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Soil chemical quality in irrigated agricultural areas

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ABSTRACT: Soil quality assessment in irrigated perimeters of the northeast region of Brazil is required for correctly applying management practices. However, univariate statistical analyses often mislead the interpretation of results. This study was carried out in the Piauí irrigated perimeter in Sergipe state, and aimed to apply multivariate analysis to evaluate the effect of different land uses (passion fruit; pepper; passion fruit + pepper intercropping; and pasture) on soil chemical quality. Soil samples were collected from the 0-15, 15-30, and 30-45 cm layers. Soil chemical attributes such as pH, organic matter, CEC, sum of bases, percent base saturation, P, K^+, Ca^{+2}, Mg^{+2} and Na^+ were determined. Multidimensional ordination analysis was used to group the soil chemical attributes according to their relative importance in each agricultural use. The results showed that cultivation of pepper alone or associated with passion fruit improved soil chemical quality, probably due to greater soil cover and higher fertilizer inputs. The use of multivariate analysis was efficient in separating soil use effects as a function of soil chemical attributes. For instance, the results showed that Ca, Mg, CEC, base saturation, OM and pH were responsible for improving the pepper and pepper + passion fruit cultivation areas. In addition, it showed that conventional cultivation and irrigation of passion fruit can increase soil salinity.

Key words: intercropping; irrigation; soil fertility; soil management

Qualidade química do solo em áreas agrícolas irrigadas

RESUMO: A avaliação da qualidade do solo em perímetros irrigados do nordeste brasileiro é necessária para a aplicação de práticas de manejo adequadas. Porém, o uso de análise univariada frequentemente dificulta a interpretação dos resultados. Este estudo foi desenvolvido no perímetro irrigado Piauí, estado de Sergipe, e objetivou utilizar análise multivariada para avaliar o efeito do uso do solo (maracujá, pimenta, consórcio de pimenta com maracujá e pastagem) nos atributos químicos do solo. Amostras de solos foram coletadas nas camadas de 0-15, 15-30 e 30-45 cm. Foram analisados os seguintes atributos químicos: pH, matéria orgânica, capacidade de troca de cátions, soma de bases, porcentagem de saturação de bases, P, K^+, Ca^{+2}, Mg^{+2} e Na^+. Análise multidimensional ordenada foi usada para agrupar os atributos químicos de acordo com sua importância em cada uso agrícola. Os resultados mostraram que o cultivo de pimenta, sozinha ou em consócio com maracujá, melhorou qualidade química do solo, possivelmente em função da maior cobertura vegetal e da maior intensidade de tratos culturais e adubações. A aplicação da técnica de análise multivariada foi eficiente na separação dos efeitos de uso do solo em função dos atributos químicos. Por exemplo, os resultados mostraram que os atributos Ca, Mg, CTC, soma de bases, matéria orgânica e pH foram os principais responsáveis pelos melhores desempenhos dos cultivos de pimenta e pimenta em consórcio com maracujá, e que o cultivo tradicional do maracujá irrigado pode aumentar o risco de salinização do solo.

Palavras-chave: irrigação; consórcio de culturas; fertilidade do solo; manejo do solo

Introduction

Long term agricultural use of soil resources requires frequent monitoring of soil quality as a means to preserve soil functions as well as to test innovative management practices. Soil quality is an assessment of how well soil performs its functions and its potential to be used in the future, such as for food or fiber production. Agricultural use of soils associated with irrigation practice changes soil attributes and can threaten an agroecosystem's sustainability (Chartzoulakis & Bertaki, 2015; Frenk et al., 2018), especially where irrigation is a mandatory means to secure crop production, such as in many regions of Brazil.

Irrigation in agriculture is a common practice in the northeast region of Brazil and it is responsible for social and economic development of many counties. In spite of the evident increase in crop yield due to irrigation, it must be considered that irrigation also affects soil quality. The sustainability of irrigated perimeters relies on maintaining soil productivity, which can be altered by modifications in its attributes such as soil fertility, organic matter content, salinity, pH, and cation exchange capacity (CEC) (Lado et al., 2004). Even with good quality water (EC < 3 dS m^{-1}), irrigation often represents a large increase in the water flux through the soil profile and has the capacity to accelerate mineral weathering, to transport and leach soluble and colloidal material, to change soil structure and to raise the local water table (Bendra et al. 2012).

There are also changes caused by applying fertilizers and agrochemicals, intense tillage and traffic, and alteration to the water regime in watersheds (Corrêa et al., 2009). Therefore, it is important to quantify how soil properties are modified in order to evaluate environmental changes and then make the adequate future decisions to preserve soil resources.

Aguiar Netto et al. (2007) reported high concentrations of exchangeable sodium (>15 $cmol_c$ kg^{-1}) in soil samples collected from irrigated perimeters in Sergipe state. They also observed a significant increase in soil pH as a result of increasing exchangeable sodium percentage on the soil surface. Such an increase in soil pH associated with high sodium content has adverse effects on soil structure and can potentially cause reduced water permeability in soil. Furthermore, the increase in soil pH can cause reductions in plant micronutrient availability, even more so jeopardizing plant productivity.

Another soil chemical attribute that is directly affected by cultivation and irrigation is soil organic matter (Assis et al. 2010; Guimarães et al., 2014), being an efficient and reliable soil quality indicator. Soil organic matter is of paramount importance, especially in tropical soils since most of them are highly weathered and rely on the organic component to hold water and increase nutrient availability (Oldfield et al., 2018). However, intensive management practices in irrigated areas, as well as the quality of irrigation water, can limit organic matter build up in soils.

Considering the many existing soil chemical parameters that are normally affected by land use in agroecosystems, a comprehensive assessment of the effect of management practices on soil quality is a difficult task. Therefore, the use of multivariate analysis has been frequently applied as an alternative strategy to understand the causes of soil variation because it enables grouping samples according to similarity, while still enabling selection of the most important variables to discriminate between pre- selected groups (Benites et al., 2010; Oliveira et al., 2017).

This study was carried out in the Piauí irrigated perimeter in Sergipe state, and aimed to apply multivariate analysis to evaluate the effect of different land uses (passion fruit; pepper; passion fruit + pepper intercropping, and pasture) on soil chemical quality.

Materials and Methods

Site characterization and sampling

Soil quality was evaluated in an irrigated agricultural farm in the estate of Sergipe, Brazil, with geographic coordinates 10° 54' 51" S and 37° 39' 50" W. This area has a megathermic sub humid climate with mean annual temperature of 24.5 ºC and annual precipitation of 1000 mm (Peel et al., 2007). The relief is flat and soils are mostly Yellow Oxisols (Santos et. al, 2013).

The soils are deep and well drained due to intense weathering. A soil textural analysis showed 758 g kg^{-1} sand, 201 g kg^{-1} silt and 40 g kg^{-1} clay (0-0.16 m: A horizon, classified as Loamy sand); 742 g kg^{-1} sand, 196 g kg^{-1} silt and, 61 g kg^{-1} clay (0.16-0.45 m: Bw1 horizon, Sandy loam); 699 g kg^{-1} sand, 220 g kg^{-1} silt and, 80 g kg^{-1} clay (0.45-0.90m: Bw2 horizon, classified as sandy loam).

This study was conducted as a completely randomized design with four treatments (agroecosystems of passion fruit (*Passiflora edulis* Sims); chili pepper (*Capsicum frutensens* L); passion fruit + chili pepper intercropping, and pasture (*Brachiaria decumbens*)), with five replications.

Pepper agroecosytem: each experimental plot contained 1 ha and was cultivated for 3 years. It used a row spacing of 1 m and inter-row spacing of 1.2 m. A moldboard plow was used for soil preparation at the time of planting, and 300 kg ha^{-1} of P_2O_5 and livestock manure were applied. Invasive plants were manually controlled. Ammonium sulfate and potassium chloride were periodically applied as source of N and K, respectively.

Passion fruit agroecosystem: each experimental plot contained 1 ha and was cultivated for 3 years. Row spacing of 2 m and inter-row spacing of 4 m were implemented. A moldboard plow was used for soil preparation at the time of planting, and 0.05 kg per plant of simple super phosphate (18% P_2O_5), livestock manure (2 kg per plant) and castor bean cake (2 kg per plant) were applied. Invasive plants were manually controlled. N-P-K 10-10-10 and 18-18-18 were periodically applied. No soil chemical analysis was performed before fertilizer application.

The same management practices were applied for the consortium (passion fruit + chili pepper intercropping) agroecosystem. Sprinkler irrigation was used in all cultivated areas. The pasture agroecosystem was not used for 5 years.

Composite soil samples were randomly collected from each experimental plot using a Dutch auger at depths of 0-15; 15-30, and 30-45 cm. Each composite soil sample came from 10 simple soil samples.

Chemical analysis and data analysis

Soil samples were air dried and passed through a 2 mm sieve for further analysis. Soil chemical properties were analyzed using the standard soil test methods (EMBRAPA, 1997). Soil pH was measured in a 1:2.5 soil:water ratio. Soil organic carbon (SOC) was determined using the dichromate oxidation method (Nelson & Sommers, 1982).

Available P, K^+ and Na^+ were extracted with Mehlich I solution and analyzed with atomic absorption spectrometry (K and Na) and colorimetric (P). Exchangeable Ca^{+2}, Mg^{+2}, K^+, and Na^+ were extracted with 1 mol L^{-1} ammonium acetate. Exchangeable H^+ and Al were extracted with 1 mol L^{-1} KCl and determined by titration. Effective cation exchange capacity (CEC) was calculated as the sum of all exchangeable cations (Ca^{+2}, Mg^{+2}, K^+, Na^+, H^+, and Al^{+3}). Base saturation percentage was calculated using Equation 1:

$$S = \left(\frac{Ca + Mg + K + Na}{CEC} \right) \times 100 \quad (1)$$

where:

S - base saturation percentage (%);
Ca - calcium concentration ($cmol_c$ dm^{-3});
Mg - magnesium concentration ($cmol_c$ dm^{-3});
K - potassium concentration ($cmol_c$ dm^{-3});
Na - sodium concentration ($cmol_c$ dm^{-3}); and,
CEC - cation exchange capacity ($cmol_c$ dm^{-3}) sum of all exchangeable cations (Ca^{+2}, Mg^{+2}, K^+, Na^+, H^+, and Al^{+3}).

The SISVAR version 5.1 statistical program and the Scott-Knottt test were used at 5% significance. Non-metric Multidimensional Scaling analysis (Kruskal, 1964) was applied to evaluate the variable effects on soil quality through the correlation of samples scores and soil chemical attributes using the PC-ORD 4.0 program. Correlation analysis was also carried out between each variable and soil quality using the SAEG 9.1 program.

Results and Discussion

Soil chemical attributes

Most of the evaluated soil chemical attributes were modified by soil use (Table 1). Soil pH varied from 5.24-6.15 (0-15 cm), 5.11-6.15 (15-30 cm) and 4.94-6.24 (30-45 cm), except for the pasture soil which presented a higher soil pH, whereas the other three areas had the same pH, with all of them in the acidic range. There was a reduction in soil pH with depth in all soil uses except pasture, which is a normal trait in this type of Oxisol due to its mineral composition and the presence of Al^{+3} in the subsoil, as the hydrolysis of Al^{+3} releases H^+ and increases soil acidity. In addition, the pH gradient observed along the soil profile in the cultivated areas was also a result of the top-dressed liming practice. Root growth can be restricted under such conditions, causing lower water and nutrient uptake, affecting above ground plant development (Dada & Ewulo, 2011). Management practices that include application of gypsum could decrease soil acidity and improve subsoil environment at lower depths.

The soils under pasture, pepper and consortium had higher organic matter content (37% higher) compared to soil under passion fruit cultivation in the 0 to 0.15m layer. This

Table 1. Soil pH, organic matter (SOM), sum of base (SB), cation exchange capacity (CEC), and base saturation percentage (V) of an Oxisol under different agricultural uses.

Soil attribute	Soil use				
	Passion fruit (1)	Pasture (2)	Pepper (3)	Intercropping (4)	CV %
0-15 cm layer					
pH	5.24 a	6.15 a	5.59 a	5.74 a	14.4
SOM (g dm^{-3})	8.64 b	14.2 a	13.6 a	13.3 a	14.5
SB (cmol dm^{-3})	2.64 d	3.17 c	4.86 a	4.26 b	16.9
CEC (cmol dm^{-3})	3.56 d	4.52 c	7.01 a	5.44 b	14.3
V (%)	74.5 a	70.0 b	69.3 b	78.4 a	9.02
15-30 cm layer					
pH	5.11 b	6.15 a	5.25 b	5.51 b	16.5
SOM (g dm^{-3})	6.76 c	8.76 b	8.47 b	9.90 a	16.1
SB (cmol dm^{-3})	1.84 b	3.13 a	2.97 a	3.02 a	21.7
CEC (cmol dm^{-3})	3.28 b	4.53 a	4.97 a	4.43 a	17.2
V (%)	56.2 b	68.6 a	60.2 b	67.9 a	9.15
30-45 cm layer					
pH	4.94 b	6.24 a	5.19 b	5.34 b	16.6
SOM (g dm^{-3})	7.84 a	5.66 c	6.86 b	8.35 a	22.2
SB (cmol dm^{-3})	1.75 c	2.49 b	3.20 a	2.18 b	21.4
CEC (cmol dm^{-3})	3.21 d	3.91 c	5.16 a	4.45 b	17.7
V (%)	54.2 d	62.9 a	61.9 a	50.1 b	13.3

Means followed by the same letter in a row are not significantly different at 5 % probability by Scott-Knott test.

is due to lower residue input of passion fruit crop, as well as less ground cover. Also, intense weed control by cleaning practices using a hoe, which revolves the soil to some degree, is a common practice in this area. Soil disturbance increases soil aeration and stimulates organic matter decomposition. Moreover, there was a reduction in soil organic matter with depth in all soil uses, which is a common soil feature since organic residue addition mostly occurs in the top soil.

Soil organic matter values at the Piaui irrigated perimeter were classified as low (<1.5%) (Sobral et al., 2007); however, according to Su et al. (2004), these are typical values of sandy soils in tropical and humid regions. Corrêa et al. (2009) reported soil organic matter content lower than 1% in irrigated perimeters of Pernambuco state. Gonzaga et al. (2016) also reported low organic matter content (1.1%) in Ultisols under irrigated coconut orchards in the state of Sergipe.

Soil CEC values in the Piaui irrigated perimeter is in agreement with the organic matter content (Sobral et al., 2007). Since sandy soils mostly rely on soil organic matter to build their exchangeable cation storage pool, inputs of organic residues, green manures and cover crops are essential management practices to maintain soil nutrient availability. Such practices were not applied in soil under passion fruit cultivation; as a result, lower soil organic matter content was observed and therefore lower CEC as compared to the other soil uses, especially in the two first soil layers. That is because passion fruit orchards in that region are usually cultivated as single crops and the soil is kept clean from weeds to facilitate plant management practices and fruit harvest.

Base saturation percentage values were high (> 50%) across the soil uses and decreased with depth. In general, high values of base saturation percentage were due to low CEC and moderate sum of base. The small mineral reserve is associated with low CEC of sandy soil, which comprise a small amount of kaolinite and Al oxides, leading to basic cation loss through leaching.

In investigating the soil quality of a Red Oxisol under citrus cultivation in an irrigated perimeter, Fidalski et al. (2007) also observed higher soil organic matter, CEC and base saturation percentage values on the soil surface. The authors also observed that areas cultivated with annual crops and fallow areas presented higher soil organic matter content when compared to areas under perennial fruit crops and pasture. However, their results are from Paraná state, being a region with lower temperatures, which could explain the higher organic matter levels under annually cultivated soils.

Ca^{2+}, Mg^{2+}, K^{+}, Na^{+1}, H+Al and P concentrations in soil cultivated with passion fruit, pasture, pepper and consortium are presented in Table 2. Soil cultivated with pepper and consortium presented better chemical quality and higher Ca^{2+}, Mg^{2+}, K^{+} and P concentrations, possibly as a result of higher fertilizer inputs required by pepper crops. Considering normal values for sandy soils of Sergipe (Sobral et al., 2007) in the same region of this study, the results of the present study showed that Ca and Mg concentrations are considered moderate (passion fruit area) to high (pepper and consortium). This is due to more intense input of amendments in soil cultivated with pepper.

Table 2. Exchangeable calcium, magnesium, aluminum, sodium, potassium and phosphorus concentrations, and potential acidity (H + Al) of an Oxisol under different agricultural uses.

Attributes	Soil use				
	Passion fruit (1)	Pasture (2)	Pepper (3)	Intercropping (4)	CV %
0-15 cm layer					
Calcium	1.68 b	1.64 b	2.70 a	2.60 a	22.4
Magnesium	0.64 c	1.27 b	1.61 a	1.52 a	22.8
Aluminum	0.08 b	0.08 b	0.10 a	0.08 b	24.8
Sodium	0.21 a	0.11 b	0.24 a	0.03 c	36.3
Potassium	0.11 b	0.14 b	0.30 a	0.11 b	52.1
H + Al	0.91 c	1.35 b	2.15 a	1.18 b	26.4
Phosphorus	48.8 c	9.66 d	142 b	165 a	30.9
15-30 cm layer					
Calcium*	0.87 b	1.45 a	1.70 a	1.58 a	35.3
Magnesium	0.57 d	1.51 a	0.80 c	1.28 b	24.0
Aluminum	0.10 b	0.08 b	0.33 a	0.08 b	81.6
Sodium	0.25 a	0.08 b	0.30 a	0.02 c	39.8
Potassium	0.13 b	0.08 c	0.16 a	0.12 b	29.0
H + Al	1.43 b	1.39 b	2.00 a	1.41 b	22.2
Phosphorus**	44.9 b	8.33 c	110.5a	105 a	42.5
30-45 cm layer					
Calcium	0.74 b	1.09 b	1.48 a	1.02 b	40.0
Magnesium	0.53 c	1.11 a	1.16 a	0.92 b	29.7
Aluminum	0.41 a	0.11 c	0.32 b	0.14 c	43.7
Sodium	0.34 a	0.15 b	0.38 a	0.02 c	36.2
Potassium	0.12 b	0.14 a	0.16 a	0.10 b	23.8
H + Al	1.46 b	1.41 b	1.96 a	2.27 a	30.8
Phosphorus	38.3 c	9.06 d	68.5 a	52.7 b	25.6

Means followed by the same letter in a row are not significantly different at 5 % probability by Scott-Knott test. * exchangeable cations (cmol dm^{-3}); ** (mg dm^{-3}).

A matter of concern is the very high P concentration in the cultivated soils (48.8-165 mg kg^{-1}, 0-15 cm), values that are from 5-17 times higher than in the pasture soil which has not been used for 5 years. Normal P concentrations in Oxisols are extremely low, usually lower than 1 mg kg^{-1}. The higher P concentration on the soil surface is due to the low mobility of this element in soil. Tropical soils such as the Oxisol of the present study have a high P adsorption capacity due to the presence of Al and Fe oxides, hydroxides and oxyhydroxides in the mineral phase which strongly bind phosphate anions by means of inner sphere reactions, forming stable complexes (Fink et al., 2016b).

In comparing soils under different uses, Corrêa et al. (2009) also observed high P concentration on the soil surface, decreasing with depth. However, results observed in the present study were 65% higher than those of Corrêa et al. (2009), except for the soil under pasture, where there was no significant difference with depth. The high P concentration observed in the cultivated areas is a result of excess P fertilizer application, a common management practice in tropical soils. These soils have high P adsorption capacity, which reduces P availability for plant uptake.

The K concentration is low across the cultivation areas, which is mostly due to the high K mobility in soil. But again, pepper cultivation showed the highest K concentration, confirming the intense fertilizer use in the area. According to Ernani et al. (2007), K mobility is reduced in cultivated soil that has high organic matter content. As for other cations, K mobility reduces as negative charge density increases.

Following the reduction in soil pH with depth, the Al concentration also decreased in soil profile, but it is still considered low (<0.5 $cmol_c$ kg^{-1}).

Multivariate analysis of soil chemical attributes

In order to better understand the multidimensionality of the soil quality concept when so many soil attributes are involved, multivariate analysis through Non-metric Multidimensional Scaling analysis we used (McCune & Grace, 2002). Figure 1 shows the soil quality variability as a function of soil chemical attributes in the three evaluated soil layers.

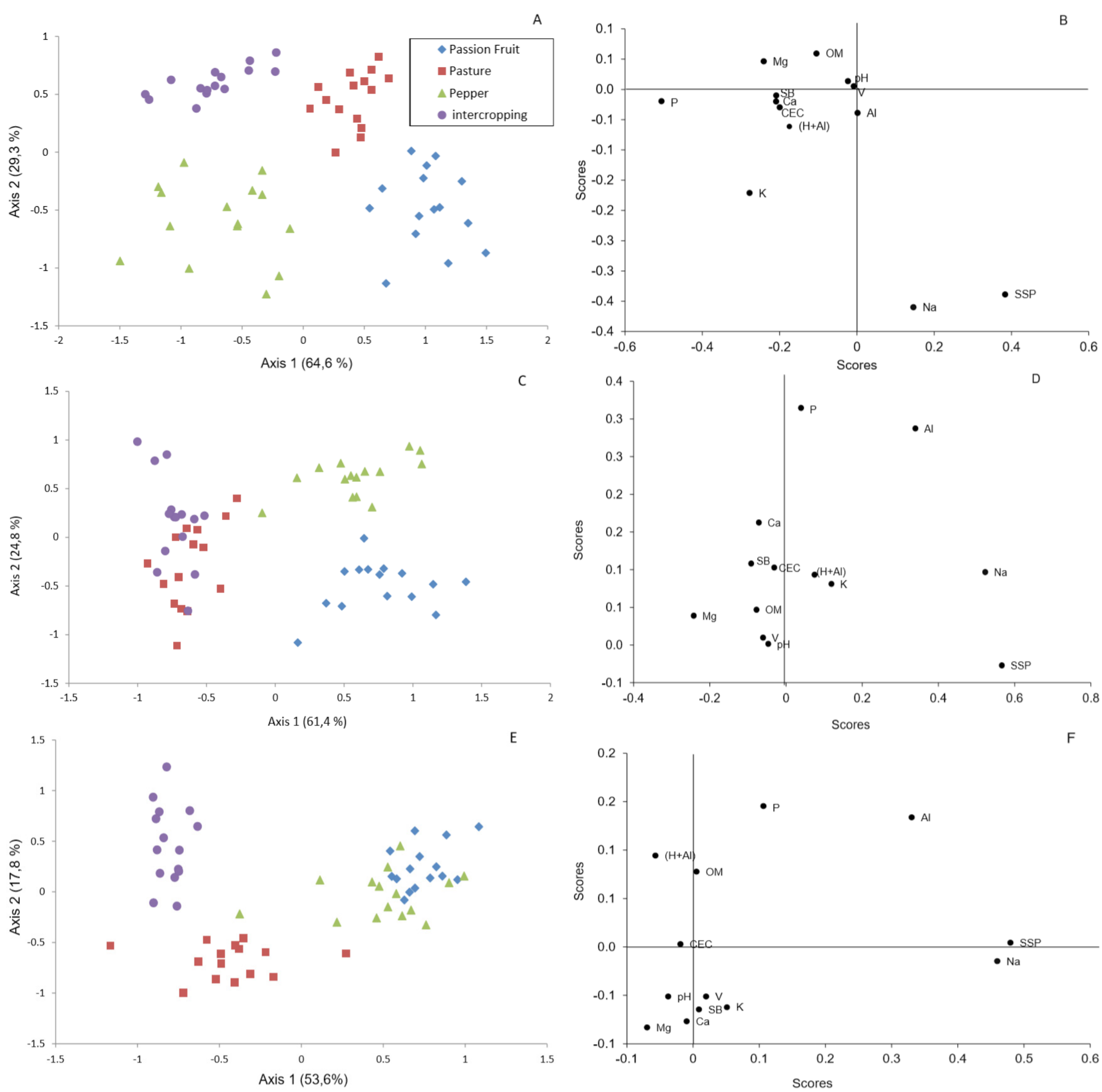

Figure 1. Multidimensional ordination of the samples in the space of the chemical variables (A, C, E), and multidimensional ordination of the chemical variables in the space of the samples (B, D, F) in the 0-15 cm, 15-30 cm and 30-45 cm layers, respectively.

Multidimensional ordination analysis of the samples from the 0-15 cm layer resulted in 93.9% variability represented in a chart with two dimensions (Figure 1A). Axis 1 and 2 contributed with 64.6% and 29.3%, respectively, for the variability in soil quality. Therefore, axis 1 is the most important in explaining variability in soil quality. It is clear that variables within the sample spacing separated soil uses into four groups. Soil attributes that are more related to improved soil fertility such as soil organic matter, Ca^{+2}, Mg^{+2}, K^{+1}, P, sum of base, and CEC presented significant correlation and a negative sign on axis 1. This means that as the scores increase from the left to the right side of the chart, the soil attribute values reduced from the right to the left. Differences were observed at 1% probability level. Soil under pepper cultivation and consortium were grouped together due to high fertility, as pointed out by attributes such as P and K concentrations (Figure 1B).

Axis 2, which represents 29.3% variability, presented higher significant correlation values, with a negative score for variables related to Na^{+} and sodium saturation percentage (Figure 1B). It can be observed that soil under pepper and passion fruit cultivation are susceptible to salinization and should be managed with care.

Multidimensional ordination analysis of the variables was applied within the space of the samples in the 0-15 cm layer in order to express the importance of each variable on the separation of the samples (Figure 1B). The closer the variable is to the origin point, the lower its importance in separating the samples in those different soils uses. Therefore, P and K were the variables that mostly influenced the effect of soil use for better soil fertility. On the other hand, Na^{+} and SSP influenced soil use with pepper and passion fruit due to the risk of soil salinization. Those results are also observed through correlation analysis in Table 3.

Multidimensional ordination analysis also showed samples variability on the space of the variables for the 15-30 cm layer (Figure 1C and D), and pointed out 86.2% variability in soil quality. Axis 1 and 2 contributed with 61.4% and 24.8% variability, respectively. In axis 1, important variables involved on the soil use variability were soil organic matter and Mg^{+2}.

Negative correlations were observed for those variables. Soil uses that are more positioned from the left to the right side of the chart (consortium and pasture) presented higher values of the variables. Those elements were significant at 1% probability level (Figure 1D; Table 3). Positive correlations were observed for Na^{+} and SSP, which means that as scores increase, the importance of Na^{+} and SSP on the definition of soil quality also increases. Soil uses were clearly separated into three groups. Soil under consortium and pasture had similar behavior.

P was the variable that most influenced soil uses in axis 2 (Figure 1C). A significant and positive correlation was observed for consortium and pepper cultivation, with higher values of P, sum of bases, CEC and SSP. Also, variables such as P, Al, Na and SSP contributed the most for differentiation across soil uses. This was probably due to the influence of the overlying layer.

Multidimensional analysis pointed out variability of 77.4% for the 30-45 cm layer. Axis 1 and 2 contributed with 53.6% and 23.8% variability, respectively (Figure 1E). Therefore, axis 1 can better explain sample variability. Three soil use groups were formed based on location of the variables on the sample space. Pearson correlation coefficients showed great significance for the variables Na, Al and SSP. Those variables were positively correlated in the axis 1, (Figure 1F) meaning that increasing scores also increase the importance of those variables, which influenced passion fruit and pepper cultivation to some extent. However, by observing axis 2, variables such as Ca, Mg, SB and CEC were positively correlated (Table 3) and significant at 1% probability level. These soil variables had great influence on soil use for consortium and pepper cultivation.

Table 3. Pearson correlation coefficients between soil chemical attributes and sample scores (axis 1 and 2) obtained from Multidimensional ordination analysis.

Soil chemical attributes	Correlation coefficients					
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
	0-15 cm layer		15-30 cm layer		30-45 cm layer	
pH	-0.194^{ns}	0.151^{ns}	-0.397**	0.018^{ns}	-0.322*	0.174^{ns}
SOM	-0.589**	0.444**	-0.523**	0.412**	0.030^{ns}	0.224^{ns}
Calcium	-0.827**	-0.105^{ns}	-0.259*	0.771**	-0.033^{ns}	0.752**
Magnesium	-0.835**	0.214^{ns}	-0.794**	0.167^{ns}	-0.272*	0.702**
Aluminum	0.008^{ns}	-0.229^{ns}	0.443**	0.491**	0.758**	-0.284*
Sodium	0.284*	-0.930**	0.934**	0.226^{ns}	0.923**	0.040^{ns}
Potassium	-0.491**	-0.403**	0.467**	0.476**	0.260*	0.388**
H + Al	-0.526**	-0.246^{ns}	0.389**	0.635**	-0.239^{ns}	0.569**
Phosphorus	-0.833**	-0.043^{ns}	0.072^{ns}	0.752**	0.266*	0.493**
SB	-0.917**	-0.104^{ns}	-0.449**	0.694**	0.043^{ns}	0.799**
CEC	-0.879**	-0.174^{ns}	-0.197^{ns}	0.846**	-0.115^{ns}	0.921**
ESP	0.685**	-0.805**	0.954**	-0.060^{ns}	0.952**	-0.307*
V	-0.101^{ns}	0.088^{ns}	-0.692**	0.147^{ns}	0.182^{ns}	0.153^{ns}

** Pearson correlation coefficient at 1 % probability level; * Pearson correlation coefficient at 5 % probability level; ^{ns} non-significant Pearson correlation coefficient.

Conclusions

Cultivation of pepper alone or in consortium intercropped with passion fruit improved soil chemical quality, probably due to a greater soil cover and higher fertilizer inputs.

The use of multivariate analysis was efficient in separating soil use effects as a function of soil chemical attributes. For instance, the results showed that Ca, Mg, CEC, base saturation, OM and pH were responsible for the improvement of the pepper and pepper + passion fruit cultivation areas; in addition, it showed that conventional cultivation and irrigation of passion fruit can increase soil salinity.

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