IOCAG 2022

MDPI

Proceeding Paper

Comparison of Soils of Two Fields for Potato Production Located in the Same Region of Portugal †

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† Presented at the 1st International Online Conference on Agriculture—Advances in Agricultural Science and Technology (IOCAG2022), 10–25 February 2022; Available online: https://iocag2022.sciforum.net/.

Abstract: Soil is considered a highly complex ecosystem, providing food, and maintaining crop and animal productivities. Soil variability can affect plant production. Accordingly, this study aimed to compare soils chemical characteristics from two different locations in the same region of Western of Portugal (Lourinhã), intended for potato production. Soil was collected and analyzed for soil chemical properties (pH, electric conductivity, organic matter, and mineral element content). Through principal components analysis (PCA) was possible to identify that the interrelations among the mineral elements are explained in the projections of components 1 and 2 for both fields. Regarding Field A, Ca, K, Fe, P, S, Mg, As, Pb, and Zn are more correlated with each other than the other mineral element (Cd). In the other hand, in Field B, all the mineral elements correlate differently compared to Field A (except Cd) and showed that K, As, Mg, Ca, Zn, Fe, and Pb are the most correlated with each other. Also, Fe and S are more correlated in Field A, however in Field B, Fe and Zn are the ones that are more correlated with each other. Additionally, although both soils have the same pH (slightly basic soil—ideal for agriculture), they showed a significantly different content of organic matter and conductivity, where Field B presented higher contents of both parameters. The obtained data is discussed, being concluded that the soils, despite being geographically close, have different relationships between elements and different content of organic matter and electrical conductivity, which may lead to differences in potato production.

Keywords: agricultural soils; principal component analysis; soil analyzes; soil characterization

Citation: Coelho, A.R.F.; Daccak, D.; Marques, A.C.; Luís, I.C.; Pessoa, C.C.; Silva, M.M.; Simões, M.; Reboredo, F.H.; Pessoa, M.F.; Legoinha, P.; et al. Comparison of Soils of Two Fields for Potato Production Located in the Same Region of Portugal. *Chem. Proc.* **2022**, *4*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s):

Published: date

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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1. Introduction

In plants, soil is the primary source for their production, being recognize that soil physical condition can affect crop production [1]. Soil is considered not only a highly complex ecosystem but also a valuable resource, providing food and maintaining crop and animal productivities. Additionally, in soil, nutrient contents are a fertility indicator [2] and its variability can affect plant production, namely in potato [3]. Potato is the 3rd most important-non-grain-food crop worldwide [4], playing a huge part in the human diet and supplying different minerals required in human body [5]. However, considering that in potato plants mineral elements uptake occurs (primary) through soil solution, if soils where crops are cultivated have low fertility, can contribute to low mineral content, due to poor uptake and translocation of some mineral elements to the edible parts [5]. Potato production is dependent of certain nutrients from soil to the plant, namely, N, P, K, Ca, Mg, S, Fe, and Zn [6]. In addition, according to [7], organic matter of soil is significantly related to crop nutrient composition, indicating that more organic matter can lead to more nutrient content in the crop. Also, soil pH can affect plant growth and influence several soil chemical, physical, and biological properties, namely nutrient absorption [8]. As such, organic matter and pH of soil are widely used as indicators in monitoring fields used for crop production [9]. Electrical conductivity (EC), according to [10], can be used as a precision farming diagnostic tool and is considered an integrated measure of several soil properties (namely, salinity, clay, and water content) being (as organic matter and pH) related to crop productivity. For instance, sandy fields have low electrical conductivity, silts have intermediate EC and clays have high EC [11]. Nevertheless, it's important to understand soil chemical composition and its variation to managing soils utilization and there is a greater demand for details about the distribution of soil properties [12]. Also, the different distribution of soils and its topography, is a difficult relationship to established due to the sensitive impact of topography on the movement of soil material (making this relationship site specific) [12]. In this context, this study aimed to compare soils chemical characteristics (pH, electrical conductivity, organic matter, and mineral element content relationship) from two different locations in the same region of Portugal (Lourinhã), intended for potato production.

2. Materials and Methods

2.1. Experimental fields

This study focused on two experimental fields, located in the same region of Western of Portugal (Lourinhã) (GPS coordinates: 39°16′38,816″ N; 9°15′9128″ W (Field A) and 39°16′12,576″ N; 9°14′14,492″ W (Field B), intended for potato (*Solanum tuberosum* L.) production. The locations of both fields are shown in Figure 1.

Figure 1. Geographic location of the two fields (Field A and Field B) (images obtained through Google Earth). Indication (in blue) of the limits of soil sample collection in the fields. (Note: when

the soil samples were taken, there was no type of plantation in the two fields. The images shown are for geographic location only—they do not correspond to the date of collection of soil samples).

2.2. Mineral Content, pH, Organic Matter, and Electrical Conductivity in Soils

In the experimental fields (intended for potato production), 9 soil samples of each field (100 g, picked up at 30 cm depth) were collected in a hexagonal grid, for physical and chemical analysis. Soil samples were sieved (using a 2.0 mm nylon sieve) to remove stones and other debris before analysis. Mineral content in soils were determined, following [13], using a XRF analyzer (model XL3t 950 He GOLDD+) under helium atmosphere, before the implementation of potato culture. Additionally, pH and electrical conductivity were carried out following [14], being these parameters determined in the decanted supernatant of a mixture (ratio 1:2.5 g_{soil} $mL^{-1}_{water\ milli\text{-}q}$) for 1 h with tiring (25 °C for 30 min) in a thermal bath. Organic matter was carried out following [15].

2.3. Statistical Analysis

Data normality and homogeneity of variance was carried out. The principal component analysis was done on the correlation matrix and the first two components were retained and rotated using Varimax rotation.

Additionally, data were statistically analyzed using a One-Way ANOVA to assess differences among the different fields, followed by a Tukey's for mean comparison. A 95% confidence level was adopted for all tests.

3. Results

Regarding macro and micro elements of soil samples of both fields (Figures 2 and 3), through principal component analysis (PCA) was possible to identify that for both fields, the interrelations among mineral elements are explained in the projections of components 1 and 2 (F1 and F2). In Field A (Figure 2), Ca, K, Fe, P, S, Mg, As, Pb, and Zn are more correlated with each other than the other mineral element (Cd). Also, considering the factorial plane F1/F2, there is a cluster in positive F1, presenting the most of variables that are closely related (Ca, K, P, Fe, S, Mg, and As). Regarding Zn, is found close to the origin according to F1 (but not close to the origin according to F2), verifying that its variability is better explained by F2 than F1. Also, Cd presents an antagonistic behavior with all other mineral elements analyzed (confirmed through a Pearson correlation (data not shown) that Cd in relation to the other mineral elements presents negative values, that is, it presents negative correlations compared to the other minerals). Additionally, Fe and S are the pair that are most related to each other (showing a correlation matrix of 0.934 (data not shown)), followed by the pair S and As with a correlation matrix of 0.866 (data not shown).

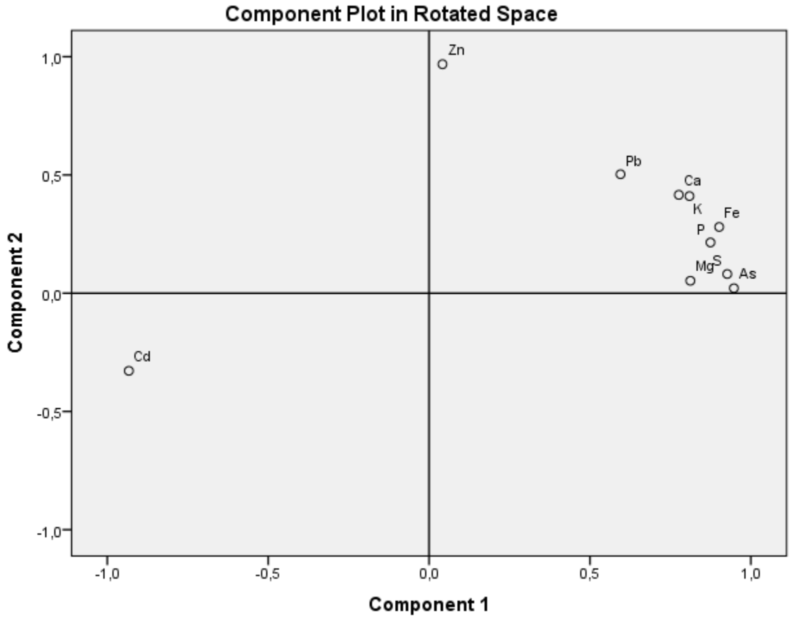

Figure 2. Projection of the factorial plane created by F1 (71.4% variance) and F2 (11.2% variance) axes of the macro and micro elements of soil samples (n = 9) of Field A. (Observation: Eigenvalues are greater than 1 only in F1 and F2).

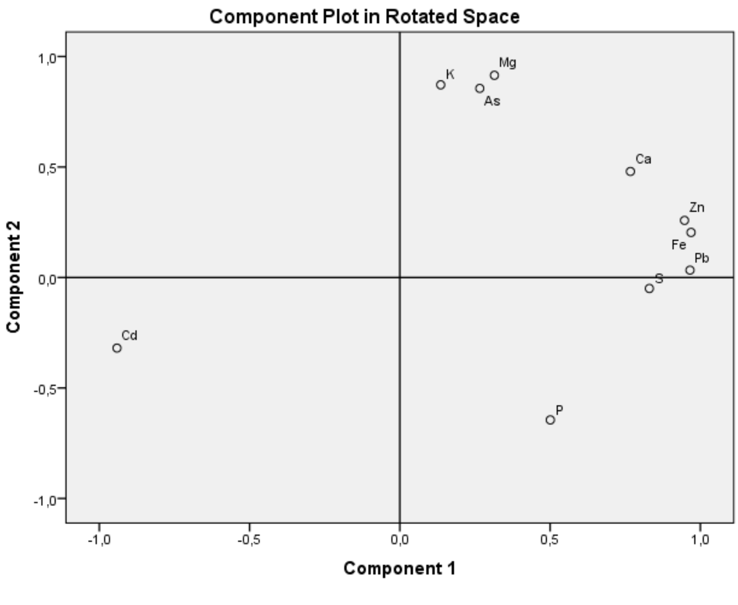

Figure 3. Projection of the factorial plane created by F1 (60.7% variance) and F2 (25.0% variance) axes of the macro and micro elements of soil samples (n = 9) of Field B. (Observation: Eigenvalues are greater than 1 only in F1 and F2).

Considering Field B (Figure 3), except for the Cd trend, all other mineral elements correlate differently compared to Field A, and showed that K, As, Mg, Ca, Zn, Fe, and Pb are the most correlated with each other. Yet, considering the factorial plane F1/F2, there is two cluster in positive F1, one with K, Mg, and As, and other with, Zn, Fe and Pb, indicate that these mineral elements (in each cluster) are closely related. Regarding, Cd there is an antagonistic behavior with several other mineral elements analyzed, confirmed through a Pearson correlation (data not shown) that Cd in relation to the other mineral elements (with exception of P and S) presents negative values, that is, it presents negative correlations compared to the other minerals (with exception of P and S). Also, regarding P there is also an antagonistic behavior with all other mineral elements (apart from Cd), presenting negative values in relation to other minerals (except Cd) through Pearson correlation (data not shown). Additionally, Fe and Zn are the pair that are most related to each other (showing a correlation matrix of 0.914—data not shown), followed by the pair As and Mg with a correlation matrix of 0.882 (data not shown).

In both field, pH was the same, average of 7.4 (pH of 7.4 ± 0.03 for Field A and 7.4 ± 0.05 for Field B). However, regarding organic matter and electrical conductivity of the soil (Figure 4), there were significant differences between the two fields. In fact, Field B showed higher values in both parameters compared to Field A.

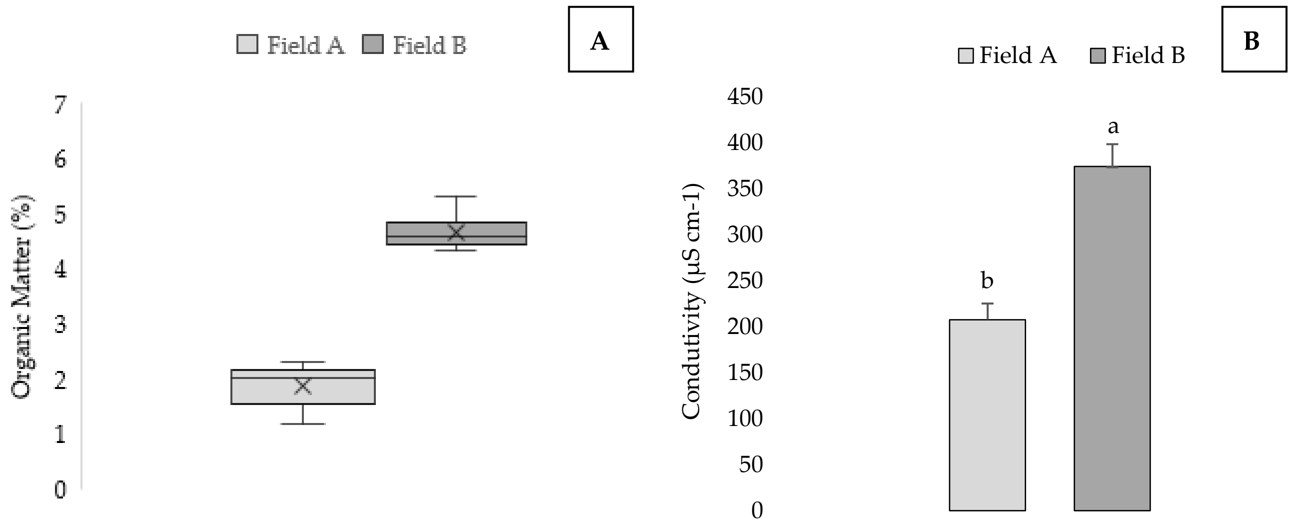

Figure 4. (**A**,**B**) Organic matter content (%) (**A**) and soil electrical conductivity (µS cm^{-1}) (**B**) of soil of both fields (Field A and Field B).

4. Discussion

Soil is the primary source of crop production and mineral accumulation to the edible parts [1,5]. As such, soil chemical characteristics from two different locations in the same region were compared. Regarding mineral content, when comparing both field—Field A (Figure 2) and Field B (Figure 3)—was possible to identify that despite Cd, all the remaining mineral elements analyzed correlated differently. This different correlation between minerals of soil in the same region is probably due to soil nutrient content variability [3] that can occur presumably due to the sensitive impact that topography has in the movement of soil material [12]. In fact, Field A presented a higher percentage in slop class of 0–5%, corresponding to low surface drainage (data not shown), and Field B in slop class of 5–30%, corresponding to moderate surface drainage (data not shown). Nevertheless, the different correlation between mineral elements is probably due to the different topography of the fields. Despite both fields are in the same region and from the same geological formation (Jurassic), are divided (geologically) into two separate parts of the Geological Chart of Portugal, Field A is located on 30A (Lourinhã) [16] and Field B in 30B (Bombarral) [17]. Regarding Field A it lies in J^3Ca (Castilian marls and stoneware), being predominantly made up of fine to coarse quartz sandstones with frequent limestone clays [16]. Field B lies in J^3C ("Camadas de Abadia"–Upper Lusitanian) being a marl complex, in which the marls are nodules and concretions ferruginous or limestone [17]. Additionally, limestone and marls can suggest an abundance of organic matter [16], explaining the higher content of organic matter presented in Field B (Figure 4A) and the ferruginous nodules and concretions can be related to Fe, being the mineral with more correlation with the remain mineral elements (Figure 3) compared to Field A. Also, for potatoes production, this crop prefers a fertile soil high in organic matter [3].

Nevertheless, it's interesting to see that in Field A, S has a higher correlation matrix with other minerals (namely, Fe and As) and in Field B, Fe was a higher correlation matrix with Zn, followed by Mg and As. Regarding both Fields, they showed a higher correlation with As (contaminating mineral element), yet the contents obtained were below the critical limits for pH > 7.0 [18]. Considering the pH of both soils (7.4), being slightly alkaline, is within the ideal range for agriculture (6.5–7.5) [19]. In fact, despite potatoes being tolerant regarding pH, this range is optimal for nutrient availability to plants [20]. According to a study carried out by [10], reported that well-drained soils (summit soils) had lower electrical conductivity compared to the poorly drained soils (with lower slopes). However, our data disagrees with the one reported by [10], being important to mention that electrical conductivity is influenced by a combination of physic and chemical properties (namely, soluble salts, clay content, soil water content, organic matter) [21]. In addition, is also important to say that Field B has a higher chance of soil salinization because the accumulation of salt (in irrigated agricultural soils) can lead to loss of stand, reducing plant growth and yield [21]. Yet can be used to potato production, being important to choose salt-tolerant varieties [22].

5. Conclusions

Through the comparison of soils of two fields intended for potato production in the same region of Portugal, was possible to verify that, despite being geographically close, they showed different relationships between mineral elements, organic matter content, and soil electrical conductivity. Additionally, despite Field A showing lower organic matter content and the different correlations between minerals elements compared to Field B, due to the lower electrical conductivity it presents a field with greater potential for potato production. Yet, it needs to be fertilized with organic matter. Regarding Field B, also can be used for potato production, however, needs to be chosen a variety or varieties with greater tolerance to salts, considering the high electrical conductivity presented in the soil. In conclusion, both fields may present differences in potato production due to the differences verified in this study. Also, if the correction of organic matter is not carried out in Field A, apparently Field B (despite greater organic matter) due to its greater electrical conductivity, can lead to a greater loss of productivity.

Author Contributions: Conceptualization, F.C.L.; methodology, F.C.L.; software, A.R.F.C.; formal analysis, A.R.F.C., A.C.M., C.C.P., I.C.L. and D.D.; resources, M.M.S., M.S., F.H.R., M.F.P., P.L., J.C.R., P.S.C., I.P.P., J.N.S.; writing—original draft preparation, A.R.F.C. and F.C.L.; writing—review and editing, A.R.F.C. and F.C.L.; supervision, F.C.L.; project administration, F.C.L.; funding acquisition, F.C.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by PDR2020, grant number 101-030719. Funding from Fundação para a Ciência e Tecnologia (FCT) UI/BD/150806/2020 is also greatly acknowledged.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors thanks to Eng. Nuno Cajão (Cooperativa de Apoio e Serviços do Concelho da Lourinhã-LOURICOOP) for technical assistance in the agricultural parcel as well as to project PDR2020-101-030719—for the financial support. We also thanks to the Research centers (GeoBioTec) UIDB/04035/2020, and (CEF) UIDB/00239/2020.

Conflicts of Interest: The authors declare no conflict of interest.

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