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Risk of Zn deficient in the Brazilian soils[1].

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ABSTRACT: Brazilian soils are commonly nutrient deficient. This work aimed to map the risk of zinc deficiency from chemical soil properties through techniques of geoprocessing. The data base is composed by samples collected in soil surface and its determined chemical properties. From this data base were generated maps of risk of Zn deficiency. There are indications that 44% of the studied area is under high risk of Zn deficiency related to pH values. Only 8% of the studied area is under low risk and it happens in the areas where the Zn contents are high and the pH are low. In relation to the clay contents, 60% of the studied area is under low risk of Zn deficiency. The interaction of all the clay classes with low Zn represents the high risk of Zn deficiency and 20% of the area is under this kind of risk. The interaction between Zn vs $P_{available}$ showed that 63% of the total areas are under high risk of Zn deficiency and it is represented by the interactions medium Zn vs high $P_{available}$, low Zn vs high $P_{available}$, low Zn vs medium $P_{available}$, and low Zn vs low $P_{available}$. Although 65% of the area has presented adequate available Zn, we noticed that high pH and high available P occurred for nearly 28% and 45% of the area, respectively. The biggest risk was observed in the interaction between Zn and available P, which showed that 63% of the total areas are under high risk of Zn deficiency.

Indexing terms: geochemistry, trace element, mapping

INTRODUCTION

Zinc is used in many industries, mainly as corrosion protection on steel components and other metals. It is an important component of various alloys and is widely used as catalyst in different chemical production (e.g., rubber, pigments, plastic, lubricants and pesticides) (Kabata-Pendias & Mukherjee, 2007).

In Brazil, zinc availability is one of the major yield constrains affecting 90-95% of the native Cerrado soils. Worldwide, it has been reported that 50% of grains in agricultural areas are Zn deficient, resulting in low productivity and low Zn status in plant tissues (Alloway, 2008; Cakmak, 2008).

This element is unevenly distributed in soils and its concentration ranges between 10 to 300 $mg.kg^{-1}$, with a mean of about 50 $mg.kg^{-1}$ (Malle, 1992). Although Zn is very mobile in most soils, the clay fraction is capable of holding Zn quite strongly, especially at neutral and alkaline pH regimes (Kabata-Pendias & Pendias, 2001). It has been estimated that the clay fraction controls up to about 60% of Zn distributed in soils (Kabata-Pendias & Krakowiak, 1995). In this context, the estimation of Zn availability at non-sampled areas in a map format, as well as pH, P and clay content that influence zinc, can be source of valuable information. Two statistics interpolation techniques (inverse distance weighting or multilevel-b spline) have been used with varying degrees of success, and improved in order to create more accurate soil property maps.

This is an application of pedometric soil mapping technique that refers to a quantitative data-driven generation of soil property map, based on use of statistical methods. Since there is no digital prediction model that fits all regions and purposes (Grunwald, 2009), one strategy that has been adopted is testing different types of interpolation methods, using statistical validation indexes to choose the more precise method. From such products generated in geographical information system, it is possible to combine different types of maps from map algebra operations, improving the information and interpretation of spatial information, such as soil attributes that could influence Zn deficiency.

The objective of this study is to map the risk of zinc deficiency from chemical soil properties that influence their availability through techniques of geoprocessing.

MATERIAL AND METHODS

The soil samples were obtained from georeferenced data base of our partners (CAMPO, MT Fundation, EMBRAPA, SIAP, AMPAR, COMIGO, UNEMAT) and Fertility Laboratory of Federal University of Lavras (UFLA).

A total of 37,904 sampling points were used. This data base was divided into prediction points (80%) and validation points (20%) for calculating accuracy statistical indexes.

The database is composed by samples collected in soil surface (0-20 cm) and the chemical properties were determined following the methodology proposed by Silva (2009). Soil pH was determined in a 1:2.5 soil:water suspension. Phosphorous (P) and zinc (Zn) contents were extracted using 100 mL of the Mehlich^{-1} solution (0.05 mol/L HCl + 0.0125 mol/L H_2SO_4) reacted with 10 cm^3 of soil sample. Zinc concentrations in the extracted solutions were determined by flame atomic absorption spectrometer, while P was determined by colorimetry.

Types of maps generated

From this data base were generated prediction maps based on different methods: inverse distance weighting (IDW) which was performed in ArcGIS 10.0 (Esri), multilevel B-spline that was performed in SAGA GIS version 2.1.4. The most accurate maps were overlayed generating maps of risk of Zn deficiency and P availability. The mean prediction of error (MPE) was calculated by comparing estimated values ($\hat{z}(s_j)$) with the validation points ($z^*(s_j)$).

$$MPE = \frac{1}{l} . \sum_{j=1}^{l} [\hat{z}(s_j) - z^*(s_j)]$$

and the root mean square prediction error (RMSPE):

$$\mathrm{RMSPE} = \sqrt{\frac{1}{l} \sum_{j=1}^{l} [\hat{z}(s_j) - z^*(s_j)]^2}$$

Where l is the number of validation points.

Considering that pH, P levels and soil texture are important factors influencing Zn availability in tropical soils, it was decided to analyze such attributes in order to better assess the risk of Zn deficiency. To provide a greater interpretation of analysis, the values of Zn, P, pH and clay were classified into different levels according to the recommendations described for the Cerrado region (Table 1 – adapted from Sousa & Lobato, 2004).

Table 1. Values for Zn, Cu, P, pH and Clay interpretation.

	P Levels (mg dm^{-3})		
Clay	Low	Medium	High
≤ 15 (Low)	0-12.0	12.1-17.9	≥18.0
16-35(Medium)	0-10.0	10.114.9	≥15.0
36-60 High)	0-5.0	5.1-7.9	≥8.0
> 60 (Very High)	0-3.0	3.1-5.9	≥6.0
Zn (mg kg^{-1})		pH	
≤ 1.0	Low	≤ 5.5	Low
1.1-1.6	Medium	5.5-6.0	Adequate
> 1.6	High	> 6.0	High

RESULTS AND DISCUSSION

A total of 719 cities had zinc, clay, pH and phosphorus mapped, totalizing 877,325.30 km^2 (87,732,530 ha).

Risk of Zn deficiency

In order to assess the risk of Zn deficiency in soils, the deficiency risk maps were based on the interactions of Zn with clay, pH and $P_{available}$ levels, since these properties influence the Zn availability. The final maps are product of map algebra operation on geographic information system (GIS).

Comparing the validation of interpolation methods IDW and multilevel B-spline for Zn, clay and phosphorus; the IDW was the method that got minor errors (RMSPE and MPE) and pH multilevel B-spline method had the lowest error (RMSPE and MPE).

As one of the most important soil chemical attributes affecting trace metals solubility, a higher soil pH is also a major factor increasing adsorption of these elements to soil constituents (Cakmak, 2008). According to this author, there is a decrease of 45-fold in the Zn concentration in soil solution for each unit increase in soil pH. In our study, there are indications that 44% of the studied area (~39 million ha) is under high risk of Zn deficiency. The high risk happens with the following interactions: low Zn vs low pH, low Zn vs medium pH, low Zn vs high pH, medium Zn vs high pH, and high Zn vs high pH. A total of 48% (~42 million ha) is under medium risk of Zn deficiency, which is represented by the interactions medium Zn vs low pH, medium Zn vs medium pH, and high Zn vs medium pH. Only 8% (~7 million ha) of the studied area is under low risk and it happens in the areas where the Zn contents are high and the pH are low (Figure 1).

In relation to the clay contents, it is known that high clay percentage can lead to increasing Zn deficiency due to adsorption of this element (Cakmak, 2008). However, in the present study, 60% of the studied area (~54 million ha) is under low risk of Zn deficiency. This low risk happens when the interactions are: high Zn vs high clay, high Zn vs medium clay, high Zn vs low clay, medium Zn vs medium clay, and medium Zn vs low clay. Approximately 17 million ha (20% of the total area) is under medium risk and it is represented by the interactions high Zn vs very high clay, medium Zn very high clay, and medium Zn vs medium clay. The interactions of all the clay classes (low, medium, high, and very high) with low Zn represents the high risk of Zn deficiency and 20% of the area is under this kind of risk.

High available P levels can promote the reduction of micronutrients uptake by plants, especially Zn. The interaction between Zn vs $P_{available}$ showed that 63% of the total areas are under high risk of Zn deficiency (~56 million ha) and it is represented by the interactions medium Zn vs high $P_{available}$, low Zn vs high $P_{available}$, low Zn vs medium $P_{available}$, and low Zn vs low $P_{available}$. Only ~9 million ha (11%) are under medium risk (interactions high Zn vs high $P_{available}$, medium Zn vs medium $P_{available}$, and medium Zn vs low $P_{available}$) and ~23 million ha (26%) are under low risk of Zn deficiency, which happens in the areas where the Zn contents are high and the $P_{avaliable}$ are low and medium.

CONCLUSION

We noticed that high pH and high available P occurred for nearly 28% and 45% of the data, respectively. Furthermore, 60% of the area presented high and very high values of clay. These properties affect the solubility of Zn and can decrease its availability.

The interaction between Zn and Clay showed that 20% of the total area (~17million ha) is under high risk of Zn deficiency, while in the interaction between Zn and pH this percentage increased to 44% (~39 million ha). The biggest risk was observed in the interaction between Zn and available P, which showed that 63% of the total areas are under high risk of Zn deficiency (~56 million ha).

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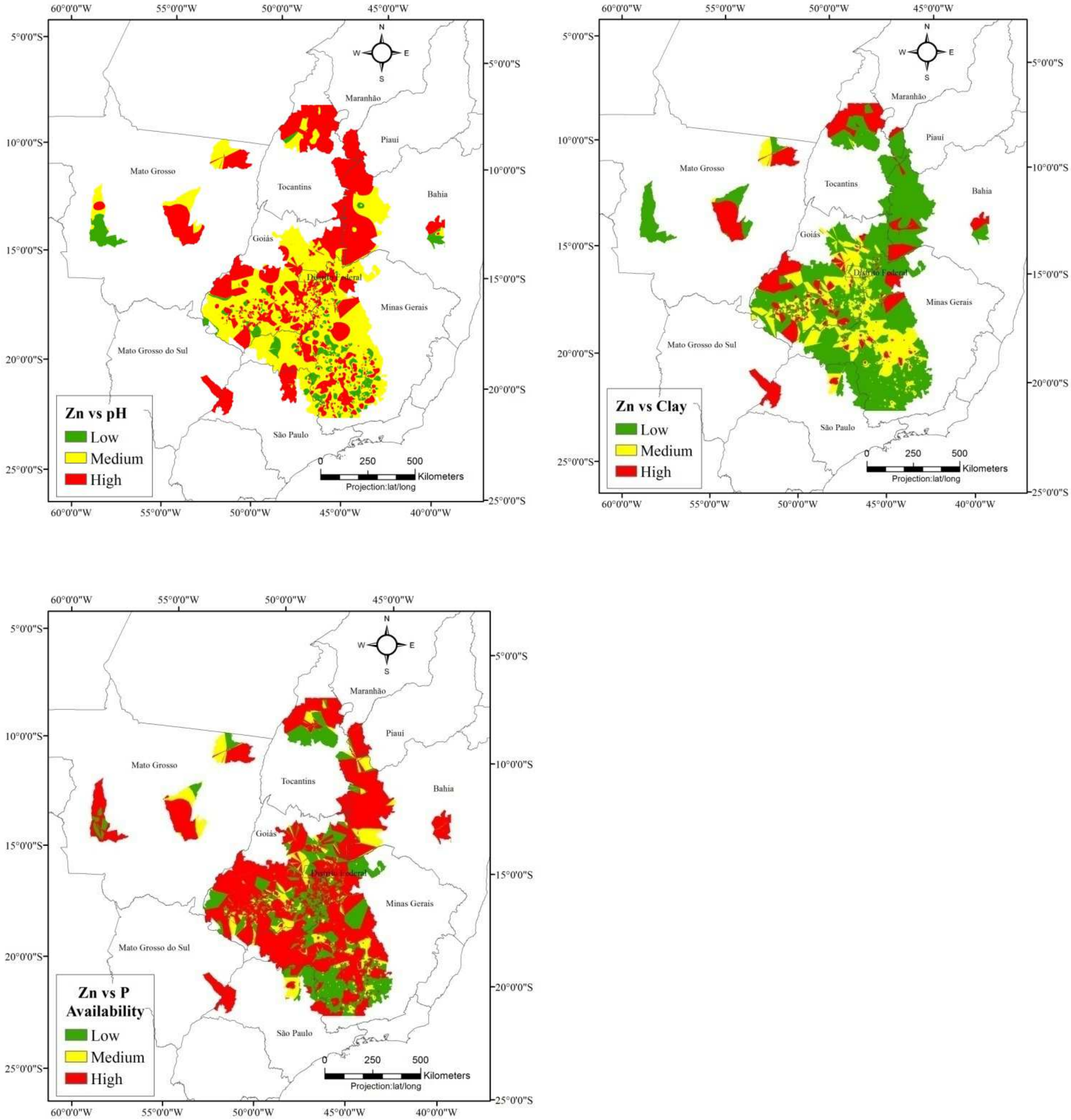

Figure 1 - Geographical data distribution of Zn vs pH, Zn vs clay and Zn vs $P_{available}$ interaction.