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# Development of a model to define a soil quality index

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## Abstract

*A model using Soft Independent Models of Class Analogy method was developed for assessing soil quality based on physical (texture), chemical (nutrient content), and biological (nematodes population) parameters together. Two datasets were constructed to develop the soil quality model. The first was based on all physical-chemical parameters. The second dataset was based on a subgroup of soil physical-chemical and the biological parameters. The model was built based on an artificial dataset and tested using real datasets from EXCALIBUR project, the Agro-chemistry Laboratory of the Piedmont Region and the soil global dataset of nematode population. When considering only the physical-chemical data, the majority of soil samples could be classified as optimal or good quality. However, their distribution was much scattered when data on nematodes were included, showing the impact of soil biological fertility on the overall soil quality.*


**Keywords:** SIMCA, soil texture, soil nutrients, nematodes

## Introduction

References to assess the quality of soil are currently based on parameters referring to either physical or chemical domains (Karlen et al., 1994), which are thus limiting the overall evaluation of soil fertility. Soft Independent Models of Class Analogy (SIMCA) is a class-modeling technique that allows to build a model for each class of data considered, based on the association of an object/data in each of the considered classes (Violino et al., 2022). A model using SIMCA was thus developed for assessing soil quality based on physical (texture), chemical (nutrient content), and biological (nematodes population) parameters.

## Material and Methods

Nine soil chemical parameters were included in the model: pH, organic matter content (OM), total phosphorus, total potassium, total calcium, total magnesium, the K/Mg ratio and the cation exchange capacity (CEC). The ranges of these parameters were based on values defining the threshold limit for each nutrient element (Mukherjee and Lal, 2014). The pH range was set considering the common range for most agricultural crops. The content of clay, sand and silt was used to define the soil texture class according to USDA classes. However, the 12 classes were merged into the 3 classes considering their relevance in terms of agronomical performance. The soil nematode population ranges were derived from the global soil nematode database (van den Hoogen et al., 2020). The total number of nematodes (TN) and of the ratio between plant parasitic (PPN) and total nematodes (PPN/TN) were considered the best parameters representing soil quality from an agronomical point of view.

Two datasets were constructed to develop the soil quality model. The first was based on all physical-chemical parameters. The second dataset was based on a subgroup of soil physical-chemical and biological parameters: 3 texture classes, OM, pH, CEC, TN and

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PPN/TN. The model was built based on an artificial dataset considering the best qualitative ranges of each dataset (Abramo et al. 2015) and tested using real datasets: for the soil physical and chemical characteristics it included 74 records from 32 trials of the EXCALIBUR project and 6919 records from the Agro-chemistry Laboratory of the Piedmont Region. The real datasets including the variables related to the soil nematode population included data from 74 samples collected within EXCALIBUR and 1899 records from the soil global dataset (van den Hoogen et al. 2020).

### Results and Discussion

The SIMCA Index built with chemical-physical variable and applied to the artificial dataset included 96.5% of the records within the critical value of 1.4138, which were accepted and included in the model, while those above it were rejected (3.5%) (Figure 1A). When applied to the real dataset, only 27 samples were accepted by the model, i.e. could be considered of optimal score (Figure 1B). Samples close to the critical distance could be considered of good quality (6476 samples), while those above the distance of 7.85 (490 samples) were classified as of bad quality.

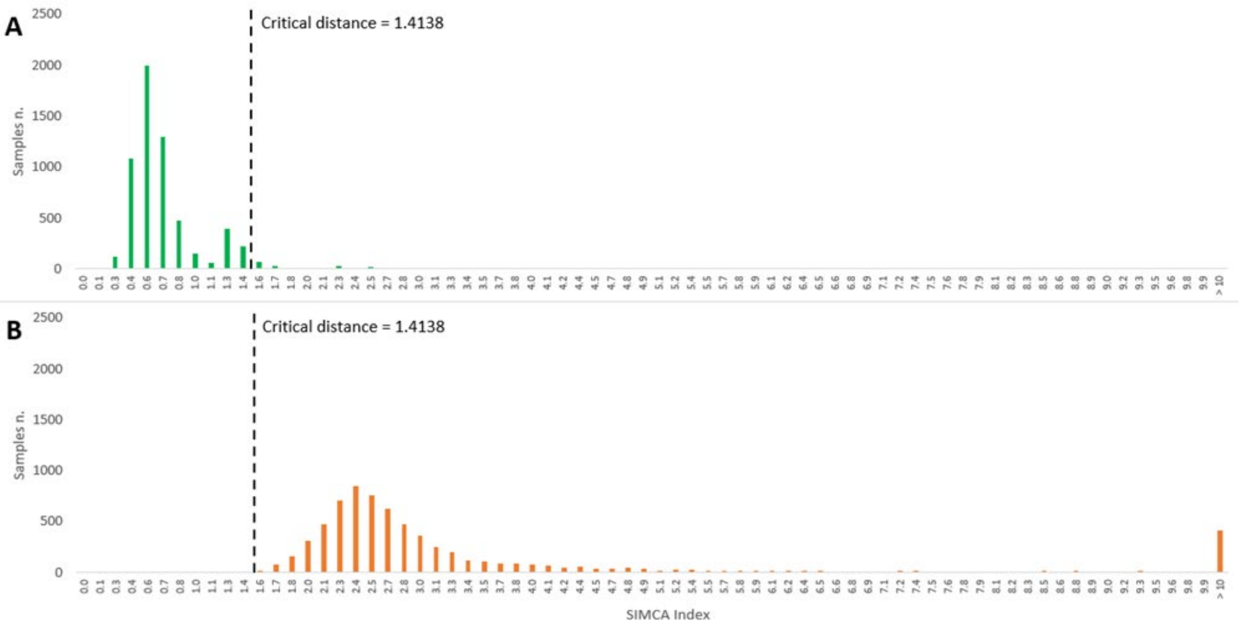


Figure 1: Distribution of the soil samples according to the SIMCA Index calculated by Soft Independent Modelling of Class Analogy analysis performed on the artificial dataset (A) and applied on the real datasets (B) of the chemical-physical parameters.

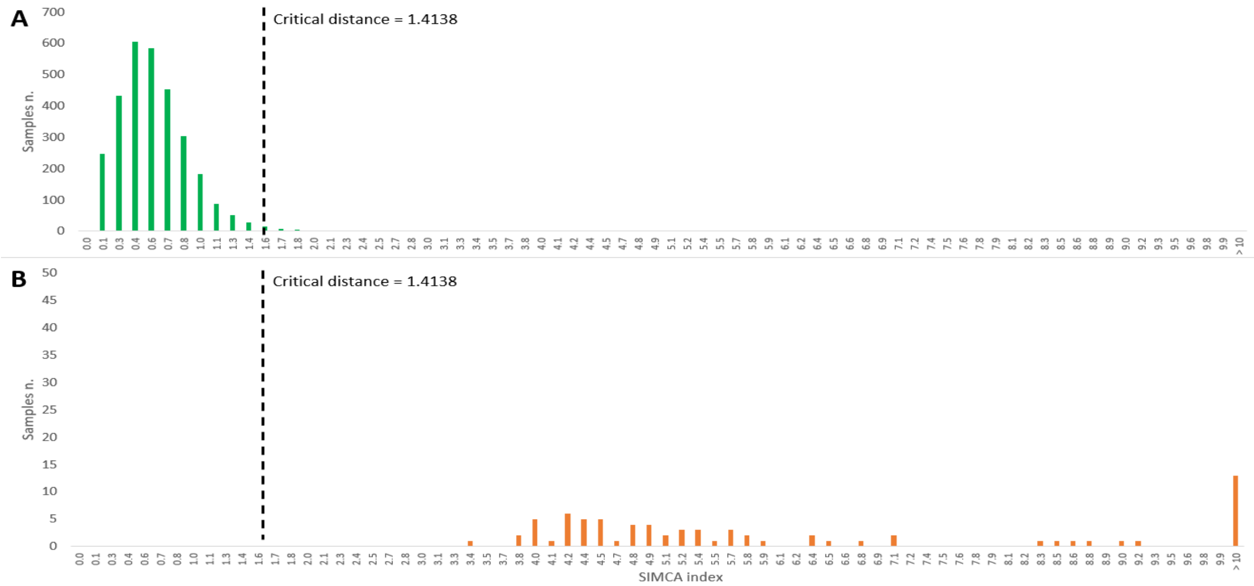


Figure 2: Frequency of the SIMCA Index performed on the artificial dataset (A) and applied on the real datasets of the nematodes' variables + numeric output of the SIMCA analysis of physical-chemical variables. The dashed lines represent the critical value (i.e., the model boundary).

However, when the data about nematodes were included in the model calculation, the distribution of the records was much sparse (Figure 2), showing how the biological data can modify the quality category of the soil.

A range of microbial processes can affect the availability of nutrient elements in soil (Finlay et al. 2020). Soil structure, being influenced by the texture, is likely to be one of the most far-reaching soil parameters modified by the soil microbiome (Lehmann et al. 2017). Considering that nematodes are highly affected by changes in the soil microorganisms population, they can represent a good indicator of the soil biological fertility (Lu et al. 2020). Their modification of the model output is thus underlining the possibility of defining an overall quality index for the soil that could be useful for a better evaluation of the management practices and their possible impact on crop performance.

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