

Bibliometric study of the use of infrared radiation in soil analysis

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Recebido em: 22/02/25
Aceito em: 15/03/26

Abstract

In the state of the art, scientific information is concentrated in scientific journal repositories, where the search for these repositories has become an important form of study and research. For this research, this is justified by the use of biometrics on data management in the field of using infrared radiation in soil analysis. Thus, the objective of this study is to identify the best and most relevant research published in two specific databases, in order to advance the operationalization of data through mapping relevant research for the use of infrared electromagnetic waves in soil analysis. The methodology used in relation to the objective is descriptive because it aims to describe the properties of a certain population or phenomenon or to establish relationships between variables. From the perspective of the data generation method, we adopt the flexible system method (SSM), which applies system principles to structural thinking. The Scopus and Web of Science (WoS) databases were selected for the study exemplified in this article, from which the results were extracted.

Keywords: Near Infrared Spectroscopy (NIR); soil analysis; infrared radiation; scientific production.

Estudo bibliométrico do uso de radiação infravermelha em análise de solo

Resumo

No estado da arte as informações científicas estão concentradas em repositórios de revistas científicas, onde a busca destes repositórios passou a ser uma importante forma de estudo e pesquisa. Para esta pesquisa, isso é



justificado pelo uso de biometria sobre gerenciamento de dados no campo do uso da radiação infravermelha na análise de solo. Assim, o objetivo deste estudo é identificar as melhores e mais relevantes pesquisas publicadas em dois bancos de dados específicos, a fim de avançar na operacionalização dos dados por meio do mapeamento de pesquisas relevantes para o uso de ondas eletromagnéticas infravermelhas na análise de solo. A metodologia utilizada em relação ao objetivo é descritiva porque visa descrever as propriedades de uma determinada população ou fenômeno ou estabelecer relações entre variáveis. Do ponto de vista do método de geração de dados, adotamos o método do sistema flexível (SSM), que aplica os princípios do sistema ao pensamento estrutural. As bases de dados Scopus e Web of Science (WoS) foram selecionadas para o estudo exemplificado neste artigo, de onde foram extraídos os resultados.

Palavras-chave: método do sistema flexível (SSM); radiação infravermelha; análise de solo produção científica;

1 INTRODUCTION

Visiting already established and published research is a way to promote new studies or investigations. The use of bibliometrics is a research tool that uses statistical and mathematical techniques to quantify research already carried out, making it possible to create indicators, such as most cited author, country where research is most effective, etc., combining technology and scientific information.

The study of the use of spectrophotometric techniques that use infrared radiation (NIRS-Near Infrared Spectroscopy and DRIFTS-Diffuse Reflectance Fourier Transformed Spectroscopy) for soil analysis has been gaining strength in recent years, and through bibliometrics we can evaluate the importance of this technology within the Soil Science. The use of NIR technology has been researched since 1970, but little implemented in laboratory routines due to the difficulty in building calibration models using multivariate statistical methods. Therefore, the use of bibliometrics as a statistical tool to map and generate various indicators, designing the study of the art of spectroscopy in soil analysis, is justified. The objective of this study is to highlight the most relevant works in the area of soil analysis using infrared spectroscopy and its advances in soil science.

In this study, referring to Bodgan and Biklen (1994), we raise the hypothesis that the studies described in this text, although they contain quantitative data, are characterized as qualitative in nature. When the results are analyzed and interpreted, the context in which they were produced is understood. From the point of view of the objective, the research is descriptive because it aims to describe the characteristics of a certain population or phenomenon, or to establish relationships between variables. In terms of data generation methods, we adopted a flexible systems methodology (SSM) that applies system principles to structure thinking about what is happening in the real world (Turrioni; Mello, 2012).

The databases chosen for the research illustrated in this article were Scopus and Web of Science (WoS). The criterion for this selection was the fact that these databases were the most relevant to the research topic, in terms of aggregation of journals. The article is presented as follows, below we present a theoretical framework, which was used in the research, next is the methodology used that achieves the proposed objective, then the results and finally some considerations.

2 RESEARCH METHOD

In this state-of-the-art study, bibliometric data was collected from one of the most referenced repositories: Scopus and Web of Science (WoS). Therefore, the result from this data repository is compared for all different scientific output growth queries. The keywords used for

the search query were: “Near infrared spectroscopy, NIR spectroscopy, NIR and Soil analysis”, and the search was carried out on August 2, 2022. Two of the most commonly used standard indices in computer science were considered: the engineering community indices, Science Citation Index Expanded (SCI-E) and Social Science Citation Index (SSCI). We retrieve several tags, such as: author, title, abstract, country, citation record, author affiliation, etc. Of the documents extracted in WoS, 91.21% constitute Articles.

3 RESULTS AND DISCUSSION

3.1 QUALITATIVE ANALYSIS

In this context of the work, the 10 most relevant articles found in the two search bases, WOS and Scopus, are analyzed. In the article *A Review on the Applications of Portable Near-Infrared Spectrometers in the Agro-Food Industry* - DOI: 10.1366/13-07228: Reports on the application of portable near-infrared (NIR) spectrometers in the agri-food industry, covering various spectrometer applications Portable NIR for characterizing fruits and vegetables, meat and fish, beverages and dairy products, cereals, soils and vineyards. The article addresses the advantages of this spectrometer, such as small size, low cost, portability and ease of use, for non-destructive analysis. Furthermore, the article highlights the importance of chemometrics, which involves multivariate statistical techniques, in analyzing NIR spectra and extracting meaningful information. This discussion on the application of portable NIR spectrometers in the agri-food industry and the importance of chemometrics for data analysis are the main theoretical contributions of the article. The problem of the study is the need for fast, non-destructive and portable analysis methods in the agri-food industry for quality control and product analysis. Aiming to study the application of portable near-infrared (NIR) spectrometers in the agri-food industry, the advantages, applications and use of chemometrics for analyzing NIR spectra were highlighted. The study seeks to demonstrate the potential of these portable devices in carrying out non-destructive analyses, online or in situ, for quality control and analysis of agri-food products. The study concluded that these portable devices can provide accurate and reliable analyzes for quality control and analysis of agri-food products, including fruits, vegetables, meat, fish, beverages, dairy products, cereals, soils and vineyards, facilitating the decision-making process in the industry. food.

In the article *Combining Vis–NIR spectroscopy and advanced statistical analysis for estimation of soil chemical properties relevant for forest road construction* (Mousavi, et al., 2021), research explores the use of visible-near-infrared spectroscopy (Vis-NIR) and advanced statistical analysis to estimate soil chemical properties relevant to forestry road construction. In this study, 60 samples of forest soil were collected, analyzing pH, Electrical Conductivity (EC), Calcium Carbonate (CaCO₃), Organic Matter (OM) and Cation Exchange Capacity (CTC). Spectral measurements were made using a Vis-NIR spectrometer, and advanced statistical techniques including partial least squares regression (PLSR), hybrid PLS models and artificial neural networks (ANN), hybrid PLS models and adaptive neural fuzzy inference system (ANFIS), as well as narrowband spectral indices were used to correlate with soil properties. The main theoretical contribution of this study is the application of visible-near-infrared (Vis-NIR) spectroscopy and advanced analysis to estimate soil chemical properties, relevant for forestry road construction. This demonstrates that Vis-NIR spectroscopy can be a rapid and cost-effective alternative to standard soil chemical analysis techniques, providing accurate sources of soil properties such as pH, EC, MO and CEC. The problem addressed in the study is the estimation of soil properties in a semi-arid mountainous ecosystem in Turkey using visible and near-infrared (Vis-NIR) spectroscopy. The study aims to develop models that can accurately predict soil properties such as organic carbon, clay content and CEC using Vis-NIR spectroscopy reflectance measurements. Reflectance measurements were made and a second-order polynomial Savitzky-Golay filter was applied for data smoothing. Raw reflectance (R) and first derived reflectance (DR) were used

separately to estimate soil properties. The models were validated using the cross-validation technique. Some conclusions were obtained in this study: Limited sample size, only 60 samples limiting the generalization of results to other areas or soil conditions; a Variation in soil composition: different geographic regions, which can affect the accuracy of estimates of soil chemical properties; Limitations of the electromagnetic spectrum: The electromagnetic spectrum range used in the study may not capture all relevant information for accurate estimation of soil chemical properties. The study used internal cross-validation to evaluate the accuracy of the models, but external validation was not performed on an independent data set.

In the article *Developing a soil spectral library using a low-cost NIR spectrometer for precision fertilization in Indonesia* (Ng *et al.*, 2020), regression models were combined to predict various soil properties from various growing regions in Indonesia, and categorical models were included for soil properties with high variability. Mitscherlich-Bray equations were used to formulate fertilizer nutrient requirements based on field trial data. Samples were scanned in triplicate and preprocessed using multiple methods. A regression model was developed to predict soil properties based on spectral data. Fertilizer recommendations were also determined based on soil test results and crop yields. Traditional soil analysis methods can be time-consuming and expensive, making it difficult for farmers to make informed decisions about fertilizer application. The aim of this study was to develop a soil spectral library using a low-cost NIR spectrometer for precision fertilization in Indonesia. The collected spectra were preprocessed using methods such as spectral fitting, Savitzky-Golay smoothing, and standard normal variance transformation. Regression models, such as Cubist, have been developed to predict soil properties based on spectral data. The Mitscherlich-Bray equation was used to formulate fertilizer recommendations based on analysis of soil test and crop yield data. The developed regression models showed moderate to good predictive performance for several soil properties such as sand, silt, clay content, pH, total nitrogen, potential phosphorus and potential potassium. The models also demonstrated the ability to classify soil properties into low, medium and high categories based on the Mitscherlich-Bray equation. Overall, this study demonstrated the feasibility of using a low-cost NIR spectrometer for rapid and cost-effective fertilizer recommendations in Indonesia.

In the article *Effects of Moisture and Particle Size on Quantitative Determination of Total Organic Carbon (TOC) in Soils Using Near-Infrared Spectroscopy* (Tamburini *et al.*, 2017), the partial least squares (PLS) regression method was used to generate calibration for three different soil sample sets: wet samples (WS), dry samples (DS), and ground and sieved samples (GSS). The models were used to predict the total organic carbon (TOC) content of soil samples based on spectral data, demonstrating good correlation and robustness, with best performance achieved when utilizing a combination of standard variable normalization pretreatments (SNV) and second derivative (DV2). The calibration models were validated using an external validation set of soil samples. The study showed that different datasets, including unprocessed, dried-only and dried, ground and sieved samples, produced similar prediction results for TOC, suggesting that NIR spectroscopy can be applied directly and quickly in situ for soil analysis without the need for extensive sample pre-processing.

The article *Integration Vis-NIR Spectroscopy and Artificial Intelligence to Predict Some Soil Parameters in Arid Region: A Case Study of Wadi Elkobaneyya, South Egypt* (El-Sayed, *et al.*, 2023) brings the combination of infrared spectroscopy with visible, evaluating the accuracy and predictive capacity of Soil Electrical Conductivity (EC), pH and Calcium Carbonate (CaCO₃) using various regression and machine learning models. The results evaluated that the partial least squares regression (PLSR) model was the best for predicting soil pH, while the support vector regression (SVR) model was the best for predicting soil EC and CaCO₃. Random forest (RF) and artificial neural network (ANN) models also performed well in predicting these parameters. The study also used the practice-based feature selection (CARS) technique to identify the most important spectral bands for predicting soil properties. Models were trained and evaluated

using calibration and validation datasets, and the performance of each model was evaluated based on its accuracy and predictive ability. This research provides valuable information on the use of spectroscopic data for soil monitoring and management in arid regions. As in other articles, the problem addressed in this study is the need for efficient and economical methods to estimate soil properties in arid lands, as traditional laboratory methods for soil analysis are time-consuming and expensive, making it difficult to obtain comprehensive soil data for agricultural management purposes. The study aims to overcome this problem by developing predictive models using visible-near-infrared spectroscopy, which can provide fast and accurate estimates of soil conductivity, pH and calcium carbonate content.

In the study presented in the article *Near infrared spectroscopy as a tool for intensive mapping of vineyards soil* (Lopo *et al.*, 2018), NIR was used as a tool for mapping different types of soil in vineyards, as this is important for management of the vineyard suitable for different types of soil affecting the growth and quality of the grapes produced. The results obtained concluded that spectroscopy was able to accurately differentiate between specific soil types, with a success rate of around 90% when applied to specific blocks within a vineyard.

The problem addressed in this study was the need for a reliable and efficient method to discriminate between different soil types in vineyards. The method used in this study involved collecting soil samples from two vineyards, Quinta dos Carvalhais and Quinta de Azevedo. The near-infrared spectra of the soil samples were then collected using a Fourier transform near-infrared spectrometer. Spectra were preprocessed using a Savitzky-Golay filter and analyzed using partial least squares discriminant analysis (PLS-DA) to discriminate between different soil types.

The data was divided into calibration and test sets, and mean centering was applied to the data. The optimal number of latent variables was determined using cross-validation. Samples were measured in three different ways: (1) Wet samples: spectra were acquired immediately upon receipt of samples in the laboratory, approximately 6 h after sample collection; (2) Dried samples: samples were dried in an oven at 45°C for two weeks and measured by NIRS; (3) Ground dry samples: Dry samples were ground using a mortar and pestle before spectra were collected. The spectra of the wet (intact) samples simulate what would be expected if a portable instrument were used to acquire the spectra directly in situ. Near-infrared spectra of all soil samples were collected in diffuse reflectance mode on a Fourier transform near-infrared spectrometer (FTLA 2000, ABB, Quebec, Canada) equipped with an indium gallium arsenide (InGaAs) detector). The main result of the study was that there was no significant difference in accuracy between using wet and dry soil samples. This finding suggests that portable NIRS instruments can be used for direct in situ field analysis.

In the article *Near-Infrared Spectroscopy Coupled with Chemometrics Tools: A Rapid and Non-Destructive Alternative on Soil Evaluation* (Carra *et al.*, 2018), the potential of near-infrared spectroscopy (NIR) in conjunction with chemometric tools as an alternative was discussed. quick and non-destructive method for soil assessment. The main theoretical contribution of this article is the demonstration of the potential of near-infrared spectroscopy (NIR) in conjunction with chemometric tools for the rapid and non-destructive assessment of organic carbon content, total emission, available phosphorus and available power in soil samples. The method used in this study involved collecting soil samples from different locations in the state of Paraná, Brazil. The samples were then analyzed using near-infrared (NIR) spectroscopy to obtain spectral data. Chemometric tools, specifically partial least squares (PLS) regression, were employed to develop calibration models to predict organic carbon, total nitrogen, available phosphorus, and available potassium content in soil samples. Models were evaluated using cross-validation and a test set approach. The test set validation approach produced higher accuracy predictions compared to cross-validation. This demonstrates the potential of NIR spectroscopy as a rapid and non-destructive technique for soil analysis.

In the article On the discrimination of soil samples by derivative diffuse reflectance UV–vis-NIR spectroscopy and chemometric methods (Chauhan *et al.*, 2021) discussed the use of derived UV–vis-NIR diffuse reflectance spectroscopy and chemometric methods for soil sample identification and classification, focusing on soil samples. soil collected from the northwestern part of India and analyzing the presence of various organic and inorganic minerals in the samples. The main theoretical contribution of this article is the application of derived UV-vis-NIR diffuse reflectance spectroscopy and chemometric methods for the description and classification of soil selection, allowing the identification of different organic and inorganic components present in the soil, as well as the segregation of samples based on their spectra. This demonstrates the potential of spectroscopic techniques and chemometric methods in forensic soil analysis and can provide valuable information about the composition and origin of soil samples. The UV-vis-NIR reflectance spectra of the soil samples were obtained using a spectrophotometer.

Pretreatment methods including drying, grinding and sieving were applied to soil samples prior to analysis. The spectra were then processed and analyzed by chemometric methods such as principal component analysis (PCA), linear discriminant analysis (LDA) and cluster analysis for data analysis and classification. PCA was used to reduce the dimensionality of the dataset and identify the main components contributing to spectral variations. LDA was employed to develop a discriminant model to classify the soil samples into their respective groups. Cluster analysis, specifically hierarchical cluster analysis (HCA) and k-means clustering, was used to group similar soil samples based on their chemical compositions.

Discriminating power (DP) of soil samples was calculated using the formula provided by Smalldon and Moffat. This measure quantifies the ability of the method to discriminate between different samples. The main outcome of the study is the successful discrimination and classification of soil samples using UV-vis-NIR diffuse reflectance spectroscopy and chemometric methods. The study also highlighted the impact of pretreatment methods such as heating and sieving on the spectral characteristics of soil samples. Overall, the study demonstrated the potential of spectroscopic and chemometric techniques for soil forensic analysis.

In the article Potential of Near-Infrared Spectroscopy for Measurement of Heavy Metals in Soil as Affected by Calibration Set Size (Todorova *et al.*, 2014) the potential of near-infrared spectroscopy (NIRS) to predict the content of heavy metals was investigated. in the soil as zinc (Zn), copper (Cu), lead (Pb), chromium (Cr) and nickel (Ni). The study found that NIRS can be used to accurately predict concentrations of certain heavy metals, such as copper (Cu), but may be less accurate for other metals such as chromium (Cr), which could be valuable for evaluating the soil quality and environmental monitoring. The main problem of this study is the limited size of the calibration set used to develop the prediction models, as the accuracy of the predictions decreased as the size of the calibration set decreased. This limitation can affect the accuracy and reliability of predictions, especially for metals with lower precision, such as chromium (Cr).

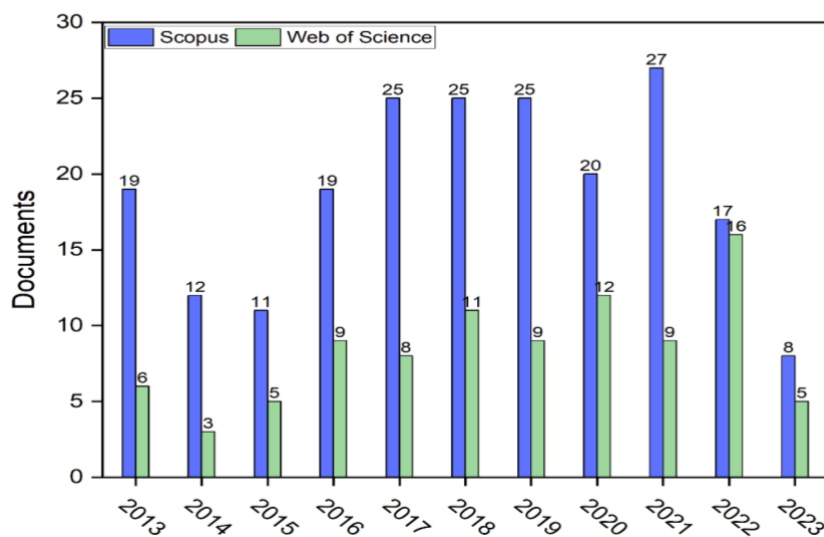
The study collected a total of 124 samples of different soil types from the Stara Zagora region of Bulgaria. Calibration models were developed using partial least squares (PLS) regression analysis with full cross-validation. The accuracy of the calibration models was evaluated using the coefficient of determination (R^2_{cv} and R^2_{pre}), root mean squared error (RMSE_{cv} and RMSE_{pre}) and ratio between prediction and deviation (RPD_{cv} or RPD_{pre}). The study also investigated the effect of calibration set size on the models' prediction error.

The main result of this study is that near-infrared spectroscopy (NIRS) has the potential to accurately predict the concentrations of certain heavy metals in soil, such as copper (Cu), zinc (Zn), lead (Pb), and nickel (Ni). Prediction accuracy varied, with Cu being the best predicted heavy metal and chromium (Cr) being the least accurately predicted. The study also found that the size of the calibration set and the variability of the soil samples had an impact on the accuracy of the predictions.

3.2 QUANTITATIVE ANALYSIS

Quantitative bibliometric results were evaluated for various performance parameters, such as: research growth, most productive and highly cited authors, most sought after discipline, main journals, analyzes by country, analyzes by institutions and highly influential articles (Chart 1).

Chart 1 - Evolution of productions at SCOPUS and WEB OF SCIENCE



Source: Authors (2023)

In 2021, the largest production was in the Scopus database, with 27 works, while in the WoS database there were only 9 works, totaling 36 works (Table 1). But in the case of WOS, the most productive year was 2020 with 12 works. It is believed that the growing search for new analysis methodologies is one of the reasons, as the traditional method of analysis in developed countries does not involve qualified labor for soil sampling and the procedures are very laborious, even in poor countries, even Traditional soil analysis is very expensive. A technology like NIR would come to make soil fertility diagnosis accessible. When it comes to the most productive authors, in the Scopus and Web of Science databases we obtained 10 main authors (Table 1).

Table 1 - Top 10 authors with the highest production

Scopus		Web of Science	
Main Author	Number of documents	Main Author	Number of documents
Mouazen, Abdul M.	19	Demattê, José A. M.	9
Demattê, José A. M.	18	Knadel, Maria	6
Minasny, Budiman	12	Minasny, Budiman	5
Knadel, Maria	7	Mouazen, Abdul M.	5
Grunwald, Sabine	6	Greve, Mogens H.	4
Chen, Songchao	5	Curi, Nilton	3

Dotto, André C.	5	De Jonge, Lis W.	3
Gomez, Cécile	5	De Santana, Felipe B.	3
Greve, Mogens H.	5	De Souza, André M.	3
McBratney, Alex B.	5	Du, Changwen	3

Source: Authors (2023)

Observing Table 2, it can be seen that the most cited author in Scopus is the fourth most cited in WoS. And the most cited in WoS is the second in Scopus, this way it verifies that the two bases are partially connected, as the main authors end up being found in both bases.

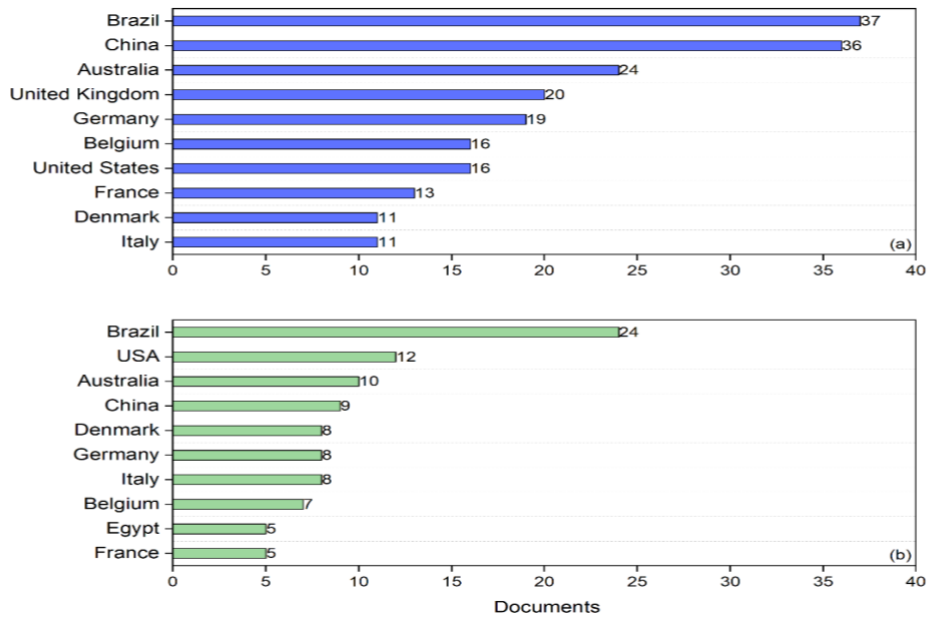
Table 2 - Main authors with the greatest production on the subject in each search platform

Scopus		Web of Science	
Main Author	Number of documents	Main Author	Number of documents
Mouazen, Abdul M.	19	Demattê, José A. M.	9
Demattê, José A. M.	18	Knadel, Maria	6
Minasny, Budiman	12	Minasny, Budiman	5
Knadel, Maria	7	Mouazen, Abdul M.	5
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Chen, Songchao	5	Curi, Nilton	3
Dotto, André C.	5	De Jonge, Lis W.	3
Gomez, Cécile	5	De Santana, Felipe B.	3
Greve, Mogens H.	5	De Souza, André M.	3
McBratney, Alex B.	5	Du, Changwen	3

Source: Authors (2023)

In terms of research institutions, the ten with the highest production were considered (Chart 2), where the University of São Paulo (USP) presents the highest production, both in the Scopus database and in the WoS database. Followed by a British and Chinese university in Scopus and a Danish and a Chinese university in WoS. In both research bases, the Brazilian Agricultural Research Corporation (EMBRAPA) appears with a reasonable production on the topic, showing that Brazilian research in the area is quite advanced.

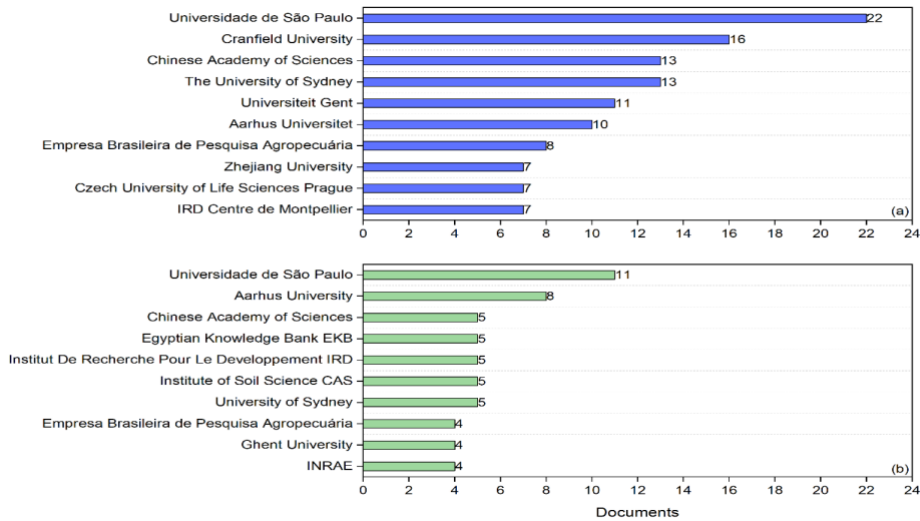
Chart 2 - Articles by institution (a) Scopus and (b) Web of Science



Source: Authors (2023)

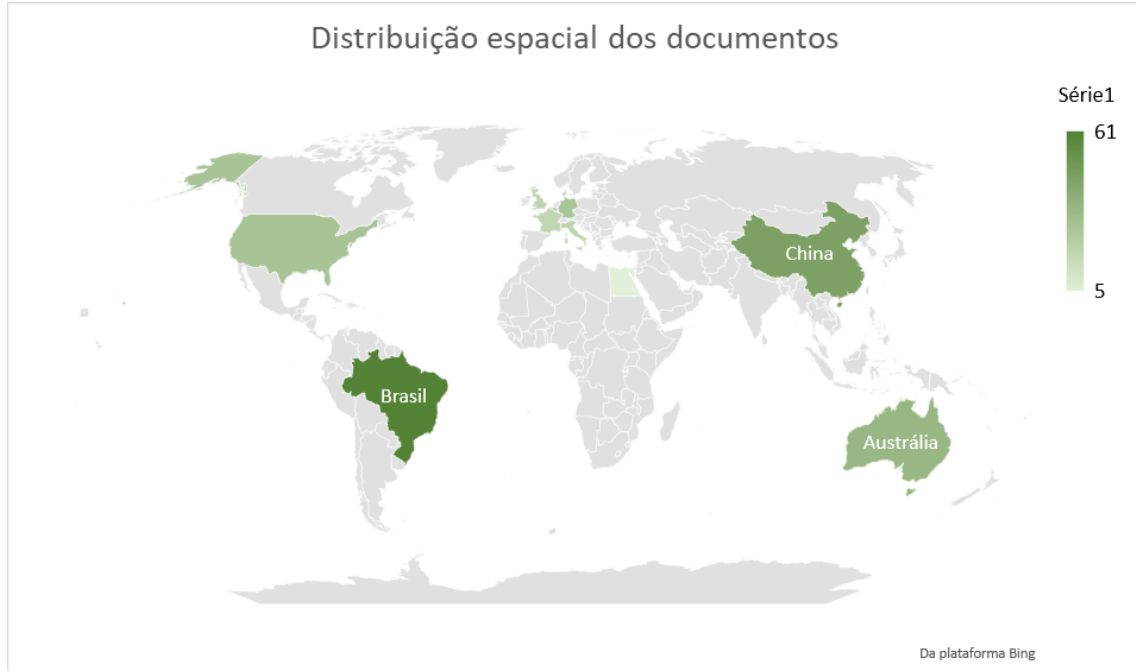
Of the countries with the highest number of research on NIR technology (Chart 3), Brazil stands out, leading in both bases. Followed by countries such as China, the United States and Australia, with large territorial and agricultural areas, looking for new soil analysis technologies.

Chart 3 - Articles by country (a) Scopus and (b) Web of Science



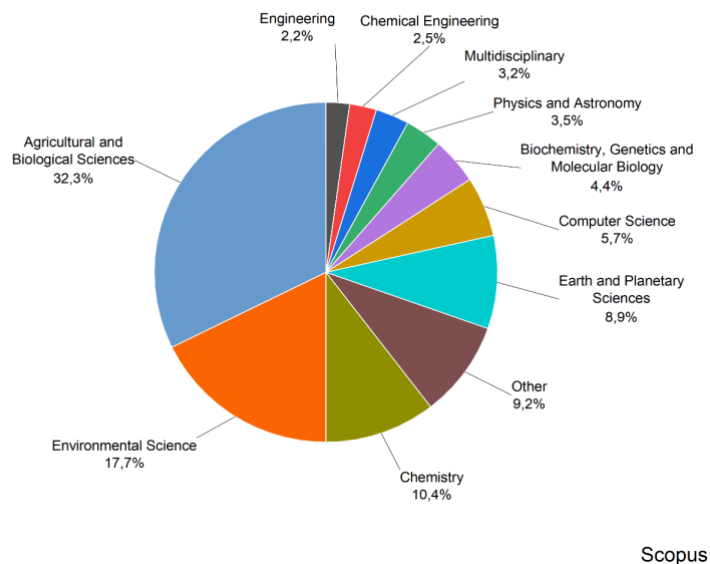
Source: Authors (2023)

Figure 1 - Adding the two platforms (but we don't know if an article can be on both platforms)



When summarizing the Scopus research database, by research area (Chart 4), the predominant area is agriculture, followed by environmental sciences, showing that this technology can be applied to the protection and study of the environment.

Chart 4 - Articles by area



Source: Authors (2023)

4 FINAL CONSIDERATIONS

The justification given for the work concludes that the use of bibliometrics as a statistical tool to map and generate various indicators for the processing and management of information and knowledge, performed a very efficient way of collecting state-of-the-art data on the proposed topic. Regarding the research question, the most relevant works were found and

described and also analyzed, providing information on the best methodologies to be used in the case of using infrared in soil analysis. The following methodologies are used to achieve the objectives of the work and answer the research question, proving to be quite effective. The main result of the study is the demonstration of the effectiveness and potential of portable NIR spectrometers in various applications in the agri-food industry

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