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Soil physico-chemical properties and Organic Carbon stocks across different land use in an urban park of Vilnius, Lithuania

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ABSTRACT

Urban areas are characterised by land use change processes. Urban and peri-urban soils degradation increase at the different land uses, and the characteristic of each land use affecting soil carbon stock and, consequently, the role of soil as a CO_2 sink. The aim of this work was to assess the effect of land use and soil management practices in urban and peri-urban soils in Vilnius (Lithuania). Studied properties were: Sand, Clay, Silt, Stoniness, bulk density (BD), pH, electrical conductivity (EC) and soil organic carbon stocks (SOCS). Ten samples were collected at depths 0-10 cm in 8 different land uses and soil management practices in the urban and peri-urban areas of Vilnius. Forests – *Quercus robur*, *Acer plantanoides*, *Pinus sylvestris* and *Picea abies*, grasslands – semi-natural grasslands (SNG) and managed semi-natural-grasslands (MSNG), both dominated by *Taraxacum officinale*, artificial grasslands (AG), and urban. SOC (t/ha) resulted significantly higher in *Pinus sylvestris* and Art. Grass than in *Quercus robur*, *Acer plantanoides*, and urban land uses. Urban land use recorded lower values of SOC (t/ha) than the other land uses except for *Acer plantanoides*. Land uses with high human intervention decline soil quality and affect the role of soil as a climate regulator.

Keywords: soil management, CO_2 sequestration, soil quality, bulk density, soil moisture

INTRODUCTION

Soils are a critical natural capital and provide a wide range of ecosystem services crucial for life, such as water purification, carbon sequestration and food provision (Daily et al., 1997). These services can be severely affected by human land use, especially in urban areas where soils are exposed to intense pressure, often sealed, reducing their capacity to provide ecosystem services (Pouyat et al., 2007; Bogunovic et al., 2020). Soils are an important carbon reservoir (Baul et al., 2022). Soil organic carbon (SOC) is fundamental in the total carbon cycle because it can act as a sink to mitigate climate change produced by greenhouse gas (Lal, 2003). Studies that analyse the soil organic carbon stocks (SOCS) are very important because small changes represent strong modifications in CO_2 concentrations and climate changes (Parras-Alcántara et al., 2015; Lozano-García et al., 2020). For these reasons, SOC conservation strategies are demanded to clarify the land use that holds higher SOCS (Barbera et al., 2012; Passos de Oliveira et al., 2021) and, consequently, high CO_2 retains, contributing to the mitigation of climate change (Lal, 2003). Precisely estimating SOC in each land use is essential for European Union (Stolbovoy et al., 2007) and climate change policies (IPCC, 2021; Lahn, 2021).

Soil degradation and, consequently, a decrease in soil quality can result from improper use that affects soil's physical, chemical and biological properties (Brevik et al., 2015). These modifications are strongly related to land use changes (Khaledian et al., 2013) produced by social decisions (e.g. political decisions and market conditions) (Keesstra et al., 2016). Land use change can modify SOCS (Smith et al., 2008; Poeplau and Don, 2013; Pereira et al., 2022). Soil parameters such as soil pH indicate land-use change (Blake et al., 1999; Brasseur et al., 2018). The management of each land use and the intensity of its management will be crucial for soil pH to be higher in high-intensity managed areas (e.g. urban land use) (Malek et al., 2018). Land use change affects SOCS and C sequestrations (Muñoz-Rojas et al., 2012). The change from forest to agriculture releases SOC and decreases soil productivity (Nair et al., 2009). Changes from natural or semi-natural forest areas to agricultural uses resulted in higher losses of SOCS (Lozano-García et al., 2017). These agroforestry practices should create opportunities to evaluate these areas, increasing productivity and improving the SOCS and CO_2 sequestration (Hombegowda et al., 2015). An adequate level of SOCS is essential to decrease degradation risk and hold water and nutrients (Lal, 2004). Land use that provides all these factors is essential for sustainable landscape management. Soil Organic Carbon Stocks are challenging to be estimated in areas with heterogeneous land uses and site patterns (Leifeld et al., 2005), as occurs in urban sprawl areas. These land use changes can modify the quantity and quality of litter inputs to the soil organic matter (SOM) dynamic (Gmach et al., 2018; James et al., 2019).

The variation of soil properties inside each land use depends on many factors as topography, parent material and vegetal cover (Schulp et al., 2008; López-Vicente et al., 2009; Muñoz-Rojas et al., 2011). In this sense, SOCS is regionally positively related to mean annual precipitation and clay content and negatively to annual grassland temperature (Burke et al., 1989). Tree species diversity greatly impacts SOM quantity and quality (Acker et al., 2002). Vegetal decomposition is a determinant in C inputs into the soil (Jobbagy and Jackson, 2000) and SOCS vary according to grass-, shrub- and tree- systems where were measured (Jackson et al., 1996).

Several studies have analyzed the effect of land use on soil physicochemical properties and concretely on SOCS (Eshetu et al., 2004; Muñoz-Rojas et al., 2012; 2015). Despite this, there are a lack of data and a precise methodology to quantify C pool in ecosystem and regions (Don et al., 2011; Muñoz-Rojas et al., 2012). In addition, there is no consensus about the causes and the effects of the modifications of land use and, consequently, land cover. Only a few studies investigate the effect of multiple land use changes on soil quality and degradation in the same urban area (Khaledian et al., 2016; Shete et al., 2016). Changes in land use and changes inside each land use as forest management that can fragment the landscape or wildfire events produce medium- to long-term effects in SOCS, changing the carbon sources and sinks (Law and Harmon, 2011). This work aims to study the SOCS and soil characteristics in 8 land uses. Forests- *Quercus robur*, *Acer plantanoides*, *Pinus sylvestris* and *Picea abies*, grasslands- semi-natural grasslands (SNG) and managed semi-natural-grasslands (MSNG), both dominated by *Taraxacum officinale*, artificial grasslands (AG), and urban. The specific objectives are: 1) examine soil physical and chemical differences according to land uses; 2) determine what land use holds high SOCS and higher soil quality; and 3) understand the impact of land uses and soil management practices on soil properties and suggest possible protective measures for the land uses according to its role as climate change regulation and mitigation.

MATERIALS AND METHODS

Study area and Experimental design

The study area is located in Vingis park in Vilnius, Lithuania (54°41′N, 25°14′E and 130 m a.s.l.), which covers an area of 162 ha (Figure 1) (Kalinauskas et al., 2023). Park's geology comprises pre- and post-Quaternary parent material composed of chalk from the Cretaceous period (first) and sand and alluvial sediments from the

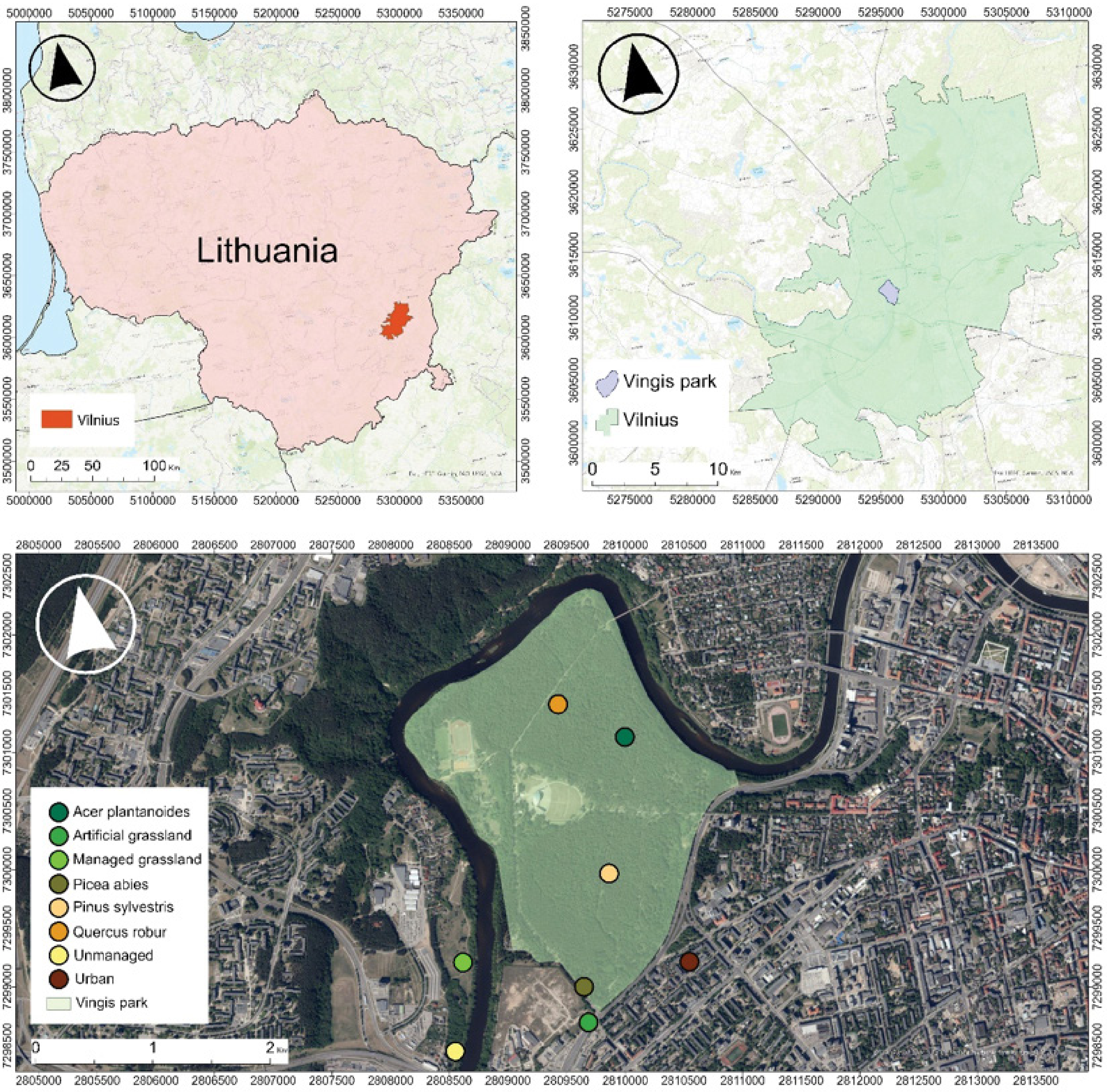

Figure 1. Location of study area

Holocene (second). Vilnius has a mean annual temperature of 8.8 °C and a mean annual rainfall of 735 mm (Pereira et al., 2014). The park's soils are classified as Albeluvisol (WRB, 2006). The vegetation cover mainly comprises *Quercus robur* L., *Acer plantanoides* L. and *Aesculus glabra* Wild (Francos et al., 2020). In this study area, eight sites were selected for the experiment: 1) *Quercus robur* forest; 2) *Acer plantanoides* forest; 3) *Pinus sylvestris* forest; 4) *Picea abies* forest; 5) Semi-Natural Grassland (SNG); 6) Managed Semi Natural Grassland (MSNG); 7) Artificial Grassland (AG), and 8) Urban. Managed semi-natural grassland was mowed in the spring and summer once per month and artificial grassland was mowed during the same period once per week. Plots had the same geomorphological characteristics. Sampling points were identified with a GPS Garmin Etrex 22x. At each site, ten disturbed and ten undisturbed soil samples were collected in July 2018 (Figure 1) throughout a transect following Bogunovic et al. (2020). Core soil sampling (10 per site, 80 in total) was carried out at the 0-10 soil depths using 100 cm^3 cylinders. Disturbed samples were storage in plastic bags to be transported to the laboratory. Samples were collected with a distance of 2 m.

Laboratory methods and Statistical analysis

Disturbed soil samples were dried for 7 days at room temperature (23 °C) and then sieved at 2 mm to analyse mechanical composition and calculate Stoniness (%). The hydrometer method determined particle size distribution by quantifying soil samples' relative proportion of clay, silt, and sand (Arshad et al., 1997). Soil pH [1:2.5] and EC (expressed in µS/cm) [1:2.5] were analysed with the extraction of deionised water (Jackson, 2005). Soil cores were dried in an oven at 105 °C for 24 h to obtain the bulk density (BD) according to Black (1965). The soil organic matter (SOM) was determined using the loss-on-ignition method (Heiri et al., 2001) The SOCS concentrations were determined for depth 0-10 cm. The SOCS content was calculated from the SOM using the following formula (Jackson, 2005):

$$SOC = SOM/1.724$$

Soil organic carbon stock, expressed for a 0-10 cm depth in t/ha, was computed as the product of SOC concentration, bulk density, depth, and gravel using the following equation (Hoffmann et al., 2014):

$$\text{SOC stock} = \text{SOC concentration} \times BD \times d \times (1 - CF)$$

where SOC is the organic carbon content (g/g), BD is the soil bulk density (g/cm^3), d is the thickness of the layer (cm), and Stoniness is the proportion (g/g) of coarse (>2 mm) fragments in the layer.

Regarding statistical analysis, data normality and homogeneity of the variances were assessed using the Shapiro-Wilk and Levene's tests. In the case where the data distribution was considered normal and followed a Gaussian distribution, a one-way ANOVA test was applied; in the cases where the data did not respect normality and homogeneity, we applied the non-parametric Mann-Whitney test. Significant differences were checked using a Tukey post-hoc ($P<0.05$). A redundancy analysis (RDA) was carried out to identify the relations between the variables. Statistical analyses were implemented using SPSS 23.0 and CANOCO for Windows 4.5.

RESULTS

Among the land-use types investigated, Sand (%) resulted significantly high in *Acer plantanoides*, *Picea abies*, and MSNG than AG. Urban land use showed significantly lower sand (%) content than the other land uses. Silt (%) content resulted significantly high in Art. Grass and Urban than in the other land-uses. Soil clay (%) resulted in significantly higher urban land use than in the other land uses except SNG. Stoniness (%) resulted significantly higher in urban use than other land uses. *Quercus robur* and *Pinus sylvestris* showed significantly higher values than the other land uses except for AG. Bulk Density (g/cm^3) resulted significantly higher in urban than in the other land uses. Regarding pH, urban land use resulted significantly higher than other land uses except for MSNG and AG. SNG land obtained a significantly higher pH than *Quercus robur*, *Acer plantanoides*, *Pinus sylvestris* and *Picea abies*. Soil pH resulted significantly lower in *Pinus sylvestris* than in the other land uses except *Acer plantanoides*. Soil EC registered significantly higher values in urban land use than *Picea abies*. SOC (g/kg) resulted significantly higher in *Pinus sylvestris* than in urban, *Quercus robur* and *Acer plantanoides*. The results show significantly lower values in urban land use than in the other areas except *Acer plantanoides*. Finally, SOC (t/ha) resulted significantly higher in *Pinus sylvestris* and AG than in *Quercus robur*, *Acer plantanoides*, and urban land uses. Urban land use recorded lower values of SOC (t/ha) than the other land uses except for *Acer plantanoides* (Table 1). The RDA allow us to know how to affect the land use of each soil property. Factor 1 in the RDA explains 45.44% of the variance, and Factor 2 explains 17.59%, being explained 63.03% of the total variance. The variables with the highest explanatory capacity are Sand, SOC and SOCT, while the properties with the lowest explanatory capacity are EC, Clay and pH. This RDA clearly separates forest (situated at the negative part of the RDA in factor 1) and urban areas (situated in a positive extreme of factor 1 in the RDA). Silt, pH, BD, stoniness, Clay and EC are grouped around SNG area and can be related to AG and Urban areas. SOC and SOCT are better explained by *Pinus* and MSNG areas. Sand is associated with *Picea area* (Figure 2).

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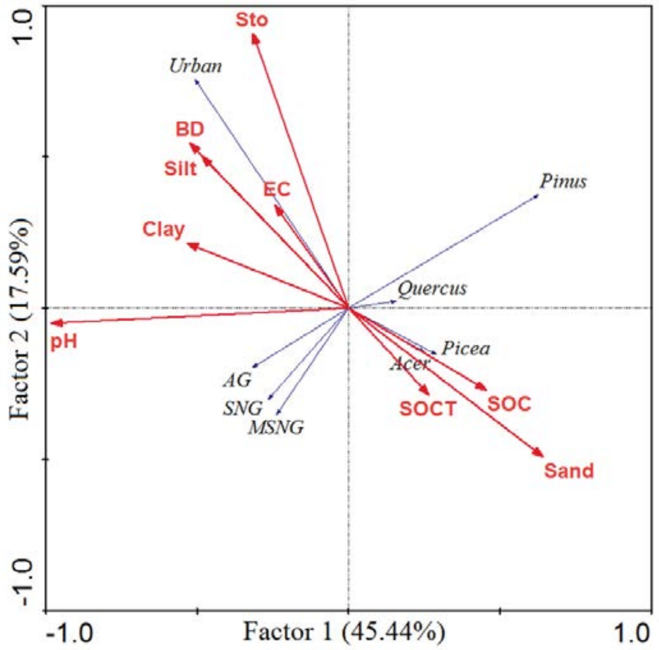
Table 1. Properties of the studied soils according to the different land use types

Land use	Sand (%)	Silt (%)	Clay (%)	Stoniness (%)	BD (g/cm^3)	pH	EC (µS/cm)	SOC (g/kg)	SOC (t/ha)
Quercus robur	83.60 (1.26) ^{ab}	4.00 (1.33) ^{b}	12.40 (0.84) ^{b}	7.72 (4.44) ^{b}	1.00 (0.20) ^{b}	5.87 (0.22) ^{c}	178.20 (152.99) ^{ab}	81.78 (27.12) ^{bc}	73.13 (29.52) ^{bc}
Acer plantanoides	84.00 (0.94) ^{a}	3.40 (1.35) ^{b}	12.60 (0.97) ^{b}	1.94 (1.08) ^{c}	1.12 (0.27) ^{b}	5.63 (0.36) ^{cd}	164.75 (180.31) ^{ab}	59.74 (32.93) ^{cd}	65.92 (49.77) ^{cd}
Pinus sylvestris	83.80 (3.19) ^{ab}	4.00 (2.31) ^{b}	12.20 (1.14) ^{b}	9.58 (3.68) ^{b}	1.14 (0.19) ^{b}	4.98 (0.23) ^{d}	109.15 (41.71)^{ab}	120.64 (20.05) ^{a}	122.57 (17.40) ^{a}
Picea abies	84.40 (1.26) ^{a}	2.80 (1.03) ^{b}	12.08 (1.03) ^{b}	2.13 (1.11) ^{c}	1.07 (0.17) ^{b}	5.71 (0.20) ^{c}	85.22 (51.09) ^{b}	98.60 (27.75) ^{ab}	103.48 (35.89) ^{ab}
SNG	81.80 (1.48) ^{b}	3.80 (1.48) ^{b}	14.40 (0.84) ^{ab}	3.42 (1.27) ^{c}	1.16 (0.10) ^{b}	6.90 (0.25) ^{b}	145.33 (107.96) ^{ab}	80.62 (12.95) ^{ab}	90.12 (16.32) ^{ab}
MSNG	84.00 (1.33) ^{a}	3.60 (1.58) ^{b}	12.40 (0.84) ^{b}	2.83 (1.30) ^{c}	1.16 (0.15) ^{b}	6.99 (0.12) ^{ab}	112.13 (36.14) ^{ab}	94.54 (22.72) ^{ab}	106.73 (30.66) ^{ab}
AG	80.40 (1.26) ^{b}	6.00 (1.93) ^{a}	13.60 (1.26) ^{b}	5.15 (2.90) ^{bc}	1.28 (0.03) ^{b}	7.06 (0.34) ^{ab}	139.61 (35.68) ^{ab}	89.32 (14.77) ^{ab}	108.65 (20.77) ^{a}
Urban	77.60 (1.58) c	7.60 (14.80) ^{a}	14.80 (1.69) ^{a}	22.10 (4.82) ^{a}	1.66 (0.15) ^{a}	7.32 (0.42) ^{a}	423.75 (585.34) ^{a}	38.28 (12.88) ^{d}	48.24 (12.53) ^{d}
P	**	**	**	**	**	**	*	**	**

Mean (Standard Deviation). Bulk Density (BD). Electric Conductivity (EC). Soil Organic Carbon (SOC). Semi-Natural Grassland (SNG). Managed Semi Natural Grassland (MSNG) and Artificial Grassland (AG). Significant differences were considered at a $P<0.05$. $P<0.05$*, $P<0.01$** and $P<0.001$***. Different lowercase letters inside the column indicate a significant difference between treatments. N=10



Stoniness (STO). Bulk Density (BD). Electrical Conductivity (EC). Soil Organic Carbon (SOC). Semi-Natural Grassland (SNG). Managed Semi Natural Grassland (MSNG) and Artificial Grassland (AG)

Figure 2. Redundancy Analysis about the relation between Factors 1 and 2

DISCUSSION

Soil mineralogical and physical properties

Soil resulted in significantly higher sand content in *Acer plantanoides*, *Picea abies* and MSNG than in SNG and AG. Urban land use showed significantly lower sandy content than the other land uses. This might be attributed to the lack of human intervention in natural land use and consequently to the soil management practice. Tye et al. (2009) observed that mixed forest that colonized agricultural abandoned areas over 30 years ago resulted in significantly higher values of sand content than the soil parks where the human pressure and intervention was higher. The growth of tree vegetal species in natural land uses can produce a slight coarsening of the soil (Jolivet et al., 2003). Silt values resulted significantly higher in AG and in urban areas than in the other studied land uses. Both areas corresponded to human intervention at land uses that can increment silt and clay content. High silt and clay content in managed soils can be due to the traffic that compacts these soils (Nawaz et al., 2013) and scarce tree vegetal species (Jolivet et al., 2003). The higher amount of clays in urban land produced low number and size of pores and consequently a high BD and low SOC (Asadu and Chibuike, 2015; Canedoli et al., 2020). High silt and clay content are related to high BD produced by human intervention in land uses that match with the results obtained by Botta et al. (2016), where they appointed an increment of BD by traffic. De Kimpe and Morel (2000) and Lehman and Stahr (2007) observed higher BD in urban land use and consequently higher contents of silts and clays by human activities such as the incorporation of novel anthropogenic materials and vegetation management practices. In this study, traffic and human intervention can be the reason because urban land use resulted in higher silt, clay, stoniness and BD content.

Soil chemical properties

Soil pH resulted significantly higher in urban than *Quercus robur*, *Acer plantanoides*, *Pinus sylvestris*, *Picea abies*, and SNG land uses. Soil pH resulted significantly higher in SNG than in *Quercus robur*, *Acer plantanoides*, *Pinus sylvestris* and *Picea abies*. Soil pH showed lower values in *Pinus sylvestris* land use than in other areas except for *Acer plantanoides*. Asabere et al. (2018) observed increased soil pH in urban areas compared to forest zones and in long-term occupied areas than in recent urban sprawl land use. The previous authors (Asabere et al., 2018) assigned the increment of soil pH to the abundance of coarse fragments consequence of urbanization process. Cofie et al. (2009) found that soil pH increase in urban areas can be due to the decomposition of organic waste. Construction waste can also increase soil pH (Jim, 1998). Stow et al. (2016) observed the influence of nearby constructions incrementing urban soil pH compared with other land uses. Blume et al. (2016) also related the alkalinisation process with the increment of anthropogenic activities as occurred in this study in urban land use. The same results were obtained in the present study, where the area with the higher decomposition of organic waste and a greater construction influence was the urban area. Singh et al. (2018) reported slightly higher values in grassland than in forest areas by higher soil washed in the second one. Finally, Rezapour and Samadi (2014) stated that soil pH resulted lower in forest areas than in grassland land uses due to leaching and base-forming compounds and free carbonates in forestland uses, which matches our results. Sun et al. (2013) and Xu et al. (2018) appointed significantly higher pH values in native grassland soils than in managed grassland soils producing differences in the soil nitrification processes. Malik et al. (2018) established the relations between pH and SOM using soil pH as a proxy of land use quality. Malik et al. (2018) stated that in areas with soil pH lower than 6.2, abiotic factors limit microbial growth and decomposition, producing the accumulation of SOM, as occurs in the present study matching the land uses with lower soil pH with areas with high SOC stock and vice-versa. Comparing managed and non-managed grassland and tree-covered areas, Li et al. (2018) observed significantly higher pH values in grassland than in tree-covered areas. The same results were obtained in the present study. Li et al. (2015) and Liu et al. (2017) appointed that the decrease of soil pH in tree cover areas can be attributed to the continuous irrigation by the leaching of base cations. In the present study, we consider that the leaching processes decrease soil pH in tree cover areas by the lower vegetal density and the higher water quantity from the rainfall that reaches the soil surface and is incorporated into the soil. Concerning *Pinus sylvestris* land use, soil pH was significantly lower than in other areas except for *Acer plantainoides*. Some tree species can acidify the soil, decreasing the pH compared to other areas (e.g. *Eucaliptus* and *Pinus* areas) (Amanuel et al., 2018). Needles, bark and roots can produce soil acidification, causing decrease in soil pH (Eshete et al., 2011).

Soil EC resulted significantly higher in urban areas than in other land uses. These results can be obtained due to using chemical products in urban forests. Bahrami et al. (2010) observed significantly higher values of EC in areas where intensive fertilizer and pesticides was carried out. The use of these substances can carry out the deterioration of soil quality (Willy et al., 2019). On the other hand, Liu et al. (2018) observed significantly higher EC in areas with low vegetation density and where plant removal was not carried out. The authors concluded that the increment of EC can be related capillary action of water. In this sense, the more water quantity available in the soil and non-absorbed by plants can produce this increment in EC. In the present study, EC was significantly higher in urban areas than in *Picea abies* land use by the absence of vegetal removal, the lower plant density and consequently higher water disposition into the soil and a capillary process. In the case of grasslands, Kodesova et al. (2011) observed that as roots increase, the number of soil ions produces an increment of EC, similar to the values obtained in urban land use soil.

On the other side, according to Schulp et al. (2008) and Vesterdal et al. (2008), forest SOC resulted significantly higher in forest plantations than in non-managed forests. Bahrami et al. (2010), observed significantly higher SOCS values in the natural forest than in managed areas and agricultural land use due to the higher production of SOC under forest natural land use. Plant species are very important for SOC (Usuga et al., 2010). In this sense, Rigobelo and Nahas (2004) observed lower SOC in *Pinus* forest than in another type of forest due to the moisture conditions and low microbial activity. In our study, the *Pinus* area holds higher SOC than the other single-species forest due to the constant accumulation of vegetal material, as appointed by Usuaga et al. (2010). *Pinus sylvestris* is deciduous specie that contributed to this accumulation of vegetation in contrast with *Quercus robur* and *Acer plantanoides*, which are evergreen species. Its contribution is seasonal and smaller. Tree-based land use systems resulted in higher SOM values due to the addition of leaf litter and organic matter from leaves and dead roots (Rhodes, 1995). Usuaga et al. (2010) analyzed the relationship between BD and SOC and observed that areas with lower BD match with areas with high SOC, despite the results were not significant. In our study, the higher BD corresponds to urban land use, where the lower SOC was registered and can result, according to previous authors, in losses of soil quality. Human activities can produce changes in SOCS (Bhattarai and Conway, 2008). Soils of urban forest areas are characterized by the diminution of SOC, as occurred in our study. This reason produces that Ren et al. (2012) appointed that urban sprawl produces a decrease in SOC. The same appointed Asabere et al. (2018) by the rapid urban sprawl and the accumulation of non-biodegradable household wastes, which dilute SOM. The transformation of agricultural land into forestlands in the urban core by the expansion of the urbanized area produces a decline of carbon stock due to human activities and the construction of roads. Thus, Ren et al. (2012) observed that the effect of urban sprawl on forest SOC decrease as the distance to the urban core increase. Kukal and Bawa (2012) ordered the land use according to its SOCS as follows: forest > grassland > cultivated. In this study, the authors observed a sharp decrease of SOCS in depth and important variations of SOCS related to different land uses. Singh et al. (2011) appointed higher SOCS values in forests and pastures than in agricultural soils. According to Benbi et al. (2015), this situation was produced due to the undisturbed conditions of forest soil and the greater plant contribution that increment SOC in forest areas and the cropping that decrease the organic carbon in agriculture areas.

Implications for land management

The RDA allows two distinct groups to be identified: one group composed of Silt, pH, BD, Stoniness, Clay and EC and another group composed of Sand, SOC and SOCS. First group trends to the urban area due to the high quantity of these soil properties in soil urban land use. Silt resulted higher in AG, and urban land uses and is positioned in the RDA close to these land uses. Clay, Stoniness, BD, pH and EC tend to the urban land use due to their higher values in this land use. The second group is placed in the negative area of factor 1, opposite to urban land use, where these three soil properties resulted significantly lower than in the other land uses. Sand resulted higher in *Acer*, *Picea* and MSNG land use and is associated with these land uses and others, as *Quercus* were the results of sands were similar to these three land uses. SOC and SOCS showed a similar trend. SOC resulted higher in *Pinus* land use and is related to *Picea*, MSNG and AG. SOCS resulted higher in *Pinus* and AG and is also associated with *Picea* and MSNG. The proximity between soil properties as occurs with SOC and SOCS and in the case of Silt, pH, Stoniness, BD, Clay and EC highlight similar trends in these properties. The study reveals that land uses without human intervention increases the ecosystem services provided and carries out an essential role as CO_2 sink than human intervened land uses. For this reason, these studies need to be taken into account in order to protect certain land uses and to curb land use change for production purposes that do not take into account environmental and human well-being.

CONCLUSIONS

The results of this work showed that particle size distribution was affected by human intervention according to the differences obtained in each land use analyzed. The differences in soil texture produce changes pores size affecting BD. Thus, BD was affected by land use and human activities. Soil pH dynamic was directly related to human pressure, the intensity of land-use cover and land-use change, and the proximity of anthropogenic activities. In the natural environment and non-human affected land uses, pH was related to leaching, species that composed vegetal cover and soil nitrification processes. Soil EC was mainly affected by vegetation density and intensity of management. Soil organic carbon and SOCS changes were mainly affected by land use. According to this study, the higher values were obtained in natural and managed forests, where a large quantity of vegetation was accumulated. The soil and its properties and dynamics must be considered when carrying out any change of land use or any modification of the vegetation cover. As a non-renewable resource, such studies are necessary to assess the possible impacts of land-use cover and soil management impacts and to avoid soil degradation.

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