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Nematodes associated with the rhizosphere of coconut (*Cocos nucifera* L.) in the Dominican Republic

Marianela Conce Conce

Pelotas, 2024

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Nematodes associated with the rhizosphere of coconut (*Cocos nucifera* L.) in the Dominican Republic

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Dedicated to the four most important women in my life, who have given me the greatest boost to achieve my goals, to whom I owe my life, and whom I deeply love and respect with all my being.

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Karolay Polanco Conce
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Resumo

CONCE-CONCE, Marianela. **Nematoides associados à rizosfera do coco (***Cocos nucifera* **L.) na República Dominicana**. Orientador: Jeronimo Vieira de Araujo Filho; Co-orientador: Cristina Antonia Gómez Moya. 2024. 142f. Tese (Doutorado em Fitossanidade) — Programa de Pós-Graduação em Fitossanidade. Universidade Federal de Pelotas, Pelotas, 2024.

A palmeira de coco (*Cocos nucifera* L.) na República Dominicana é afetada por várias pragas, incluindo-se fitonematoides (PPNs). Os objetivos deste estudo foram: (*i*) avaliar a diversidade de nematoides associados a diferentes biótipos de coqueiro na República Dominicana; (*ii*) avaliar a distribuição de PPNs associados ao coqueiro em diferentes províncias da República Dominicana em dois cenários de mudanças climáticas. A coleta das amostras foi realizada em padrão zigue-zague e as extrações dos nematoides foram realizadas utilizando a técnica de flutuação-centrifugação para as raízes e o funil de Baermann modificado com placa de Cobb para o solo. Nas raízes, foram observados os gêneros *Helicotylenchus, Meloidogyne, Pratylenchus, Rotylenchulus* e *Xiphinema*. No solo, foram identificados *Helicotylenchus, Longidorus, Meloidogyne, Mesocriconema, Pratylenchus, Radopholus, Rotylenchulus, Tylenchus, Tylenchorhynchus* e *Xiphinema*. Nematoides de vida livre (FLNs) encontrados na rizosfera da cultura incluíram *Acrobeles, Axonolaimus, Alaimus, Aphelenchus, Cephalobus, Dorylaimus, Diploscapter, Diplogaster, Monhystera, Mononchus, Rhabditis, Tripyla, Filenchus, Plectus, Prismatolaimus, Wilsonema* e *Tylencholaimellus*. Foram observados valores elevados de densidade, prevalência e dominância de PPNs associados à rizosfera da cultura (*Helicotylenchus, Tylenchus, Rotylenchulus, Meloidogyne* e *Pratylenchus*) e FLNs (*Rhabditis, Aphelenchus, Trypila* e *Dorylaimus*). Houve variações quanto ao número de gêneros de nematoides registrados para diferentes biótipos do coqueiro, a saber: o grupo “Gigante” com 25 gêneros, o grupo “Anão” com 20 gêneros e Híbrido com 17 gêneros. As espécies incluíram *Helicotylenchus californicus*, *H. dihystera*, *H. multicinctus*, *H. abunaamai*, *Rotylenchulus reniformis*, *Pratylenchus coffeae*, *P. vulnus*, *M. arenaria*, *M. incognita*, *M. javanica* e *M. hapla*. A análise de correspondência mostrou padrões de associação entre biótipos de coqueiros e gêneros de nematoides em diferentes dimensões. Os grupos p-p 2 e p-p 3 dos PPNs e os grupos c-p 1 e c-p 2 dos FLNs apresentaram as maiores percentagens entre os biótipos. *Helicotylenchus* mostrou a maior variabilidade e menor distância, enquanto *Meloidogyne, Pratylenchus* e *Rotylenchulus* tiveram menor variabilidade, mas uma distribuição mais ampla. *Helicotylenchus* foi influenciado positivamente pela temperatura média do trimestre mais seco e faixa anual de temperatura, *Rotylenchulus* pela temperatura média do trimestre mais seco, *Pratylenchus* pela temperatura mínima do mês mais frio e *Meloidogyne* pela temperatura média do trimestre mais úmido. No entanto, a incidência de *Helicotylenchus* foi afetada negativamente pela sazonalidade da temperatura e pela sazonalidade da precipitação, enquanto *Meloidogyne* e *Rotylenchulus* foram negativamente influenciadas pela sazonalidade da precipitação. Áreas adequadas em referente as coodenadas geograficas para o desenvolvimento e distribuição de PPNs (*Helicotylenchus, Meloidogyne, Pratylenchus* e *Rotylenchulus*) foram encontradas entre as latitudes 18,0 - 19.5 N e longitudes 65,5 - 72,0. Em relação às projeções futuras, espera-se que *Helicotylenchus* e *Pratylenchus* aumentem sua distribuição na fase de projeção socioeconômica SSP245, enquanto *Meloidogyne* e *Rotylenchulus* o farão na fase SSP585. Este trabalho representa o primeiro estudo científico sobre o cultivo do coco na área de nematologia da República Dominicana. O modelo matemático proposto foi capaz de prever a distribuição desses PPNs e avaliar os riscos de doenças associadas. Estas descobertas fornecem orientações importantes para a prevenção e o manejo oportuno desses PPNs.

Palavras-chave: Dominância; biótipos; grupos tróficos; aspectos ecológicos; modelo linear generalizado; projeções futuras.

Abstract

CONCE-CONCE, Marianela. **Nematodes associated with the rhizosphere of coconut (*Cocos nucifera* L.) in the Dominican Republic**. Advisor: Jeronimo Vieira de Araujo Filho; Co-advisor**:** Cristina Antonia Gómez Moya. 2024. 142p. Thesis (Doctorate in Crop Protection) — Graduate Program in Crop Protection. Federal University of Pelotas, Pelotas, 2024.

The coconut palm (*Cocos nucifera* L.) in the Dominican Republic is affected by various pests, including plant-parasitic nematodes (PPNs). The objectives of this study were: (*i*) to assess the diversity of nematodes associated with different coconut biotypes in the Dominican Republic, and (*ii*) to assess the distribution of PPNs associated with coconut palms in the Dominican Republic under two climate change scenarios. The samples were collected in a zig-zag pattern, and nematode extractions were performed using the flotation-centrifugation technique for roots and the modified Baermann funnel method with Cobb's sieving plate for soil. In the roots, *Helicotylenchus, Meloidogyne, Pratylenchus, Rotylenchulus,* and *Xiphinema* were observed. In the soil, *Helicotylenchus, Longidorus, Meloidogyne, Mesocriconema, Pratylenchus, Radopholus, Rotylenchulus, Tylenchus, Tylenchorhynchus,* and *Xiphinema* were identified. Free-living nematodes (FLNs) found in the crop rhizosphere included *Acrobeles, Axonolaimus, Alaimus, Aphelenchus, Cephalobus, Dorylaimus, Diploscapter, Diplogaster, Monhystera, Mononchus, Rhabditis, Tripyla, Filenchus, Plectus, Prismatolaimus, Wilsonema,* and *Tylencholaimellus*. Higher values of density, prevalence, and dominance were observed for PPNs associated with the crop rhizosphere (*Helicotylenchus, Tylenchus, Rotylenchulus, Meloidogyne,* and *Pratylenchus*) and FLNs (*Rhabditis, Aphelenchus, Trypila,* and *Dorylaimus*). There were variations in the number of nematode genera recorded for different coconut biotypes, namely: the "Tall" group with 25 genera, the "Dwarf" group with 20 genera, and the Hybrid group with 17 genera. The species included *Helicotylenchus californicus, H. dihystera, H. multicinctus, H. abunaamai, Rotylenchulus reniformis, Pratylenchus coffeae, P. vulnus, Meloidogyne arenaria, M. incognita, M. javanica,* and *M. hapla*. Correspondence analysis revealed patterns of association between coconut biotypes and nematode genera across different dimensions. The p-p 2 and p-p 3 groups of PPNs, as well as the c-p 1 and c-p 2 groups of FLNs, presented the highest percentages among the biotypes. *Helicotylenchus* exhibited the highest variability and the shortest distance, while *Meloidogyne, Pratylenchus,* and *Rotylenchulus* showed lower variability but a wider distribution. *Helicotylenchus* was positively influenced by the average temperature of driest quarter and the annual temperature range, *Rotylenchulus* by the average temperature of driest quarter, *Pratylenchus* by the minimum temperature of coldest month, and *Meloidogyne* by the average temperature of wettest quarter. However, the incidence of *Helicotylenchus* was negatively affected by temperature seasonality and precipitation seasonality, while *Meloidogyne* and *Rotylenchulus* were negatively influenced by precipitation seasonality. Suitable areas concerning geographical coordinates for the development and distribution of PPNs (*Helicotylenchus, Meloidogyne, Pratylenchus,* and *Rotylenchulus*) were found between latitudes 18.0 - 19.5 N and longitudes 65.5 - 72.0. Regarding future projections, it is expected that *Helicotylenchus* and *Pratylenchus* will increase their distribution in the SSP245 socioeconomic projection phase, while *Meloidogyne* and *Rotylenchulus* will do so in the SSP585 phase. This work represents the first scientific study on coconut cultivation in the field of nematology in the Dominican Republic. The proposed mathematical model was able to predict the distribution of these PPNs and assess the risks of associated diseases. These findings provide important guidance for the prevention and timely management of these PPNs.

Keywords: Dominance; biotypes; trophic groups; ecological aspects; generalized linear model; future projections.

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1. GENERAL INTRODUCTION

The coconut (*Cocos nucifera* L.) is one of the most important and cultivated plants of the Arecaceae family worldwide (USDA, 2020). It is specially grown for its significant industrial and medicinal contributions (Debmandal; Mandal, 2011). From this plant, various natural products can be derived for pharmaceutical manufacturing as well as for development in industrial markets (Debmandal; Mandal, 2011). Due to its wide range of uses, it is considered a primary source of food, drink, and shelter for rural and coastal areas in tropical regions (Granados-Sánchez; López-Ríos, 2002).

In 2020, Asia was the largest coconut producer, accounting for 84.2%, followed by the Americas with 8.3%, Oceania with 4.1%, and Africa with 3.4%. During the same year, the global harvested area reached 11,307,699 hectares, while the production was higher, with 63,683,595 tons (FAOSTAT, 2023), with Indonesia, the Philippines, and India being the top producers, respectively. In 2017, in the Americas, the countries that exported the most coconuts were Mexico, the United States, and the Dominican Republic (FAOSTAT, 2023). In the Dominican Republic, specifically, coconut production is extensive, particularly in the coastal regions of Samaná, María Trinidad Sánchez, Puerto Plata, El Seibo, and La Altagracia, and to a lesser extent in the provinces of Barahona and Bahoruco (MA, 2016). In 2020, the harvested area of coconut trees was 46,072 hectares, with a production of 433,807 tons (FAOSTAT, 2023).

In the Dominican Republic, coconut cultivation is affected by insects, mites (Gómez-Moya *et al*. 2018), phytoplasmas (Martínez *et al*. 2008), and plant-parasitic nematodes (PPNs) (Valdez; Matos; Álvarez, 2016). Several PPNs that cause severe damage have been associated with coconut trees (Griffith *et al*. 2018), some of which can greatly affect coconut cultivation. The symptoms start from the older leaves towards the younger ones, showing yellowing at the leaf tips that progress towards the rachis, leading to leaf collapse and affecting the plant's growth and fruiting (Salas, 1980). With the abundant presence of PPNs, the adult plant can die three to four months after the appearance of the first symptoms (Salas, 1980). This disease is caused specifically by the nematode *Bursaphelenchus cocophilus* (Cobb, 1919) Boujard, 1998, transmitted by the insect *Rhynchophorus palmaram* L., 1758 (Griffith *et al*. 2018). In the national territory, PPNs associated with the rhizosphere of coconut trees have been poorly studied, with records of identification only at the genus level (Valdez; Matos; Álvarez, 2016). So far, the recorded genera include *Helicotylenchus*, *Meloidogyne*, *Pratylenchus*, and *Rotylenchulus* (Valdez; Matos; Álvarez, 2016).

Rodríguez *et al*. (2007) state that favorable management strategies can be applied only when the geographic distribution, abundance, and prevalence of these nematode genera are known. However, in the Dominican Republic, it is not known which genera of these PPNs are present, their diversity, distribution, influence, and future projections associated with coconut cultivation. Additionally, it is important to note the presence of free-living nematodes (FLNs) in the rhizosphere of crops, which can play a significant role in organic matter decomposition, and its diversity can be used as a biological indicator of overall soil quality (Romero; Castilla Díaz; Millán Páramo, 2016).

In the soil ecosystems, the biodiversity of the nematode community is measured to gain knowledge of the ecology of these organisms and to have indicators that allow us to make decisions and/or recommendations that benefit the protection of taxa or threatened areas, or to monitor the impact of human disturbances on the environment (Castilla-Díaz *et al*. 2017).

The abundance and functional structure of nematodes in the soil provide signals of destructive or beneficial factors in soil dynamics (Bongers, 1990). Furthermore, the understanding of these signals can provide insights into the overall health and productivity of the soil. Under this aspect, climate emerges as one of the critical factors influencing the global distribution of diseases (Rutherford; Webster, 1987). Recognizing the interplay between climate patterns and disease spread is essential for devising effective disease management strategies. Climate change can directly and indirectly influence the distribution and abundance of invasive pathogens (Song *et al*. 2023). For instance, high temperatures cause stress in trees and exacerbate disease outbreaks and tree mortality (Raffa *et al.* 2015). The high levels of carbon dioxide have raised the air temperature and affected the natural ecosystems, including the correlation between plants and diseases. The warming effect has also influenced the incidence and risk of diseases, causing many of these diseases to increase faster in response to the shorter plant growth cycle (Trumble; Butler, 2009).

Plants and diseases respond differently to climate change, showing their particularities and differences in adaptation to the environment (Hódar; Castro; Zamora, 2003). Tang *et al*. (2021) reported a significant effect of climate change on plants and disease incidence. Therefore, the authors suggested predicting trends in plants and diseases under climate change. Considering that the niche model could be used to evaluate and predict the effect of climate change on plants and diseases. Numerous studies have analyzed the invasion and distribution of invasive insects influenced by climate change (Trumble; Butler, 2009; Barbet-Massin *et al*. 2013; Wei *et al*. 2018), but few studies have reported on PPNs (Song *et al*. 2023). Global warming offers a potential opportunity for *Meloidogyne enterolobii* Yang and Eisenback, 1983, to spread from low-latitude to high-latitude areas (Song *et al*. 2023). The range of highly suitable habitats for this nematode increased and shifted towards higher latitudes under future climate scenarios compared to the current climate scenario (Dutta; Phani, 2023).

Nematodes and other soil animals are highly sensitive to changes in temperature. The optimal temperature for the survival and spread of soil nematodes is between 20°C and 25°C; when it is below 5°C or above 30°C, soil nematodes are significantly inhibited (Song *et al*. 2017). Invasive nematode species jeopardize natural environments by engaging in competition with native species, while also presenting risks to human-managed sectors like agriculture, animal welfare, and forestry (Wei *et al*. 2018).

Considerable evidence has shown that climate change will exacerbate the impacts of naturalization and subsequent invasion of invasive species in new communities and ecosystems (Ekesi *et al*. 2016; Wei *et al*. 2018). Understanding the change in potential distribution due to climate change is a fundamental basis required to manage and control the introduction of exotic species (Barbet-Massin *et al*. 2013; Wei *et al*. 2018). Currently, several models, such as bioclimatic modeling (BIOCLIM) (Beaumont; Hughes; Poulsen, 2005), global geographic information system for medicinal plants (GMPGIS) (Du *et al*. 2017), climate change experiment (CLIMEX) (Pattison; Mack, 2008), and maximum entropy (MaxEnt) (Zhang *et al*. 2018; Tang *et al*. 2021), have been used to predict the potential distribution of species. Therefore, modeling the impact of climate change on the distribution of nematodes can provide vital information for controlling and managing the spread of *M*. *enterolobii* (Song *et al*. 2023). Some studies have applied species distribution models (SDMs) to predict the potential impact of invasive species, facilitating early warning and planning for future impacts (Ekesi *et al*. 2016; Wei *et al*. 2018). There are often situations where it cannot be assumed that models for continuous data are appropriate for discrete data. This would be the case when the number of observed individuals to determine proportions is small in each replicate, or when the counts do not have a wide range of values in the particular study. For data of this type, generalized linear models (GLMs) are required (Garrett *et al*. 2004). That is why in this research, we used this type of modeling to assess the present and future distribution of the main parasitic nematodes associated with coconut cultivation in the Dominican Republic. Also, in this study, maps of the potential distribution of *Helicotylenchus, Meloidogyne, Pratylenchus, and Rotylenchulus* in the Dominican Republic are presented for the first time, considering current and future climate scenarios for these nematodes in the country.

The main objective of this research is to assess the diversity and distribution of the nematode community associated with coconut in the Dominican Republic. The specific objectives of this study were (*i*) to assess the diversity of nematodes associated with coconut trees in the Dominican Republic in different biotypes [Atlantic Tall, Brazilian Green Dwarf, Chactemal Hybrid, Malayan Yellow Dwarf, Maypan Hybrid, unknown hybrids 1 and unknow hybrid 2 (dissimilar origins); (*ii*) to evaluate the distribution of *Helicotylenchus, Meloidogyne, Pratylenchus,* and *Rotylenchulus* nematodes associated with coconut trees in the provinces in the Dominican Republic. Collectively, our findings provide new insights into the nematode community associated with the rhizosphere of coconut trees rhizosphere and their ecological aspects, thereby supporting increases in production and the quality of the crop.

2 CHAPTER I – Nematode diversity associated with coconut biotypes in the Dominican Republic

2.1 Introduction

The coconut palm (*Cocos nucifera* L.) is among the most significant economic crops within the Arecaceae that thrive in tropical and subtropical regions due to its substantial industrial and medicinal contributions (Debmandal; Mandal, 2011; Niral; Jerard, 2019; Khadke *et al.* 2019), and it is currently regarded as a subsistence asset in agricultural communities (Wankhede; Shinde; Ghavale, 2019). In the Dominican Republic, coconut production represented 433,807 tons, for a harvest of 46,072 ha (FAOSTAT, 2023), being grown mainly in Samaná, María Trinidad Sánchez, Duarte, La Romana, La Altagracia, Hato Mayor, San Cristóbal, Monte Plata, and El Seibo (FEDOCAMARAS, 2022; MA, 2023).

Despite an increasing global demand for coconuts worldwide, production has decreased due to biotic and abiotic stresses (Beveridge *et al.* 2022). The coconut is affected by several pests and diseases in both roots and aerial parts (Castro; Santana; Barbosa, 2009; Chinchilla, 1997; Griffith *et al*. 2018). More than 20 plant parasitic nematodes (PPNs) have been associated with coconut worldwide and the most important have been *Meloidogyne, Pratylenchus, Radopholus* (Anes; Arsha; Josephrajkumar, 2021), *Bursaphelenchus* (Griffith *et al.* 2018), *Helicotylenchus, Rotylenchulus* (Ekanayake; Lamberti, 1987), and others (Youssef; Lashein, 2013). Taking into account the Index of Pests and Diseases of Economic Importance in the Dominican Republic only refers to *Helicotylenchus*, *Meloidogyne*, *Pratylenchus,* and *Rotylenchulus* associated with coconut plants (Valdez; Matos; Álvarez, 2016).

Free-living nematodes (FLNs), beneficial organisms in the soil and indicators of nutrient flux (Fitoussi; Pen-Mouratov; Steinberger, 2016; Khanum; Mehmood; Javed, 2021), feed on soil-resident microorganisms, including the bacterivores, fungivores, predators and omnivores (Bongers, 1990; Krashevska *et al*. 2019; Parveen *et al*. 2022). These nematodes can also be grouped according to their life strategies as colonizers (c) and persisters (p), these are extremes on a scale (c-p scale) from 1 to 5, respectively

(Bongers, 1990), being the colonizers and the persister equivalent to the r and K strategists, respectively. Large populations of some FLNs can help control PPNs in the soils (Ferris; Sánchez-Moreno; Brennan, 2012) while incorporating soil amendments compost can improve the release of nematode antagonists and/or nematicidal compounds (Bahadur, 2021). Previous studies have demonstrated FLNs associated with the palm rhizosphere, including *Oscheius* species (Tabassum; Shahina, 2010), dorylaimids*,* rhabditids and monochids (Pradhan; Patra; Sahoo, 2020).

The biodiversity, densities, and prevalence of PPNs and FLNs are influenced by several environmental factors (soil moisture and texture, temperature) as well as plant diversity (Manzanilla-Lopez, 2008; Pan *et al*. 2020; Schlüter *et al*. 2022). Nevertheless, studies on this topic in coconut agroecosystems in the provinces of the Dominican Republic have been poorly documented, which limits the availability of information on PPNs and FLNs. This lack of documentation also makes it difficult to represent the c-p groups and analyze the feeding of FLNs in coconut cultivation. Therefore, the purposes of our study were: (*i*) to identify and determine the taxonomic diversity, population densities and prevalence of PPNs and FLNs in the community associated with different coconut biotypes and provinces; (*ii*) to analyze the structure of functional diversity within the nematode community, including PPNs and FLNs; and (*iii*) to evaluate how the diversity of coconut biotypes could impact the diversity and community composition of PPNs and FLNs.

2.2 Materials and methods

2.2.1 Study permission and notification

For the sampling of soil and roots, the Ministry of the Environment in the Dominican Republic was notified, and permission was granted to carry out the sampling of soil and roots in coconut cultivation across various provinces. In addition, the genera and species registered in this investigation were notified, with the approval number and verification being VRF-DR-02229-2021.

2.2.2 Sampling and nematodes extraction

A total of 69 samples from 10 biotypes of coconut were taken in 11 provinces (25 municipalities) of the Dominican Republic during February and September 2021 (Table 1). Sampling (soil and roots) was carried out in *zig-zag*, in areas without weeds, at a depth of 20 cm. Each sample was composed of seven subsamples, comprising approximately 2 kg of soil and 1 kg of roots. The data regarding the biotypes were provided by the growers of the sampled farms. The altitude was obtained by using the geographical coordinates of each sampling site and the Google Earth Pro online tool.

The nematode extraction was carried out using the modified Baermann funnel technique with a Cobb plate (Baermann, 1917). For this, 250 cm^3 of soil was placed on a paper-layered filter above the sieve (2 mm), water was added for incubation (24 hours), and then specimens were retrieved on the sieve (500 mesh). Specimens from the roots were extracted using the flotation-centrifugation technique (Coolen; D´Herde, 1972). Briefly, the roots were washed, cut (0.5 - 1.0 cm), crushed (1 minute) before sieved (mesh 20 and 500) and submitted to centrifugation (1,750 rpm). The specimens were fixed (4% formalin) for posterior studies.

2.2.3 Identification, quantification, and conceptual aspects

The identification (genera) and estimates of population densities (250 cm^3 of soil and 20 g of fresh roots) were obtained with Petri dishes, using a compound microscope AmScope T690C-PL, v. 2017 (10 – 40 x magnification). In relation to PPNs, the main morphological characteristics examined were determined by the size of the stylet, esophagus, reproductive system, oral cavity, lips and stoma (Ferraz, 2016; Mai; Lion, 1975). For FLNs, the presence or absence of sensory organs, structures associated with the body wall (cuticle), and the shape and size of the tail, lips and stoma, were used (Bongers; Bongers, 1998; Scholze; Sudhaus, 2011).

Density and prevalence in this manuscript were based on the standardization of ecological terms (Boag, 1992), where the density was calculated by the number of individuals of a particular genus of nematodes per unit volume in soil (250 cm^3) and weight of fresh root (20 g). The prevalence (%) was calculated by the number of samples where the genus of nematode was present divided by the total number of samples and multiplied the result by 100.

Specimens of each genus were examined for morphological and morphometric characterization. For identification of species, 10 specimens of the selected genus with higher density and prevalence (*Helicotylenchus, Pratylenchus, Rotylenchulus,* and *Meloidogyne*) were observed also. Measurements were conducted using the AmScope T690C-PL compound microscope (10-100X) (Erhunmwunse; Tongo; Ezemonye, 2021; Peraza-Padilla *et al*. 2013). To compare morphology and morphometry, we consulted studies conducted by Niloofar *et al*. (2021), Riascos-Ortiz *et al*. (2020), Van Den Berg and Heyns (1975), Budiman; Supramana and Giyanto (2019), Chihani-Hammas *et al*. (2018), and Riasco-Ortiz *et al*. (2019). For *Meloidogyne* species, ten adult females were dissected from the roots of tomato plants and observed under a stereoscope (Chihani-Hammas *et al*. 2018). The perineal patterns were compared and referenced using the methods described by Hartman and Sasser (1985), Eisenback and Triantaphyllou (1991), and Taylor and Sasser (1983).

2.2.4 Taxonomic diversity of nematodes

We obtained the taxonomic diversity indices, as described to follow: (*i*) the total number of the nematode community (N) (total abundance of the PPNs and FLNs nematode community); (*ii*) richness (R) (number of genera in a community); (*iii*) the Shannon-Wiener index (H’), which quantifies local diversity or diversity heterogeneity (H′ varies from 0 to lnR); (*iv*) the Pielou uniformity index (J) (E=H′/lnR), quantifies the regularity of the distribution of genus within the community (E varies between 0 and 1), where lnR is equal to the natural logarithm of the total number of a genus in the area and, (*v*) the Simpson index (S), which quantifies the probability that two randomly selected individuals in a sample belong to different species (Gotelli; Chao, 2013; Magurran; McGill, 2011; Whittaker, 1960).

We used the Whittaker Diagram to evaluate the relative dominance of PPNs and FLNs. This method classifies genera in decreasing order on the X-axis and represents their relative abundances on a logarithmic scale ($\log_{10}$) on the Y-axis (Matthews; Whittaker, 2015). This visual approach allowed us to identify the dominant, intermediate, and rare genera in nematode communities, highlighting the contribution of each genus concisely. To carry out these analyses, the nematodes were reclassified and grouped into three coconut biotype groups (“Talls”, “Dwarfs”, and “Hybrids”), as follows: (*i*) within the “Tall” biotype group, we have the Atlantic Tall, (*ii*) In the “Dwarfs” biotype group, we find the Brazilian Green Dwarf and Malayan Yellow Dwarf, and (*iii*), finally, within the Hybrids biotype group, we have the Chactemal Hybrid, Maypan Hybrid, unknown hybrid 1 and 2 (different origins and distinctive morphological characteristics). The reclassification and grouping of biotype groups was done to standardize the population densities and the diversity index within each group and to determine if the biotypes influenced the nematode densities.

2.2.5 Functional diversity of nematodes

To estimate the functional diversity of the nematode community, the dataset was subjected to the Nematode Indicator Joint Analysis – NINJA (https://shiny.wur.nl/ninja/) (Sieriebriennikov; Ferris; de Goede, 2014). Therefore, we obtained the Plant Parasitic Index (PPI) (Bongers, 1990; Freckman; Ettema, 1993), which measures the maturity index for parasites, as well as the footprints of herbivores and fungivores nematodes (Ferris, 2010). Additionally, the feeding type composition for FLNs and PPNs (trophic groups), c-p groups for FLNs, and p-p groups for PPNs were assessed. Furthermore, maturity index (MI), structure index, and enrichment index were evaluated for FLNs. From the herbivores nematode set, classification based on the trophic diversity index (Freckman; Ettema, 1993) was assigned as follows: sedentary endoparasites, migratory endoparasites, semi-endoparasites, ectoparasites, and epidermal and root hair feeders. In order to carry out these analyses, the nematodes were reclassified and grouped into the same three coconut biotype groups previously mentioned: “Talls”, “Dwarfs”, and “Hybrids”.

2.2.6 Statistical analysis of the data

Statistical estimations of taxonomic diversity were performed using R 4.2.0 (R Development Core Team, 2021) and the packages Vegan and Biodiversity R (Oksanen, 2022; Kindt; Kindt, 2023). The analyzed variables underwent several stages to verify their distribution and detect possible errors. The Negative Binomial Generalized Linear Model (GLM.BN) was used to analyze the slight overdispersion of categorical and count variables, using the AIC information criteria and the MASS library (Ripley *et al*. 2013). The data from taxonomic and functional indices were expressed to $\log_{10}$ for mean tests and to determine its statistical significance ($p < 0.05$).

To analyze the correspondence between coconut biotypes and the nematode community, correspondence analysis (CA) was performed using R packages FactoMineR (Husson *et al*. 2016) and Factoextra (Kassambara; Mundt, 2016). CA is a multivariate ordination technique that enables the visualization of relationships between variables and groups. Through this technique, the structure of the nematode community could be analyzed, and the association between coconut biotypes and the composition of the nematode community could be determined.

Table 1 Sites studied in the Dominican Republic, number of samples collected in each coconut biotype (parentheses) and management from February to September 2021.

Provinces	Municipalities	Latitude	Longitude	Altitude (m)	Biotypes (n)	management
Maria Trinidad Sánchez	Matancita	19.36168	-69.83471	10[1]	Atlantic Tall (4)[2]	conventional
Maria Trinidad Sánchez		19.32119	-69.82322	4	Atlantic Tall (2)	conventional
Maria Trinidad Sánchez		19.34139	-69.83215	7	Atlantic Tall (1)	conventional
Maria Trinidad Sánchez		19.34102	-69.82521	11	Atlantic Tall (2)	conventional
Maria Trinidad Sánchez	Sabaneta	19.41839	-69.89157	24	Atlantic Tall (1)	organic
San Cristóbal	Villa Altagracia	18.71009	-70.20540	198	Brazilian Green Dwarf (1)	conventional
San Cristóbal		18.70998	-70.20489	197	Brazilian Green Dwarf (1)	conventional
San Cristóbal		18.71028	-70.20942	205	Brazilian Green Dwarf (1)	conventional
San Cristóbal		18.71788	-70.20927	197	Brazilian Green Dwarf (1)	conventional
San Cristóbal		18.71572	-70.20825	197	Brazilian Green Dwarf (1)	conventional
San Cristóbal		18.71061	-70.20525	197	Brazilian Green Dwarf (1)	conventional
San Cristóbal		18.71572	-70.20830	196	Brazilian Green Dwarf (2)	conventional
Montecristi	Guayubín	19.59721	-71.20558	67	Brazilian Green Dwarf (1)	organic
Montecristi	Castañuela	19.71532	-71.53129	20	Brazilian Green Dwarf (1)	organic
Montecristi	Castañuela	19.60156	-71.22822	60	Brazilian Green Dwarf (1)	organic
Montecristi	Castañuela	19.72819	-71.52417	20	Brazilian Green Dwarf (1)	none
Montecristi	Palo Verde	19.76978	-71.65921	9	Brazilian Green Dwarf (1)	organic
Montecristi	Juliana Jaramillo	19.76977	-71.65915	8	Brazilian Green Dwarf (1)	organic
Bahoruco	Galván	18.48108	-71.27933	14	Atlantic Tall (1)	none
Bahoruco	Galván	18.48108	-71.27933	14	Malayan Yellow Dwarf (1)	none
Bahoruco	Galván	18.48683	-71.27711	16	Atlantic Tall (1)	none
Bahoruco	Galván	18.48525	-71.27675	13	Atlantic Tall (1)	none
Bahoruco	Galván	18.48633	-71.27892	14	Atlantic Tall (1)	none
Bahoruco	Galván	18.48581	-71.27689	14	Atlantic Tall (1)	none
Barahona	La Isleta	18.27722	-71.19808	10	Brazilian Green Dwarf (2)	none
Barahona	Fundación	18.27044	-71.20252	13	Atlantic Tall (1)	none
Barahona	Fundación	18.26969	-71.20342	12	Unknown hybrid 2 (1)	none
Barahona	Fundación	18.26997	-71.20308	12	Malayan Yellow Dwarf (1)	none
Barahona	Fundación	18.27067	-71.20178	14	Brazilian Green Dwarf (1)	none
Barahona	Paso Real	18.28542	-71.19672	16	Atlantic Tall (1)	none
Barahona	Palo Alto	18.29189	-71.16603	10	Atlantic Tall (1)	

Provinces	Municipalities	Latitude	Longitude	Altitude (m)	Biotypes (n)	management
Monte Plata	Sabana Grande de Boya	18.91401	-69.72182	240	Atlantic Tall (1)	conventional
Monte Plata	La Luisa Blanca	18.72886	-69.89533	30	Brazilian Green Dwarf (1)	none
Monte Plata	Bayaguana	18.76425	-69.68225	56	Atlantic Tall (1)	none
La Altagracia	La Piñita	18.50792	-68.72380	60	Brazilian Green Dwarf (1)	none
La Altagracia	Laguna de Nisibón	18.87631	-68.70293	42	Atlantic Tall 2)	conventional
La Altagracia	Laguna de Nisibón	18.88160	-68.65052	1	Atlantic Tall (1)	none
El Seibo	Sabana de Nisibón	18.93834	-69.81751	237	MayPan hybrid (2)	none
El Seibo	Arroyo Rico	18.98788	-69.17764	32	Atlantic Tall (1)	none
El Seibo	Arroyo Rico	18.98767	-69.17360	30	Atlantic Tall (1)	none
El Seibo	Arroyo Rico	18.98737	-69.17809	33	Atlantic Tall (2)	conventional
El Seibo	El Cedro	18.98475	-68.88759	11	Atlantic Tall (1)	none
El Seibo	Miches	18.48633	-71.27893	14	Atlantic Tall (1)	organic
Samaná	Sánchez	19.23769	-69.63506	34	Atlantic Tall (1)	none
Samaná	Sánchez	18.72887	-69.89534	30	Atlantic Tall (1)	conventional
Samaná	Sánchez	19.24385	-69.66677	35	Atlantic Tall (2)	none
Samaná	Sánchez	19.23911	-69.64479	28	Atlantic Tall (2)	none
Samaná	Sánchez	19.23317	-69.62367	33	Atlantic Tall (1)	conventional
Hato Mayor	Sabana de la Mar	19.02596	-69.32775	18	Atlantic Tall (1)	conventional
Hato Mayor	Hato Mayor del Rey	18.63733	-69.32775	42	Brazilian Green Dwarf (1)	conventional
Hato Mayor	Mango el Limpio	18.85731	-69.38730	271	Chactemal (1)	conventional
Hato Mayor	Sabana de la Mar	19.02897	-69.32860	17	Atlantic Tall (1)	conventional
Hato Mayor	Sabana de la Mar	19.03444	-69.32836	15	Atlantic Tall (1)	none
Hato Mayor	Sabana de la Mar	18.87955	-69.38009	327	Unknown Hybrid 1 (1)	none
Hato Mayor	Sabana de la Mar	18.85731	-69.38730	271	Atlantic Tall (1)	conventional
San Pedro de Macorís	San José de los Llanos	18.63733	-69.47635	37	Malayan Yellow Dwarf (1)	conventional
San Pedro de Macorís	San José de los Llanos	18.63733	-69.47635	37	Chactemal Hybrid	conventional

[1] m: the altitude of the sampling sites recorded in meters.

[2] n: total number of samples taken by coconut biotypes by locations.

2.3 Results and Discussion

2.3.1 Community of nematodes associated with coconut biotypes

A total of 27 nematode genera were detected in the soil, while five were found in the roots. These taxa are distributed across 17 families of Rhabditida, five families of Dorylaimida, three families of Enoplida, one family of Aerolaimida, one family of Monhysterida, and one family of Plectida. Among these genera, 17 belong to the FLNs group, whereas 10 genera belong to the PPNs group (Table 2).

Most genera were identified in the Atlantic Tall biotype (25 genera in the soil and five in the roots), followed by the Brazilian Green Dwarf (18 genera in the soil and two in the roots), Maypan Hybrid (13 genera in the soil and two in the roots), Malayan Yellow Dwarf (12 genera in the soil and three in the roots), unknown hybrid 1 (eight genera in the soil), Chactemal Hybrid (six genera in the soil and two in the roots), unknown hybrid 2 (five genera in the soil and one in the roots). The biotype with the lowest prevalence of genera was the unknown hybrid 2. *Tylenchus, Rotylenchulus, Helicotylenchus, Meloidogyne,* and *Pratylenchus* were the PPNs with the highest density and prevalence, while *Aphelenchus, Rhabditis, Dorylaimus, a*nd *Tripyla* were the most notable FLNs. In contrast, *Mesocriconema, Longidorus, Tylenchorhynchus, Filenchus, Plectus,* and *Tylencholaimellus* were only reported in the Atlantic Tall whereas *Radopholus* and *Wilsonema* were only recorded in the Brazilian Green Dwarf.

Regarding the population densities of PPNs, Atlantic Tall and Brazilian Green Dwarf exhibited higher densities of *Helicotylenchus*, *Meloidogyne*, *Rotylenchulus*, *Pratylenchus*, and *Tylenchus*. Additionally, all biotypes exhibited higher densities of the FLNs *Aphelenchus, Rhabditis, Dorylaimus,* and *Tripyla*. In the roots, the nematodes were observed in the biotype Atlantic Tall (*Helicotylenchus, Meloidogyne, Pratylenchus, Rotylenchulus,* and *Xiphinema*), Chactemal Hybrid (*Helicotylenchus* and *Meloidogyne*), unknown hybrid 2 (*Helicotylenchus*), Malayan Yellow Dwarf (*Helicotylenchus, Meloidogyne,* and *Rotylenchulus*), and Maypan

Hybrid (*Helicotylenchus* and *Pratylenchus*). It is important to note that, for some biotypes, the prevalence of all recorded nematodes reached 100% due to only being sampled once in those biotypes. In the case of the high Atlantic biotype, which has the highest density and prevalence compared to the other biotypes, this could be attributed to the fact that most samplings were conducted in this biotype. It appears to be the most cultivated coconut biotype in the Dominican Republic (Table 3).

Regarding the morphology and morphometry of the nematodes found in the roots, we identified four species of *Helicotylenchus*, including *H*. *californicus* Sher, 1966, *H*. *dihystera* (Cobb, 1893) Sher, 1961, *H*. *multicinctus* (Cobb, 1893) Golden, 1956, and *H*. *abunaamai* Siddiqi, 1972. Additionally, two species of *Pratylenchus* were identified: *P*. *coffeae* (Zimmermann, 1898) Filipjev & Schuurmans Stekhoven, 1941, and *P*. *vulnus* Allen & Jensen, 1951. We also found the species *Rotylenchulus reniformis* Linford & Oliveira, 1940. In the genus *Meloidogyne*, we identified four species based on the perineal pattern analysis: *M*. *arenaria* (Neal, 1889) Chitwood, 1949, *M*. *incognita* (Kofoid & White, 1919) Chitwood, 1949, *M*. *javanica* (Treub, 1885) Chitwood, 1949, and *M*. *hapla* Chitwood, 1949.

The results revealed a broad distribution of PPNs associated with coconut. In the soil, PPNs were recorded in 90% of the samples, but PPNs were observed only in 25 root samples (36%). For FLNs, the presence of at least one nematode was recorded in 67 soil samples (97%), demonstrating the richness and diversity in soils associated with coconut. There is a potential interaction between plants and soil organisms, where plants provide the necessary organic carbon for decomposers and resources for root-associated organisms, such as PPNs (Wardle *et al*. 2004). On the other hand, root-associated organisms influence the quality, direction, and flow of energy and nutrients between plants and decomposers (Wardle *et al*. 2004).

Compounds exuded by roots can either attract or repel PPNs and then, the plant could act as a host that either favors or inhibits the proliferation of PPNs (Ali, 2023). In this study, 27 nematode genera associated with coconut were identified, which is less diverse than the 48 genera reported in oil palm and rubber plantations in Indonesia (Krashevska *et al*. 2019). These differences may be associated with the type of habitat sampled by Krashevska *et al*. (2019) as well as the frequent and recent use of the soil. Among the PPNs reported in the rhizosphere soil of doum palm (*Hyphaene thebaica* (L.) Mart.) in Egypt are *Meloidogyne, Rotylenchulus* and *Helicotylenchus* (El-Sherbiny, 2019). For FLNs, *Acrobeloides* (42.9 per 100 g of soil), *Aphelenchus* (0.6 per 100 g of soil), and the family Tylenchidae (65.9 per 100 g of soil) have been reported in soil (Sánchez-Moreno; Ferris, 2007). In our study, the densities were low, but the prevalence was high, which could be attributed to the type of management and genetic characteristics. Diversity, density, and prevalence are influenced by pesticides and/or organic fertilizers, and frequent soil tillage disturbances lead to a reduction in soil microorganism diversity and a general imbalance in agroecosystems (Bongers; Bongers, 1998).

The PPNs of the genera *Helicotylenchus, Meloidogyne, Pratylenchus,* and *Rotylenchulus* exhibited high density and prevalence in the sampled biotypes. This high density and prevalence could be influenced by the geographic altitude of their locations. The analysis conducted in the second chapter of this work, as shown in Figure 6 depicting the suitability areas for each of these genera, aligns with Figure 3B of the second chapter. These figures indicate that these nematode genera tend to thrive in areas with lower geographic altitudes. Therefore, it is plausible that the elevation gradient plays a role in their density and prevalence. Zhang; Li and Yang, (2021) demonstrated that altitude was the main factor affecting soil nematode diversity in higher latitudes.

In our study, high densities and prevalence were observed for *Helicotylenchus, Meloidogyne, Rotylenchulus,* and *Tylenchus*, which are not only associated with coconut but also with other economic crops. It's plausible that these PPNs are adapting to the climatic and soil and establishing themselves in these areas. Furthermore, there might be remnants in the soil from previous crops or the intercropping of coconut cultivation with other crops within the same cycle. Similarly, Rama and Dasgupta (2000) recorded *Helicotylenchus, Meloidogyne* and *Rotylenchulus* as the most important in coconut cultivation in India. In the case of the *Tylenchus*, it is also included among FLNs and has also been classified as nematodes that feed on fungal hyphae (Yeates *et al*. 1993). Like *Tylenchus*, *Aphelenchus* is another nematode identified in our study, with a high density and prevalence in soils associated with coconut cultivation. Some species of the genus, such as *A. avenae*, although mycophagous (Okada; Kadota, 2003), have also been studied as a cause of damage to some crops (Barker; Darling, 1965). The great abundance of this genus observed in this study highlights the importance of carrying out specific studies regarding this topic to better understand its contribution to Dominican soils associated with coconut cultivation.

To our knowledge, *Tylencholaimellus* and *Filenchus* were reported for the first time in the Dominican Republic. Some species of *Filenchus* (*F. misellus* Andrássy, 1958, and *F. discrepans* Andrássy, 1954) are fungivores (Okada; Harada; Kadot, 2005), but can also associate with algae, lichens, mosses, and plant roots (Yeates *et al*. 1993). Explorations were carried out in the Nemaplex database (http://nemaplex.ucdavis.edu/HostLists/CoconutHostList.htm) and the pest index of the Dominican Republic (Valdez; Matos; Álvarez, 2016), but no documented reports were found in relation to coconut. Since *Filenchus* has not been studied as a potential pathogen, it is recommended to test its pathogenicity in coconuts in the future.

Table 2 Nematode taxa, common name, place of reporting and type of feeding of the nematode community associated with coconut biotypes of the Dominican Republic, from February to September 2021.

Order	**Family or Superfamily**	**Genus**	**sample**	**Feeding type**
Rhabditida	Cephalobidea	*Acrobeles*	Soil	Bacterivores
Araeolaimida	Axolaimidae	*Axonolaimus*	Soil	Bacterivores
Enoplida	Alaimidae	*Alaimus*	Soil	Bacterivores
Rhabditida	Aphelenchidae	*Aphelenchus*	Soil	Fungivores
	Cephalobidea	*Cephalobus*	Soil	Bacterivores
Dorylaimida	Dorylaimidae	*Dorylaimus*	Soil	Omnivores
Rhabditida	Rhabditidae	*Diploscapter*	Soil	bacterivores
	Diplogasteridae	*Diplogaster*	Soil	Bacterivores
	Tylenchidae	*Filenchus*	Soil	Fungivores
	Hoplolamidae	*Helicotylenchus*	Soil/Root	Herbivores - semi-endoparasites
Dorylamida	Longidoridae	*Longidorus*	Soil	Herbivores - ectoparasites
Rhabditida	Meloidogynidae	*Meloidogyne*	Soil/Root	Herbivores - sedentary parasites
	Criconematidae	*Mesocriconema*	Soil	Herbivores - ectoparasites
Monhysterida	Monhysteridae	*Monhystera*	Soil	Bacterivores
Dorylaimida	Mononchidae	*Mononchus*	Soil	Predators
Rhabditida	Plectidae	*Plectus*	Soil	Bacterivores
	Pratylenchidae	*Pratylenchus*	Soil/Root	Herbivores - migratory endoparasites
	Pratylenchidae	*Radopholus*	Soil	Herbivores - migratory endoparasites
	Hoplolamidae	*Rotylenchulus*	Soil/Root	Herbivores - sedentary parasites
	Rhabditidae	*Rhabditis*	Soil	Bacterivores
Enoplida	Tripyloidea	*Tripyla*	Soil	Predators
Rhabditida	Tylenchidae	*Tylenchus*	Soil	Herbivores - epidermal/root hair feeders
	Telotylenchidae	*Tylenchorhynchus*	Soil	Herbivores - ectoparasites
Enoplida	Prismatolaimidae	*Prismatolaimus*	Soil	Bacterivores
Dorylaimida	Longidoridae	*Xiphinema*	Soil/Root	Herbivores - ectoparasites
	Tylencholaimellidae	*Tylencholaimellus*	Soil	Fungivores
Plectida	Plectidae	*Wilsonema*	Soil	Bacterivores

Table 3 Prevalence and population densities of the nematode community in each coconut biotype studied in agroecosystems of the Dominican Republic, from February to September 2021.

Biotypes	**Genus**	**n**[3]	**Prevelance**[1]	**Density**[2]
Atlantic Tall (39)[4]	*Acrobeles*	3	7.69	0.77
	Axonolaimus	2	5.13	0.51
	Alaimus	4	10.26	2.31
	Aphelenchus	31	79.49	35.38
	Cephalobus	6	15.38	2.82
	Dorylaimus	24	61.54	14.87
	Diplocapter	7	17.95	3.85
	Diplogaster	2	5.13	0.51
	Filenchus	2	5.13	1.28
	Helicotylenchus	21	53.85	70.77
	Longidorus	1	2.56	0.26
	Meloidogyne	15	38.46	19.23
	Mesocriconema	5	12.82	2.05
	Monhystera	7	17.95	2.31
	Mononchus	1	2.56	0.26
	Plectus	6	15.38	1.03
	Pratylenchus	9	23.08	4.87
	Rotylenchulus	11	28.21	11.79
	Rhabditis	30	76.92	42.31
	Tripyla	19	48.72	9.74
	Tylenchus	32	82.05	48.21
	Tylenchorhynchus	4	10.26	1.79
	Prismatolaimus	5	12.82	2.31
	Xiphinema	3	7.69	0.77
	Tylencholaimellus	11	28.21	16.15
	Helicotylenchus [5]	16	41.03	4.87
	Meloidogyne[5]	3	7.69	1.03
	Pratylenchus[5]	7	17.95	2.05
	Rotylenchulus[5]	8	20.51	2.31
	Xiphinema[5]	1	2.56	0.26
Brazilian Green Dwarf (20)	*Acrobeles*	3	15	3.5
	Alaimus	2	10	1
	Aphelenchus	16	80	25.5
	Cephalobus	4	20	4.5
	Dorylaimus	12	60	14
	Diplocapter	1	5	1
	Helicotylenchus	9	45	9.5
	Meloidogyne	7	35	9
	Monhystera	4	20	2.5

Biotypes	Genus	n[3]	Prevelance[1]	Density[2]
	Mononchus	1	5	0.5
	Pratylenchus	3	15	3.5
	Radopholus	1	5	1
	Rotylenchulus	7	35	17.5
	Rhabditis	17	85	32
	Tripyla	3	15	2
	Tylenchus	18	90	34.5
	Xiphinema	1	5	5.5
	Wilsonema	2	10	1.5
	Helicotylenchus[5]	1	5	1.5
	Rotylenchulus[5]	1	5	0.5
Unknown hybrid 1 (1)[6]	*Aphelenchus*	1	100	70
	Dorylaimus	1	100	60
	Diplocapter	1	100	10
	Monhystera	1	100	10
	Rotylenchulus	1	100	20
	Rhabditis	1	100	100
	Tripyla	1	100	10
	Tylenchus	1	100	50
Unknown hybrid 2 (1)[6]	*Aphelenchus*	1	100	20
	Helicotylenchus	1	100	20
	Rotylenchulus	1	100	3.33
	Rhabditis	1	100	60
	Tylenchus	1	100	50
	Helicotylenchus [5]	1	100	10
Malayan Yellow Dwarf (3)	*Axonolaimus*	1	33.33	3.33
	Aphelenchus	3	100	90
	Cephalobus	2	66.67	30
	Dorylaimus	2	66.67	26.67
	Monhystera	1	33.33	3.33
	Mononchus	1	33.33	3.33
	Pratylenchus	1	33.33	3.33
	Rotylenchulus	2	66.67	30
	Rhabditis	2	66.67	50
	Tripyla	1	33.33	3.33
	Tylenchus	3	100	173.33
	Xiphinema	1	33.33	3.33
	Helicotylenchus[5]	1	33.33	3.33
	Meloidogyne [5]	1	33.33	3.33

Biotypes	**Genus**	**n**[3]	**Prevelance**[1]	**Density**[2]
Maypan Hybrid (3)	*Aphelenchus*	3	100	66.67
	Dorylaimus	2	66.66	20
	Helicotylenchus	1	33.33	3.33
	Meloidogyne	1	33.33	3.33
	Monhystera	1	33.33	3.33
	Mononchus	1	33.33	3.33
	Pratylenchus	1	33.33	6.67
	Prismatolaimus	1	33.33	10
	Rotylenchulus	1	33.33	3.33
	Rhabditis	3	100	80
	Tripyla	2	66.66	10
	Tylenchus	3	100	23.33
	Xiphinema	2	66.66	6.67
	Helicotylenchus[5]	1	33.33	3.33
	Pratylenchus [5]	1	33.33	3.33
Chactemal Hybrid (2)	*Aphelenchus*	2	100	15
	Cephalobus	1	50	5
	Helicotylenchus	1	50	10
	Meloidogyne	1	50	5
	Rhabditis	1	50	10
	Tylenchus	1	50	10
	Helicotylenchus[5]	1	50	5
	Meloidogyne[5]	1	50	5

[1] Prevalence: (number of nematodes of given nematodes/total number of nematodes) x 100.

[2] Density (expressed as average, in number of individuals in 250 cm^3 of Soil and 20 grams of root respectively).

[3] n (is the total number of samples in which each genus was found within each biotype).

[4] Number in parentheses is the number that each biotype was sampled. [5] (root nematodes)

[6] Unknown hybrid 1 and 2 (different origins and distinctive morphological characteristics)

2.3.2Taxonomical diversity of nematodes associated with coconut biotypes

The density of nematodes is higher in the Tall coconut biotypes (mean 259.38 individuals per 250 cm^3 of soil), followed by the Dwarf biotype group (mean 191.86 individuals per 250 cm^3 of soil), and finally the Hybrid biotype group (mean 184.12 individuals per 250 cm^3 of soil). The R index revealed that the most diversified communities of PPNs and FLNs were associated with the Tall biotypes (6.42 genera), followed by the Hybrid group (5.61 genera), and the Dwarf biotype (5.35 genera). Although H' values did not vary much between biotypes, lower values were reported in the Hybrid group (1.33) (Table 4).

The index J and S showed similar values between the biotype groups. The Dwarf and Tall biotypes obtained the highest mean in both indices, with 0.85 for J in the Dwarf biotype group and 0.71 for S in the Tall biotype group. The index PPI ranged between 2.51 and 2.60, with the highest average observed in the Hybrid biotype group (2.60), while the lowest indices were found in the Tall group (2.51). The root nematode indices did not show much variability in terms of density, genus richness, diversity, dominance, evenness, interaction with herbivores, and herbivore footprint. The Tall and Dwarf biotypes had higher density and diversity, while the Hybrid biotype had the lowest density. The Tall and Hybrid biotypes showed low significance regarding density at the 0.05% level for soil samples. For the other indices, no significant differences were observed between the biotypes (Table 4).

The taxonomic diversity associated with coconut reported in our study differs from that observed in the coconut in India (Koshy; Sosamma; Premachandran, 1977), coconut nurseries in Pakistan (Khan *et al.* 1992), and in coconut plantations in India (Rama; Dasgupta, 2000). The variations in reported diversities could be attributed to the specific scopes of the studies and the varying densities documented. For instance, soil samples from date palm in Egypt reported 250 nematodes per 250 cm^3 of soil (Ibrahim; Handoo; El-Sherbiny, 2000), while in coconut plantations across three districts of India, a density of 54.8 nematodes per liter of soil was recorded (Rama; Dasgupta, 2000). The FLNs with higher density in our study were *Aphelenchus, Dorylaimus, Rhabditis,* and *Trypila*, while other studies report that dorylaimids, rhabditids, and mononchids recorded higher density associated with fruit crops (Pradhan; Patra; Sahoo, 2020). In this scenario, taxonomic diversity emphasizes both PPNs and FLNs, with the reported density and prevalence fluctuating based on the crop type, soil, and environmental factors specific to each sampled location.

Table 4 Taxonomic and functional diversity indices (mean) and analysis of metabolic footprints of the nematode community between coconut biotypes in Dominican Republic, from February to September 2021.

Sample	**Biotype**	**Taxonomic diversity**						**Functional diversity**	
		R	**D**	**H’**	**S**	**J**	**PPI**	**Herbivore footprint**	**Fungivore footprint**
soil	Tall	6.42	259.38	1.46	0.71	0.83	2.51	228.59	7.23
	Dwarf	5.61	191.86	1.39	0.69	0.85	2.52	107.24	3.28
	Hybrid	5.35	184.12	1.33	0.69	0.84	2.60	28.00	3.22
	p-value	**0.1**	**0.01**	**0.1**	**0.1**	**0.1**	**0.8**	**0.2**	**0.07**
root	Tall	1.58	18.08	0.36	0.24	0.97	3.05	23.14	------
	Dwarf	1.40	14.00	0.28	0.20	1.00	3.00	56.36	--------
	Hybrid	1.10	11.00	0.07	0.05	1.00	3.00	36.60	--------
	p-value	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.9**	**0.7**	----------

R: Richness = generic richness (number of genera), D: Density = total number of PPN in 250 cm^3 of soil/ in root (20 g), Shannon (H') = Shannon index or local diversity, S: Simpson, J: Pielou's evenness index, uniformity, PPI = plant parasitic nematodes index

2.3.3 Functional diversity of nematodes associated with coconut biotypes

The abundance of herbivores and fungivores nematodes showed marked variability among the studied biotypes. The analysis revealed that herbivores nematodes were the most prevalent in the communities of PPNs associated with coconut biotypes (10 herbivores *versus* 3 fungivores) (Table 5). The Tall biotypes recorded the highest herbivore footprint (228.59), while the Hybrid biotypes showed the lowest herbivore footprint (28.00). The footprint of fungal nematodes also showed higher values in the Tall biotypes (7.23) and Hybrid biotypes (3.22) (Table 5).

Regarding soil nematodes, our findings reveal patterns of association between biotypes and genera in different dimensions. In relation to PPNs, a greater distribution of nematodes that feed on the epidermis and root hairs was generally observed, with the Hybrid biotypes showing the highest percentage (46.60%), followed by Dwarf biotypes (43.33%), and Tall biotypes (43.10%). For FLNs, both fungivores and bacterivores nematodes were present in all biotypes. In relation to fungivores, the Tall biotypes stood out with a recorded percentage of 38.90%, while for bacterivores nematodes, the Hybrid biotypes obtained the highest percentage (47.90%) (Table 5).

The p-p 2 and p-p 3 groups (PPNs) exhibited the highest density. In the p-p 2 group, the highest percentage was observed in the Dwarf biotypes (54.60%), followed by Hybrid biotypes (50.80%), and Tall biotypes (45.80%). In the p-p 3 group, the highest percentage was observed in the Tall biotypes (53.10%), followed by Hybrid biotypes (45.90%), and Dwarf biotypes (42.0%). The c-p 1 group (FLNs) was observed in the Hybrid biotypes (36.40%), Tall biotypes (32.80%), and Dwarf biotypes (25.30%). Meanwhile, in the c-p 2 group, the highest percentage was observed in the Dwarf biotypes (46.60%), Hybrid biotypes (39.60%), and Tall biotypes (39.0%) (Table 5). In our study, for FLNs, groups c-p 1 and c-p 2 have the highest percentage in the Hybrids biotypes of the c-p 1 group, mostly represented by *Rhabditis* and, to a lesser extent by *Diplogaster*. For the c-p 2 group, the highest percentages were recorded in the Dwarf and Tall biotypes, with *Aphelenchus, Filenchus, Acrobeles, Cephalobus, Monhystera, Plectus,* and *Wilsonema* (Table 5).

The highest proportion in the structure index and enrichment index in our study is found in the Hybrid biotypes (enrichment = 78.39%) and Tall biotypes (structure = 64.20%). The index MI of the soils associated with coconut was relatively low (< 3), with the highest index being obtained by the Tall biotypes (mean of 2.31) (Table 5). This type of habitat is considered to have a higher content of organic matter and greater bacterial activity, favoring colonizing nematodes that feed on bacteria and reproduce rapidly compared to persistent nematodes that decrease (Freckman; Ettema, 1993). The application of nitrogen fertilization in the agroecosystem yields varied outcomes. While it enhances microbial activity and diminishes the maturity index of nematodes, it also boosts plant biomass, potentially elevating the parasite ratio index as a greater number of nematodes feed on the plants (Bongers; Bongers, 1998).

In our study, it was observed that *Tylenchus* was the only genus of nematode recorded to feed on the epidermis and absorbing roots, and it exhibited a percentage greater than 45% in all three groups of biotypes (Table 5). In contrast, the report on functional diversity in oil palm plantations also highlights the Tylenchidae, but in a smaller proportion (6.7%), with the herbivores group in a higher proportion (31.2%) (Krashevska *et al*. 2019). Other studies report *Pratylenchus* and *Radopholus* parasitizing the cortex and endodermis cells, leading to tissue death and necrosis (Guzmán-Piedrahita; Zamorano-Montañez; López-Nicora, 2020). Among the 17 FLNs, the most predominant were bacterivores and fungivores. This functional diversity has also been documented in oil palm (Krashevska *et al*. 2019), as well as in fertile alfalfa cultivation soils harboring bacterivores (Cephalobidae) (Parveen *et al*. 2022), with high densities of this group typically observed in warm climates (Fitoussi; Pen-Mouratov; Steinberger, 2016). However, the presence of bacterivores and fungivores nematodes in our study might be influenced by the availability of nitrogen and phosphorus in the sampled agroecosystems. Moreover, these nematodes could be engaged in the consumption and dispersal of both beneficial and pathogenic bacteria (Cares; Huang, 2012).

In contrast to our study, a study conducted on soil quality found that omnivorous nematodes were more prevalent than bacterivores, fungivores, and predators. This is likely attributed to soil disturbances caused by intensive agricultural and livestock activities (Romero; Castilla Díaz; Millán Páramo, 2016).

The PPNs in our study are primarily associated with *Tylenchus*, which is more prevalent in the Dwarf and Hybrid biotypes. Additionally, in the p-p3 group, other genera (*Helicotylenchus, Rotylenchulus,* and *Meloidogyne*) were more prevalent in the Tall biotypes. However, these nematodes were also reported in tomato cultivation in p-p 2 (Tylenchidae) and p-p 3 (*Pratylenchus*) groups, along with the significant parasite *Xiphinema* (p-p 5) in soils with pore spaces less than 250 mm (Briar *et al.* 2011). Although there is a significant difference in phenology between coconut and tomato crops, our results show similarities in some of the p-p groups found. It is worth noting that these nematode groups have a wide range of hosts and have been previously recorded in various crops (Davis; MacGuidwin, 2000; Archidona-Yuste *et al*. 2016; Qing; Bert, 2019).

Organisms in the c-p 1 group feed on bacteria, and have a short life cycle, high reproductive capacity, manifest their activity only during phases of high bacterial biomass and are known as enrichment colonizers. On the other hand, the c-p 2 group has a relatively short life (bacterivores and fungivores) and shows tolerance to environmental disturbances (disturbance colonizer) (Bongers, 1990). In intensive agricultural systems and under conditions of soil disturbance, the exclusion of persistent nematodes, such as those identified by Bongers (1990) as c-p 4 and c-p 5, which are sensitive to environmental disturbances, can occur. Therefore, it is possible that nematodes belonging to the c-p 5 group were not recorded in our study, as they are sensitive to environmental disturbances.

Our results are similar to those reported by Bhuiyan *et al*. (2020), indicating low maturity of the soil food web and the constant use of chemical fertilizers. The MI assesses the average contribution of each cp group to the nematode community so that in soils with higher MI values, there is a greater participation of nematodes especially susceptible to disturbances. Thus, the MI serves as an indicator of the state of ecological succession (Sánchez-Moreno; Taravela, 2013).

Table 5 Nematode taxa, common name, place of reporting and type of feeding of the nematode community associated with coconut biotypes of the Dominican Republic, from February to September 2021.

	Soil				**Root**			
Index name	**Dwarf**	**Hybrid**	**Tall**	**Anova,p**	**Dwarf**	**Hybrid**	**Tall**	**Anova,p**
Maturity Index*	2.14	1.98	2.31	0.44	NA	NA	NA	-
Plant Parasitic Index*	2.52	2.60	2.51	0.84	3.00	3.00	3.05	0.90
Enrichment Index*	73.39	78.39	74.61	0.85	NA	NA	NA	-
Structure Index*	54.56	45.22	64.20	0.32	NA	NA	NA	-
Herbivore footprint*	107.24	28.00	228.59	0.22	56.36	36.60	23.14	0.68
Fungivore footprint*	3.28	3.22	7.23	0.07	NA	NA	NA	-
Herbivores, % (PPNs)	43.30	46.60	43.10	-	100.00	100.00	100.00	-
Fungivores, % (FLNs)	37.80	34.20	38.90	-	NA	NA	NA	-
Bacterivores, % (FLNs)	38.20	47.90	44.00	-	NA	NA	NA	-
Predators, % (FLNs)	3.50	3.80	6.80	-	NA	NA	NA	-
Omnivores, % (FLNs)	20.40	14.10	10.30	-	NA	NA	NA	-
Sedentary parasites, % (PPNs)	29.10	25.00	20.70	-	75.00	16.70	28.40	-
Migratory endoparasites, % (PPNs)	5.00	2.90	2.80	-	0.00	33.30	20.10	-
Semi-endoparasites, % (PPNs)	7.90	18.00	27.00	-	25.00	50.00	49.20	-
Ectoparasites, % (PPNs)	3.40	3.40	3.70	-	-	-	-	-
Epidermal/root hair feeders, % (PPNs)	54.60	50.80	45.80	-	-	-	-	-
C-P 1, % (FLNs)	25.30	36.40	32.80	-	NA	NA	NA	-
C-P 2, % (FLNs)	47.60	39.60	39.00	-	NA	NA	NA	-
C-P 3, % (FLNs)	3.40	8.50	7.80	-	NA	NA	NA	-
C-P 4, % (FLNs)	23.70	15.40	20.40	-	NA	NA	NA	-
P-P 2, % (PPNs)	54.60	50.80	45.80	-	-	-	-	-
P-P 3, % (PPNs)	42.00	45.90	53.10	-	100.00	100.00	97.70	-
P-P 5, % (PPNs)	3.40	3.40	1.10	-	0.00	0.00	2.30	-

PPNs: plant-parasitic nematodes, FLNs: free-living nematodes.

* Expressed population average

N/A: does not apply

2.3.4 Dominance of nematode genera associated with coconut biotypes

The dominance of soil and root nematodes was examined in different coconut biotypes. A total of six genera were identified, with four being the most dominant among the coconut biotype groups. These six genera were equally divided between three PPNs (*Helicotylenchus, Rotylenchulus,* and *Tylenchus*) and three FLNs (*Aphelenchus, Dorylaimus,* and *Rhabditis*) (Figure 1). In the Tall biotype group, 25 genera were recorded, with *Helicotylenchus, Tylenchus, Rhabditis,* and *Aphelenchus* being the most abundant. In the Dwarf biotype group, 20 genera were recorded, with *Tylenchus, Rhabditis, Aphelenchus,* and *Rotylenchulus* being the most abundant. In the Hybrid biotype group, 17 genera were recorded, with *Rhabditis, Tylenchus, Aphelenchus,* and *Dorylaimus* being the most abundant.

Among the four most dominant genera in the biotype groups, *Helicotylenchus*, *Tylenchus, Rhabditis,* and *Aphelenchus* were observed. *Rhabditis* was recorded in the Tall biotypes with an abundance of 1,650 specimens by 250 cm^3, in the Dwarf biotypes with an abundance of 750 specimens by 250 cm^3, and in the Hybrid biotypes with an abundance of 280 specimens by 250 cm^3. *Tylenchus* showed dominance in the Tall biotypes with an abundance of 1,880 specimens by 250 cm^3, in the Dwarf biotypes with an abundance of 1,200 specimens by 250 cm^3, and in the Hybrid biotypes with an abundance of 220 specimens by 250 cm^3. *Aphelenchus* displayed dominance in the Tall biotypes with an abundance of 1,380 specimens by 250 cm^3, in the Dwarf biotypes with an abundance of 740 specimens by 250 cm^3, and in the Hybrid biotypes with an abundance of 260 specimens by 250 cm^3. *Helicotylenchus* with an abundance of 2,760 specimens by 250 cm^3 was the most dominant genus, primarily observed in the Tall biotypes. Additionally, *Dorylaimus* was observed in the Hybrid biotypes with an abundance of 140 specimens/250 cm^3, and *Rotylenchulus* was identified as dominant in the Tall biotypes with an abundance of 460 specimens/250 cm^3 (Figure 1).

2.3.5 Correspondence analysis between nematodes and coconut biotypes

The correspondence analysis shows no significant association between the two variables with a chi-square of independence of 49.90 (p = 0.6331). From correspondence analysis, we observed that the first and second dimensions explain 72.88% and 27.12%, respectively (Figure 2). The biotype groups "Tall" are positively associated with dimension 1, while the biotype groups "Dwarf and Hybrid" are negatively associated with dimension 1. In relation to genus, *Diplocapter*, *Diplogaster* and *Filenchus* are strongly associated with dimension 1, and A*xonolaimus*, *Acrobeles* and *Alaimus* are associated with dimension 2.

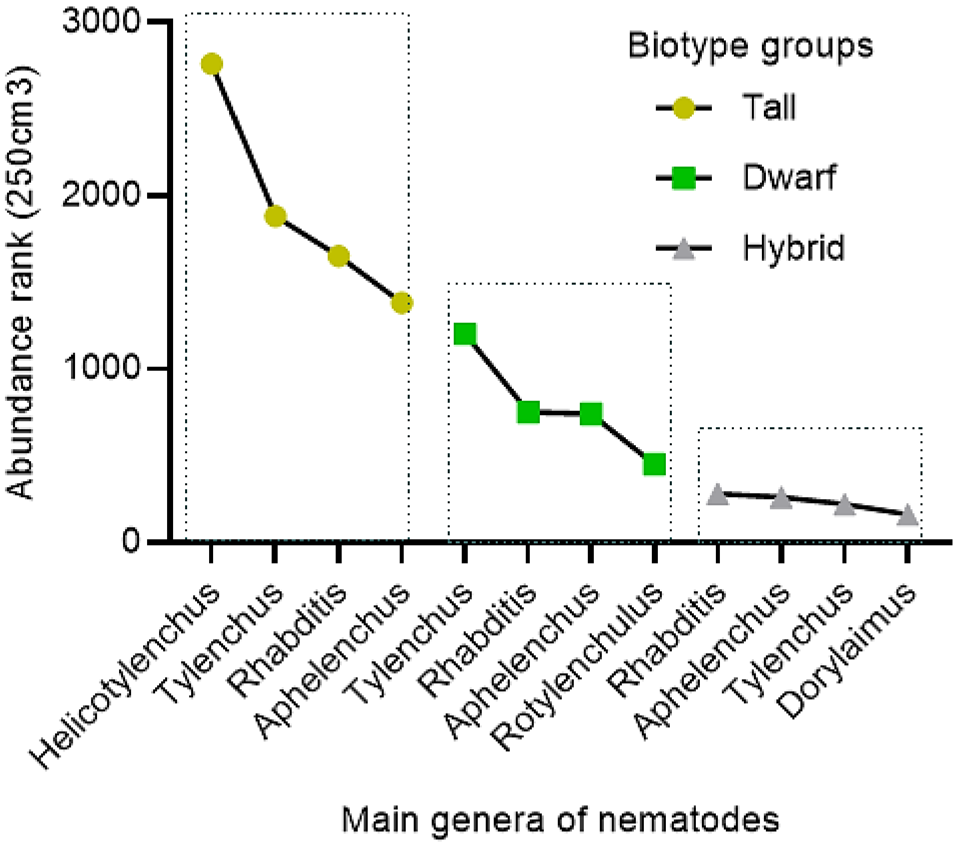
The correspondence analysis for coconut biotypes and nematodes shows in root samples that there is no significant association between the two variables with a chi-square of independence of 4.1272 (p = 0.8455). The correspondence for the root nematode community and biotypes explains 62.13% and 37.87% of the variance in CA (eigenvalues), with dimensions 1 and 2 explaining most of the variance. However, patterns of association were observed between some coconut biotypes and nematode genera in different dimensions. These results indicate that some biotypes and genera are related in certain dimensions, although the overall association is not significant.

The functional diversity of nematodes is associated with soil quality and crop health, and their functional inference could help better understand management in agroecosystems (Sánchez-Moreno; Talavera, 2013). Temperature, humidity, larval quantity, body size, stylet length, and colonization pattern influence nematode competitiveness. Periodic disturbances such as plowing, pesticides, and fertilization reduce agroecosystem diversity. Plowing stimulates mineral release and favors opportunistic organisms, while pesticides affect soil biota through plants. Manure fertilization can increase the biomass of a nematode group known as Ba-1 (Bongers; Bongers, 1998).

The findings underscored the impact of various coconut biotypes examined through analysis of D and metabolic footprints of fungal nematodes. There were no notable effects observed on H', S, J, PPI and the compositions of herbivores nematodes. It is worth noting that the richness of nematode genera/coconut biotype groups documented in this study was relatively modest, ranging from 5.63 to 6.89. The limited diversity in richness observed could be attributed to the restricted number of samples collected, which was influenced by the accessibility of producers and the prevalence of specific coconut biotypes at each sampling site. For instance, the Hybrid group consisted of five biotypes, but each of those biotypes had only one sample, except for the Hybrid biotype. This implies the necessity for more samples to conduct a comprehensive evaluation study. It can also be influenced by soil characteristics or human interventions on each farm through agricultural practices such as tillage, irrigation, fertilization, and the use of nematicides, among others, which promote the proliferation and predominance of certain nematodes at the expense of others, increasing their population levels (Ali, 2023).

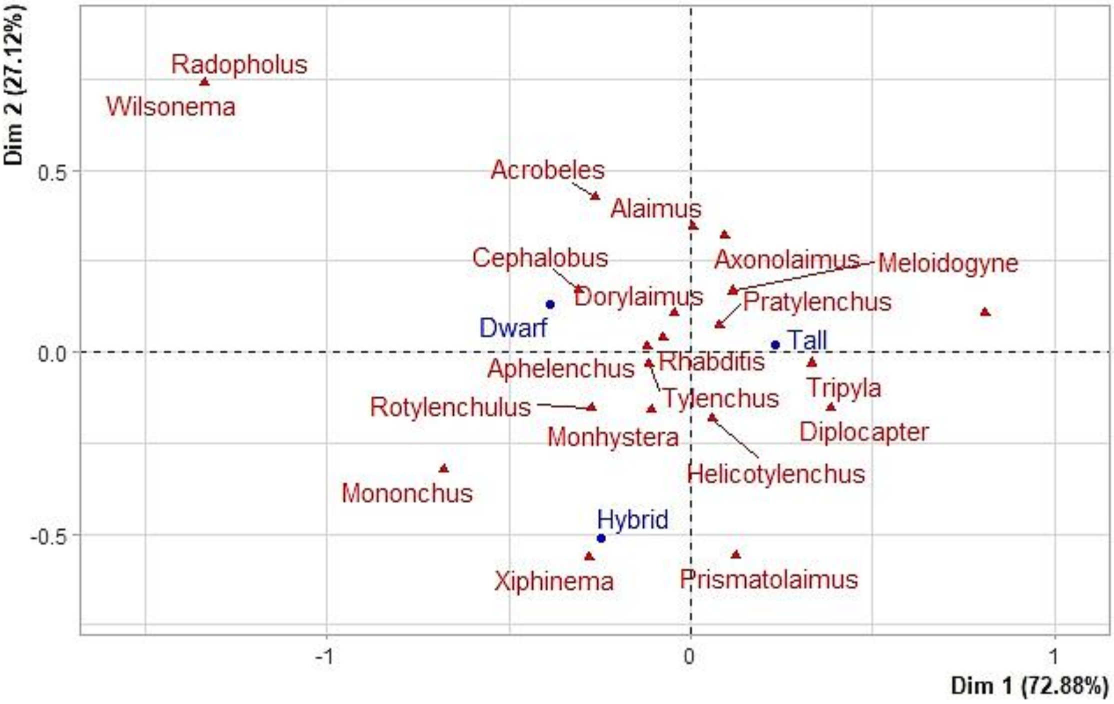
Regarding herbivores nematodes, high dominance and prevalence are observed in the studied biotype groups, except in the Hybrid biotype group, where a low average of herbivores nematodes was detected. In this biotype, dominance is primarily attributed to bacterivores nematodes. Therefore, the prevalence of herbivores, identified by their feeding behavior as obligate parasites, could anticipate potential damage in the biotypes. It also suggests a higher accumulation of carbon and energy in the system (Ali, 2023). This phenomenon could indicate the existence of an intensive agricultural system with significant soil disturbance and high herbivores pressure (Bhuiyan *et al*. 2020). This highlights that different biotypes belonging to the same crop may react differently to nematode infection, showing some sensitivity while others exhibit resistance (Ali, 2023).

Figure 1 Dominance diagram of nematodes in the soil rhizosphere in coconut crops, Dominican Republic, from February to September 2021



The dotted lines represent the transition (laminar) between the ranges of nematode genera with low and high relative abundance, as described by the Whittaker Diagram for 3 coconut biotypes groups (Tall, Dwarf and Hybrid)

Figure 2 Correspondence analysis of nematode in the soil rhizosphere and coconut biotypes in coconut crops, Dominican Republic, from February to September 2021



2.4 Conclusions

The highest density and prevalence of PPNs are associated with the crop rhizosphere (*Helicotylenchus*, *Tylenchus, Rotylenchulus, Meloidogyne* and *Pratylenchus*) and FLNs (*Rhabditis, Aphelenchus, Trypila* and *Dorylaimus*).

In the Tall biotypes, we record 25 genera, in the Dwarf biotypes, we observe 20 genera, and in the Hybrid biotypes, we record 17 genera.

The most dominant PPNs are *Helicotylenchus, Rotylenchulus* and *Tylenchus*, while the FLNs are *Aphelenchus, Dorylaimus* and *Rhabditis*.

Regarding the soil, the correspondence analysis reveals patterns of association between coconut biotypes and nematode genera in different dimensions. Dimensions 1 and 2 explain most of the variability in the data.

The biotype groups "Tall" are positively associated with dimension 1, while the biotype groups "Dwarf and Hybrid" are negatively associated with dimension 1. In relation to genus, *Diplocapter*, *Diplogaster* and *Filenchus* are strongly associated with dimension 1, and A*xonolaimus*, *Acrobeles* and *Alaimus* are associated with dimension 2.

The p-p 2 and p-p 3 nematode groups are the ones with the highest percentage associated with the biotype’s groups. The c-p 1 and c-p 2 nematode groups are recorded with the highest percentage in the biotype’s groups.

3 CHAPTER II – Distribution of plant parasitic nematodes associated with coconut in the Dominican Republic

3.1 Introduction

The coconut (*Cocos nucifera* L.) is a species belonging to the family Arecaceae which encompasses approximately 190 genera and 2,800 species (Niral; Jerard, 2019). This plant plays a fundamental role in the economic, cultural, and social life of over 80 tropical countries (Khadke *et al*. 2019). It constitutes the most essential and versatile tree crop in the tropics, providing livelihoods and job security for rural farmers (Wankhede; Shinde; Ghavale, 2019). Notwithstanding, various biotic and abiotic factors have restricted the overall yield of this palm (Beveridge *et al*. 2022; Sujithra *et al*. 2022).

The coconut is attacked by various diseases that can affect the trunk, young nuts, and roots (Wankhede; Shinde; Ghavale, 2019). Plant parasitic nematodes (PPNs) can impact plant health by discreetly infesting its roots and reducing water and nutrient absorption (Briar; Wichman; Reddy, 2016; Guzmán-Piedrahita; Zamorano-Montañez; López-Nicora, 2020). Although PPNs rarely kill their host plant, they compromise the harvest. The most important PPNs in coconut are species of *Meloidogyne, Pratylenchus* (Anes; Arsha; Josephrajkumar, 2021), *Radopholus, Bursaphelenchus* (Griffith *et al*. 2018), *Helicotylenchus* (Rama; Dasgupta, 2000), *Rotylenchulus* (Ekanayake; Lamberti, 1987), *Xiphinema, Tylenchus,* and *Tylenchorhynchus* (Youssef; Lashein, 2013). These parasites can cause lesions, rotting, and gall formation in the roots and underground stems (Guzmán-Piedrahita; Zamorano-Montañez; López-Nicora, 2020).

Understanding the distribution of PPNs and their relationship with bioclimatic variables is crucial for developing effective management strategies to control their population levels and minimize the impact on crops (Márquez *et al*. 2021; Tang *et al*. 2021). For this reason, the spatial distribution of PPNs has been determined on different crops, such as *Vitis vinifera* L. (Howland; Schreiner; Zasada, 2014), *Citrus* (Mahfouz, 1992), *Solanum tuberosum* L. (Contina; Dandurand; Knudsen, 2020), *Coffea arabica* L. (Ghini *et al*. 2008), and *Zea mays* (Robertson; Freckman, 1995). In coconut, the distribution of *Bursaphelenchus cocophilus* in the aerial part of the plants has been determined in Brazil, but no association has been made with PPNs in the rhizosphere (Da Silva *et al*. 2016). Currently, there is no available information spatial on the distribution of PPNs in coconut in the Dominican Republic.

Climate change will affect plant-host relationships with an increase in disease problems (Ghini *et al*. 2008). In this context, the distribution of PPNs in crops can also be influenced by various bioclimatic factors, such as temperature, humidity, precipitation, and water availability (Hamza *et al*. 2018; Hirschfeld *et al*. 2020). The species distribution model (SDMs) is a machine learning-based prediction tool that helps forecast how climatic conditions will affect species dispersal (Tang *et al*. 2021).

Geospatial analysis of PPN and the use of bioclimatic variables could assist in the integrated management of PPN in coconut trees in the Dominican Republic, including future predictions of PPN populations. Here, we hypothesize that there is a large variation in PPNs taxa in the main productive regions and that there are variations in the distribution and influence of climatic factors. Then, we aimed in this study: (*i*) to map the spatial distribution of PPNs (*Helicotylenchus, Meloidogyne, Pratylenchus,* and *Rotylenchulus*) in coconut in the Dominican Republic to observe how they vary in relation to distance of distribution; (*ii*) to analyze the impact of bioclimatic variables on these PPNs using generalized linear models (GLMs); (*iii*) to evaluate the current and future predictions of the studied PPNs based on the collected geospatial and climatic dataset.

3.2 Materials and methods

All analyses of this study were carried out with the data obtained in the first chapter, in which soils and roots of coconut were sampled from biotypes Atlantic Tall, Brazilian Green Dwarf, Malayan Yellow Dwarf, Chactemal hybrid, MayPan hybrid, and unknown hybrid 1 on farms in the Dominican Republic. During this analysis, only the four most prevalent and abundant PPNs (*Helicotylenchus, Meloidogyne, Pratylenchus,* and *Rotylenchulus*) were used. The species identified within these genera were *Helicotylenchus abunaamai, H. californicus, H. dihystera, H. multicinctus, Meloidogyne arenaria, M. hapla, M. javanica, M. incognita, Pratylenchus coffeae, P. vulnus,* and *Rotylenchulus reniformis.*

In this work, prevalence (%) was defined as the ratio between the number of individuals belonging to a specific group (genus) and the total number of individuals recovered in 250 cm^3 of soil (Fleming *et al*. 2016). The abundance (nematodes by 250 cm^3 of soil) was defined as the number of individuals of a specific genus in the samples (Boag, 1992).

3.2.1 Building maps to obtain spatial distribution of major plant parasitic nematodes

The maps were created from the geographic coordinates and population information of the recorded PPNs using QGIS software version 3.18, a free tool accessible at http://qgis.osgeo.org (QGIS Development Team, 2022). The Environmental Systems Research Institute (ESRI) format with EPSG 4326-WGS 84 was employed, along with a 1:1700,000 scale vector map depicting the administrative divisions of the Dominican Republic. To obtain the territorial division boundaries, we used Shapefile data from the Dominican Republic. (https://data.humdata.org/dataset/cod-ab-dom).

3.2.2 Geostatistical analysis

Variogram analyses allowed us to examine the spatial variability of these PPNs in each province, aiming to quantify the variance (Vargas *et al*. 2009). This analysis was carried out using the free software QGIS and adjusted to the model with the highest R^2 and the lowest nugget.

The variogram assessed the relationship between semi-variance and increasing lag distance, indicating the presence of spatial autocorrelation, where ^z(x) values are spatially correlated within a specific distance (spatial dependence). As the lag distance increases, the values become progressively independent of each other (spatial independence) (Contina; Dandurand; Knudsen, 2020). Variograms assessed the variability between pairs of data points for these PPNs at different distances, fitting linear models to the resulting coefficients (Olmo, 2005). In all fields, the experimental variograms were fitted using a linear sill model (LTS). The LTS variogram models used allow for describing these trends in the spatial structure of the data for each type of PPN. The formula is below:

$$\mathbf{Y(h)=} \frac{1}{2NP(h)} \sum_{i=1}^{NP(h)} \{z(xi)-z(xi+h)\}^2$$

Where:

Y= experimental estimation of the function

h= increment in space of the point xi,

NP(h)= number of pairs of observations at distance h,

Z(Xi)= values of PPNs by provinces,

Xi= Location or point of measurement of z(Xi) values.

For the variogram data interpolation, we utilized the Inverse Distance Weighting (IDW) method. This technique assumes the values of the variables to be predicted at a specific location resemble the values observed at nearby points. The IDW method assigns weights to each observation point, with the weights decreasing as the distance from the prediction location increases. The control of this distance decay is determined by a power parameter (Yavuz; Erdogan, 2012; Kumar *et al*. 2018).

$$\mathbf{\hat{Z}(X)=} \sum_{i=1}^{n} \lambda_i Z(si)$$

Where:

Ẑ (S0) = represents the predicted value for the location S0,

n= stands for the count of sampled data points surrounding the location being predicted,

λi = symbolize the assigned weights for each sampled point,

Z(Si) = corresponds to the recorded value at the location si.

3.2.3 Relationships between plant parasitic nematodes and bioclimatic variables

Based on geographic coordinates (longitude and latitude), we collected data for 19 climate variables (Table 6) from the WorldClim database (https://www.worldclim.org/) (Fick; Hijmans, 2017). To avoid collinearity, we selected predictor variables that specifically influenced the studied nematode genera. This selection was based on a Pearson correlation coefficient greater than 0.8 (Yan *et al*. 2020; Tang *et al*. 2021), considering the respective variance inflation factors (VIF < 10) (Dormann *et al*. 2013). Subsequently, we employed generalized linear models (GLMs) (Garrett *et al*. 2004) incorporating bioclimatic variables and PPNs, with the selection criteria based on the Akaike Information Criterion (AIC) and VIF values. The GLMs selected for incidence underwent analysis of variance (ANOVA).

3.2.4 Present and future predictions of plant parasitic nematodes

Correlational distribution models were performed to determine the potential distribution of the selected PPNs. The climatic layers used for both present and future predictions were obtained from version 2.1 of WorldClim (Fick; Hijmans, 2017). For each PPN, variables with a VIF < 1.0 were selected. The climatic layers used in current and future predictions have a spatial resolution of 2.5 arc-minutes (approximately 4.5 km). For the future prediction, the MIROC6 climate prediction model from the Coupled Model Intercomparison Project 6 (CMIP6) was used, under two future socioeconomic projections (SSP). The SSP245 corresponds to the scenario in which efforts are made to reduce gas emissions by increasing the use of non-fossil energy sources and mitigating emissions from land use. On the other hand, the SSP585 corresponds to the scenario in which an economy based on fossil fuel use leads to increasing gas emissions over time (O'Neill *et al*. 2016; Riahi *et al*. 2017). These projections were considered for two different time intervals: 2021-2040 and 2041-2060. The different scenarios were presented with the following references: sglmf24530binary = SSP245 period 2020-2040, sglmf24550binary = SSP245 period 2041-2060, sglmf58530binary = SSP585 period 2020-2040, sglmf58550binary = SSP585 period 2041-2060. The baseline was used as a control to make comparisons.

To perform the modeling, the GLM method was chosen using the SSDM package (Schmitt *et al*. 2017). The 'modelling' function was employed to adjust the parameters, using 100 randomly distributed pseudo-absences and 10 repetitions for each prediction. These predictions were evaluated using the Total Sum of Squares (TSS) and Area Under the Curve (AUC) metrics. A total of 75% of the occurrence records were used to train the model, and the remaining 25% were used to evaluate the predictive capability of the model (Yan *et al*. 2020; Tang *et al*. 2021). Subsequently, maps were created for the projections.

3.2.5 Statistical analysis and packages used

The analyses for the bioclimatic variables and genus predictions were performed using R software version 4.2.1 (R Development Core Team, 2022). The following packages were utilized for the preparation of the bioclimatic variable data involved the use of the corrplot, usdm (Wei *et al.* 2017), vegan (Oksanen *et al*. 2022), terra (Hijmans *et al*. 2022), geodata (Hijmans *et al*. 2023), sdm (Naimi; Araujo, 2016), rgdal (Bivand *et al*. 2015), glm2 (Marschner *et al*. 2018), Maptools (Bivand *et al*. 2023) packages. For the present and future projections of PPNs and map creation, the Pacman package (Pontén *et al*. 2023) was used.

Table 6 Bioclimatic variables used in plant parasitic nematodes distribution models obtained from the WordClim database

Bioclimatic Variables	Description	Unit
BIO1	Average annual temperature	º C
BIO2	Average diurnal range (monthly average (maximum temperature - minimum temperature))	º C
BIO3	Isothermality (BIO2/BIO7) (*100)	º C
BIO4	Temperature seasonality (standard deviation of temperatures * 100)	º C
BIO5	Maximum temperature of the hottest month	º C
BIO6	Minimum temperature of the coldest month	º C
BIO7	Annual temperature range (BIO5-BIO6)	º C
BIO8	Average temperature of the wettest quarter	º C
BIO9	Average temperature of the driest quarter	º C
BIO10	Average temperature of the warmest quarter	º C
BIO11	Average temperature of the coldest quarter	º C
BIO12	Annual precipitation	mm
BIO13	Precipitation of the wettest month	mm
BIO14	Precipitation of the driest month	mm
BIO15	Precipitation seasonality (coefficient of variation)	mm
BIO16	Wettest room precipitation	mm
BIO17	Precipitation of the driest quarter	mm
BIO18	Precipitation of warmest quarter	mm
BIO19	Precipitation of the coldest quarter	mm

3.3 Results and discussion

3.3.1 Spatial distribution of the major plant parasitic nematodes associated with coconut in the Dominican Republic

The spatial prevalence of *Helicotylenchus* varies significantly among provinces. It is highest in Maria Trinidad Sánchez (75.45%), followed by La Altagracia (66.67%), Hato Mayor and Samana (57.14%), El Seibo (53.33%), Monte Cristi (32.14%), San Cristóbal (25.00%), Barahona (7.69%), and Bahoruco (4.76%). *Helicotylenchus* was not detected in Monte Plata and San Pedro de Macoris (Table 7, Fig. 3).

Meloidogyne has a spatial prevalence of 100% in Monte Plata and 62.50% in San Cristóbal. It was also found in Hato Mayor (14.29%), Maria Trinidad Sánchez (16.17%), and Bahoruco (28.57%). The highest spatial prevalence of

Pratylenchus was found in Barahona (25.64%) and Bahoruco (23.81%). It was also found in Hato Mayor (14.29%), El Seibo (10.00%), and Maria Trinidad Sánchez (1.50%). *Rotylenchulus* has the highest spatial prevalence in San Pedro de Macorís (100%), Barahona (66.67%), and Monte Cristi (57.14%), followed by Samaná (42.86%), Bahoruco (42.86%), and Maria Trinidad Sánchez (6.89%). It was also detected in El Seibo (13.33%) and San Cristóbal (12.50%) (Table 7, Fig. 3). These data reveal how different the nematode genera are distributed across the different provinces. Some provinces have a high prevalence of certain PPNs genera, while other genera may be absent or present in much lower proportions. These results are valuable for understanding the spatial distribution of these nematodes and may have implications for agricultural practices and crop management in each province.

Our study provides a comprehensive analysis of the spatiotemporal dynamics of *Helicotylenchus, Meloidogyne, Pratylenchus,* and *Rotylenchulus* in the Dominican Republic. Our study presents the first data on the spatial distribution, the influence of bioclimatic variables, and future predictions of the major PPNs associated with coconut in the Dominican Republic. These PPNs have been reported in several studies on coconut conducted by different authors (Ekanayake; Lamberti, 1987; Rama; Dasgupta, 2000). The spatial prevalence of *Rotylenchulus* was recorded in ten provinces, being the genus with the widest distribution among them. On the other hand, *Helicotylenchus* was observed in nine provinces, *Meloidogyne* in seven provinces, and *Pratylenchus* was only recorded in five provinces. These findings demonstrate a wide distribution of PPNs in coconut, which could represent a significant limitation in the future.

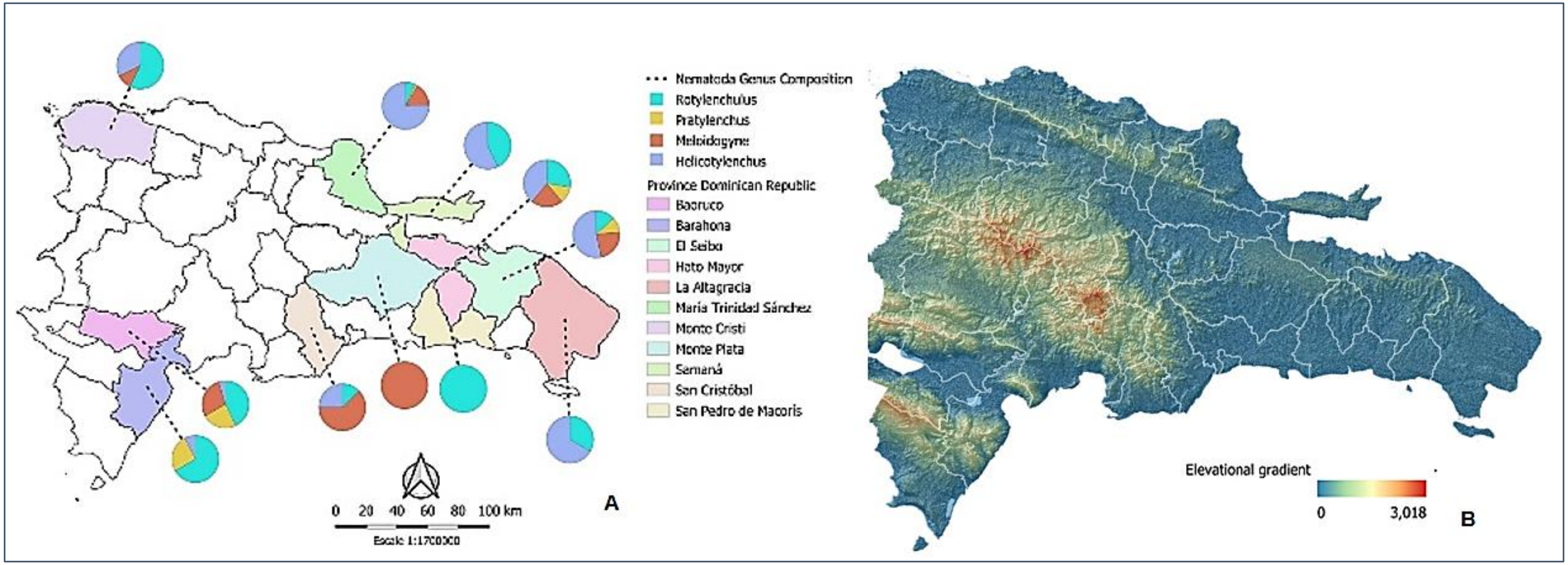
The genera *Meloidogyne* (Monte Plata province) and *Rotylenchulus* (San Pedro de Macorís province) showed the highest prevalences, reaching 100%. On the other hand, the genus *Helicotylenchus* recorded a prevalence of 75.45% in María Trinidad Sánchez province, while *Pratylenchus* showed a prevalence of 25.64% in Barahona province, which was the lowest among the four genera. El-Sherbiny (2019) reported a prevalence of *Meloidogyne* (46.7%), *Rotylenchulus* (33.3%), *Helicotylenchus* (27.6%), and *Pratylenchus* (6.7%) in doum palms (*Hyphaene thebaica*). Similar to our study, *Meloidogyne* and *Rotylenchulus* showed the highest prevalence, although, in our work, this prevalence was localized by province. In studies of biology, ecology and plant pathology, accurate information on the prevalence and spatial distribution of PPNs is essential for decision-making (Cruz-Cárdenas *et al*. 2013).

Table 7 Spatial prevalence of the plant parasitic nematodes (*Helicotylenchus, Meloidogyne, Pratylenchus,* and *Rotylenchulus*) from provinces in coconut crops, Dominican Republic, from February to September 2021.

	Spatial prevalence (%)			
Provinces	***Helicotylenchus***	***Meloidogyne***	***Pratylenchus***	***Rotylenchulus***
Bahoruco	4.76	28.57	23.81	42.86
Barahona	7.69	0.00	25.64	66.67
El Seibo	53.33	23.33	10.00	13.33
Hato Mayor	57.14	14.29	14.29	14.29
La Altagracia	66.67	0.00	0.00	33.33
Maria Trinidad Sánchez	75.45	16.17	1.50	6.89
Monte Cristi	32.14	10.71	0.00	57.14
Monte Plata	0.00	100.00	0.00	0.00
Samaná	57.14	0.00	0.00	42.86
San Cristóbal	25.00	62.50	0.00	12.50
San Pedro de Macorís	0.00	0.00	0.00	100.00

Prevalence: (number of nematodes of given PPN/total number of PPNs) x 100.

Figure 3 Map of the Dominican Republic. (A) Spatial distribution map of the plant parasitic nematodes (*Helicotylenchus, Meloidogyne, Pratylenchus,* and *Rotylenchulus*) from provinces in coconut crops, Dominican Republic, from February to September 2021 (B) Elevation gradient visualization



3.3.2 Variogram analysis for plant parasitic nematodes

The variogram values indicate that the data exhibit strong variability at very short or zero distances (nugget effect), and the spatial autocorrelation resembles an LTS model. These parameters indicate that the data show a linear trend in variability as the distance increases, and this variability of the variance stabilizes at a value of 986.6 at approximately 100,410.3 hectares for *Helicotylenchus* (Figure 4A). In contrast, for *Meloidogyne*, the variability stabilizes at a value of 56.7 at an approximate distance of 106,305.6 hectares (Figure 4B). For *Pratylenchus*, the variability stabilizes starting from 45.9 with a nearby distance of 133,357.3 hectares (Figure 4C). However, for *Rotylenchulus*, the variability reaches 306.4 at an approximate distance of 230,434.2 hectares (Figure 4D). These data indicate how the variability of different PPNs varies as the distance between points increases.

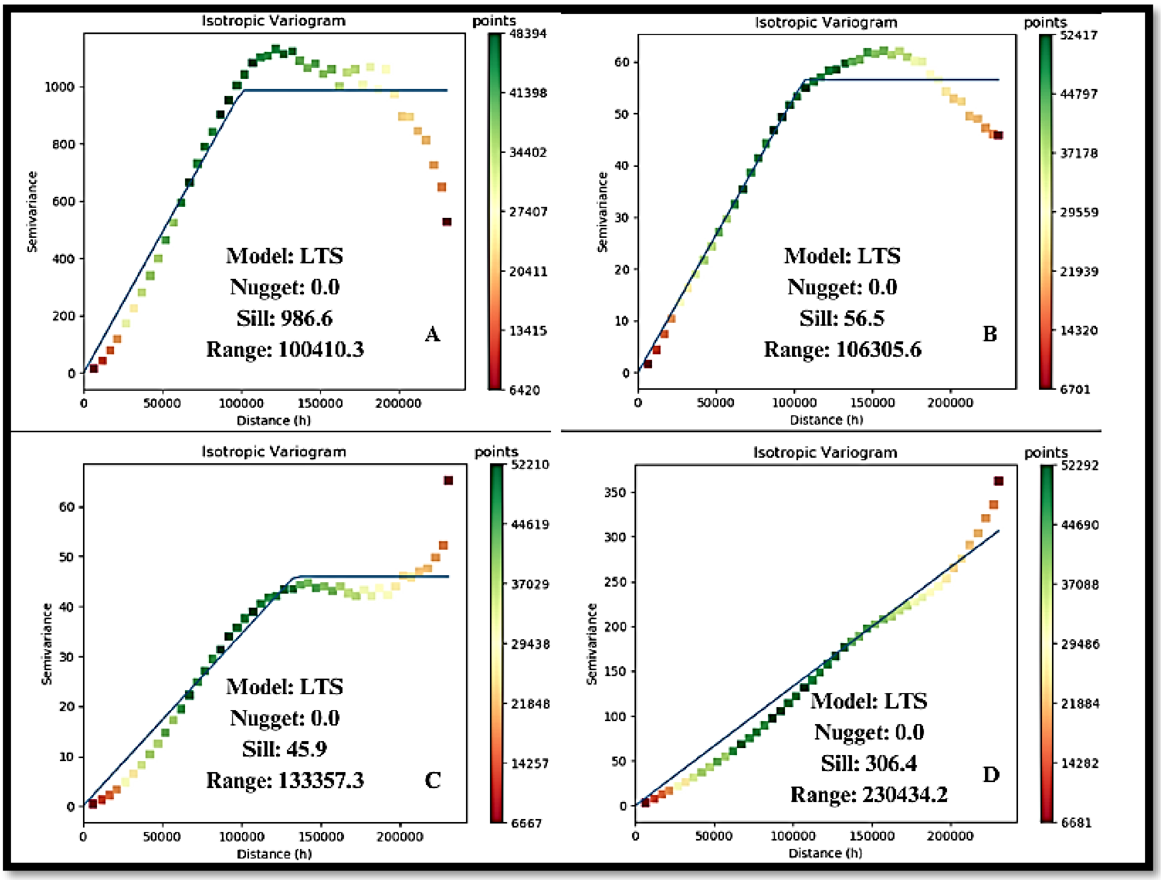
Although there have not been many reports on the spatial distribution in coconut, the genera analyzed in this study have been studied for their spatial distribution in other crops. It has been demonstrated that there is a spatial dependence of nematodes with the distance they travel (Howland; Schreiner; Zasada, 2014; Da Silva *et al*. 2016; Contina; Dandurand; Knudsen, 2020). This knowledge of the spatial distribution of PPNs can be utilized to optimize sample size using different models (Mahfouz, 1992). Therefore, this work demonstrates that nematodes such as *Meloidogyne, Pratylenchus,* and *Rotylenchulus* can travel longer distances, or in other words, they can easily distribute themselves in a suitable environment. It is necessary to implement control measures for them. One of the control measures is to prevent the dissemination of contaminated seeds and plants (Taylor; Sasser, 1983), especially for *Meloidogyne*, as it has a high reproduction rate and is recognized as the economically most important nematode in crops (Taylor; Sasser, 1983).

For variogram analysis, the linear model was chosen for *Helicotylenchus, Meloidogyne,* and *Rotylenchulus*, while the Gaussian model was employed for *Pratylenchus*. These models were selected because they better fit the data, displaying a coefficient of determination (R^2) closer to one and a nugget of 0.0. Although the spherical model is one of the most recommended and used (Gallardo, 2006), in this study, the linear model was chosen due to the nature of the data, which counts data rather than continuous. The use of linear models is more advisable in this case (Warton, 2018; Da Silva *et al*. 2022). In contrast to our work, Da Silva *et al*. (2016) made adjustments to the exponential model, where they observed the formation of disease dissemination foci in the coconut plantation area. On the other hand, Contina; Dandurand; Knudsen, (2020) adjusted the variogram using the Ste model (Matern parametrization, M. Stein) and the spherical model, finding that the autocorrelation increased indefinitely as distances increased (beyond a range of 500 m). Da Silva *et al.* (2016) fitted their data to the exponential model for red ring incidence, where they observed an aggregated distribution with moderate spatial dependence. In recent years, geostatistical methods have been employed in analyzing data related to PPNs (Da Silva *et al*. 2016; Contina; Dandurand; Knudsen, 2020).

Variogram analysis is one of the most used geostatistical techniques. Through this analysis, we can gain a deeper understanding of the spatial arrangements of different PPNs groups and comprehend the potential relevance of these arrangements in ecosystem functioning (Robertson; Freckman, 1995). Geostatistical techniques offer a suitable approach for examining data showing spatial correlation. These techniques allow for measuring spatial relationships among samples in the field, provided that it is possible to map PPNs intensities (Gallardo, 2006).

In our research, we found that *Helicotylenchus* demonstrated the greatest variability. However, it had the narrowest range in terms of hectares when compared to the other nematode genera. This implies that as the variance increases for these PPNs, their range continues to increase. This range does not decrease dramatically as in the case of *Helicotylenchus* and *Meloidogyne*. In our study, we demonstrated that spatial distribution in the field was correlated with space. We found that spatial dependency was similar, with a distance range of distribution between 100 and 133 hectares, except for the nematode *Rotylenchulus*, where spatial dependency reached a distance range of 230 hectares. Contina; Dandurand and Knudsen, (2020) recorded short ranges that could be defined as the level of extension of the presence of spatial autocorrelation when spatial dependency is associated with isotropic and bounded processes. Ferris; Mullens and Foord, (1990) defined two components that affect the spatiotemporal distribution of PPNs: (*i*) The macro-distributional component occurs at the field scale and involves environmental factors (soil texture, soil moisture, or drainage pattern) as well as cropping history and differential selection pressure from host plants, and (*ii*) The micro-distributive component occurs at a smaller point scale and is primarily influenced by the distribution of food resources.

Figure 4 Variogram analysis for the major plant parasitic nematodes.



Helicotylenchus (A), *Meloidogyne* (B), *Pratylenchus* (C), and *Rotylenchulus* (D). LTS= Lineal to sill

3.3.3 Relationships between plant parasitic nematodes and bioclimatic variables

Table 8 presents the structures of the selected models with their respective VIF values. Regarding the incidence of PPNs, several trends were identified based on the analyzed variables. Several factors exert a positive influence on PPNs incidence. The variables BIO7 ($p < 0.05$) and BIO9 ($p < 0.01$) showed a significant positive association with the incidence of *Helicotylenchus* whereas the BIO6 was positively correlated with the incidence of *Pratylenchus* ($p < 0.01$), and BIO9 exhibited a strong positive relationship with *Rotylenchulus* ($p < 0.001$). On the other hand, a negative impact on the incidence of certain PPNs was observed. The variables BIO4 ($p < 0.01$) and BIO15 ($p < 0.001$) showed a negative correlation with the incidence of *Helicotylenchus*. The variable BIO15 also negatively influenced *Meloidogyne* ($p < 0.01$) as well as *Rotylenchulus* ($p < 0.05$). The variables BIO8, BIO11, BIO13, and BIO18 did not demonstrate a significant effect on the studied PPNs.

In our study, BIO7 and BIO9 showed a positive effect on *Helicotylenchus*. Márquez *et al*. (2021) obtained different results regarding PPNs, where they found a positive impact of variable BIO5 on *Meloidogyne* and variable BIO1 on *Helicotylenchus.* Contrary to our findings, Fleming *et al.* (2016) documented significant trends of increasing nematode diversity and higher prevalence of *Meloidogyne* and *Pratylenchus* as the amount of precipitation increased. In this research, the incidence of *Pratylenchus* was only positively related to the BIO6. Kandel *et al*. (2013), similar to our study, found a positive correlation between minimum air temperature in winter and nematode densities. However, these authors also presented results contrary to our work, as they showed that *Pratylenchus* positively correlated with all precipitation-related bioclimatic variables, while maximum air temperature in summer correlated negatively. A study conducted by Hamza *et al*. (2018) revealed divergent results, suggesting that environments with higher aridity tend to favor the presence of individuals from the families Meloidogynidae and Pratylenchidae in olive trees in Morocco. In our results, the variables BIO4, BIO15, and BIO18 recorded negative effects on the genera of nematodes. Márquez *et al*. (2021) also found similar results for *Meloidogyne,* related to variable BIO12. Additionally, increased temperatures may negatively affect the nematode *Meloidogyne* in coffee plantations (Ghini *et al*. 2008). An increase in the quantity of nematodes was observed in correlation with rising relative humidity (RH), precipitation, and air temperature (Khan; Ghosh, 2011).

Table 8 Generalized linear models used to examine the relationships between environmental variables and plant parasitic nematodes associated with coconut crops [*Helicotylenchus* (*Helic*), *Meloidogyne* (*Meloi*), *Pratylenchus* (*Praty*), *Rotylenchulus* (*Roty*)] from Dominican Republic.

Model	Chosen Model	binding function	VIF
1	Incid_*Helic* ~ -BIO4** + BIO7* + BIO8 + BIO9** -BIO15*** + BIO18	Binomial (logit)	7.90;6.77;5.82;5.78;7.40;5.48
2	Incid_Meloi ~ -BIO4 + BIO8* + BIO11 + BIO13 -BIO15**	Binomial (logit)	1.72;8.53;4.23;6.17;3.97
3	Incid_Praty ~ BIO6** -BIO15 -BIO18	Binomial (logit)	1.33;1.90;2.27
4	Incid_Roty ~ -BIO4· + BIO7 + BIO9*** -BIO15*	Binomial (logit)	5.27;4.92;1.84;5.67

Incid: Incidence; VIF: Variation Inflation Factors; ( ): absent; (+) positive effect; (−) negative effect. *** p < 0.01; ns p > 0.01. 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

BIO4 Temperature seasonality (standard deviation of temperatures * 100); BIO6 Minimum temperature of the coldest month; BIO7 Annual temperature range (BIO5-BIO6); BIO8 Average temperature of the wettest quarter; BIO9 Average temperature of the driest quarter; BIO11 Average temperature of the coldest quarter; BIO13 Precipitation of the wettest month; BIO15 Seasonality of precipitation (coefficient of variation); BIO18 Precipitation from the warmest room.

3.3.4 Suitability of habitat for plant-parasitic nematodes

The suitability scores for different PPNs in the provinces sampled varied between 0.0 and 1.0. A score of 1.0 was only found in specific locations with different latitudes and longitudes, which varied for each PPN, and these areas were limited due to the low population of the studied PPNs. On the other hand, a score of 0.75 had a more extensive distribution, as shown in the maps (Figure 5).

For *Helicotylenchus*, the highest suitability score of 1.0 was recorded between latitudes 18.0-18.5N and longitudes 65.5-70.0W, although this score was observed in very few instances. A score of 0.75 was more commonly found in the coastal areas of the country (Figure 5, 6A). In the case of *Meloidogyne*, the highest suitability score of 1.0 was found between latitudes 19.0-19.5N and longitudes 69.0-70.0W, specifically in the provinces of Maria Trinidad Sánchez, Samaná, and Hato Mayor. On the other hand, the score of 0.75 was predominantly recorded in the northern and coastal regions of the country (Figure 5, 6B).

For *Pratylenchus*, the highest suitability score of 1.0 was identified between latitudes 18.0-18.5N and longitudes 71.5-72.0W. This score was seeing the province Bahoruco. Nevertheless, a score of 0.75 was present across nearly all latitudes and longitudes where sampling was conducted, with a higher concentration in the coastal zones where the country's largest coconut production occurs (Figure 5, 6C).

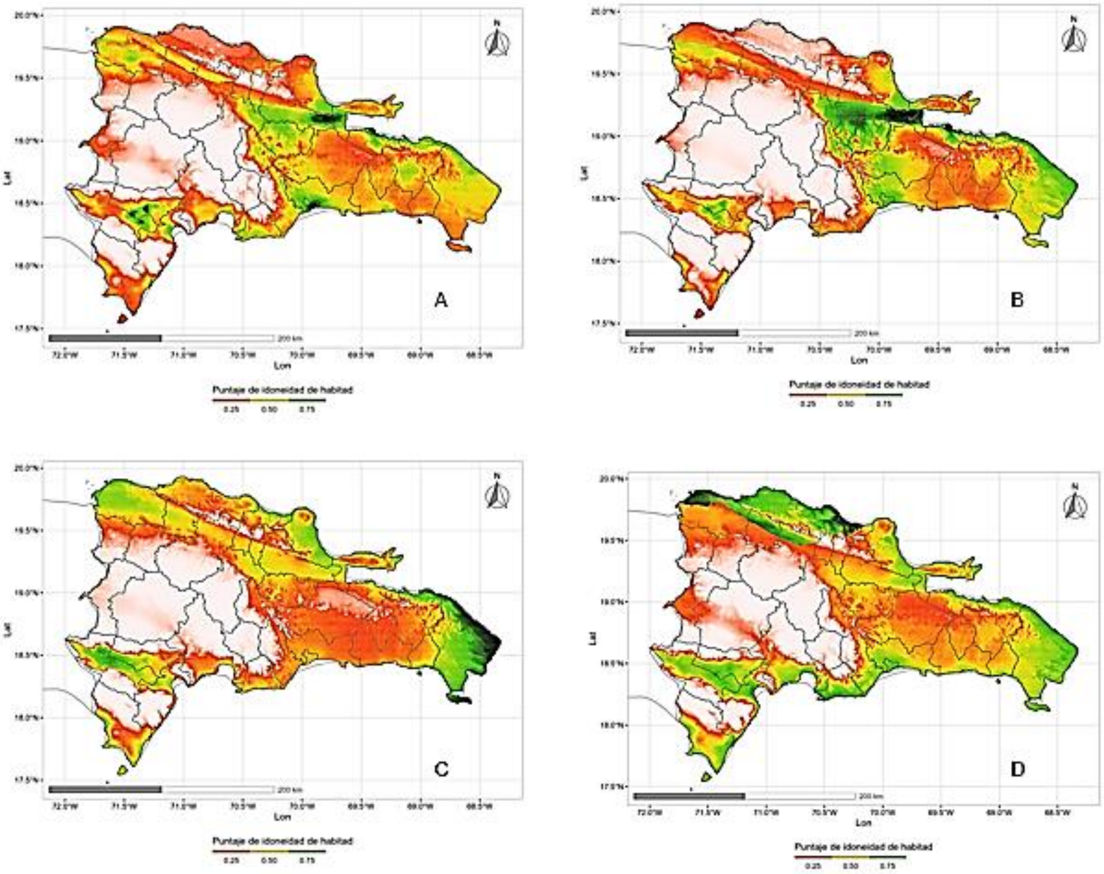
The suitability score map for *Rotylenchulus* is depicted (Figure 5, 6D). For this genus, the highest score of 1.0 was recorded between latitudes 18.5-19.0N and longitude 68.5W in the province La Altagracia. The score of 0.75 was more intense in the eastern part of the country, showing a heterogeneous distribution of scores ranging from 0.5 to 0.75 along the coastal areas.

Predicting the current and future distribution of PPNs can be useful in assessing potential disease distribution risks in coconut cultivation due to climate change. The impact of climate change on pathogens may increase the risk of plant diseases (Contina; Dandurand; Knudsen, 2020). Based on the results of this investigation, we can demonstrate that bioclimatic variables such as temperature and precipitation primarily have a positive effect on the populations of the most important PPNs associated with coconut crops in the Dominican

Republic. However, in some cases, these variables may have a negative effect. Therefore, it is necessary to continue studying and seeking control measures for these nematodes, especially when there are favorable environmental factors that can increase their abundance and frequency in coconut cultivation.

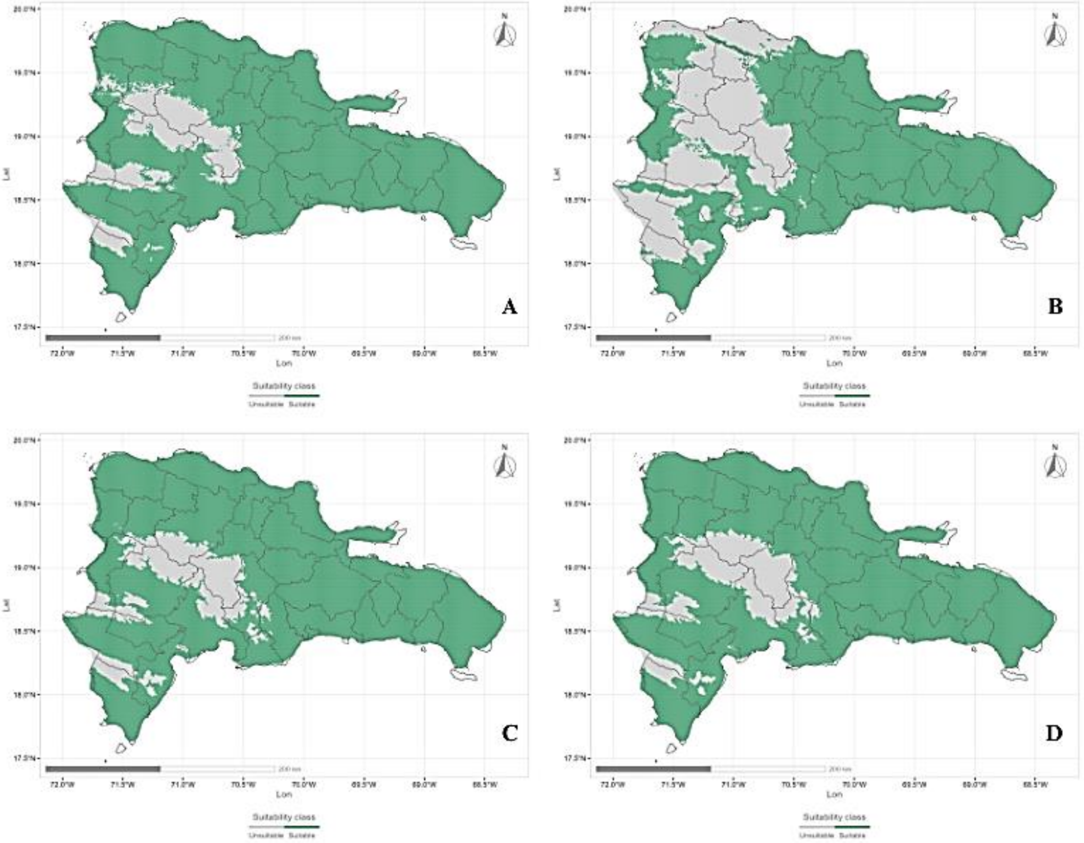
For habitat suitability, in coconut producing regions situated between latitude 18.0 - 19.5 N and longitude 65.5 - 72.0 W easily form a large-scale diffusion area for nematodes *Helicotylenchus, Meloidogyne, Pratylenchus,* and *Rotylenchulus*. However, regions outside of that range are not, at the moment, a suitable habitat for the proliferation of these PPNs. For an environment or soil to be suitable for microorganism habitation, it cannot be water-saturated, as this limits their development (Gupta; Gupta; Singh, 2017). Precipitation causes changes in soil moisture (Koster *et al.* 2004), while soil that is too dry or too wet will affect its ability to support microorganism development (Yan *et al*. 2020).

Figure 5 Favorable habitats where plant-parasitic nematodes distributed in the Dominican Republic using Generalized Linear Models.



The chromatic gradient, ranging from transparent to black, reflects the probability of presence on a scale from 0.25 to 1.0. Different levels of habitat suitability are represented by a variety of colors: transparency indicates absence of the nematode genus, red denotes low density with a probability between 0.25 and 0.49, yellow indicates moderate density with a probability between 0.5 and 0.6, green indicates high density with a probability ranging from above 0.6 to 0.75, while black represents the highest population density with a probability ranging from above 0.75 to 1.0. (A) *Helicotylenchus*, (B) *Meloidogyne*, (C) *Pratylenchus*, (D) *Rotylenchulus*

Figure 6 Projected suitable habitat for plant parasitic nematodes estimated through Generalized Linear Models in the Dominican Republic.



The color shade, ranging from gray to green, denotes habitat suitability shown through various colors: the gray shade indicates lack of suitability, and green indicates high suitability. (A) *Helicotylenchus*, (B) *Meloidogyne*, (C) *Pratylenchus*, (D) *Rotylenchulus*

3.3.5 Analysis of accuracy and importance of variables

In this study, AUC values greater than 0.65 were considered indicative of moderate reliability and accuracy of the prediction model. The model performance was satisfactory, aligning with the distribution of occurrence records. The prediction of current habitat suitability was consistent with the actual distribution of the four PPNs. Additionally, the model anticipated changes in habitat suitability under different future climate scenarios (Table 9).

The total contribution of all variables for each of the PPN was summed up to 100%. Among the variables used in the model for *Helicotylenchus*, the BIO3 (53.95%) and BIO15 (32.18%) had the greatest impact. For *Meloidogyne*, BIO4 (22.26%), BIO11 (24.01%), and BIO15 (43.61%) were the variables with the highest impact for predicting this genus. However, for *Pratylenchus*, the BIO11, with a contribution of 98.17%, had the highest influence on the prediction. The

BIO7 (16.32%) and BIO11 (82.59%) were the two most significant variables for predicting the potential distribution of *Rotylenchulus* (Table 9). In this regard, the proposed GLM model in our study has the potential to predict species distribution and disease risks, providing guidance for the prevention and timely management of the studied PPNs.

Table 9 Contribution of bioclimatic variables to the preparation of the GLM for each genus of plant parasitic nematodes in Dominican Republic

Genus	Bioclimatic variables	Contribution (%)
Helicotylenchus	BIO3	53.95
Helicotylenchus	BIO7	2.20
Helicotylenchus	BIO9	2.12
Helicotylenchus	BIO15	32.18
Helicotylenchus	BIO18	9.55
Meloidogyne	BIO4	22.26
Meloidogyne	BIO11	24.01
Meloidogyne	BIO15	43.61
Meloidogyne	BIO18	10.12
Pratylenchus	BIO11	98.17
Pratylenchus	BIO15	1.63
Pratylenchus	BIO18	0.20
Rotylenchulus	BIO3	0.31
Rotylenchulus	BIO7	16.32
Rotylenchulus	BIO11	82.59
Rotylenchulus	BIO15	0.77

BIO3: Isothermality (BIO2/BIO7) (*100); BIO4: Temperature seasonality (standard deviation of temperatures * 100); BIO7: Annual temperature range (BIO5-BIO6); BIO9: Average temperature of the driest quarter; BIO11: Average temperature of the coldest quarter; BIO15: Precipitation seasonality (coefficient of variation); BIO18: Precipitation of warmest quarter

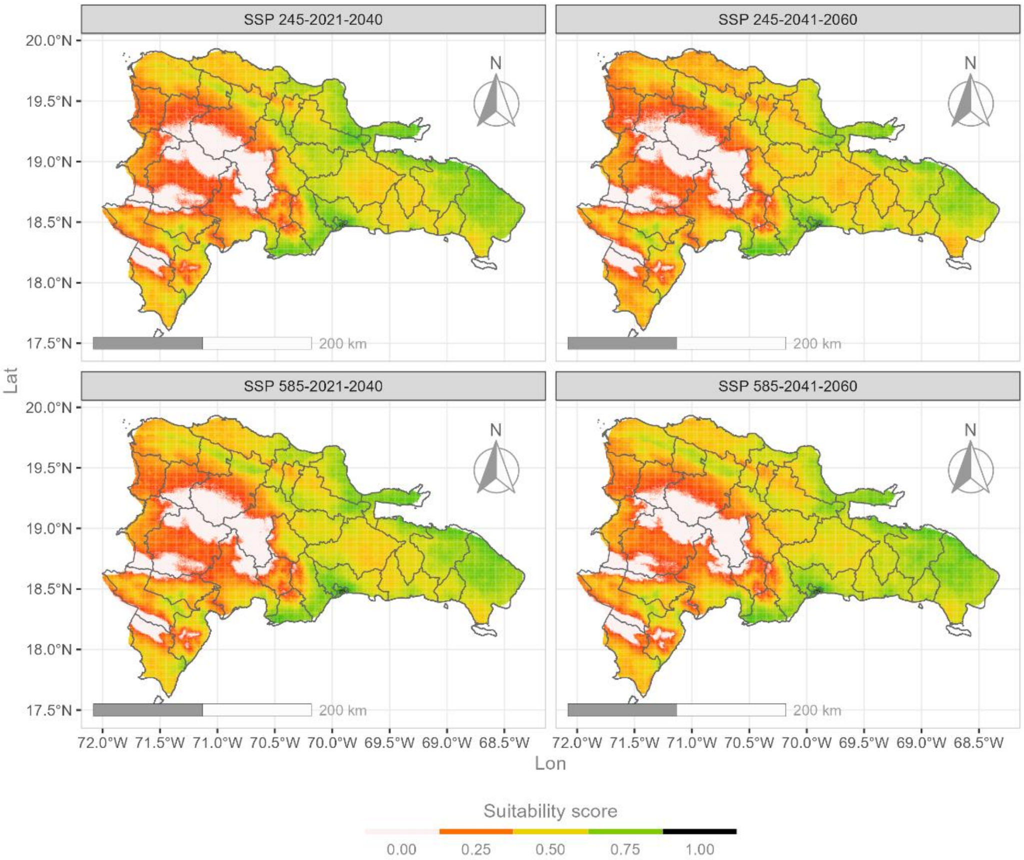
3.3.6 Future risks of PPN distribution

Climate change will affect the distribution of PPNs, impacting the risk of nematode diseases. In the future, an increase in the spatial distribution range of *Helicotylenchus, Meloidogyne, Pratylenchus,* and *Rotylenchulus* was observed in some scenarios SSP 245 aims to reduce gas emissions by increasing non-fossil energy sources and controlling emissions from land use. In contrast, SSP 585 involves an economy heavily dependent on fossil fuels, resulting in a continuous increase in gas emissions, while it remained stable compared to the baseline model for others (Figure 13). Both the SSP 245 and SSP 585 scenarios resulted in a continuous increase in the distribution of all PPNs in at least one period, indicating that the risk area will be more extensive (Figure 13).

The SSP 2455 scenario indicates a continuous increase in the distribution of *Helicotylenchus* for the period 2041-2060, while the SSP 2453, SSP 5853, and SSP 5855 scenarios show an initial increase followed by a decrease (Figure 7,8,15 A). On the other hand, in the case of *Meloidogyne*, the SSP 5855 scenario shows an increase in the distribution for the period 2041-2060 while the 2453 and 2455 scenarios show a decrease in both periods (Figure 9,10, 15 B). For *Pratylenchus*, under the conditions of the SSP 5855 and 2455 scenarios in the period 2041-2060, an increase in distribution will be favored (Figure 11,12,15 C). In the SSP 2453 scenario during the period 2021-2040, the distribution of *Rotylenchulus* will experience an increase, while in the SSP 5853 scenarios for the period 2021-2040 and SSP 5855 for the period 2041-2060, a downward trend will be observed (Figure 13,14,15 D).

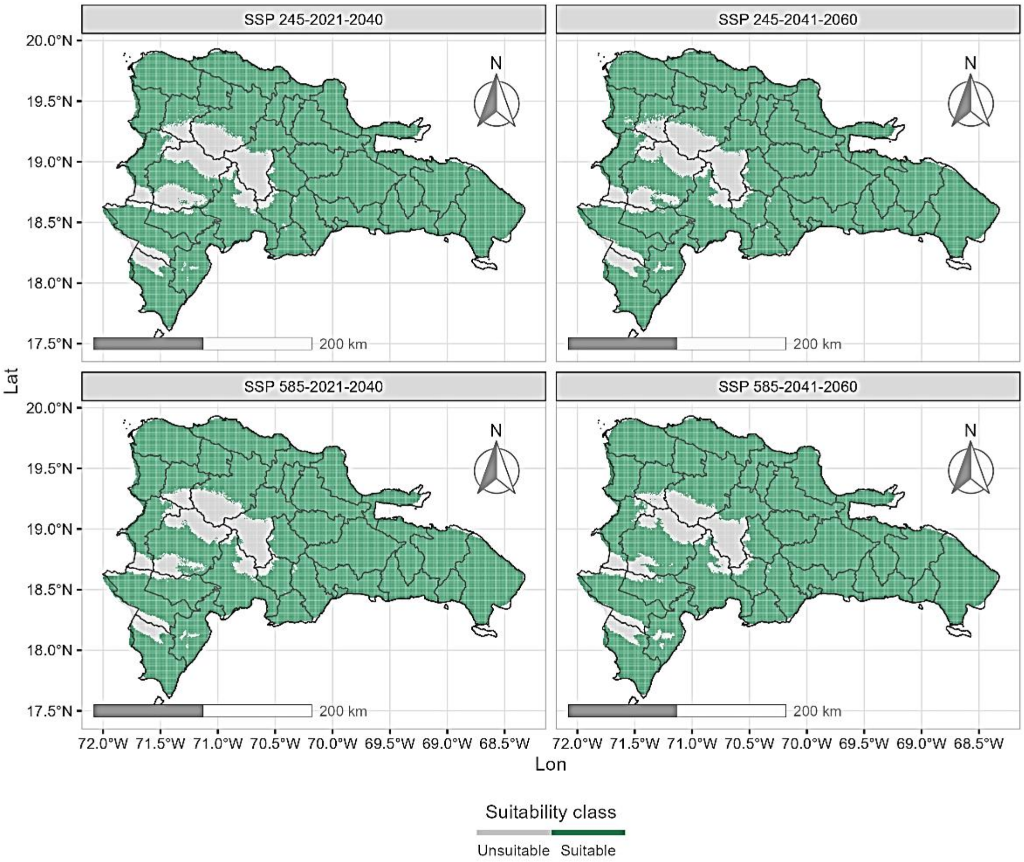
In our study, future projections for *Helicotylenchus* indicate an increase in the distribution for the period 2041-2060 under the low greenhouse gas emission scenario SSP2-4.5. This suggests that it is a favorable scenario for the development of soil microorganisms (Riahi *et al*. 2017). Similarly, an increase in the distribution of *Pratylenchus* is projected during the period 2021-2040 (Tang *et al.* 2021). Some authors claim that the threat of damage caused by nematodes in crops will persist until 2050, as indicated by the low greenhouse gas emissions scenario (RCP2.6) Tang *et al*. (2021). Regarding *Meloidogyne* and *Rotylenchulus,* an increase in their distribution area is observed during the periods 2041-2060 and 2021-2040, respectively, under the high greenhouse gas emission scenario (SSP5-8.5). The relationship between PPNs and the environment plays a crucial role in studying the spatial distribution of the ecological requirements of these PPNs (Yi *et al*. 2018). Over the last three decades, climate change has caused a series of modifications in the distributions and quantities of various PPNs (Thomas *et al*. 2004). Unlike our work, Thomas *et al*. (2004) investigated three different approaches in which the estimated probability of extinction is exponentially related to the size of the geographic range. Additionally, they made predictions based on scenarios of moderate climate warming for the year 2050. These predictions indicated that between 15% and 37% of the species in their samples of regions and taxa will be endangered.

Figure 7 Habitat suitability maps depicting the presence of *Helicotylenchus* by 2021-2040 and 2041-2060 are presented for two different climate change scenarios in Dominican Republic.



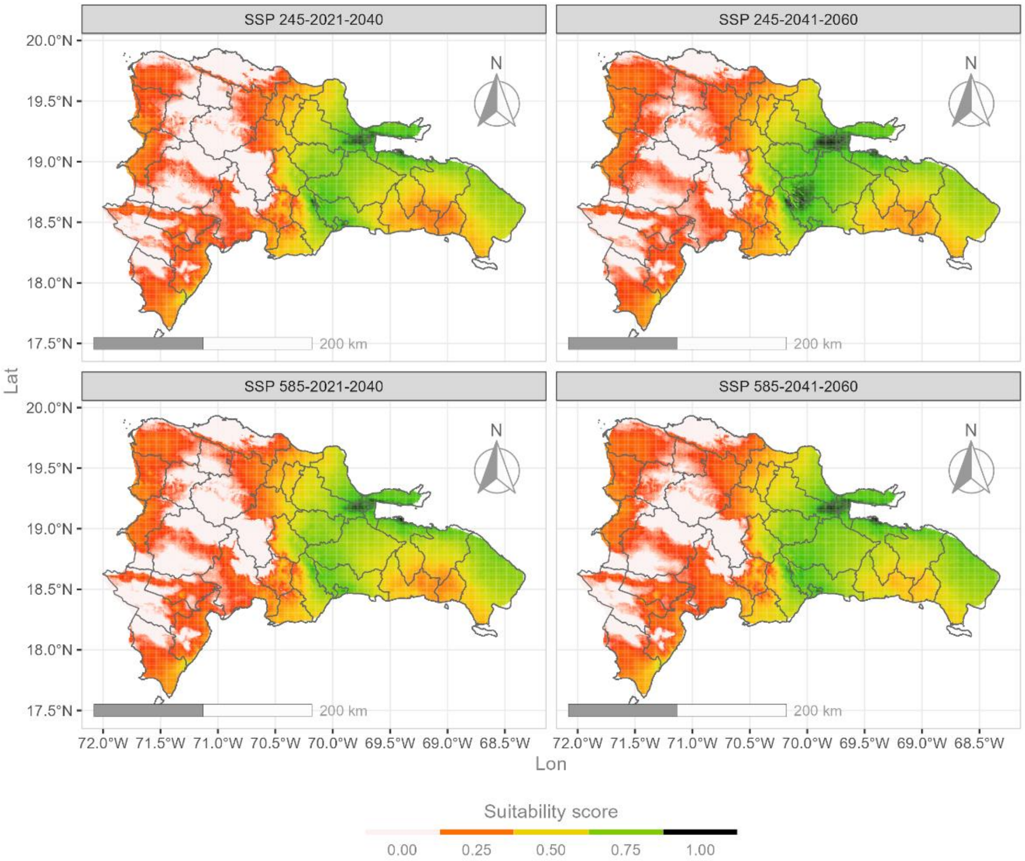
These scenarios are as follows:
(A) sglmf24530binary= SSP 245 period 2021-2040,
(B) sglmf24550binary= SSP 245 period 2041-2060
(C) sglmf58530binary= SSP 585-2021-2040, and
(D) sglmf58550binary= SSP 585 2041-2060

Figure 8 Suitability class maps depicting the presence of *Helicotylenchus* by 2021-2040 and 2041-2060 are presented for two different climate change scenarios in Dominican Republic.



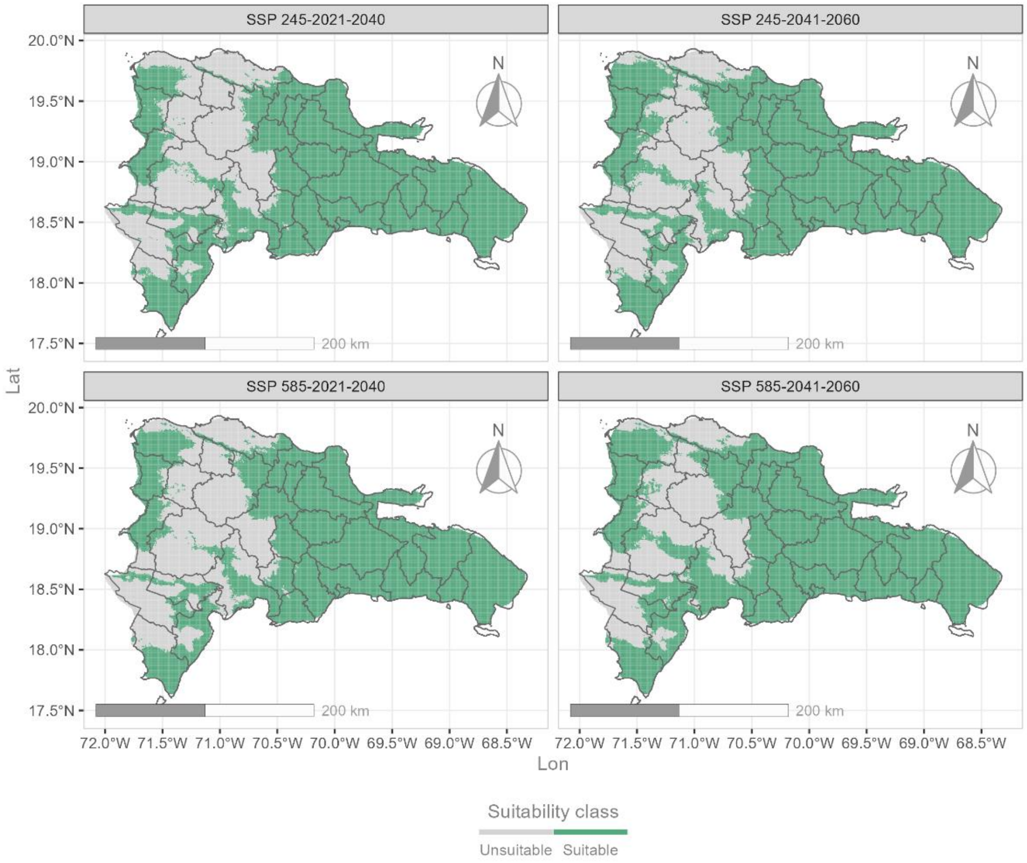
These scenarios are as follows:
(A) sglmf24530binary= SSP 245 period 2021-2040,
(B) sglmf24550binary= SSP 245 period 2041-2060
(C) sglmf58530binary= SSP 585-2021-2040, and
(D) sglmf58550binary= SSP 585 2041-2060

Figure 9 Habitat suitability maps depicting the presence of *Meloidogyne* by 2021-2040 and 2041-2060 are presented for two different climate change scenarios in Dominican Republic.



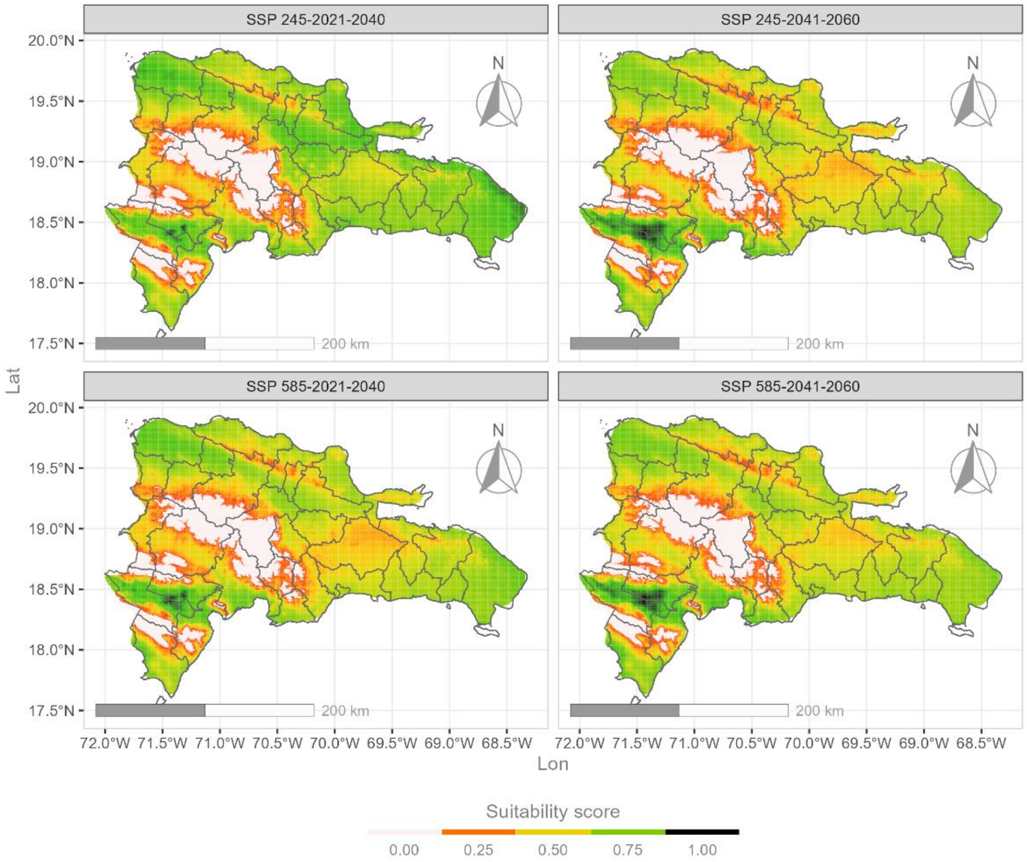
These scenarios are as follows:
(A) sglmf24530binary= SSP 245 period 2021-2040,
(B) sglmf24550binary= SSP 245 period 2041-2060
(C) sglmf58530binary= SSP 585-2021-2040, and
(D) sglmf58550binary= SSP 585 2041-2060

Figure 10 Suitability class maps depicting the presence of *Meloidogyne* by 2021-2040 and 2041-2060 are presented for two different climate change scenarios in Dominican Republic.



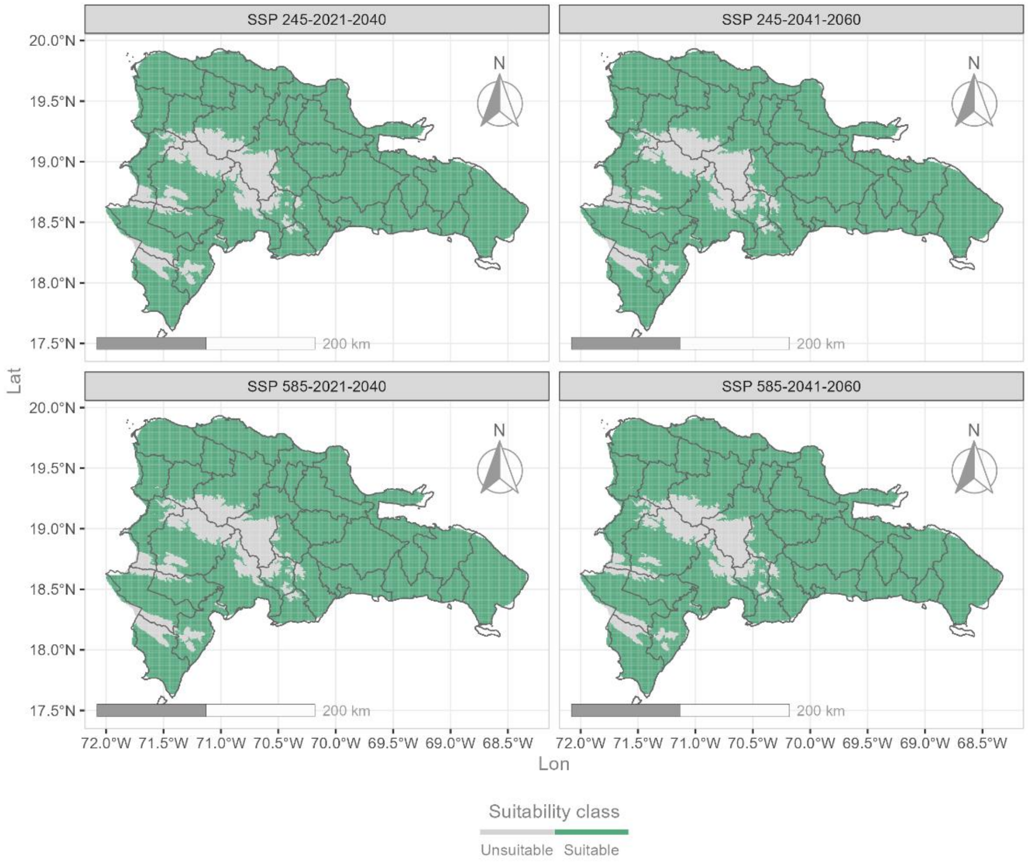
These scenarios are as follows:
(A) sglmf24530binary= SSP 245 period 2021-2040,
(B) sglmf24550binary= SSP 245 period 2041-2060
(C) sglmf58530binary= SSP 585-2021-2040, and
(D) SGLMF58550BINARY= SSP 585 2041-2060

Figure 11 Habitat suitability maps depicting the presence of *Pratylenchus* by 2021-2040 and 2041-2060 are presented for two different climate change scenarios in Dominican Republic.



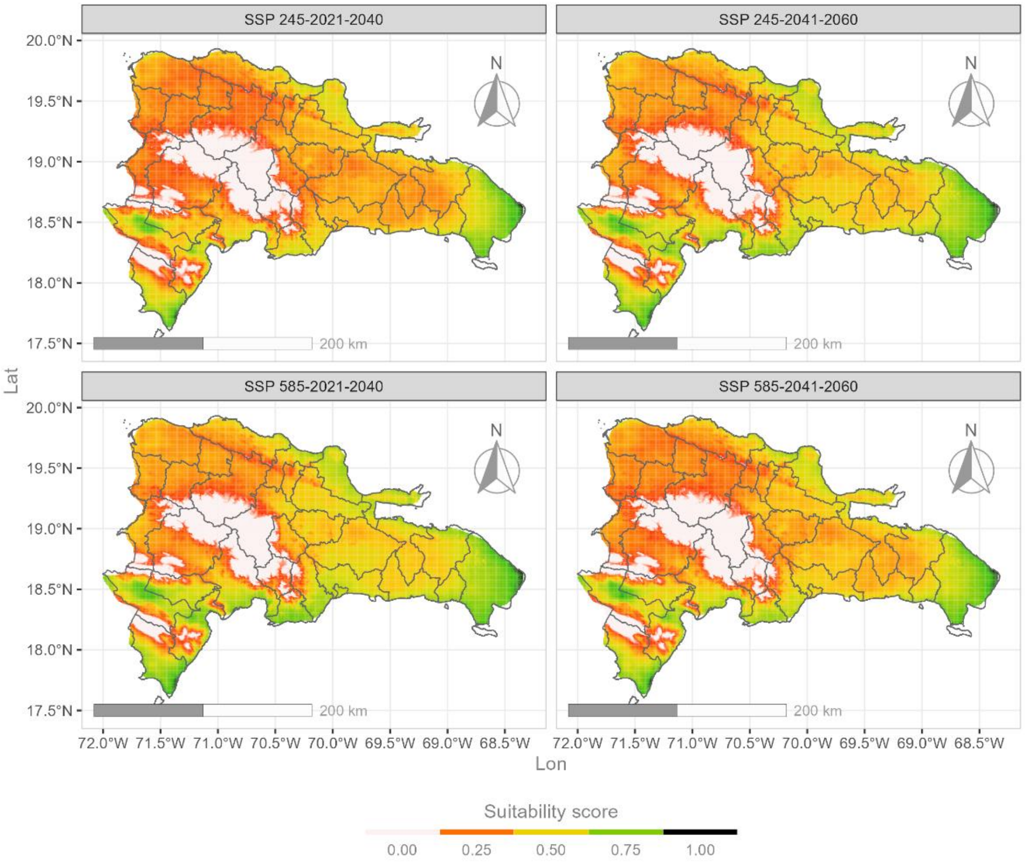
Legend: These scenarios are as follows:
(A) sglmf24530binary= SSP 245 period 2021-2040,
(B) sglmf24550binary= SSP 245 period 2041-2060
(C) sglmf58530binary= SSP 585-2021-2040, and
(D) sglmf58550binary= SSP 585 2041-2060

Figure 12 Suitability class maps depicting the presence of *Pratylenchus* by 2021-2040 and 2041-2060 are presented for two different climate change scenarios in Dominican Republic.



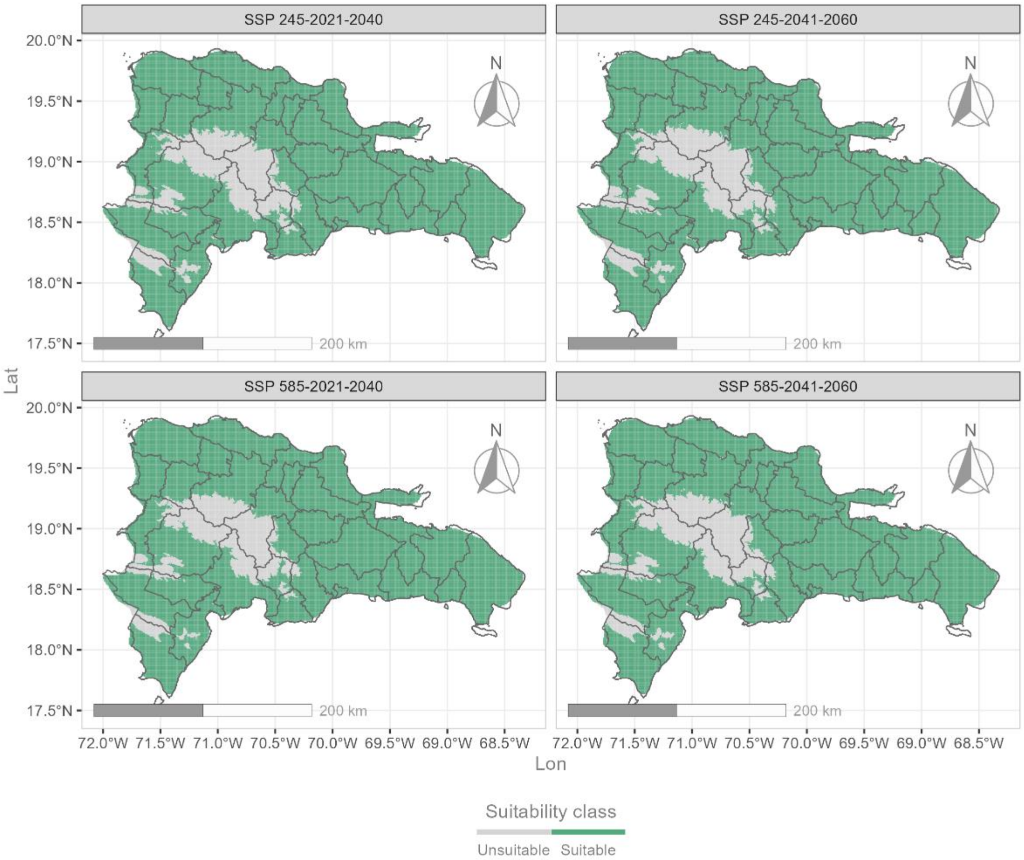
These scenarios are as follows:
(A) sglmf24530binary= SSP 245 period 2021-2040,
(B) sglmf24550binary= SSP 245 period 2041-2060
(C) sglmf58530binary= SSP 585-2021-2040, and
(D) sglmf58550binary= SSP 585 2041-2060

Figure 13 Habitat suitability maps depicting the presence of *Rotylenchulus* by 2021-2040 and 2041-2060 are presented for two different climate change scenarios in Dominican Republic.



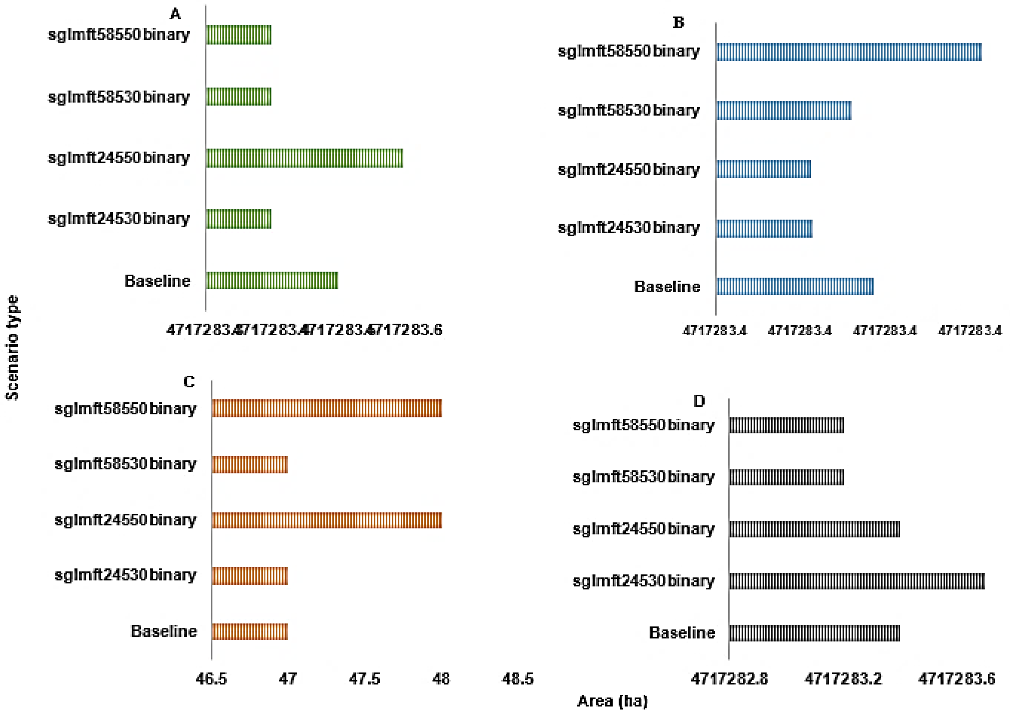
These scenarios are as follows:
(A) sglmf24530binary= SSP 245 period 2021-2040,
(B) sglmf24550binary= SSP 245 period 2041-2060
(C) sglmf58530binary= SSP 585-2021-2040, and
(D) sglmf58550binary= SSP 585 2041-2060

Figure 14 Suitability class maps depicting the presence of *Rotylenchulus* by 2021-2040 and 2041-2060 are presented for two different climate change scenarios in Dominican Republic.



These scenarios are as follows:
(A) sglmf24530binary= SSP 245 period 2021-2040,
(B) sglmf24550binary= SSP 245 period 2041-2060
(C) sglmf58530binary= SSP 585-2021-2040, and
(D) sglmf58550binary= SSP 585 2041-2060

Figure 15 Risk of future projections for plant-parasitic nematodes under different scenarios in Dominican Republic



Helicotylenchus (A), *Meloidogyne* (B), *Pratylenchus* (C), and *Rotylenchulus* (D)

3.4 Conclusions

From variogram analysis, *Helicotylenchus* exhibits the highest variability, and less distance travels, while the genera *Meloidogyne, Pratylenchus,* and *Rotylenchulus* have lower variability but a greater distribution range.

The incidence of PPNs is influenced positively and negatively by different environmental variables. *Helicotylenchus* is positively influenced by BIO7 and BIO9, while *Rotylenchulus* is influenced by BIO9 and *Pratylenchus* is affected by BIO6. However, the incidence of *Helicotylenchus* is negatively affected by BIO4 and BIO15, while the incidence of *Meloidogyne* and *Rotylenchulus* is negatively influenced by BIO15.

According to our generalized linear model, suitable areas for the development and distribution of the four genera of PPNs were found between latitudes 18.0 - 19.5 N and longitudes 65.5 - 72.0 W. In relation to future projections, *Helicotylenchus* and *Pratylenchus* are expected to increase their distribution on stage SSP245, while *Meloidogyne* and *Rotylenchulus* will do so on stage SSP585.

The GLM model proposed could predict the distribution of these PPNs and assess the risks of associated diseases. Our findings provide valuable guidance for the prevention and timely management of these PPNs.

4. GENERAL CONCLUSIONS

A total of 27 nematodes are found in soil samples and 5 nematodes are found in root samples, including 10 (PPNs) and 17 (FLNs).

The crop rhizosphere shows the highest density and prevalence of PPNs such as *Helicotylenchus, Tylenchus, Rotylenchulus, Meloidogyne,* and *Pratylenchus*, as well as FLNs like *Rhabditis, Aphelenchus, Trypila,* and *Dorylaimus*.

Among the different biotypes, the Tall biotypes record 25 genera, the Dwarf biotypes present 20 genera, and the Hybrid biotypes record 17 genera of nematodes.

The most dominant PPNs are *Helicotylenchus, Rotylenchulus*, and *Tylenchus*, while the dominant FLNs are *Aphelenchus, Dorylaimus*, and *Rhabditis*.

Correspondence analysis reveals patterns of association between coconut biotypes and genera in various dimensions.

The biotype groups "Tall " are positively associated with dimension 1, while the biotype groups "Dwarf and Hybrid" are negatively associated with dimension 1. In relation to genus, *Diplocapter*, *Diplogaster* and *Filenchus* are strongly associated with dimension 1, and A*xonolaimus*, *Acrobeles* and *Alaimus* are associated with dimension 2.

The p-p 2 and p-p 3 groups have the highest density, with the Dwarf biotypes showing the highest percentage in the p-p 2 group, and the Hybrid biotypes observed in the c-p 1 group. In the c-p 2 group, the Dwarf biotypes have the highest percentage.

Helicotylenchus and *Rotylenchulus* are the most common PPNs found in different provinces of the Dominican Republic.

Variogram analysis shows that *Helicotylenchus, Rotylenchulus, Pratylenchus,* and *Meloidogyne* exhibit different levels of variability.

The incidence of PPNs is influenced both positively and negatively by various environmental variables. According to our generalized linear model, suitable areas for the development and distribution of the four genera of PPNs are between latitudes 18.0 - 19.5 N and longitudes 65.5 - 72.0 W.

Regarding future projections, *Helicotylenchus* and *Pratylenchus* are expected to increase their distribution in stage SSP245, while *Meloidogyne* and *Rotylenchulus* will do so in stage SSP585.

For future work, it is recommended to identify the species within those genera that exhibit free-living characteristics in the soil, as well as species that are known to be parasitic to crops. It is advisable to conduct pathogenicity tests on these identified species.

Additionally, performing molecular analyses and further pathogenicity testing on the species identified in this study is recommended.

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ANNEXES

ANNEXES FIRST CHAPTER

Table 1. Groups c-p and ´p-p (colonizers-persistenters) and body mass of nematodes associated with coconut in the Dominican Republic.

Nematodes	C-p class	P-p class	Feeding type	Mass (µg)
Helicotylenchus	0	3	Herbivores - semi-endoparasites	0.294
Longidorus	0	5	Herbivores - ectoparasites	16.386
Meloidogyne	0	3	Herbivores - sedentary parasites	86.985
Mesocriconema	0	3	Herbivores - ectoparasites	0.504
Pratylenchus	0	3	Herbivores - migratory endoparasites	0.144
Radopholus	0	3	Herbivores - migratory endoparasites	0.212
Rotylenchulus	0	3	Herbivores - sedentary parasites	1.77
Tylenchorhynchus	0	3	Herbivores - ectoparasites	0.234
Tylenchus	0	2	Herbivores - epidermal/root hair feeders	0.353
Xiphinema	0	5	Herbivores - ectoparasites	5.515
Aphelenchus	2	0	Fungivores	0.218
Filenchus	2	0	Fungivores	0.1
Tylencholaimellus	4	0	Fungivores	0.709
Acrobeles	2	0	Bacterivores	0.64
Alaimus	4	0	Bacterivores	0.561
Cephalobus	2	0	Bacterivores	0.266
Diploscapter	1	0	Bacterivores	1.886
Diplogaster	1	0	Bacterivores	1.604
Axonolaimus	1	0	Bacterivores	0.00
Monhystera	2	0	Bacterivores	1.011
Plectus	2	0	Bacterivores	0.858
Prismatolaimus	3	0	Bacterivores	0.374
Rhabditis	1	0	Bacterivores	7.5
Wilsonema	2	0	Bacterivores	0.054
Mononchus	4	0	Predators	4.394
Tripyla	3	0	Predators	4.994
Dorylaimus	4	0	Omnivores	42.765

Table 2. Statistical analysis (Whittaker diagram) of genus dominance by coconut biotype groups.

Biotype	Genus	rank	abundance	proportion	accumfreq	logabun	rankfreq
Dwarf	*Tylenchus*	1	1200	26.9	26.9	3.1	5
Dwarf	*Rhabditis*	2	750	16.8	43.7	2.9	10
Dwarf	*Aphelenchus*	3	740	16.6	60.3	2.9	15
Dwarf	*Rotylenchulus*	4	450	10.1	70.4	2.7	20
Dwarf	*Dorylaimus*	5	320	7.2	77.6	2.5	25
Dwarf	*Cephalobus*	6	180	4	81.6	2.3	30
Dwarf	*Meloidogyne*	7	180	4	85.7	2.3	35
Dwarf	*Helicotylenchus*	8	170	3.8	89.5	2.2	40
Dwarf	*Xiphinema*	9	120	2.7	92.2	2.1	45
Dwarf	*Pratylenchus*	10	80	1.8	93.9	1.9	50
Dwarf	*Acrobeles*	11	60	1.3	95.3	1.8	55
Dwarf	*Tripyla*	12	50	1.1	96.4	1.7	60
Dwarf	*Monhystera*	13	30	0.7	97.1	1.5	65
Dwarf	*Wilsonema*	14	30	0.7	97.8	1.5	70
Dwarf	*Alaimus*	15	20	0.4	98.2	1.3	75
Dwarf	*Diplocapter*	16	20	0.4	98.7	1.3	80
Dwarf	*Mononchus*	17	20	0.4	99.1	1.3	85
Dwarf	*Radopholus*	18	20	0.4	99.6	1.3	90
Dwarf	*Axonolaimus*	19	10	0.2	99.8	1	95
Dwarf	*Prismatolaimus*	20	10	0.2	100	1	100
Hybrid	*Rhabditis*	1	280	23	23	2.4	5.9
Hybrid	*Aphelenchus*	2	260	21.3	44.3	2.4	11.8
Hybrid	*Tylenchus*	3	220	18	62.3	2.3	17.6
Hybrid	*Dorylaimus*	4	160	13.1	75.4	2.2	23.5
Hybrid	*Rotylenchulus*	5	60	4.9	80.3	1.8	29.4
Hybrid	*Helicotylenchus*	6	50	4.1	84.4	1.7	35.3
Hybrid	*Prismatolaimus*	7	40	3.3	87.7	1.6	41.2
Hybrid	*Monhystera*	8	30	2.5	90.2	1.5	47.1
Hybrid	*Pratylenchus*	9	20	1.6	91.8	1.3	52.9
Hybrid	*Tripyla*	10	20	1.6	93.4	1.3	58.8
Hybrid	*Xiphinema*	11	20	1.6	95.1	1.3	64.7
Hybrid	*Acrobeles*	12	10	0.8	95.9	1	70.6
Hybrid	*Alaimus*	13	10	0.8	96.7	1	76.5
Hybrid	*Cephalobus*	14	10	0.8	97.5	1	82.4
Hybrid	*Diplocapter*	15	10	0.8	98.4	1	88.2
Hybrid	*Meloidogyne*	16	10	0.8	99.2	1	94.1
Hybrid	*Mononchus*	17	10	0.8	100	1	100
Tall	*Helicotylenchus*	1	2760	23.9	23.9	3.4	4
Tall	*Tylenchus*	2	1880	16.3	40.2	3.3	8
Tall	*Rhabditis*	3	1650	14.3	54.5	3.2	12
Tall	*Aphelenchus*	4	1380	11.9	66.4	3.1	16
Tall	*Meloidogyne*	5	750	6.5	72.9	2.9	20
Tall	*Rotylenchulus*	8	460	4	87.4	2.7	32
Tall	*Tripyla*	9	380	3.3	90.6	2.6	36
Tall	*Pratylenchus*	10	190	1.6	92.3	2.3	40
Tall	*Diplocapter*	11	150	1.3	93.6	2.2	44

Table 2. Statistical analysis (Whittaker diagram) of genus dominance by coconut biotype groups.

Biotype	Genus	rank	abundance	proportion	accumfreq	logabun	rankfreq
Tall	*Cephalobus*	12	110	1	94.5	2	48
Tall	*Alaimus*	13	90	0.8	95.3	2	52
Tall	*Monhystera*	14	90	0.8	96.1	2	56
Tall	*Prismatolaimus*	15	90	0.8	96.9	2	60
Tall	*Mesocriconema*	16	80	0.7	97.6	1.9	64
Tall	*Tylenchorhynchus*	17	70	0.6	98.2	1.8	68
Tall	*Filenchus*	18	50	0.4	98.6	1.7	72
Tall	*Plectus*	19	40	0.3	99	1.6	76
Tall	*Acrobeles*	20	30	0.3	99.2	1.5	80
Tall	*Xiphinema*	21	30	0.3	99.5	1.5	84
Tall	*Axonolaimus*	22	20	0.2	99.7	1.3	88
Tall	*Diplogaster*	23	20	0.2	99.8	1.3	92
Tall	*Longidorus*	24	10	0.1	99.9	1	96
Tall	*Mononchus*	25	10	0.1	100	1	100

Table 3. Statistical analysis of correspondence, dimensioned by coconut biotypes groups and dimensioned by nematode genera.

Biotypes	**Dim.1**[†]	**Dim.2**
Dwarf	-0.387	0.131
Hybrid	-0.248	-0.51
Tall	0.234	0.019
Genus	**Dim.1**	**Dim.2**
Acrobeles	-0.263	0.424
Alaimus	0.005	0.345
Aphelenchus	-0.118	0.014
Axonolaimus	0.094	0.318
Cephalobus	-0.308	0.169
Diplocapter	0.386	-0.155
Diplogaster	0.809	0.107
Dorylaimus	-0.045	0.104
Filenchus	0.809	0.107

[†] Dim: Dimention

Annexes tables of morphometric

Morphological and morphometric characteristics of prevalent plant parasitic nematodes

Genus *Meloidogyne* Göldi, 1887

Table 1. *Meloidogyne* species recorded in the different provinces of the Dominican Republic studied.

	Prevalence† (%)			
Provinces	***M. arenaria***	***M. hapla***	***M. incognita***	***M. javanica***
Bahoruco	0	0	60	40
Hato Mayor	0	20	80	0
Maria Trinidad Sánchez	20	30	50	0
Montecristi	20	0	80	0
Monte Plata	30	10	60	0
Samaná	40	10	30	20
San Cristóbal	20	30	50	0
Total prevalence (%)	18.6	14.3	58.6	8.6

†The prevalence was calculated considering the percentage of the proportion observed in the morphological identification by perineal patterns of the females.

Genus *Helicotylenchus* Steiner, 1945

Table 2. Morphometric characteristics of *Helicotylenchus californicus* present in two provinces of the Dominican Republic and populations found in Brazil and South Africa.

	Maria Trinidad Sánchez	**El Seibo**	**Brasil (Riascos-Ortiz *et al.* 2020)**	**South África (Van Den Berg and Heyns, 1975)**
Variables	**n=10**	**n=10**	**n=12**	**n=25**
L	600.2±89.0 (473.6-724.2)[†]	600.7±36.8 (514.9-649.4)	0.6 (0.5-0.6) *	0.7 (0.6-0.8) *
Body width	25.9±4.5 (20.0-34.1)	23.3±0.7 (21.9-24.1)	-	-
% vulva	62.2±1.3 (60-64.0)	62.5±1.5 (60.3-64.4)	62.1(59.3-64.8)	63 (60-64)
Stylet length	24.2±2.0 (21.1-27.0)	22.4±1.3 (20.8-24.4)	22.4(20.0-23.0)	24.1 (22.8-27.2)
Esophagus	96.3±12.9 (80.9-119.4)	130.8±18.8 (110.7-177.6)	-	-
Tail length	15.9±2.2 (13.1-19.6)	21.8±1.2 (19.4-23.2)	15.9(13.0-19.0)	17.9 (15. I-25.0).
Anal body diam.	17.5±1.4 (15.8-19.3)	14.9±2.6 (8.7-18.2)	-	-
a	23.4±2.3 (20.1-26.1)	25.9±1.4 (22.8-27.4)	23.5(22.0-25.2)	28.8 (23.4-35.0)
b	6.3±1.3 (4.8-8.6)	4.7±0.7 (3.3-5.4)	-	-
c	38.2±6.3 (31-48.2)	27.5±2.2 (23.4-31.6)	35.5(27.2-45.8)	39 (30.8-53.0)

[†] Measurements in µm; mean ± s.d. (interval), * millimeter, n= adult females, L=body length, a = body length/width, b = body length/esophagus, C = body length/tail length.

Table 3. Morphometric characteristics of *Helicotylenchus dihystera* present in two provinces of the Dominican Republic and populations in Colombia and South Africa.

	Bahoruco	**La Altagracia**	**Colombia (Riascos-Ortiz *et al.* 2020)**	**South Africa (Van Den Berg and Heyns, 1975)**
Variables	**n=10**	**n=10**	**n=10**	**n=476**
L	706.2±44.9 (641.1-784.4) †	717.5±28.4 (650.0-755.5)	0.62 (0.53-0.77) *	0.6 (0.5-0.9) *
Body width	26.2±2.9 (22.8-31.1)	27.0±2.6 (22.3-32.0)	-	-
% vulva	63.8±1.6 (61.0-65.9)	63.6±2.0 (59.1-67.2)	64.6 (62.2-66.6)	64.0 (59.0-71.0)
Stylet length	23.6±0.9 (21.6-24.9)	23.9±0.9 (22.8-25.3)	24.4 (23.0-26.0)	24.7 (20.9-27.6)
Esophagus	151.5±7.0 (142.8-164.0)	151.2±5.0 (144.0-161.1)	-	-
Tail length	17.3±2.6 (13.3-20.7)	16.0±3.6 (12.3-21.0)	14.5 (11.0-21.0)	15.0 (11.0-20.6)
Anal body diam.	17.5±1.5 (14.4-19.7)	17.4±1.6 (15.7-21.2)	-	-
a	27.2±2.9 (24.0-32.7)	26.8±2.2 (22.3-29.2)	25.5 (22.9-29.7)	27.9 (19.4-36.0)
b	4.7±0.4 (4.1-5.3)	4.8±0.2 (4.4-5.0)	-	5.6 (4.6-6.8)
c	41.4±7.9 (32.9-59.2)	48.0±11.1 (33.9-58.3)	43.8 (25.1-55.5)	43.7 (30.0-62.0)

†Measurements in µm; mean ± s.d. (interval), ‡ millimeter, N= adult females, L=body length, a = body length/width, b = body length/esophagus, c = body length/tail length.

Table 4. Morphometric characteristics of *Helicotylenchus multicinctus* in the provinces of the Dominican Republic and in relation to reports from a population in Colombia.

	Barahona	**Hato Mayor**	**Colombia (Riascos-Ortiz *et al.* 2020)**
Variables	**n=10**	**n=10**	**n=19**
L	651.6±55.59 (641.1-784.4) †	616.4±56.5 (525.8-694.4)	0.6 (0.4-0.8) *
Body width	25.6±1.9 (22.8-31.1)	26.2±4.1 (20.3-33.6)	-
% vulva	68.2±1.9 (65.8-71.2)	67.2±1.4(65.3-69.4)	68.4 (65.9-71.7)
Stylet length	22.7±1.0 (21.1-24.2)	22.8±1.8 (18.7-25.4)	23.4 (21.0-26.0)
Esophagus	152.5±6.9 (142.8-164.0)	138.7±17.84 (109.6-172.9)	
Tail length	13.5±1.6 (11.1-15.6)	13.6±2.0 (10.4-15.6)	13.0 (10.0-16.0)
Anal body diam.	18.3±0.9 (14.4-19.7)	17.6±2.7 (13.4-21.6)	-
a	25.6±2.7(23.0-31.0)	23.9±2.7 (19.1-27.2)	26.1 (22.5-31.1)
b	4.3±0.5 (3.7-5.0)	4.5±0.8 (3.2-6.3)	-
c	47.9±4.6 (38-53.2)	46.8±10.6 (35.4-64.8)	45.6 (36.1-55.2)

†Measurements in µm; mean ± s.d. (interval), * millimeter, N= adult females, L=body length, a = body length/width, b = body length/esophagus, c = body length/tail length.

Table 5. Morphometric characteristics of *Helicotylenchus abunaamai* present in Bahoruco province. Dominican Republic and a population from Iran.

	Bahoruco	**Iran (Ehtesham *et al*. 2021)**
Variables	**n=2**	**n=10**
L	642.0±37.1 (615.7-668.2) †	646.2 (612-691)
Body width	21.0±3.2 (18.7-23.2)	21.4 (17.6-24.7)
% vulva	62.6±1.3(61.6-63.5)	62.1 (59.1-65.2)
Stylet length	24.0±0.1 (23.9-24.0)	24.0 (22.5-25.3)
Esophagus	153.6±9.1 (147.1-160.0)	-
Tail length	14.4±1.1 (13.6-15.2)	14.0 (11.7-16.8)
Anal body diam.	13.8±7.6 (8.4-19.1)	-
a	31.2±6.6 (26.5-35.8)	30.2 (25.8-37.2)
b	4.2±0.0 (4.2-4.2	6.8 (5.8-7.6)
c	44.8±6.1 (40.5-49.1)	50.8 (41.1-53.3)

†Measurements in µm; mean ± s.d. (interval), N= adult females, L=body length. a = body length/width, b = body length/esophagus, c = body length/tail length.

Genus *Pratylenchus* Filipjev, 1936

Table 6. Morphometric characteristics of *Pratylenchus coffeae* present in Maria Trinidad Sánchez and Hato Mayor provinces in the Dominican Republic and populations in Indonesia.

	Maria Trinidad Sánchez	**Hato Mayor**	**Indonesia (Budiman *et al.* 2019)**
Variables	**n=10**	**n=10**	**n=26**
L	529.8±39.7 (448.2-580.3)†	553.9±51. (472.0-641.3)	556.4 ± 47.2 (487.4-654.4)
Body width	22.9±2.5(18.0-25)	22.5±2.5 (18.4-25.0)	19.6 ± 2.2 (15.8-24.8)
% vulva	80.7±1.7(77.9-82.8)	79.6±1.9 (76.9-82.2)	81.7 ± 1.2 (79.5-83.9)
Stylet length	16.7±1.0 (14.9-17.9)	15.9±1.2 (14.3-17.6)	16 ± 0.6 (14.6-16.7)
Esophagus	127.7±10.2 (113.9-148.2)	125.8±11.7 (113.2-151.0)	-
Tail length	32.9±12.4 (23.6-66.5)	28.6±3.6 (24.3-34.3)	27.9 ± 3.5 (21.1-34.4)
Anal body diam.	13.5±2.0 (10.2-16.4)	13.5±2.0 (10.1-16.2)	12.5 ± 1.7 (10.5-16)
a	23.4±3.6 (18.9-30.1)	23.9±2.6 (19.2-27.7)	28.5 ± 3 (23.4-34.2)
b	4.2±0.3 (3.7-4.5)	4.3±0.6 (3.4-5.5)	6.1 ± 0.6 (4.8-7.8)
c	17.5±4.6(8.1-24.6)	19.0±3.4 (14.0-26.4)	20.1 ± 2.4 (15-24.1)

†Measurements in µm; mean ± s.d. (interval), N= adult females, L=body length, a = body length/width, b = body length/esophagus, c = body length/tail length.

Table 7. Morphometric characteristics of *Pratylenchus vulnus* present in Hato Mayor province in the Dominican Republic and a Tunisian population.

Variables	**Hato Mayor** **n=2**	**Tunísia (Chihani-Hamma *et al.* 2018)** **n=5**
L	445.4±6.9 (440.5-450.2)[†]	444.4 (415.7-485.9)
Body width	23.5±1.6 (22.4-24.6)	-
% vulva	81.1±1.2 (80.2-81.9)	81.2 (80.6-82.4)
Stylet length	14.4±0.1 (14.3-14.5)	14.3 (14.2-14.6)
Esophagus	84.0±4.9 (80.5-87.4)	-
Tail length	25.9±0.4 (25.7-26.2)	-
Anal body diam.	10.6±0.7 (10.1-11.1)	-
a	19.0±1.0 (18.3-19.7)	26.7 (24.6-28.1)
b	5.4±0.2 (5.2-5.5)	7.6 (6.9-8.2)
c	17.2±0.5 (16.8-17.5)	19.1 (18.6-19.5)

[†] Measurements in µm; mean ± s.d. (interval). N= adult females. L=body length. a = body length/width. b = body length/esophagus. c = body length/tail length.

Genus *Rotylenchulus* (Linford and Oliveira, 1940)

Table 8: Morphometric characteristics of *Rotylenchulus reniformis* of young females (mobile) present in the provinces Maria Trinidad Sánchez, Bahoruco and Hato Mayor in Dominican Republic and a population of Valle del Cauca, Colombia.

	Maria Trinidad Sánchez	Bahoruco	Hato Mayor	Colombia (Riascos-Ortiz *et al*. 2019)
Variables	**n=10**	**n=10**	**n=10**	**n=15**
L	402.4±3.2 (399.0-408.2)†	404.5±3.3 (400.3-409.4)	400.8±2.3 (397.2-407.1)	367.2 ± 23.8 (345.0–425.0)
Body width	19.3±1.4 (16.6-21.0)	17.1±1.0 (15.5-18.7)	18.1±2.0(15.4-21.5)	15.9 ± 1.2 (15.0–19.0)
% vulva	71.9±0.6 (71.0-72.7)	71.8±1.0 (69.4-73.1)	71.9±0.7 (70.5-72.6)	72.0 ± 0.9 (71.0–73.8)
Stylet length	15.9±0.3 (15.4-16.4)	16.2±0.5 (15.5-16.9)	16.0±0.5 (15.4-16.8)	16.0 ± 0.6 (15.0–17.0)
Esophagus	105.4±14.9 (87.4-137.4)	118.7±9.5 (105.0-141.4)	122.6±26.4 (76.2-169.0)	-
Tail length	24.7±1.61 (23.4-28.6)	24.5±0.7 (23.7-25.7)	24.0±0.6(23.2-25.2)	22.8 ± 2.3 (20.0–27.0)
Anal body diam.	11.3±1.1 (8.9-13.3)	11.3±1.2 (9.0-13.0)	12.5±1.3 (10.2-14.2)	9.9 ± 1.1 (8.0–12.0)
a	21.0±1.7 (19.2-24.1)	23.7±1.3 (21.8-26.1)	22.4±2.4 (18.6-26.0)	23.8 ± 1.1 (21.8–26.6)
b	3.9±0.5 (2.9-4.6)	3.4±0.3 (2.8-3.9)	3.4±0.8(2.4-5.3)	2.9 ± 0.2 (2.5–3.1)
c	16.3±1.0 (14.0-17.5)	16.6±0.4 (15.7-16.9)	16.7±0.4(16.2-17.3)	16.1 ± 1.1 (14.1–17.6)

†Measurements in µm; mean ± s.d. (interval), N= adult females, L=body length, a = body length/width, b = body length/esophagus, c = body length/tail length.

ANNEXES SECOND CHAPTER

Table 1. Contribution of the Generalized Linear model to the future projections of plant parasitic nematodes.

	Genus			
Variables	***Helicotylenchus***	***Meloidogyne***	***Pratylenchus***	***Rotylenchulus***
Threshold	0.05	0.09	0.03	0.04
AUC	0.69	0.79	0.74	0.67
Omission.rate	0.07	0.29	0.00	0.25
Sensitivity	0.93	0.71	1.00	0.75
Specificity	0.46	0.88	0.49	0.60
Prop.correct	0.48	0.87	0.50	0.60
Kappa	0.06	0.30	0.04	0.05

Table 2. Distribution area for future projections of *Helicotylenchus*.

Province names	class	Area range (ha)	Percentage	Types of scenarios
Azua	Suitable	235676.9433	4.87	Baseline
Azua	Unsuitable	26228.17383	0.54	Baseline
Bahoruco	Suitable	114505.3511	2.36	Baseline
Bahoruco	Unsuitable	15909.84293	0.33	Baseline
Barahona	Suitable	150526.4554	3.11	Baseline
Barahona	Unsuitable	5005.659169	0.10	Baseline
Dajabón	Suitable	79986.10071	1.65	Baseline
Dajabón	Unsuitable	22446.00066	0.46	Baseline
Distrito Nacional	Suitable	8639.711004	0.18	Baseline
Duarte	Suitable	162367.6529	3.35	Baseline
El Seybo	Suitable	168702.429	3.48	Baseline
Espaillat	Suitable	85026.68021	1.76	Baseline
Hato Mayor	Suitable	130390.7636	2.69	Baseline
Independencia	Suitable	158143.3919	3.26	Baseline
Independencia	Unsuitable	36529.9705	0.75	Baseline
La Altagracia	Suitable	289166.5218	5.97	Baseline
La Estrelleta	Suitable	96690.70322	2.00	Baseline
La Estrelleta	Unsuitable	43317.38945	0.89	Baseline
La Romana	Suitable	54376.99309	1.12	Baseline
La Vega	Suitable	116722.4885	2.41	Baseline
La Vega	Unsuitable	107795.8325	2.23	Baseline
María Trinidad Sánchez	Suitable	119458.6917	2.47	Baseline
Monseñor Nouel	Suitable	93350.11171	1.93	Baseline
Monseñor Nouel	Unsuitable	3826.119304	0.08	Baseline
Monte Cristi	Suitable	188570.2694	3.89	Baseline
Monte Plata	Suitable	258911.5404	5.34	Baseline
Pedernales	Suitable	156048.8479	3.22	Baseline
Pedernales	Unsuitable	40279.0804	0.83	Baseline
Peravia	Suitable	72906.76009	1.51	Baseline
Puerto Plata	Suitable	183890.2532	3.80	Baseline
Salcedo	Suitable	42337.73782	0.87	Baseline
Samaná	Suitable	71080.6437	1.47	Baseline
San Cristóbal	Suitable	119105.2364	2.46	Baseline
San José de Ocoa	Suitable	75244.33427	1.55	Baseline
San José de Ocoa	Unsuitable	9583.761509	0.20	Baseline
San Juan	Suitable	179672.3148	3.71	Baseline
San Juan	Unsuitable	153321.0251	3.17	Baseline
San Pedro de Macorís	Suitable	125301.8573	2.59	Baseline

Table 2. Distribution area for future projections of *Helicotylenchus*.

Province names	class	Area range (ha)	Percentage	Types of scenarios
Santiago	Suitable	172075.5714	3.55	Baseline
Santiago	Unsuitable	105159.6533	2.17	Baseline
Santiago Rodríguez	Suitable	56163.887	1.16	Baseline
Santiago Rodríguez	Unsuitable	58160.63931	1.20	Baseline
Santo Domingo	Suitable	127511.1915	2.63	Baseline
Sánchez Ramírez	Suitable	117725.8478	2.43	Baseline
Valverde	Suitable	79442.99924	1.64	Baseline
Azua	Suitable	208090.5441	4.30	sglmft24530binary
Azua	Unsuitable	53814.57302	1.11	sglmft24530binary
Bahoruco	Suitable	114699.6993	2.37	sglmft24530binary
Bahoruco	Unsuitable	15715.49473	0.32	sglmft24530binary
Barahona	Suitable	152205.7408	3.14	sglmft24530binary
Barahona	Unsuitable	3326.373754	0.07	sglmft24530binary
Dajabón	Suitable	102363.5316	2.11	sglmft24530binary
Dajabón	Unsuitable	68.56973359	0.00	sglmft24530binary
Distrito Nacional	Suitable	8639.711004	0.18	sglmft24530binary
Duarte	Suitable	162367.6529	3.35	sglmft24530binary
El Seybo	Suitable	168702.429	3.48	sglmft24530binary
Espaillat	Suitable	85026.68021	1.76	sglmft24530binary
Hato Mayor	Suitable	130390.7636	2.69	sglmft24530binary
Independencia	Suitable	160355.8127	3.31	sglmft24530binary
Independencia	Unsuitable	34317.54974	0.71	sglmft24530binary
La Altagracia	Suitable	289166.5218	5.97	sglmft24530binary
La Estrelleta	Suitable	95765.0647	1.98	sglmft24530binary
La Estrelleta	Unsuitable	44243.02792	0.91	sglmft24530binary
La Romana	Suitable	54376.99309	1.12	sglmft24530binary
La Vega	Suitable	97830.68883	2.02	sglmft24530binary
La Vega	Unsuitable	126687.6323	2.62	sglmft24530binary
María Trinidad Sánchez	Suitable	119458.6917	2.47	sglmft24530binary
Monseñor Nouel	Suitable	90321.83806	1.86	sglmft24530binary
Monseñor Nouel	Unsuitable	6854.392971	0.14	sglmft24530binary
Monte Cristi	Suitable	188570.2694	3.89	sglmft24530binary
Monte Plata	Suitable	258911.5404	5.34	sglmft24530binary
Pedernales	Suitable	158010.2717	3.26	sglmft24530binary
Pedernales	Unsuitable	38317.65661	0.79	sglmft24530binary
Peravia	Suitable	72636.74636	1.50	sglmft24530binary
Peravia	Unsuitable	270.0137341	0.01	sglmft24530binary
Puerto Plata	Suitable	183890.2532	3.80	sglmft24530binary
Salcedo	Suitable	42337.73782	0.87	sglmft24530binary

Table 2. Distribution area for future projections of *Helicotylenchus*.

Province names	class	Area range (ha)	Percentage	Types of scenarios
Samaná	Suitable	71080.6437	1.47	sglmft24530binary
San Cristóbal	Suitable	118469.6017	2.45	sglmft24530binary
San Cristóbal	Unsuitable	635.6347345	0.01	sglmft24530binary
San José de Ocoa	Suitable	68564.95783	1.42	sglmft24530binary
San José de Ocoa	Unsuitable	16263.13792	0.34	sglmft24530binary
San Juan	Suitable	152286.8782	3.14	sglmft24530binary
San Juan	Unsuitable	180706.4618	3.73	sglmft24530binary
San Pedro de Macorís	Suitable	125301.8573	2.59	sglmft24530binary
Santiago	Suitable	177354.2556	3.66	sglmft24530binary
Santiago	Unsuitable	99880.96904	2.06	sglmft24530binary
Santiago Rodríguez	Suitable	78347.72736	1.62	sglmft24530binary
Santiago Rodríguez	Unsuitable	35976.79896	0.74	sglmft24530binary
Santo Domingo	Suitable	127511.1915	2.63	sglmft24530binary
Sánchez Ramírez	Suitable	117725.8478	2.43	sglmft24530binary
Valverde	Suitable	79442.99924	1.64	sglmft24530binary
Azua	Suitable	220052.7196	4.54	sglmft24550binary
Azua	Unsuitable	41852.39758	0.86	sglmft24550binary
Bahoruco	Suitable	118225.2023	2.44	sglmft24550binary
Bahoruco	Unsuitable	12189.99181	0.25	sglmft24550binary
Barahona	Suitable	149650.5505	3.09	sglmft24550binary
Barahona	Unsuitable	5881.56406	0.12	sglmft24550binary
Dajabón	Suitable	99638.36319	2.06	sglmft24550binary
Dajabón	Unsuitable	2793.738174	0.06	sglmft24550binary
Distrito Nacional	Suitable	8639.711004	0.18	sglmft24550binary
Duarte	Suitable	162367.6529	3.35	sglmft24550binary
El Seybo	Suitable	168702.429	3.48	sglmft24550binary
Espaillat	Suitable	85026.68021	1.76	sglmft24550binary
Hato Mayor	Suitable	130390.7636	2.69	sglmft24550binary
Independencia	Suitable	158189.8032	3.27	sglmft24550binary
Independencia	Unsuitable	36483.55697	0.75	sglmft24550binary
La Altagracia	Suitable	289166.5218	5.97	sglmft24550binary
La Estrelleta	Suitable	97873.74929	2.02	sglmft24550binary
La Estrelleta	Unsuitable	42134.34338	0.87	sglmft24550binary
La Romana	Suitable	54376.99309	1.12	sglmft24550binary
La Vega	Suitable	97831.0234	2.02	sglmft24550binary
La Vega	Unsuitable	126687.2976	2.62	sglmft24550binary
María Trinidad Sánchez	Suitable	119458.6917	2.47	sglmft24550binary
Monseñor Nouel	Suitable	89462.45878	1.85	sglmft24550binary

Table 2. Distribution area for future projections of *Helicotylenchus*.

Province names	class	Area range (ha)	Percentage	Types of scenarios
Monseñor Nouel	Unsuitable	7713.772248	0.16	sglmft24550binary
Monte Cristi	Suitable	188570.2694	3.89	sglmft24550binary
Monte Plata	Suitable	258911.5404	5.34	sglmft24550binary
Pedernales	Suitable	154783.8712	3.20	sglmft24550binary
Pedernales	Unsuitable	41544.05709	0.86	sglmft24550binary
Peravia	Suitable	72477.84965	1.50	sglmft24550binary
Peravia	Unsuitable	428.910438	0.01	sglmft24550binary
Puerto Plata	Suitable	183890.2532	3.80	sglmft24550binary
Salcedo	Suitable	42337.73782	0.87	sglmft24550binary
Samaná	Suitable	71080.6437	1.47	sglmft24550binary
San Cristóbal	Suitable	118072.3376	2.44	sglmft24550binary
San Cristóbal	Unsuitable	1032.898853	0.02	sglmft24550binary
San José de Ocoa	Suitable	70082.85405	1.45	sglmft24550binary
San José de Ocoa	Unsuitable	14745.24168	0.30	sglmft24550binary
San Juan	Suitable	179608.3569	3.71	sglmft24550binary
San Juan	Unsuitable	153384.983	3.17	sglmft24550binary
San Pedro de Macorís	Suitable	125301.8573	2.59	sglmft24550binary
Santiago	Suitable	176403.4085	3.64	sglmft24550binary
Santiago	Unsuitable	100831.8162	2.08	sglmft24550binary
Santiago Rodríguez	Suitable	70949.45316	1.46	sglmft24550binary
Santiago Rodríguez	Unsuitable	43375.07316	0.90	sglmft24550binary
Santo Domingo	Suitable	127511.1915	2.63	sglmft24550binary
Sánchez Ramírez	Suitable	117725.8478	2.43	sglmft24550binary
Valverde	Suitable	79442.99924	1.64	sglmft24550binary
Azua	Suitable	216955.2381	4.48	sglmft58530binary
Azua	Unsuitable	44949.87908	0.93	sglmft58530binary
Bahoruco	Suitable	119050.5933	2.46	sglmft58530binary
Bahoruco	Unsuitable	11364.60077	0.23	sglmft58530binary
Barahona	Suitable	149889.4401	3.09	sglmft58530binary
Barahona	Unsuitable	5642.674483	0.12	sglmft58530binary
Dajabón	Suitable	102154.3344	2.11	sglmft58530binary
Dajabón	Unsuitable	277.7669216	0.01	sglmft58530binary
Distrito Nacional	Suitable	8639.711004	0.18	sglmft58530binary
Duarte	Suitable	162367.6529	3.35	sglmft58530binary
El Seybo	Suitable	168702.429	3.48	sglmft58530binary
Espaillat	Suitable	85026.68021	1.76	sglmft58530binary
Hato Mayor	Suitable	130390.7636	2.69	sglmft58530binary
Independencia	Suitable	161429.0204	3.33	sglmft58530binary

Table 2. Distribution area for future projections of *Helicotylenchus*.

Province names	class	Area range (ha)	Percentage	Types of scenarios
Independencia	Unsuitable	33244.34185	0.69	sglmft58530binary
La Altagracia	Suitable	289166.5218	5.97	sglmft58530binary
La Estrelleta	Suitable	99057.05216	2.04	sglmft58530binary
La Estrelleta	Unsuitable	40951.04052	0.85	sglmft58530binary
La Romana	Suitable	54376.99309	1.12	sglmft58530binary
La Vega	Suitable	100930.6042	2.08	sglmft58530binary
La Vega	Unsuitable	123587.7168	2.55	sglmft58530binary
María Trinidad Sánchez	Suitable	119458.6917	2.47	sglmft58530binary
Monseñor Nouel	Suitable	91224.65431	1.88	sglmft58530binary
Monseñor Nouel	Unsuitable	5951.576725	0.12	sglmft58530binary
Monte Cristi	Suitable	188570.2694	3.89	sglmft58530binary
Monte Plata	Suitable	258911.5404	5.34	sglmft58530binary
Pedernales	Suitable	158660.1324	3.28	sglmft58530binary
Pedernales	Unsuitable	37667.79583	0.78	sglmft58530binary
Peravia	Suitable	72875.1529	1.50	sglmft58530binary
Peravia	Unsuitable	31.60719613	0.00	sglmft58530binary
Puerto Plata	Suitable	183890.2532	3.80	sglmft58530binary
Salcedo	Suitable	42337.73782	0.87	sglmft58530binary
Samaná	Suitable	71080.6437	1.47	sglmft58530binary
San Cristóbal	Suitable	117754.5064	2.43	sglmft58530binary
San Cristóbal	Unsuitable	1350.730045	0.03	sglmft58530binary
San José de Ocoa	Suitable	70075.286	1.45	sglmft58530binary
San José de Ocoa	Unsuitable	14752.80975	0.30	sglmft58530binary
San Juan	Suitable	184836.5824	3.82	sglmft58530binary
San Juan	Unsuitable	148156.7575	3.06	sglmft58530binary
San Pedro de Macorís	Suitable	125301.8573	2.59	sglmft58530binary
Santiago	Suitable	173880.287	3.59	sglmft58530binary
Santiago	Unsuitable	103354.9376	2.13	sglmft58530binary
Santiago Rodríguez	Suitable	80768.00442	1.67	sglmft58530binary
Santiago Rodríguez	Unsuitable	33556.52189	0.69	sglmft58530binary
Santo Domingo	Suitable	127511.1915	2.63	sglmft58530binary
Sánchez Ramírez	Suitable	117725.8478	2.43	sglmft58530binary
Valverde	Suitable	79442.99924	1.64	sglmft58530binary
Azua	Suitable	222126.9926	4.59	sglmft58550binary
Azua	Unsuitable	39778.1246	0.82	sglmft58550binary
Bahoruco	Suitable	115711.0612	2.39	sglmft58550binary
Bahoruco	Unsuitable	14704.1329	0.30	sglmft58550binary
Barahona	Suitable	142645.3285	2.94	sglmft58550binary

Table 2. Distribution area for future projections of *Helicotylenchus*.

Province names	class	Area range (ha)	Percentage	Types of scenarios
Barahona	Unsuitable	12886.78606	0.27	sglmft58550binary
Dajabón	Suitable	102108.6343	2.11	sglmft58550binary
Dajabón	Unsuitable	323.4671122	0.01	sglmft58550binary
Distrito Nacional	Suitable	8639.711004	0.18	sglmft58550binary
Duarte	Suitable	162367.6529	3.35	sglmft58550binary
El Seybo	Suitable	168702.429	3.48	sglmft58550binary
Espaillat	Suitable	85026.68021	1.76	sglmft58550binary
Hato Mayor	Suitable	130390.7636	2.69	sglmft58550binary
Independencia	Suitable	158054.8526	3.26	sglmft58550binary
Independencia	Unsuitable	36618.50974	0.76	sglmft58550binary
La Altagracia	Suitable	289166.5218	5.97	sglmft58550binary
La Estrelleta	Suitable	98737.89122	2.04	sglmft58550binary
La Estrelleta	Unsuitable	41270.20146	0.85	sglmft58550binary
La Romana	Suitable	54376.99309	1.12	sglmft58550binary
La Vega	Suitable	101318.5118	2.09	sglmft58550binary
La Vega	Unsuitable	123199.8092	2.54	sglmft58550binary
María Trinidad Sánchez	Suitable	119458.6917	2.47	sglmft58550binary
Monseñor Nouel	Suitable	86731.4103	1.79	sglmft58550binary
Monseñor Nouel	Unsuitable	10444.82073	0.22	sglmft58550binary
Monte Cristi	Suitable	188570.2694	3.89	sglmft58550binary
Monte Plata	Suitable	258911.5404	5.34	sglmft58550binary
Pedernales	Suitable	154787.9344	3.20	sglmft58550binary
Pedernales	Unsuitable	41539.99383	0.86	sglmft58550binary
Peravia	Suitable	72875.1529	1.50	sglmft58550binary
Peravia	Unsuitable	31.60719613	0.00	sglmft58550binary
Puerto Plata	Suitable	183890.2532	3.80	sglmft58550binary
Salcedo	Suitable	42337.73782	0.87	sglmft58550binary
Samaná	Suitable	71080.6437	1.47	sglmft58550binary
San Cristóbal	Suitable	118231.2359	2.44	sglmft58550binary
San Cristóbal	Unsuitable	874.0005516	0.02	sglmft58550binary
San José de Ocoa	Suitable	69595.04025	1.44	sglmft58550binary
San José de Ocoa	Unsuitable	15233.0555	0.31	sglmft58550binary
San Juan	Suitable	200374.5613	4.14	sglmft58550binary
San Juan	Unsuitable	132618.7786	2.74	sglmft58550binary
San Pedro de Macorís	Suitable	125301.8573	2.59	sglmft58550binary
Santiago	Suitable	193295.786	3.99	sglmft58550binary
Santiago	Unsuitable	83939.43866	1.73	sglmft58550binary
Santiago Rodríguez	Suitable	85646.43509	1.77	sglmft58550binary
Santiago Rodríguez	Unsuitable	28678.09123	0.59	sglmft58550binary

Table 2. Distribution area for future projections of *Helicotylenchus*.

Province names	class	Area range (ha)	Percentage	Types of scenarios
Santo Domingo	Suitable	127511.1915	2.63	sglmft58550binary
Sánchez Ramírez	Suitable	117725.8478	2.43	sglmft58550binary
Valverde	Suitable	79442.99924	1.64	sglmft58550binary

Table 3. Distribution area for future projections of *Meloidogyne.*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Azua	Suitable	158404.14	3.27	Baseline
Azua	Unsuitable	103500.97	2.14	Baseline
Bahoruco	Suitable	75868.52	1.57	Baseline
Bahoruco	Unsuitable	54546.68	1.13	Baseline
Barahona	Suitable	116488.25	2.40	Baseline
Barahona	Unsuitable	39043.86	0.81	Baseline
Dajabón	Suitable	71800.76	1.48	Baseline
Dajabón	Unsuitable	30631.34	0.63	Baseline
Distrito Nacional	Suitable	8639.71	0.18	Baseline
Duarte	Suitable	162367.65	3.35	Baseline
El Seybo	Suitable	168702.43	3.48	Baseline
Espaillat	Suitable	85026.68	1.76	Baseline
Hato Mayor	Suitable	130390.76	2.69	Baseline
Independencia	Suitable	55998.14	1.16	Baseline
Independencia	Unsuitable	138675.22	2.86	Baseline
La Altagracia	Suitable	289166.52	5.97	Baseline
La Estrelleta	Suitable	88169.69	1.82	Baseline
La Estrelleta	Unsuitable	51838.40	1.07	Baseline
La Romana	Suitable	54376.99	1.12	Baseline
La Vega	Suitable	94589.35	1.95	Baseline
La Vega	Unsuitable	129928.97	2.68	Baseline
María Trinidad Sánchez	Suitable	119458.69	2.47	Baseline
Monseñor Nouel	Suitable	90461.01	1.87	Baseline
Monseñor Nouel	Unsuitable	6715.22	0.14	Baseline
Monte Cristi	Suitable	103509.89	2.14	Baseline
Monte Cristi	Unsuitable	85060.38	1.76	Baseline
Monte Plata	Suitable	258911.54	5.34	Baseline
Pedernales	Suitable	116282.41	2.40	Baseline
Pedernales	Unsuitable	80045.52	1.65	Baseline
Peravia	Suitable	72440.69	1.50	Baseline
Peravia	Unsuitable	466.07	0.01	Baseline
Puerto Plata	Suitable	56907.20	1.17	Baseline
Puerto Plata	Unsuitable	126983.05	2.62	Baseline
Salcedo	Suitable	42337.74	0.87	Baseline

Table 3. Distribution area for future projections of *Meloidogyne.*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Samaná	Suitable	71080.64	1.47	Baseline
San Critóbal	Suitable	118628.50	2.45	Baseline
San Critóbal	Unsuitable	476.74	0.01	Baseline
San José de Ocoa	Suitable	62514.19	1.29	Baseline
San José de Ocoa	Unsuitable	22313.91	0.46	Baseline
San Juan	Suitable	61581.48	1.27	Baseline
San Juan	Unsuitable	271411.86	5.60	Baseline
San Pedro de Macorís	Suitable	125301.86	2.59	Baseline
Santiago	Suitable	87530.35	1.81	Baseline
Santiago	Unsuitable	189704.88	3.92	Baseline
Santiago Rodríguez	Suitable	2622.88	0.05	Baseline
Santiago Rodríguez	Unsuitable	111701.65	2.31	Baseline
Santo Domingo	Suitable	127511.19	2.63	Baseline
Sánchez Ramírez	Suitable	117725.85	2.43	Baseline
Valverde	Suitable	6171.84	0.13	Baseline
Valverde	Unsuitable	73271.16	1.51	Baseline
Azua	Suitable	152105.21	3.14	sglmft24530binary
Azua	Unsuitable	109799.90	2.27	sglmft24530binary
Bahoruco	Suitable	72810.02	1.50	sglmft24530binary
Bahoruco	Unsuitable	57605.18	1.19	sglmft24530binary
Barahona	Suitable	127406.65	2.63	sglmft24530binary
Barahona	Unsuitable	28125.46	0.58	sglmft24530binary
Dajabón	Suitable	88866.42	1.83	sglmft24530binary
Dajabón	Unsuitable	13565.68	0.28	sglmft24530binary
Distrito Nacional	Suitable	8639.71	0.18	sglmft24530binary
Duarte	Suitable	162367.65	3.35	sglmft24530binary
El Seybo	Suitable	168702.43	3.48	sglmft24530binary
Espaillat	Suitable	85026.68	1.76	sglmft24530binary
Hato Mayor	Suitable	130390.76	2.69	sglmft24530binary
Independencia	Suitable	55867.91	1.15	sglmft24530binary
Independencia	Unsuitable	138805.45	2.87	sglmft24530binary
La Altagracia	Suitable	289166.52	5.97	sglmft24530binary
La Estrelleta	Suitable	90775.55	1.87	sglmft24530binary
La Estrelleta	Unsuitable	49232.54	1.02	sglmft24530binary
La Romana	Suitable	54376.99	1.12	sglmft24530binary
La Vega	Suitable	95836.95	1.98	sglmft24530binary
La Vega	Unsuitable	128681.37	2.66	sglmft24530binary
María Trinidad Sánchez	Suitable	119458.69	2.47	sglmft24530binary
Monseñor Nouel	Suitable	90657.03	1.87	sglmft24530binary
Monseñor Nouel	Unsuitable	6519.20	0.13	sglmft24530binary

Table 3. Distribution area for future projections of *Meloidogyne.*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Monte Cristi	Suitable	91467.41	1.89	sglmft24530binary
Monte Cristi	Unsuitable	97102.86	2.00	sglmft24530binary
Monte Plata	Suitable	258911.54	5.34	sglmft24530binary
Pedernales	Suitable	132788.61	2.74	sglmft24530binary
Pedernales	Unsuitable	63539.32	1.31	sglmft24530binary
Peravia	Suitable	72440.69	1.50	sglmft24530binary
Peravia	Unsuitable	466.07	0.01	sglmft24530binary
Puerto Plata	Suitable	45310.40	0.94	sglmft24530binary
Puerto Plata	Unsuitable	138579.85	2.86	sglmft24530binary
Salcedo	Suitable	42337.74	0.87	sglmft24530binary
Samaná	Suitable	71080.64	1.47	sglmft24530binary
San Critóbal	Suitable	119105.24	2.46	sglmft24530binary
San José de Ocoa	Suitable	64024.39	1.32	sglmft24530binary
San José de Ocoa	Unsuitable	20803.70	0.43	sglmft24530binary
San Juan	Suitable	56397.58	1.16	sglmft24530binary
San Juan	Unsuitable	276595.76	5.71	sglmft24530binary
San Pedro de Macorís	Suitable	125301.86	2.59	sglmft24530binary
Santiago	Suitable	73467.72	1.52	sglmft24530binary
Santiago	Unsuitable	203767.51	4.21	sglmft24530binary
Santiago Rodríguez	Suitable	5508.02	0.11	sglmft24530binary
Santiago Rodríguez	Unsuitable	108816.50	2.25	sglmft24530binary
Santo Domingo	Suitable	127511.19	2.63	sglmft24530binary
Sánchez Ramírez	Suitable	117725.85	2.43	sglmft24530binary
Valverde	Suitable	3286.41	0.07	sglmft24530binary
Valverde	Unsuitable	76156.59	1.57	sglmft24530binary
Azua	Suitable	127909.68	2.64	sglmft24550binary
Azua	Unsuitable	133995.44	2.77	sglmft24550binary
Bahoruco	Suitable	61174.53	1.26	sglmft24550binary
Bahoruco	Unsuitable	69240.67	1.43	sglmft24550binary
Barahona	Suitable	109065.79	2.25	sglmft24550binary
Barahona	Unsuitable	46466.32	0.96	sglmft24550binary
Dajabón	Suitable	102432.10	2.11	sglmft24550binary
Distrito Nacional	Suitable	8639.71	0.18	sglmft24550binary
Duarte	Suitable	162367.65	3.35	sglmft24550binary
El Seybo	Suitable	168702.43	3.48	sglmft24550binary
Espaillat	Suitable	85026.68	1.76	sglmft24550binary
Hato Mayor	Suitable	130390.76	2.69	sglmft24550binary
Independencia	Suitable	42730.75	0.88	sglmft24550binary
Independencia	Unsuitable	151942.61	3.14	sglmft24550binary
La Altagracia	Suitable	289166.52	5.97	sglmft24550binary
La Estrelleta	Suitable	98234.03	2.03	sglmft24550binary

Table 3. Distribution area for future projections of *Meloidogyne.*

Province names	**class**	**Area range (ha)**	**Percentage**	**Types of scenarios**
La Estrelleta	Unsuitable	41774.07	0.86	sglmft24550binary
La Romana	Suitable	54376.99	1.12	sglmft24550binary
La Vega	Suitable	101151.34	2.09	sglmft24550binary
La Vega	Unsuitable	123366.98	2.55	sglmft24550binary
María Trinidad Sánchez	Suitable	119458.69	2.47	sglmft24550binary
Monseñor Nouel	Suitable	91459.33	1.89	sglmft24550binary
Monseñor Nouel	Unsuitable	5716.91	0.12	sglmft24550binary
Monte Cristi	Suitable	146709.03	3.03	sglmft24550binary
Monte Cristi	Unsuitable	41861.24	0.86	sglmft24550binary
Monte Plata	Suitable	258911.54	5.34	sglmft24550binary
Pedernales	Suitable	123401.14	2.55	sglmft24550binary
Pedernales	Unsuitable	72926.78	1.51	sglmft24550binary
Peravia	Suitable	72557.27	1.50	sglmft24550binary
Peravia	Unsuitable	349.49	0.01	sglmft24550binary
Puerto Plata	Suitable	69827.33	1.44	sglmft24550binary
Puerto Plata	Unsuitable	114062.92	2.35	sglmft24550binary
Salcedo	Suitable	42337.74	0.87	sglmft24550binary
Samaná	Suitable	71080.64	1.47	sglmft24550binary
San Critóbal	Suitable	119105.24	2.46	sglmft24550binary
San José de Ocoa	Suitable	65252.95	1.35	sglmft24550binary
San José de Ocoa	Unsuitable	19575.14	0.40	sglmft24550binary
San Juan	Suitable	74890.42	1.55	sglmft24550binary
San Juan	Unsuitable	258102.92	5.33	sglmft24550binary
San Pedro de Macorís	Suitable	125301.86	2.59	sglmft24550binary
Santiago	Suitable	121514.01	2.51	sglmft24550binary
Santiago	Unsuitable	155721.22	3.21	sglmft24550binary
Santiago Rodríguez	Suitable	50620.59	1.04	sglmft24550binary
Santiago Rodríguez	Unsuitable	63703.94	1.32	sglmft24550binary
Santo Domingo	Suitable	127511.19	2.63	sglmft24550binary
Sánchez Ramírez	Suitable	117725.85	2.43	sglmft24550binary
Valverde	Suitable	23663.63	0.49	sglmft24550binary
Valverde	Unsuitable	55779.37	1.15	sglmft24550binary
Azua	Suitable	122544.13	2.53	sglmft58530binary
Azua	Unsuitable	139360.98	2.88	sglmft58530binary
Bahoruco	Suitable	55951.01	1.16	sglmft58530binary
Bahoruco	Unsuitable	74464.18	1.54	sglmft58530binary
Barahona	Suitable	101487.64	2.10	sglmft58530binary
Barahona	Unsuitable	54044.47	1.12	sglmft58530binary
Dajabón	Suitable	92397.52	1.91	sglmft58530binary
Dajabón	Unsuitable	10034.58	0.21	sglmft58530binary

Table 3. Distribution area for future projections of *Meloidogyne.*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Distrito Nacional	Suitable	8639.71	0.18	sglmft58530binary
Duarte	Suitable	162367.65	3.35	sglmft58530binary
El Seybo	Suitable	168702.43	3.48	sglmft58530binary
Espaillat	Suitable	85026.68	1.76	sglmft58530binary
Hato Mayor	Suitable	130390.76	2.69	sglmft58530binary
Independencia	Suitable	42189.51	0.87	sglmft58530binary
Independencia	Unsuitable	152483.85	3.15	sglmft58530binary
La Altagracia	Suitable	289166.52	5.97	sglmft58530binary
La Estrelleta	Suitable	84608.41	1.75	sglmft58530binary
La Estrelleta	Unsuitable	55399.68	1.14	sglmft58530binary
La Romana	Suitable	54376.99	1.12	sglmft58530binary
La Vega	Suitable	96191.66	1.99	sglmft58530binary
La Vega	Unsuitable	128326.66	2.65	sglmft58530binary
María Trinidad Sánchez	Suitable	119458.69	2.47	sglmft58530binary
Monseñor Nouel	Suitable	90485.51	1.87	sglmft58530binary
Monseñor Nouel	Unsuitable	6690.72	0.14	sglmft58530binary
Monte Cristi	Suitable	117877.75	2.43	sglmft58530binary
Monte Cristi	Unsuitable	70692.52	1.46	sglmft58530binary
Monte Plata	Suitable	258911.54	5.34	sglmft58530binary
Pedernales	Suitable	110661.16	2.28	sglmft58530binary
Pedernales	Unsuitable	85666.77	1.77	sglmft58530binary
Peravia	Suitable	72272.66	1.49	sglmft58530binary
Peravia	Unsuitable	634.10	0.01	sglmft58530binary
Puerto Plata	Suitable	58461.25	1.21	sglmft58530binary
Puerto Plata	Unsuitable	125429.00	2.59	sglmft58530binary
Salcedo	Suitable	42337.74	0.87	sglmft58530binary
Samaná	Suitable	71080.64	1.47	sglmft58530binary
San Critóbal	Suitable	118549.04	2.45	sglmft58530binary
San Critóbal	Unsuitable	556.19	0.01	sglmft58530binary
San José de Ocoa	Suitable	60320.68	1.25	sglmft58530binary
San José de Ocoa	Unsuitable	24507.42	0.51	sglmft58530binary
San Juan	Suitable	38346.50	0.79	sglmft58530binary
San Juan	Unsuitable	294646.84	6.08	sglmft58530binary
San Pedro de Macorís	Suitable	125301.86	2.59	sglmft58530binary
Santiago	Suitable	90687.69	1.87	sglmft58530binary
Santiago	Unsuitable	186547.54	3.85	sglmft58530binary
Santiago Rodríguez	Suitable	8337.86	0.17	sglmft58530binary
Santiago Rodríguez	Unsuitable	105986.67	2.19	sglmft58530binary
Santo Domingo	Suitable	127511.19	2.63	sglmft58530binary
Sánchez Ramírez	Suitable	117725.85	2.43	sglmft58530binary

Table 3. Distribution area for future projections of *Meloidogyne.*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Valverde	Suitable	8518.09	0.18	sglmft58530binary
Valverde	Unsuitable	70924.91	1.46	sglmft58530binary
Azua	Suitable	185365.09	3.83	sglmft58550binary
Azua	Unsuitable	76540.03	1.58	sglmft58550binary
Bahoruco	Suitable	85846.93	1.77	sglmft58550binary
Bahoruco	Unsuitable	44568.26	0.92	sglmft58550binary
Barahona	Suitable	125875.62	2.60	sglmft58550binary
Barahona	Unsuitable	29656.49	0.61	sglmft58550binary
Dajabón	Suitable	100562.31	2.08	sglmft58550binary
Dajabón	Unsuitable	1869.79	0.04	sglmft58550binary
Distrito Nacional	Suitable	8639.71	0.18	sglmft58550binary
Duarte	Suitable	162367.65	3.35	sglmft58550binary
El Seybo	Suitable	168702.43	3.48	sglmft58550binary
Espaillat	Suitable	85026.68	1.76	sglmft58550binary
Hato Mayor	Suitable	130390.76	2.69	sglmft58550binary
Independencia	Suitable	56402.33	1.16	sglmft58550binary
Independencia	Unsuitable	138271.03	2.85	sglmft58550binary
La Altagracia	Suitable	289166.52	5.97	sglmft58550binary
La Estrelleta	Suitable	91309.99	1.88	sglmft58550binary
La Estrelleta	Unsuitable	48698.10	1.01	sglmft58550binary
La Romana	Suitable	54376.99	1.12	sglmft58550binary
La Vega	Suitable	98838.08	2.04	sglmft58550binary
La Vega	Unsuitable	125680.24	2.59	sglmft58550binary
María Trinidad Sánchez	Suitable	119458.69	2.47	sglmft58550binary
Monseñor Nouel	Suitable	91242.62	1.88	sglmft58550binary
Monseñor Nouel	Unsuitable	5933.61	0.12	sglmft58550binary
Monte Cristi	Suitable	140073.32	2.89	sglmft58550binary
Monte Cristi	Unsuitable	48496.95	1.00	sglmft58550binary
Monte Plata	Suitable	258911.54	5.34	sglmft58550binary
Pedernales	Suitable	130735.21	2.70	sglmft58550binary
Pedernales	Unsuitable	65592.72	1.35	sglmft58550binary
Peravia	Suitable	72716.21	1.50	sglmft58550binary
Peravia	Unsuitable	190.55	0.00	sglmft58550binary
Puerto Plata	Suitable	70911.61	1.46	sglmft58550binary
Puerto Plata	Unsuitable	112978.64	2.33	sglmft58550binary
Salcedo	Suitable	42337.74	0.87	sglmft58550binary
Samaná	Suitable	71080.64	1.47	sglmft58550binary
San Critóbal	Suitable	119105.24	2.46	sglmft58550binary
San José de Ocoa	Suitable	66762.41	1.38	sglmft58550binary
San José de Ocoa	Unsuitable	18065.69	0.37	sglmft58550binary
San Juan	Suitable	93389.46	1.93	sglmft58550binary

Table 3. Distribution area for future projections of *Meloidogyne.*

Province names	**class**	**Area range (ha)**	**Percentage**	**Types of scenarios**
San Juan	Unsuitable	239603.88	4.95	sglmft58550binary
San Pedro de Macorís	Suitable	125301.86	2.59	sglmft58550binary
Santiago	Suitable	112473.73	2.32	sglmft58550binary
Santiago	Unsuitable	164761.50	3.40	sglmft58550binary
Santiago Rodríguez	Suitable	28077.19	0.58	sglmft58550binary
Santiago Rodríguez	Unsuitable	86247.34	1.78	sglmft58550binary
Santo Domingo	Suitable	127511.19	2.63	sglmft58550binary
Sánchez Ramírez	Suitable	117725.85	2.43	sglmft58550binary
Valverde	Suitable	25620.28	0.53	sglmft58550binary
Valverde	Unsuitable	53822.72	1.11	sglmft58550binary

Table 4. Distribution area for future projections of *Pratylenchus*.

Province names	**class**	**Area range (ha)**	**Percentage**	**types of scenarios**
Azua	Suitable	193760.485	4.00	Baseline
Azua	Unsuitable	68144.6327	1.41	Baseline
Bahoruco	Suitable	117294.469	2.42	Baseline
Bahoruco	Unsuitable	13120.725	0.27	Baseline
Barahona	Suitable	130359.917	2.69	Baseline
Barahona	Unsuitable	25172.1979	0.52	Baseline
Dajabón	Suitable	101916.824	2.10	Baseline
Dajabón	Unsuitable	515.277092	0.01	Baseline
Distrito Nacional	Suitable	8639.711	0.18	Baseline
Duarte	Suitable	162367.653	3.35	Baseline
El Seybo	Suitable	168702.429	3.48	Baseline
Espaillat	Suitable	85026.6802	1.76	Baseline
Hato Mayor	Suitable	130390.764	2.69	Baseline
Independencia	Suitable	158993.25	3.28	Baseline
Independencia	Unsuitable	35680.1128	0.74	Baseline
La Altagracia	Suitable	289166.522	5.97	Baseline
La Estrelleta	Suitable	98134.0662	2.03	Baseline
La Estrelleta	Unsuitable	41874.0264	0.86	Baseline
La Romana	Suitable	54376.9931	1.12	Baseline
La Vega	Suitable	98493.3125	2.03	Baseline
La Vega	Unsuitable	126025.009	2.60	Baseline
María Trinidad Sánchez	Suitable	119458.692	2.47	Baseline
Monseñor Nouel	Suitable	82934.098	1.71	Baseline
Monseñor Nouel	Unsuitable	14242.1332	0.29	Baseline
Monte Cristi	Suitable	188570.269	3.89	Baseline
Monte Plata	Suitable	258911.54	5.34	Baseline

Table 4. Distribution area for future projections of *Pratylenchus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Pedernales	Suitable	155848.594	3.22	Baseline
Pedernales	Unsuitable	40479.3347	0.84	Baseline
Peravia	Suitable	67032.581	1.38	Baseline
Peravia	Unsuitable	5874.17905	0.12	Baseline
Puerto Plata	Suitable	183890.253	3.80	Baseline
Salcedo	Suitable	42337.7378	0.87	Baseline
Samaná	Suitable	71080.6437	1.47	Baseline
San Cristóbal	Suitable	109857.239	2.27	Baseline
San Cristóbal	Unsuitable	9247.99719	0.19	Baseline
San José de Ocoa	Suitable	48345.0916	1.00	Baseline
San José de Ocoa	Unsuitable	36483.0039	0.75	Baseline
San Juan	Suitable	200061.216	4.13	Baseline
San Juan	Unsuitable	132932.124	2.74	Baseline
San Pedro de Macorís	Suitable	125301.857	2.59	Baseline
Santiago	Suitable	202426.088	4.18	Baseline
Santiago	Unsuitable	74809.1366	1.54	Baseline
Santiago Rodríguez	Suitable	101202.71	2.09	Baseline
Santiago Rodríguez	Unsuitable	13121.8159	0.27	Baseline
Santo Domingo	Suitable	127511.191	2.63	Baseline
Sánchez Ramírez	Suitable	117725.848	2.43	Baseline
Valverde	Suitable	79442.9992	1.64	Baseline
Azua	Suitable	194158.157	4.01	sglmft24530binary
Azua	Unsuitable	67746.9603	1.40	sglmft24530binary
Bahoruco	Suitable	116736.924	2.41	sglmft24530binary
Bahoruco	Unsuitable	13678.2697	0.28	sglmft24530binary
Barahona	Suitable	127565.644	2.63	sglmft24530binary
Barahona	Unsuitable	27966.4702	0.58	sglmft24530binary
Dajabón	Suitable	102126.993	2.11	sglmft24530binary
Dajabón	Unsuitable	305.108276	0.01	sglmft24530binary
Distrito Nacional	Suitable	8639.711	0.18	sglmft24530binary
Duarte	Suitable	162367.653	3.35	sglmft24530binary
El Seybo	Suitable	168702.429	3.48	sglmft24530binary
Espaillat	Suitable	85026.6802	1.76	sglmft24530binary
Hato Mayor	Suitable	130390.764	2.69	sglmft24530binary
Independencia	Suitable	158086.312	3.26	sglmft24530binary
Independencia	Unsuitable	36587.05	0.76	sglmft24530binary
La Altagracia	Suitable	289166.522	5.97	sglmft24530binary
La Estrelleta	Suitable	97646.0694	2.02	sglmft24530binary
La Estrelleta	Unsuitable	42362.0232	0.87	sglmft24530binary

Table 4. Distribution area for future projections of *Pratylenchus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
La Romana	Suitable	54376.9931	1.12	sglmft24530binary
La Vega	Suitable	101818.818	2.10	sglmft24530binary
La Vega	Unsuitable	122699.503	2.53	sglmft24530binary
María Trinidad Sánchez	Suitable	119458.692	2.47	sglmft24530binary
Monseñor Nouel	Suitable	85198.4368	1.76	sglmft24530binary
Monseñor Nouel	Unsuitable	11977.7944	0.25	sglmft24530binary
Monte Cristi	Suitable	188570.269	3.89	sglmft24530binary
Monte Plata	Suitable	258911.54	5.34	sglmft24530binary
Pedernales	Suitable	154315.272	3.19	sglmft24530binary
Pedernales	Unsuitable	42012.6566	0.87	sglmft24530binary
Peravia	Suitable	67588.8057	1.40	sglmft24530binary
Peravia	Unsuitable	5317.95443	0.11	sglmft24530binary
Puerto Plata	Suitable	183890.253	3.80	sglmft24530binary
Salcedo	Suitable	42337.7378	0.87	sglmft24530binary
Samaná	Suitable	71080.6437	1.47	sglmft24530binary
San Cristóbal	Suitable	113488.379	2.34	sglmft24530binary
San Cristóbal	Unsuitable	5616.85726	0.12	sglmft24530binary
San José de Ocoa	Suitable	53537.3787	1.11	sglmft24530binary
San José de Ocoa	Unsuitable	31290.7168	0.65	sglmft24530binary
San Juan	Suitable	198069.837	4.09	sglmft24530binary
San Juan	Unsuitable	134923.503	2.79	sglmft24530binary
San Pedro de Macorís	Suitable	125301.857	2.59	sglmft24530binary
Santiago	Suitable	205580.269	4.24	sglmft24530binary
Santiago	Unsuitable	71654.9555	1.48	sglmft24530binary
Santiago Rodríguez	Suitable	101880.34	2.10	sglmft24530binary
Santiago Rodríguez	Unsuitable	12444.1862	0.26	sglmft24530binary
Santo Domingo	Suitable	127511.191	2.63	sglmft24530binary
Sánchez Ramírez	Suitable	117725.848	2.43	sglmft24530binary
Valverde	Suitable	79442.9992	1.64	sglmft24530binary
Azua	Suitable	199358.268	4.12	sglmft24550binary
Azua	Unsuitable	62546.8496	1.29	sglmft24550binary
Bahoruco	Suitable	118683.59	2.45	sglmft24550binary
Bahoruco	Unsuitable	11731.6042	0.24	sglmft24550binary
Barahona	Suitable	133904.388	2.76	sglmft24550binary
Barahona	Unsuitable	21627.7267	0.45	sglmft24550binary
Dajabón	Suitable	101677.804	2.10	sglmft24550binary
Dajabón	Unsuitable	754.297019	0.02	sglmft24550binary
Distrito Nacional	Suitable	8639.711	0.18	sglmft24550binary

Table 4. Distribution area for future projections of *Pratylenchus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Duarte	Suitable	162367.653	3.35	sglmft24550binary
El Seybo	Suitable	168702.429	3.48	sglmft24550binary
Espaillat	Suitable	85026.6802	1.76	sglmft24550binary
Hato Mayor	Suitable	130390.764	2.69	sglmft24550binary
Independencia	Suitable	160362.794	3.31	sglmft24550binary
Independencia	Unsuitable	34310.5688	0.71	sglmft24550binary
La Altagracia	Suitable	289166.522	5.97	sglmft24550binary
La Estrelleta	Suitable	100234.871	2.07	sglmft24550binary
La Estrelleta	Unsuitable	39773.2219	0.82	sglmft24550binary
La Romana	Suitable	54376.9931	1.12	sglmft24550binary
La Vega	Suitable	98394.0898	2.03	sglmft24550binary
La Vega	Unsuitable	126124.231	2.60	sglmft24550binary
María Trinidad Sánchez	Suitable	119458.692	2.47	sglmft24550binary
Monseñor Nouel	Suitable	80218.919	1.66	sglmft24550binary
Monseñor Nouel	Unsuitable	16957.3123	0.35	sglmft24550binary
Monte Cristi	Suitable	188570.269	3.89	sglmft24550binary
Monte Plata	Suitable	258911.54	5.34	sglmft24550binary
Pedernales	Suitable	157928.921	3.26	sglmft24550binary
Pedernales	Unsuitable	38399.0075	0.79	sglmft24550binary
Peravia	Suitable	66953.156	1.38	sglmft24550binary
Peravia	Unsuitable	5953.60405	0.12	sglmft24550binary
Puerto Plata	Suitable	183706.358	3.79	sglmft24550binary
Puerto Plata	Unsuitable	183.895183	0.00	sglmft24550binary
Salcedo	Suitable	42337.7378	0.87	sglmft24550binary
Samaná	Suitable	71080.6437	1.47	sglmft24550binary
San Cristóbal	Suitable	108325.105	2.24	sglmft24550binary
San Cristóbal	Unsuitable	10780.1313	0.22	sglmft24550binary
San José de Ocoa	Suitable	45489.8203	0.94	sglmft24550binary
San José de Ocoa	Unsuitable	39338.2752	0.81	sglmft24550binary
San Juan	Suitable	210449.171	4.34	sglmft24550binary
San Juan	Unsuitable	122544.169	2.53	sglmft24550binary
San Pedro de Macorís	Suitable	125301.857	2.59	sglmft24550binary
Santiago	Suitable	202053.13	4.17	sglmft24550binary
Santiago	Unsuitable	75182.0945	1.55	sglmft24550binary
Santiago Rodríguez	Suitable	101123.062	2.09	sglmft24550binary
Santiago Rodríguez	Unsuitable	13201.4638	0.27	sglmft24550binary
Santo Domingo	Suitable	127511.191	2.63	sglmft24550binary
Sánchez Ramírez	Suitable	117725.848	2.43	sglmft24550binary

Table 4. Distribution area for future projections of *Pratylenchus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Valverde	Suitable	79442.9992	1.64	sglmft24550binary
Azua	Suitable	195510.615	4.04	sglmft58530binary
Azua	Unsuitable	66394.502	1.37	sglmft58530binary
Bahoruco	Suitable	116497.895	2.40	sglmft58530binary
Bahoruco	Unsuitable	13917.2991	0.29	sglmft58530binary
Barahona	Suitable	128043.411	2.64	sglmft58530binary
Barahona	Unsuitable	27488.7038	0.57	sglmft58530binary
Dajabón	Suitable	101677.804	2.10	sglmft58530binary
Dajabón	Unsuitable	754.297019	0.02	sglmft58530binary
Distrito Nacional	Suitable	8639.711	0.18	sglmft58530binary
Duarte	Suitable	162367.653	3.35	sglmft58530binary
El Seybo	Suitable	168702.429	3.48	sglmft58530binary
Espaillat	Suitable	85026.6802	1.76	sglmft58530binary
Hato Mayor	Suitable	130390.764	2.69	sglmft58530binary
Independencia	Suitable	157767.523	3.26	sglmft58530binary
Independencia	Unsuitable	36905.8395	0.76	sglmft58530binary
La Altagracia	Suitable	289166.522	5.97	sglmft58530binary
La Estrelleta	Suitable	95929.0081	1.98	sglmft58530binary
La Estrelleta	Unsuitable	44079.0845	0.91	sglmft58530binary
La Romana	Suitable	54376.9931	1.12	sglmft58530binary
La Vega	Suitable	99479.7908	2.05	sglmft58530binary
La Vega	Unsuitable	125038.53	2.58	sglmft58530binary
María Trinidad Sánchez	Suitable	119458.692	2.47	sglmft58530binary
Monseñor Nouel	Suitable	83009.7486	1.71	sglmft58530binary
Monseñor Nouel	Unsuitable	14166.4826	0.29	sglmft58530binary
Monte Cristi	Suitable	188570.269	3.89	sglmft58530binary
Monte Plata	Suitable	258911.54	5.34	sglmft58530binary
Pedernales	Suitable	154554.26	3.19	sglmft58530binary
Pedernales	Unsuitable	41773.6685	0.86	sglmft58530binary
Peravia	Suitable	66794.2041	1.38	sglmft58530binary
Peravia	Unsuitable	6112.55604	0.13	sglmft58530binary
Puerto Plata	Suitable	183890.253	3.80	sglmft58530binary
Salcedo	Suitable	42337.7378	0.87	sglmft58530binary
Samaná	Suitable	71080.6437	1.47	sglmft58530binary
San Cristóbal	Suitable	108912.996	2.25	sglmft58530binary
San Cristóbal	Unsuitable	10192.2401	0.21	sglmft58530binary
San José de Ocoa	Suitable	47619.5015	0.98	sglmft58530binary
San José de Ocoa	Unsuitable	37208.594	0.77	sglmft58530binary
San Juan	Suitable	198270.093	4.09	sglmft58530binary
San Juan	Unsuitable	134723.247	2.78	sglmft58530binary

Table 4. Distribution area for future projections of *Pratylenchus*

Province names	**class**	**Area range (ha)**	**Percentage**	**Types of scenarios**
San Pedro de Macorís	Suitable	125301.857	2.59	sglmft58530binary
Santiago	Suitable	203035.852	4.19	sglmft58530binary
Santiago	Unsuitable	74199.3725	1.53	sglmft58530binary
Santiago Rodríguez	Suitable	100896.625	2.08	sglmft58530binary
Santiago Rodríguez	Unsuitable	13427.9017	0.28	sglmft58530binary
Santo Domingo	Suitable	127511.191	2.63	sglmft58530binary
Sánchez Ramírez	Suitable	117725.848	2.43	sglmft58530binary
Valverde	Suitable	79442.9992	1.64	sglmft58530binary
Azua	Suitable	201247.091	4.15	sglmft58550binary
Azua	Unsuitable	60658.0258	1.25	sglmft58550binary
Bahoruco	Suitable	119480.146	2.47	sglmft58550binary
Bahoruco	Unsuitable	10935.0481	0.23	sglmft58550binary
Barahona	Suitable	136295.324	2.81	sglmft58550binary
Barahona	Unsuitable	19236.7906	0.40	sglmft58550binary
Dajabón	Suitable	102272.751	2.11	sglmft58550binary
Dajabón	Unsuitable	159.350664	0.00	sglmft58550binary
Distrito Nacional	Suitable	8639.711	0.18	sglmft58550binary
Duarte	Suitable	162367.653	3.35	sglmft58550binary
El Seybo	Suitable	168702.429	3.48	sglmft58550binary
Espaillat	Suitable	85026.6802	1.76	sglmft58550binary
Hato Mayor	Suitable	130390.764	2.69	sglmft58550binary
Independencia	Suitable	161681.74	3.34	sglmft58550binary
Independencia	Unsuitable	32991.6225	0.68	sglmft58550binary
La Altagracia	Suitable	289166.522	5.97	sglmft58550binary
La Estrelleta	Suitable	104679.998	2.16	sglmft58550binary
La Estrelleta	Unsuitable	35328.0946	0.73	sglmft58550binary
La Romana	Suitable	54376.9931	1.12	sglmft58550binary
La Vega	Suitable	100034.706	2.07	sglmft58550binary
La Vega	Unsuitable	124483.615	2.57	sglmft58550binary
María Trinidad Sánchez	Suitable	119458.692	2.47	sglmft58550binary
Monseñor Nouel	Suitable	83011.5044	1.71	sglmft58550binary
Monseñor Nouel	Unsuitable	14164.7269	0.29	sglmft58550binary
Monte Cristi	Suitable	188570.269	3.89	sglmft58550binary
Monte Plata	Suitable	258911.54	5.34	sglmft58550binary
Pedernales	Suitable	159300.751	3.29	sglmft58550binary
Pedernales	Unsuitable	37027.1776	0.76	sglmft58550binary
Peravia	Suitable	67429.8958	1.39	sglmft58550binary
Peravia	Unsuitable	5476.86432	0.11	sglmft58550binary
Puerto Plata	Suitable	183836.509	3.79	sglmft58550binary

Table 4. Distribution area for future projections of *Pratylenchus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Puerto Plata	Unsuitable	53.7439226	0.00	sglmft58550binary
Salcedo	Suitable	42337.7378	0.87	sglmft58550binary
Samaná	Suitable	71080.6437	1.47	sglmft58550binary
San Cristóbal	Suitable	109776.539	2.27	sglmft58550binary
San Cristóbal	Unsuitable	9328.69764	0.19	sglmft58550binary
San José de Ocoa	Suitable	50362.4939	1.04	sglmft58550binary
San José de Ocoa	Unsuitable	34465.6016	0.71	sglmft58550binary
San Juan	Suitable	216481.55	4.47	sglmft58550binary
San Juan	Unsuitable	116511.79	2.41	sglmft58550binary
San Pedro de Macorís	Suitable	125301.857	2.59	sglmft58550binary
Santiago	Suitable	204520.246	4.22	sglmft58550binary
Santiago	Unsuitable	72714.9782	1.50	sglmft58550binary
Santiago Rodríguez	Suitable	102690.372	2.12	sglmft58550binary
Santiago Rodríguez	Unsuitable	11634.1544	0.24	sglmft58550binary
Santo Domingo	Suitable	127511.191	2.63	sglmft58550binary
Sánchez Ramírez	Suitable	117725.848	2.43	sglmft58550binary
Valverde	Suitable	79442.9992	1.64	sglmft58550binary

Table 5. Distribution area for future projections of *Rotylenchulus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Azua	Suitable	235676.94	4.87	Baseline
Azua	Unsuitable	26228.17	0.54	Baseline
Bahoruco	Suitable	114505.35	2.36	Baseline
Bahoruco	Unsuitable	15909.84	0.33	Baseline
Barahona	Suitable	150526.46	3.11	Baseline
Barahona	Unsuitable	5005.66	0.10	Baseline
Dajabón	Suitable	79986.10	1.65	Baseline
Dajabón	Unsuitable	22446.00	0.46	Baseline
Distrito Nacional	Suitable	8639.71	0.18	Baseline
Duarte	Suitable	162367.65	3.35	Baseline
El Seybo	Suitable	168702.43	3.48	Baseline
Espaillat	Suitable	85026.68	1.76	Baseline
Hato Mayor	Suitable	130390.76	2.69	Baseline
Independencia	Suitable	158143.39	3.26	Baseline
Independencia	Unsuitable	36529.97	0.75	Baseline
La Altagracia	Suitable	289166.52	5.97	Baseline
La Estrelleta	Suitable	96690.70	2.00	Baseline
La Estrelleta	Unsuitable	43317.39	0.89	Baseline

Table 5. Distribution area for future projections of *Rotylenchulus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
La Romana	Suitable	54376.99	1.12	Baseline
La Vega	Suitable	116722.49	2.41	Baseline
La Vega	Unsuitable	107795.83	2.23	Baseline
María Trinidad Sánchez	Suitable	119458.69	2.47	Baseline
Monseñor Nouel	Suitable	93350.11	1.93	Baseline
Monseñor Nouel	Unsuitable	3826.12	0.08	Baseline
Monte Cristi	Suitable	188570.27	3.89	Baseline
Monte Plata	Suitable	258911.54	5.34	Baseline
Pedernales	Suitable	156048.85	3.22	Baseline
Pedernales	Unsuitable	40279.08	0.83	Baseline
Peravia	Suitable	72906.76	1.51	Baseline
Puerto Plata	Suitable	183890.25	3.80	Baseline
Salcedo	Suitable	42337.74	0.87	Baseline
Samaná	Suitable	71080.64	1.47	Baseline
San Cristóbal	Suitable	119105.24	2.46	Baseline
San José de Ocoa	Suitable	75244.33	1.55	Baseline
San José de Ocoa	Unsuitable	9583.76	0.20	Baseline
San Juan	Suitable	179672.31	3.71	Baseline
San Juan	Unsuitable	153321.03	3.17	Baseline
San Pedro de Macorís	Suitable	125301.86	2.59	Baseline
Santiago	Suitable	172075.57	3.55	Baseline
Santiago	Unsuitable	105159.65	2.17	Baseline
Santiago Rodríguez	Suitable	56163.89	1.16	Baseline
Santiago Rodríguez	Unsuitable	58160.64	1.20	Baseline
Santo Domingo	Suitable	127511.19	2.63	Baseline
Sánchez Ramírez	Suitable	117725.85	2.43	Baseline
Valverde	Suitable	79443.00	1.64	Baseline
Azua	Suitable	208090.54	4.30	sglmft24530binary
Azua	Unsuitable	53814.57	1.11	sglmft24530binary
Bahoruco	Suitable	114699.70	2.37	sglmft24530binary
Bahoruco	Unsuitable	15715.49	0.32	sglmft24530binary
Barahona	Suitable	152205.74	3.14	sglmft24530binary
Barahona	Unsuitable	3326.37	0.07	sglmft24530binary
Dajabón	Suitable	102363.53	2.11	sglmft24530binary
Dajabón	Unsuitable	68.57	0.00	sglmft24530binary
Distrito Nacional	Suitable	8639.71	0.18	sglmft24530binary
Duarte	Suitable	162367.65	3.35	sglmft24530binary
El Seybo	Suitable	168702.43	3.48	sglmft24530binary
Espaillat	Suitable	85026.68	1.76	sglmft24530binary
Hato Mayor	Suitable	130390.76	2.69	sglmft24530binary

Table 5. Distribution area for future projections of *Rotylenchulus*

Province names	**class**	**Area range (ha)**	**Percentage**	**Types of scenarios**
Independencia	Suitable	160355.81	3.31	sglmft24530binary
Independencia	Unsuitable	34317.55	0.71	sglmft24530binary
La Altagracia	Suitable	289166.52	5.97	sglmft24530binary
La Estrelleta	Suitable	95765.06	1.98	sglmft24530binary
La Estrelleta	Unsuitable	44243.03	0.91	sglmft24530binary
La Romana	Suitable	54376.99	1.12	sglmft24530binary
La Vega	Suitable	97830.69	2.02	sglmft24530binary
La Vega	Unsuitable	126687.63	2.62	sglmft24530binary
María Trinidad Sánchez	Suitable	119458.69	2.47	sglmft24530binary
Monseñor Nouel	Suitable	90321.84	1.86	sglmft24530binary
Monseñor Nouel	Unsuitable	6854.39	0.14	sglmft24530binary
Monte Cristi	Suitable	188570.27	3.89	sglmft24530binary
Monte Plata	Suitable	258911.54	5.34	sglmft24530binary
Pedernales	Suitable	158010.27	3.26	sglmft24530binary
Pedernales	Unsuitable	38317.66	0.79	sglmft24530binary
Peravia	Suitable	72636.75	1.50	sglmft24530binary
Peravia	Unsuitable	270.01	0.01	sglmft24530binary
Puerto Plata	Suitable	183890.25	3.80	sglmft24530binary
Salcedo	Suitable	42337.74	0.87	sglmft24530binary
Samaná	Suitable	71080.64	1.47	sglmft24530binary
San Cristóbal	Suitable	118469.60	2.45	sglmft24530binary
San Cristóbal	Unsuitable	635.63	0.01	sglmft24530binary
San José de Ocoa	Suitable	68564.96	1.42	sglmft24530binary
San José de Ocoa	Unsuitable	16263.14	0.34	sglmft24530binary
San Juan	Suitable	152286.88	3.14	sglmft24530binary
San Juan	Unsuitable	180706.46	3.73	sglmft24530binary
San Pedro de Macorís	Suitable	125301.86	2.59	sglmft24530binary
Santiago	Suitable	177354.26	3.66	sglmft24530binary
Santiago	Unsuitable	99880.97	2.06	sglmft24530binary
Santiago Rodríguez	Suitable	78347.73	1.62	sglmft24530binary
Santiago Rodríguez	Unsuitable	35976.80	0.74	sglmft24530binary
Santo Domingo	Suitable	127511.19	2.63	sglmft24530binary
Sánchez Ramírez	Suitable	117725.85	2.43	sglmft24530binary
Valverde	Suitable	79443.00	1.64	sglmft24530binary
Azua	Suitable	220052.72	4.54	sglmft24550binary
Azua	Unsuitable	41852.40	0.86	sglmft24550binary
Bahoruco	Suitable	118225.20	2.44	sglmft24550binary
Bahoruco	Unsuitable	12189.99	0.25	sglmft24550binary
Barahona	Suitable	149650.55	3.09	sglmft24550binary
Barahona	Unsuitable	5881.56	0.12	sglmft24550binary

Table 5. Distribution area for future projections of *Rotylenchulus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Dajabón	Suitable	99638.36	2.06	sglmft24550binary
Dajabón	Unsuitable	2793.74	0.06	sglmft24550binary
Distrito Nacional	Suitable	8639.71	0.18	sglmft24550binary
Duarte	Suitable	162367.65	3.35	sglmft24550binary
El Seybo	Suitable	168702.43	3.48	sglmft24550binary
Espaillat	Suitable	85026.68	1.76	sglmft24550binary
Hato Mayor	Suitable	130390.76	2.69	sglmft24550binary
Independencia	Suitable	158189.80	3.27	sglmft24550binary
Independencia	Unsuitable	36483.56	0.75	sglmft24550binary
La Altagracia	Suitable	289166.52	5.97	sglmft24550binary
La Estrelleta	Suitable	97873.75	2.02	sglmft24550binary
La Estrelleta	Unsuitable	42134.34	0.87	sglmft24550binary
La Romana	Suitable	54376.99	1.12	sglmft24550binary
La Vega	Suitable	97831.02	2.02	sglmft24550binary
La Vega	Unsuitable	126687.30	2.62	sglmft24550binary
María Trinidad Sánchez	Suitable	119458.69	2.47	sglmft24550binary
Monseñor Nouel	Suitable	89462.46	1.85	sglmft24550binary
Monseñor Nouel	Unsuitable	7713.77	0.16	sglmft24550binary
Monte Cristi	Suitable	188570.27	3.89	sglmft24550binary
Monte Plata	Suitable	258911.54	5.34	sglmft24550binary
Pedernales	Suitable	154783.87	3.20	sglmft24550binary
Pedernales	Unsuitable	41544.06	0.86	sglmft24550binary
Peravia	Suitable	72477.85	1.50	sglmft24550binary
Peravia	Unsuitable	428.91	0.01	sglmft24550binary
Puerto Plata	Suitable	183890.25	3.80	sglmft24550binary
Salcedo	Suitable	42337.74	0.87	sglmft24550binary
Samaná	Suitable	71080.64	1.47	sglmft24550binary
San Cristóbal	Suitable	118072.34	2.44	sglmft24550binary
San Cristóbal	Unsuitable	1032.90	0.02	sglmft24550binary
San José de Ocoa	Suitable	70082.85	1.45	sglmft24550binary
San José de Ocoa	Unsuitable	14745.24	0.30	sglmft24550binary
San Juan	Suitable	179608.36	3.71	sglmft24550binary
San Juan	Unsuitable	153384.98	3.17	sglmft24550binary
San Pedro de Macorís	Suitable	125301.86	2.59	sglmft24550binary
Santiago	Suitable	176403.41	3.64	sglmft24550binary
Santiago	Unsuitable	100831.82	2.08	sglmft24550binary
Santiago Rodríguez	Suitable	70949.45	1.46	sglmft24550binary
Santiago Rodríguez	Unsuitable	43375.07	0.90	sglmft24550binary
Santo Domingo	Suitable	127511.19	2.63	sglmft24550binary
Sánchez Ramírez	Suitable	117725.85	2.43	sglmft24550binary

Table 5. Distribution area for future projections of *Rotylenchulus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Valverde	Suitable	79443.00	1.64	sglmft24550binary
Azua	Suitable	216955.24	4.48	sglmft58530binary
Azua	Unsuitable	44949.88	0.93	sglmft58530binary
Bahoruco	Suitable	119050.59	2.46	sglmft58530binary
Bahoruco	Unsuitable	11364.60	0.23	sglmft58530binary
Barahona	Suitable	149889.44	3.09	sglmft58530binary
Barahona	Unsuitable	5642.67	0.12	sglmft58530binary
Dajabón	Suitable	102154.33	2.11	sglmft58530binary
Dajabón	Unsuitable	277.77	0.01	sglmft58530binary
Distrito Nacional	Suitable	8639.71	0.18	sglmft58530binary
Duarte	Suitable	162367.65	3.35	sglmft58530binary
El Seybo	Suitable	168702.43	3.48	sglmft58530binary
Espaillat	Suitable	85026.68	1.76	sglmft58530binary
Hato Mayor	Suitable	130390.76	2.69	sglmft58530binary
Independencia	Suitable	161429.02	3.33	sglmft58530binary
Independencia	Unsuitable	33244.34	0.69	sglmft58530binary
La Altagracia	Suitable	289166.52	5.97	sglmft58530binary
La Estrelleta	Suitable	99057.05	2.04	sglmft58530binary
La Estrelleta	Unsuitable	40951.04	0.85	sglmft58530binary
La Romana	Suitable	54376.99	1.12	sglmft58530binary
La Vega	Suitable	100930.60	2.08	sglmft58530binary
La Vega	Unsuitable	123587.72	2.55	sglmft58530binary
María Trinidad Sánchez	Suitable	119458.69	2.47	sglmft58530binary
Monseñor Nouel	Suitable	91224.65	1.88	sglmft58530binary
Monseñor Nouel	Unsuitable	5951.58	0.12	sglmft58530binary
Monte Cristi	Suitable	188570.27	3.89	sglmft58530binary
Monte Plata	Suitable	258911.54	5.34	sglmft58530binary
Pedernales	Suitable	158660.13	3.28	sglmft58530binary
Pedernales	Unsuitable	37667.80	0.78	sglmft58530binary
Peravia	Suitable	72875.15	1.50	sglmft58530binary
Peravia	Unsuitable	31.61	0.00	sglmft58530binary
Puerto Plata	Suitable	183890.25	3.80	sglmft58530binary
Salcedo	Suitable	42337.74	0.87	sglmft58530binary
Samaná	Suitable	71080.64	1.47	sglmft58530binary
San Cristóbal	Suitable	117754.51	2.43	sglmft58530binary
San Cristóbal	Unsuitable	1350.73	0.03	sglmft58530binary
San José de Ocoa	Suitable	70075.29	1.45	sglmft58530binary
San José de Ocoa	Unsuitable	14752.81	0.30	sglmft58530binary
San Juan	Suitable	184836.58	3.82	sglmft58530binary
San Juan	Unsuitable	148156.76	3.06	sglmft58530binary
San Pedro de Macorís	Suitable	125301.86	2.59	sglmft58530binary

Table 5. Distribution area for future projections of *Rotylenchulus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
Santiago	Suitable	173880.29	3.59	sglmft58530binary
Santiago	Unsuitable	103354.94	2.13	sglmft58530binary
Santiago Rodríguez	Suitable	80768.00	1.67	sglmft58530binary
Santiago Rodríguez	Unsuitable	33556.52	0.69	sglmft58530binary
Santo Domingo	Suitable	127511.19	2.63	sglmft58530binary
Sánchez Ramírez	Suitable	117725.85	2.43	sglmft58530binary
Valverde	Suitable	79443.00	1.64	sglmft58530binary
Azua	Suitable	222126.99	4.59	sglmft58550binary
Azua	Unsuitable	39778.12	0.82	sglmft58550binary
Bahoruco	Suitable	115711.06	2.39	sglmft58550binary
Bahoruco	Unsuitable	14704.13	0.30	sglmft58550binary
Barahona	Suitable	142645.33	2.94	sglmft58550binary
Barahona	Unsuitable	12886.79	0.27	sglmft58550binary
Dajabón	Suitable	102108.63	2.11	sglmft58550binary
Dajabón	Unsuitable	323.47	0.01	sglmft58550binary
Distrito Nacional	Suitable	8639.71	0.18	sglmft58550binary
Duarte	Suitable	162367.65	3.35	sglmft58550binary
El Seybo	Suitable	168702.43	3.48	sglmft58550binary
Espaillat	Suitable	85026.68	1.76	sglmft58550binary
Hato Mayor	Suitable	130390.76	2.69	sglmft58550binary
Independencia	Suitable	158054.85	3.26	sglmft58550binary
Independencia	Unsuitable	36618.51	0.76	sglmft58550binary
La Altagracia	Suitable	289166.52	5.97	sglmft58550binary
La Estrelleta	Suitable	98737.89	2.04	sglmft58550binary
La Estrelleta	Unsuitable	41270.20	0.85	sglmft58550binary
La Romana	Suitable	54376.99	1.12	sglmft58550binary
La Vega	Suitable	101318.51	2.09	sglmft58550binary
La Vega	Unsuitable	123199.81	2.54	sglmft58550binary
María Trinidad Sánchez	Suitable	119458.69	2.47	sglmft58550binary
Monseñor Nouel	Suitable	86731.41	1.79	sglmft58550binary
Monseñor Nouel	Unsuitable	10444.82	0.22	sglmft58550binary
Monte Cristi	Suitable	188570.27	3.89	sglmft58550binary
Monte Plata	Suitable	258911.54	5.34	sglmft58550binary
Pedernales	Suitable	154787.93	3.20	sglmft58550binary
Pedernales	Unsuitable	41539.99	0.86	sglmft58550binary
Peravia	Suitable	72875.15	1.50	sglmft58550binary
Peravia	Unsuitable	31.61	0.00	sglmft58550binary
Puerto Plata	Suitable	183890.25	3.80	sglmft58550binary
Salcedo	Suitable	42337.74	0.87	sglmft58550binary
Samaná	Suitable	71080.64	1.47	sglmft58550binary

Table 5. Distribution area for future projections of *Rotylenchulus*

Province names	class	Area range (ha)	Percentage	Types of scenarios
San Cristóbal	Suitable	118231.24	2.44	sglmft58550binary
San Cristóbal	Unsuitable	874.00	0.02	sglmft58550binary
San José de Ocoa	Suitable	69595.04	1.44	sglmft58550binary
San José de Ocoa	Unsuitable	15233.06	0.31	sglmft58550binary
San Juan	Suitable	200374.56	4.14	sglmft58550binary
San Juan	Unsuitable	132618.78	2.74	sglmft58550binary
San Pedro de Macorís	Suitable	125301.86	2.59	sglmft58550binary
Santiago	Suitable	193295.79	3.99	sglmft58550binary
Santiago	Unsuitable	83939.44	1.73	sglmft58550binary
Santiago Rodríguez	Suitable	85646.44	1.77	sglmft58550binary
Santiago Rodríguez	Unsuitable	28678.09	0.59	sglmft58550binary
Santo Domingo	Suitable	127511.19	2.63	sglmft58550binary
Sánchez Ramírez	Suitable	117725.85	2.43	sglmft58550binary
Valverde	Suitable	79443.00	1.64	sglmft58550binary