from −1 to 1. Negative values indicate the presence of water, while values close to zero represent bare soil or areas with little or no vegetation. Conversely, values close to 1 indicate dense and healthy vegetation.

In annual crops, under normal conditions, the NDVI increases as the crop grows and develops, then falls again as the crop matures or loses vigour. Adverse factors such as drought, hail, or disease alter this natural pattern.

In the case of diseases, these can reduce chlorophyll content and internal organisation, causing a transformation of spectral reflectance by reducing assimilation (increasing reflectance) in the visible spectrum [8].

The general objective of this study is to analyse the validity of remote sensing tools for evaluating the impact of corn stunt disease on maize. The specific objective is to analyse the use of NDVI and SR as indicators of corn stunt damage. Additionally, the study aims to validate the use of these indices for crop mapping and damage estimation from satellite imagery.

2. Methodology

2.1 Study Area

The province of Santiago del Estero was selected due to data availability and the known influence of the corn leafhopper in the region [9].

The Random Segment Method[1] is the methodology used by the Dirección de Estimaciones Agrícolas, de la Secretaría de Agricultura, Ganadería y Pesca de la Nación to collect field data—through direct observation—for estimating areas sown with extensive crops. Data recorded within segments include crop coverage, phenological stage, sowing method, weed presence, and any other particularity noted in the "Observations" field.

Based on information collected during the 2023/24 summer crop survey, conducted between March and April 2024, fields with maize as the recorded crop were selected. A total of 293 polygons were obtained, from which fields reported as affected by *Spiroplasma* were separated from those that were not (Fig. 1, Table 1).

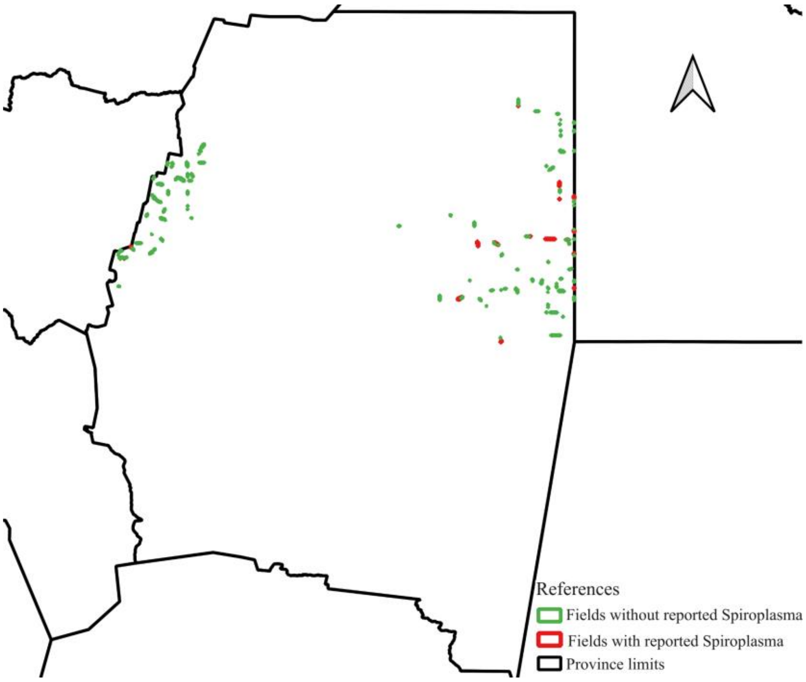

Fig. 1. *Segment Map. Green polygons represent fields without reported Spiroplasma; red polygons represent affected fields.*

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[1] *Random Segment Method:* https://www.magyp.gob.ar/sitio/areas/estimaciones/acerca_de/metodologia/_archivos//000000_Metodo-de-segmentos-aleatorios-Version-5.pdf

Province	**Fields with *Spiroplasma* reported**	**Fields without *Spiroplasma* reported**
Santiago del Estero	41	251

Table 1. *Number of fields analysed.*

2.2 Calculation of Indices

To obtain the curves for the vegetation indices (SR, NDVI) the Google Earth Engine platform was used. The average index was calculated for each group of fields (with and without *Spiroplasma*) every 8 days using the VNP09H1 product, which provides surface reflectance estimates derived from the VIIRS sensor aboard the Suomi NPP satellite, at a spatial resolution of 500 metres. The analysed period for the 2023–2024 summer crop season ran from 27 December 2023 to 13 April 2024, coinciding with the maize cycle from early stages through to maturity in the study region.

Additionally, based on the maize fields surveyed over the five previous seasons (2018 to 2022), the average NDVI curve was obtained to serve as a baseline for detecting anomalies. The 2022/23 season was excluded due to the effect of drought on the study parameters.

To evaluate the significance of the differences found in NDVI decline between fields with and without reported *Spiroplasma*, an analysis of variance (ANOVA) was performed.

2.3 Crop Map

Having detected a differential behaviour in NDVI between affected and non-affected fields in the sample, the aim was to expand these results to the full study area and infer the percentage of affected area. To this end, and based on field data collected, a preliminary land cover map was produced for the Alberdi, Moreno, and J. F. Ibarra departments (administrative district within a province) in the eastern zone of Santiago del Estero.

The map was produced on the Google Earth Engine platform, where a time-series mosaic of Sentinel-2 images was obtained, from which various vegetation indices were calculated. Once the data were compiled, a supervised classification was performed using a random forest algorithm.

From the resulting map, maize fields were vectorised, and a square grid was overlaid on these fields to divide larger polygons into units of 200 metres per side, thereby obtaining more detailed statistics. Only squares completely contained within the fields were used—partly to minimise edge effects and to reduce data volumes and processing times—yielding a total of 83,347 polygons.

Using the MODIS sensor, a multitemporal NDVI raster was produced with the MOD13Q1 product. This satellite has a revisit period of one to two days, but the product is generated every 16 days based on the best reflectance values for that period, at a spatial resolution of 250 metres. The polygon grid was overlaid on the resulting raster, and NDVI values were extracted for each polygon across eleven dates. Finally, the difference between the values of 5 March and 6 April was calculated, and polygons with a decline of 0.37 or greater were selected.

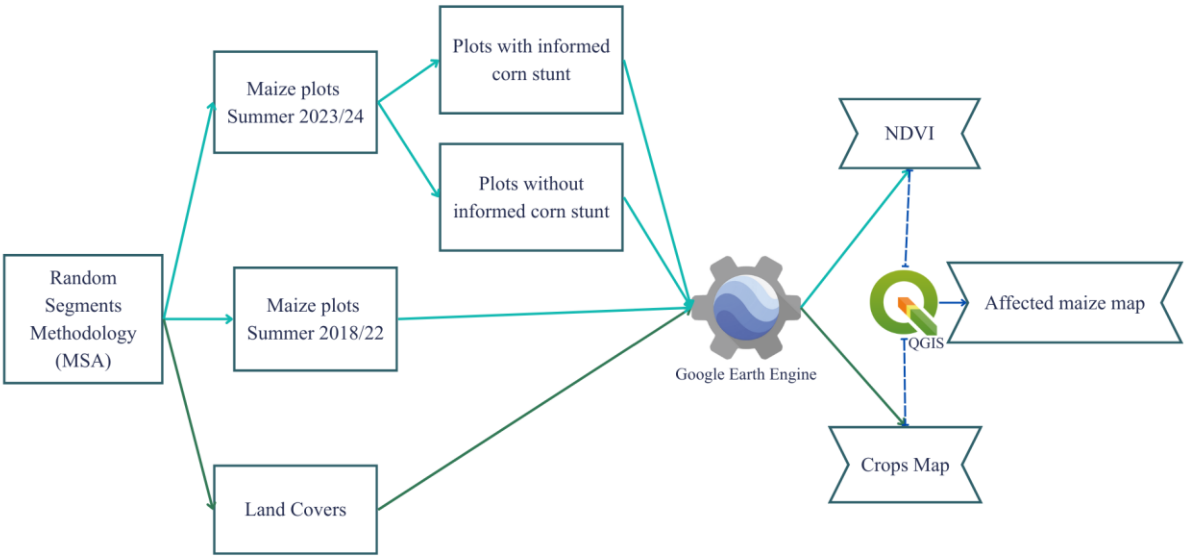


Fig. 2. *Conceptual summary of the methodology used.*

3. Results

Comparing the curves for the current season with the five-season average (excluding 2022/23), a temporal shift in sowing date compared to previous years is first observed, followed by an early and abrupt decline in the index for affected fields (Fig. 3). Important differences were also found between the NDVI curves of fields reported as affected and those not affected. In particular, an abrupt NDVI decline from peak values was observed over the two subsequent periods.

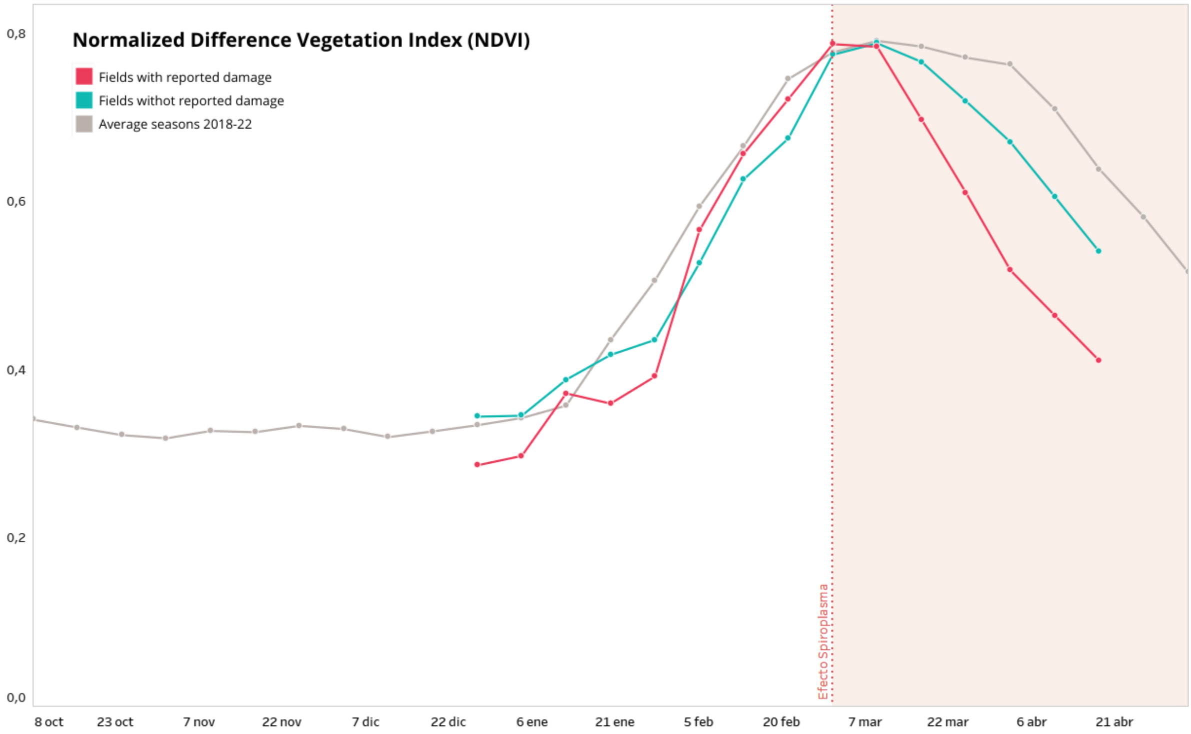


Fig. 3. *NDVI evolution chart. Light blue: fields without reported Spiroplasma; red: affected fields. The grey curve represents the 2018/22 average.*

On average, the NDVI decline in fields without reported Spiroplasma damage between March and April was 0.248, while in reported fields this decline was 0.373. The five-year average decline over the same months was 0.152.

Differences in reflectance were also identified using the Simple Ratio (SR) index (Fig. 4). In this case, unlike NDVI, the disparity is already apparent at the growth peak. This is consistent with Jackson & Huete [7] who explained that SR is more sensitive to changes during the period of maximum vegetation growth, while NDVI loses sensitivity at high densities.

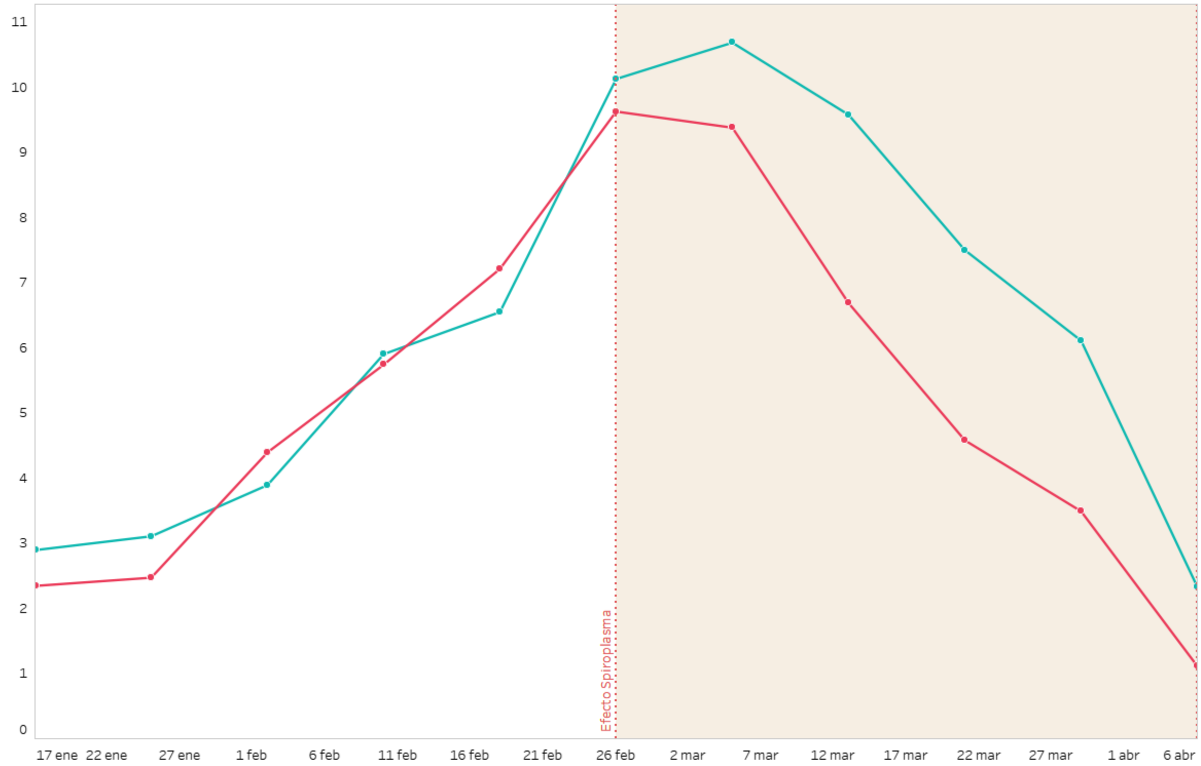
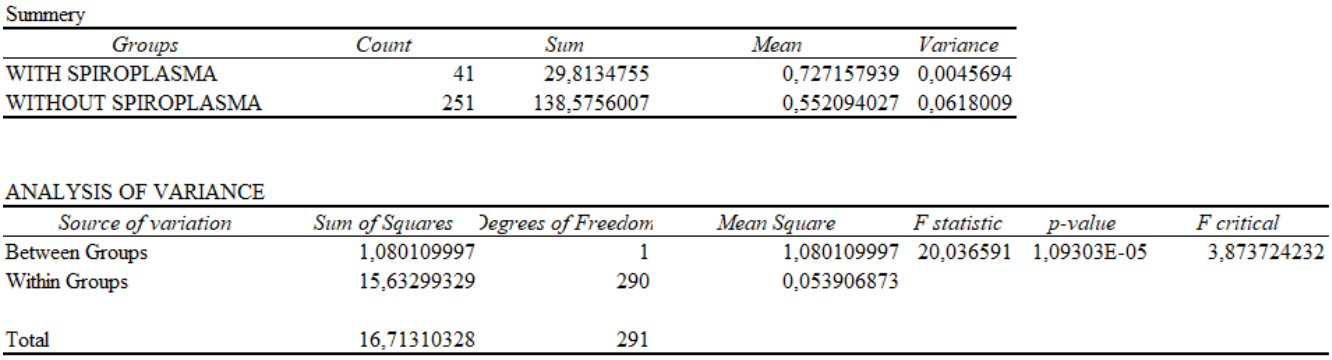


Fig. 4. *Simple Ratio (SR) evolution chart. Light blue: fields without reported Spiroplasma; red: affected fields.*

The results of ANOVA for NDVI are presented in Table 2.



Summery

Groups	*Count*	*Sum*	*Mean*	*Variance*
WITH SPIROPLASMA	41	29,8134755	0,727157939	0,0045694
WITHOUT SPIROPLASMA	251	138,5756007	0,552094027	0,0618009

ANALYSIS OF VARIANCE

Source of variation	*Sum of Squares*	*Degrees of Freedom*	*Mean Square*	*F statistic*	*p-value*	*F critical*
Between Groups	1,080109997	1	1,080109997	20,036591	1,09303E-05	3,873724232
Within Groups	15,63299329	290	0,053906873			
Total	16,71310328	291				

Table 2. *ANOVA results for the difference in NDVI between March and April between fields with and without reported Spiroplasma.*

The result showed that F > F-critical, leading to the rejection of the null hypothesis of equal means, at a significance level of $\alpha = 0.05$. It is concluded that the difference in NDVI decline between March and April is statistically significant between maize fields with and without reported Spiroplasma.

As mentioned in the methodology, based on these results, the aim was to expand them to the entire study area and infer the percentage of affected surface.

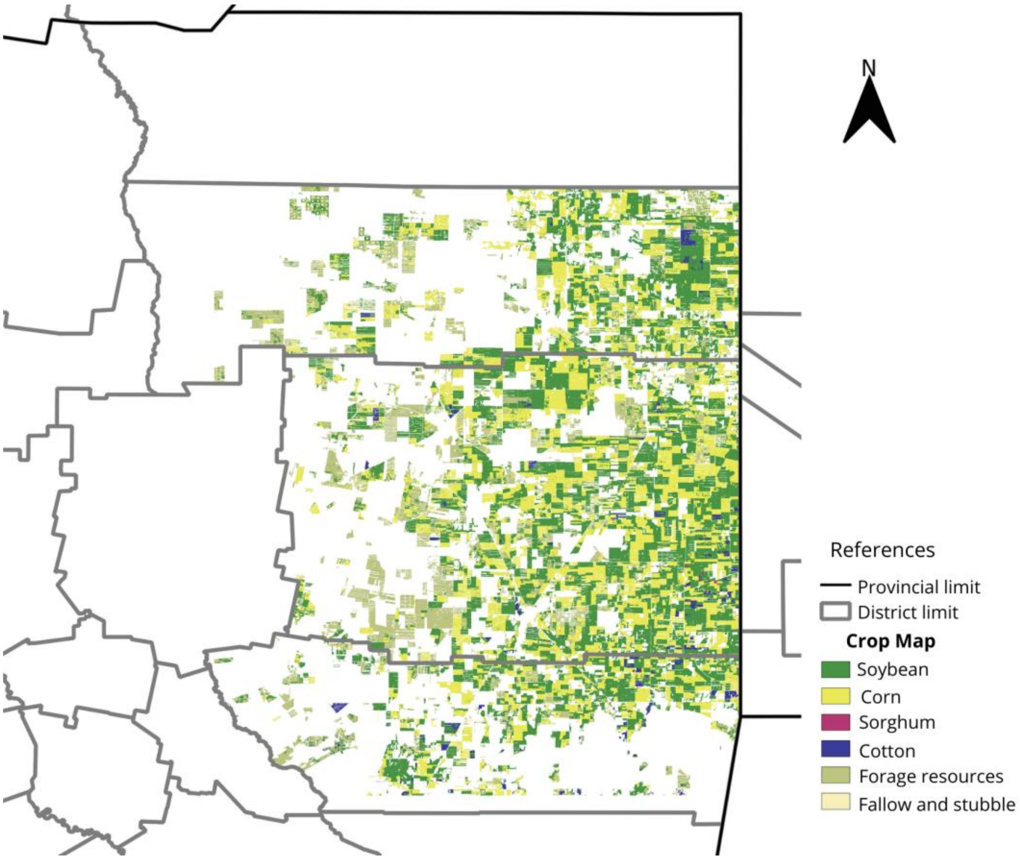


Fig. 5. *Crop Map. Alberdi, Moreno, and J. F. Ibarra Departments, Santiago del Estero.*

The NDVI decline for maize fields between the March peak and April was assessed. A larger difference indicates a more pronounced decline relative to normal values, which allows a higher level of Corn Stunt affectation to be inferred. Based on this difference, a maize damage map was produced.

Using the value of 0.37[2] as the affectation threshold, it was found that 41.7% of the polygons showed evident corn stunt damage.

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[2] Value obtained from the NDVI difference between March and April for fields reported with Spiroplasma (Fig. 3).

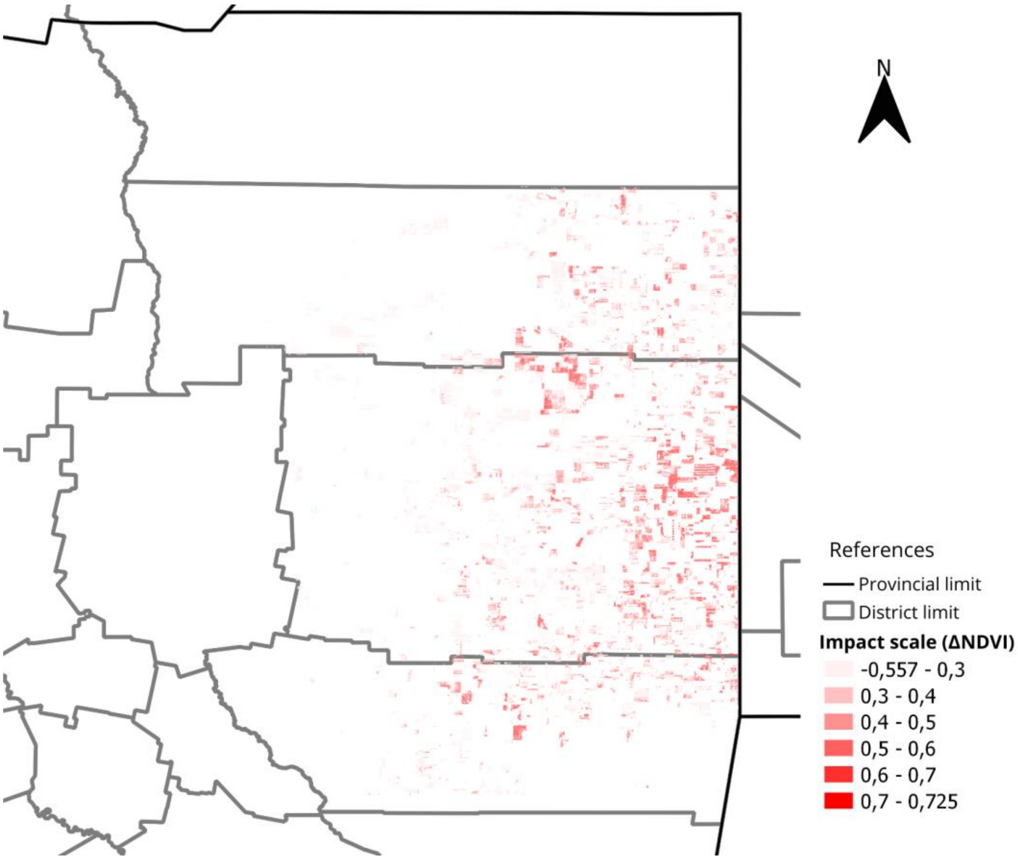

Fig. 6. *Maize damage map for the study area. The redder the color, the greater difference in NDVI values.*

4. Conclusions

This study aimed to develop a methodology for objectively assessing the spread of Corn Stunt in maize.

While the results initially suggest the suitability of NDVI as a predictor of corn stunt affectation, several relevant points should be noted.

First, considering that the disease has been observed in late-sown maize, there is a high uniformity in sowing dates within the study area, where almost all maize is late-sown—particularly in the current season. If this study were to be replicated in other regions, it would likely be necessary to first differentiate between early and late maize, and especially those intended for forage use.

Second, the interaction of other natural factors that directly influence NDVI must be considered, such as rainfall deficits and heat stress, which were more pronounced during January and early February in the current season. Nevertheless, it is observed that on average the curves reach similar peak values, after which the divergence occurs.

Third, when considering field data, it is important to bear in mind the possibility that the disease may not have been apparent at the time of observation. Therefore, it is possible that some fields not reporting the disease had in fact experienced it. If so, this would partially mask the difference that was observed and quantified in this study.

In conclusion, vegetation indices are a suitable tool for studying the various factors that alter the normal development of crops. In the case presented, the results show a strong correlation between the anomalous evolution of NDVI throughout the crop cycle and the presence of corn stunt disease.

It is recommended to explore the utility of other indices in evaluating this phenomenon and its applicability to the different productive zones of the country, particularly where sowing windows are broader and livestock activity could mask or alter the analysed effects.

Finally, it is worth highlighting the importance of having timely and accurate field information that enables remote sensing tools to be used reliably.

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