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Estimation of soil organic carbon (SOC) at different soil depths and soil use in the Sumapaz paramo, Cundinamarca - Colombia

Estimación de carbón orgánico del suelo (COS) a diferentes profundidades y uso del suelo en el páramo de Sumapaz, Cundinamarca- Colombia

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Abstract

The vertical distribution of soil organic carbon (SOC), considered to be a key component of the carbon cycle, is still poorly understood in tropical highest mountain ecosystems such as the Andean paramo. The estimation of the SOC in the presence and absence of anthropic intervention, will help to define policies to mitigate CO_2 emissions into the atmosphere from this ecosystem. The aim of this research was to determine soil organic carbon sequestration at three soil depths under two types of soil use in the paramo of Sumapaz, Colombia. The soil variations of pH, phosphorus, aluminum, bulk density, carbon sequestration, cation exchange capacity, texture and to estimate the vertical distribution of soil organic carbon SOC, were evaluated, respectively. Two sites were selected to establish the soil estimations according to soil use: natural vegetation cover and potato (*Solanum tuberosum* L.) crop. Samples were taken from 0-25, 25-50 and > 50 cm soil depths. Consequently, eight physical-chemical variables were analyzed in terms of the SOC sequestration estimated for each soil depth and soil. The averages for SOC under natural vegetation cover were: 188 $tC.ha^{-1}$ to 25 cm, 183 $tC.ha^{-1}$ to 50 cm, and 178 $tC.ha^{-1}$ at soil depths below 50cm. For potato (*Solanum tuberosum* L.) crops, SOC sequestration were: 119 $tC.ha^{-1}$ to 25 cm, 83 $tC.ha^{-1}$ to 50 cm, and 71.8 $tC.ha^{-1}$ at soil depths below 50cm. These results allow to support the soil management strategies that addressed to preserve SOC and regulate water level within the ecosystem of the Andean paramo.

Key words: Andisols, root carbon, soil organic matter, vertical distribution.

Resumen

La distribución vertical de carbono orgánico del suelo (COS), que se considera un componente clave del ciclo del carbono, aún es poco conocido en los ecosistemas tropicales más altos de montaña, como lo es el páramo andino. La estimación del COS en presencia y ausencia de la intervención antrópica, ayudará a definir las políticas para mitigar las emisiones de CO_2 a la atmósfera a partir de este ecosistema. El objetivo de esta investigación fue determinar el secuestro del carbono orgánico del suelo a tres profundidades bajo dos tipos de uso del suelo en el páramo de Sumapaz, Colombia. Las variaciones del suelo de pH, fósforo, aluminio, densidad aparente, la captura de carbono, la capacidad de intercambio catiónico, la textura y para estimar la distribución vertical del COS carbono orgánico del suelo, se evaluaron, respectivamente. Se seleccionaron dos sitios para establecer las estimaciones del suelo de acuerdo con el uso del suelo: la cubertura vegetal natural y el cultivo de la papa (*Solanum tuberosum* L.). Se tomaron muestras a diferentes profundidades: 0-25, 25-50 y > 50 cm del suelo. En consecuencia, ocho variables físico-químicas se analizaron en términos de la captura de COS estimado para cada profundidad del suelo y el uso del suelo. Los promedios del COS bajo la cubertura vegetal natural fueron: 188 $tC.ha^{-1}$ a 25 cm, 183 $tC.ha^{-1}$ a 50 cm, y 178 $tC.ha^{-1}$ a profundidades del suelo inferiores a 50 cm. Para los cultivos de papa (*Solanum tuberosum* L.), el secuestro del COS fue: 119 $tC.ha^{-1}$ a 25 cm, 83 $tC.ha^{-1}$ a 50 cm, y 71.8 $tC.ha^{-1}$ a profundidades del suelo inferiores a 50 cm. Estos resultados permiten apoyar las estrategias de manejo del suelo direccionados a preservar el COS y regular el nivel de agua dentro del ecosistema de páramo andino.

Palabras clave: Andisoles, carbono de raíces, distribución vertical, materia orgánica del suelo, páramo.

Introduction

Approximately 98% of the carbon sequestrated at the highest mountain ecosystems, accumulates in the soil (Ward, Dargusch, Grussu, & Romeo, 2015). Carbon sequestration, understood as the carbon transfer from the atmosphere to the soil, is possible throughout the plant system, carbon residues and other type of solid organic residues. These residues, are stored as part of the soil organic matter (Olson, 2010). However, distribution of soil organic carbon (SOC) is considered the most important component of the carbon cycle (Rumpel & Kogel-Knabner, 2011), and continues poorly understood. The soil depth performs the greatest potential to sequestrate CO_2 from the atmosphere throughout mechanisms that help to stabilize the organic materials in the soil and the recalcitrance of plant residues (Lorenz *et al.,* 2005). Additionally, several changes in the vertical distribution of SOC in the highest mountain ecosystems, may lead to establish some underestimations of carbon sequestration in tropical soils.

The cold paramo ecosystems occur in isolated fragmentary ecological niches, which is located in the Andes mountains (Buytaert, *et al.*, 2006). In this mountainous relief, the majority of valleys are of glacial origin. Theses ecosystems, contain a great variety of lagoons and swamps with natural grassland associated with shrub population. The lowest paramo altitudinal boundary is close to 3100 m.a.s.l. and is called: byparamo. The highest, is close to 4100 m.a.s.l. and is called: superparamo. The paramo ecosystem helps mitigate climate change due to the availability to sequestrate more carbon in the soil respect to other ecosystems (Zimmermann *et al.*, 2010). This type of ecosystem produces and sustains a large flow of water that feeds the rivers, which descend to the basins of the Magdalena and Amazon rivers (Buytaert *et al.,* 2006). Nevertheless, agriculture practices, cattle grazing and other human activities, affects SOC and can result in several negative impacts on the paramo. Despite this, there is a few variation studies of carbon sequestration in the paramo soil depth due to the agricultural activities (Henry *et al.,* 2013). The aim of this research was to estimate SOC distributions at three soil depths under natural vegetation and potato (*Solanum tuberosum* L.) crop, established in the paramo of Sumapaz, Colombia.

Materials and methods

Study area

The study was conducted at two locations in a rural area of the northern Andean mountains, to southern of Bogota, Cundinamarca-Colombia, among 3573 and 3590 m.a.s.l. at 4°19’23.50”N - 74°12’13.38”E and 4°19’35.26”N-74°12’22.05”E. Both locations, present a homogenous slope of less than 20%, and each site, exemplifies one of the two types of soil use under evaluation: six hectares of natural vegetation with a vast population of *Espeletia alternifolia* Cuatrec., commonly known as frailejon. Other species such as bryophytes and native grasses are included in the study area. Additionally, six hectares of soil devoted to potato (*Solanum tuberosum* L.) crop establishment and cattle grazing. On the second site, the potato (*Solanum tuberosum* L.) crop, is growing at intervals of three to five years. Each site, was divided into one hundred 30 meter by 20 m^2. Additionally, squares were chosen at random for georreferenciation. One-Piece Combination Edelman Auger, was used to take soil samples from 0-25 cm, 25-50 cm, and > 50cm depth. The soil parent material is found below 75 cm soil depth, this feature performs the maximum depth for soil sample. Accordingly to the methodology proposed by Berhongaray *et al.* (2013), one composite kg of all samples taken from each soil depth were obtained. A total of 30 samples, 15 from frailejon soil site and 15 from potato crop site, were collected, respectively. Samples from the same depth in the same evaluated site, were considered to be identical and were stored in a labelled polyethylene container. The purpose of the containers was to avoid spillage, dispersal and rupture of the aggregate samples while maintaining soil moisture levels. Soil samples were transported to the laboratory on the same day that they were taken on field conditions.

Laboratory analyses

The samples were analyzed in a quality certified soil laboratory in Bogota, Cundinamarca. Bulk densities were obtained with the paraffin method, soil particle size distribution was determined with the Bouyoucos hydrometer method(1951), interchangeable aluminum was measured by titration (Van Raij,1978), soluble phosphorus was measured with the Morgan (1941) method, cation exchange capacity (CEC) was determined with the atomic absorption method, and organic carbon, expressed as percentages, was measured with spectrophotometry.

Data analysis

Descriptive statistics for central dispersion were performed to analyze all parameters within the data set. It was analyzed for all the soil samples with measurements of descriptive statistics. The Kruskal–Wallis test was used to compare soil samples from the two different soil uses. Spearman correlation coefficient was used to estimate correlations among soil parameters. Soil organic carbon SOC, was calculated for all three depth intervals (0-25; 25-50 y > 50 cm) under natural vegetation and potato crop. All statistical analyses were carried out with IBM SPSS Statistics 21 ™.

All SOC measurements were estimated as products of carbon sequestration determined in the laboratory conditions (%C), soil bulk density ρb (t.m-^{3}), the sample layer depth *pm* (0,25 cm) and a conversion factor of 10.000 (m^{2} to hectares), expressed by COS= *%C**ρb* *pm**10.000. (Rosenzweig & Hillel, 2000).

Results and discussion

Soil use and parameters

Differences were established among the two soil use for the analyzed parameters in every soil depth range (Table 1). In the top layer (0-25 cm), there was a significantly phosphorus content (28.8 ppm) under potato crop soil and 8.17 ppm under influence of the natural vegetation. Bulk density (ρb) was 0.51g.cm^{-3} and 0.26 g.cm^{-3}, respectively in both locations. Carbon sequestrations were performed 50% lower under potato crop soil (11.06 %) than in soil under natural vegetation (26%). Under natural vegetation, silt content was 95.6 % while under potato crop soil, it was only 86.80 %. Clay content varied from 0% under natural vegetation to 6.40% under potato crop soil. Sand content increased from 4.33% to 6.8%. Volumetric humidity percentages under soil pressures among 0.0 and 15.0 atmospheres were on average: 20% less under potato crop soil than under natural vegetation. Phosphorus (P), bulk density (ρb*)*, carbon sequestration and volumetric humidity percentages, differed significantly among two soil uses evaluated. The other parameters, pH, Al, CEC, and soil texture did not varied significantly.

In the next range of soil depth among 25cm and 50 cm, P and ρb*,* performed a similar pattern in the soil superficial layer. Carbon sequestration in potato crop soil was 4.87% and 24.97%, respectively. Clay and sand percentages, were higher under potato crop soil than under natural vegetation, but silt content was higher under natural vegetation (96.67%) than under potato crop soil (74.40%). At this depth range, volumetric humidity percentages from 0.0 to 15.0 atmospheres were 19% and 36% lower than under potato crop soil than under natural vegetation. Except for pH, Al, and CEC, all parameters varied significantly among two soil uses (Table 2).

In the deepest soil sample (>50 cm), the following variations in edaphic parameters were found: under potato crop soil, ρb was 0.76 g.cm^{-3} compared with only 0.28 g.cm^{-3} under natural vegetation soil. Carbon sequestration under potato crop soil

Table 1. Mean and standard deviation of edaphic parameter in soils under influence of natural vegetation and potato crop, in Sumapaz paramo, Colombia

Soil parameters	**Natural vegetation**	**Potato crop**	**Natural vegetation**	**Potato crop**	**Natural vegetation**	**Potato crop**	**Natural vegetation**	**Potato crop**
	0-25 cm		**25-50 cm**		**> 50 cm**		**Mean**	
pH	4,22±0,22	4,63±0,40	4,38±0,17	4,68±0,44	4,61±0,16	4,74±0,47	**4,41**±0,24	**4,68**±0,41
P (ppm)	**8,17**±3,6	**28,8**±15,9	**5,17**±1,83	**16,8**±8,78	3,16±0,98	4,80±2,49	**5,50**±3,09	**16,8**±11,2
Al (meq/100g)	3,63±0,79	2,80±0,67	2,88±0,69	2,80±0,43	2,13±0,73	2,80±0,60	2,88±0,93	2,80±0,53
ρb (g/cm^{3})	**0,26**±0,05	**0,51**±0,14	**0,28**±0,05	**0,66**±0,14	**0,28**±0,07	**0,76**±0,16	**0,28**±0,05	**0,64**±0,17
Carbon (%)	**27,09**±2,88	**11,06**±9,06	**24,97**±3,64	**4,87**±1,57	**26,00**±7,28	**3,91**±1,43	**26,02**±4,76	**6,61**±5,95
CEC (meq/100g)	6,17±0,75	6,20±0,84	5,00±0,63	5,80±0,84	4,83±0,75	5,60±0,89	5,33±0,91	5,87±0,83
Sand (%)	4,33±3,20	6,80±4,60	**3,00**±3,58	**9,60**±1,67	**1,83**±4,02	**8,00**±3,74	**3,06**±2,55	**8,13**±3,50
Silt (%)	95,67±3,20	86,80±9,86	**96,67**±3,33	**74,40**±5,55	**97,5**±3,99	**64,2**±8,93	**96,61**±3,39	**75,13**±12,28
Clay (%)	n.d.	6,40±9,21	**0,33**±0,82	**16,00**±6,78	**0,66**±1,63	**27,80**±12,11	**0,35**±1,03	**16,73**±11,70
VHC% (0,0 atm)	**74,82**±7,14	**63,50**±7,23	**70,94**±3,66	**56,99**±6,48	**67,26**±4,10	**51,42**±6,77	**71,01**±5,82	**57,30**±8,13
VHC% (0,3 atm)	**68,76**±6,85	**53,16**±9,20	**64,85**±3,88	**47,48**±7,47	**61,06**±4,50	**41,56**±6,41	**64,89**±5,88	**47,40**±8,71
VHC% (1,0 atm)	**63,21**±6,45	**46,91**±9,50	**59,59**±3,84	**41,90**±7,65	**55,84**±4,57	**36,20**±6,11	**59,55**±5,68	**41,67**±8,58
VHC% (5,0 atm)	**58,03**±6,05	**41,05**±9,82	**54,67**±3,54	**35,96**±7,96	**50,91**±4,64	**30,90**±5,83	**54,54**±5,45	**35,97**±8,59
VHC% (15 atm)	**53,38**±5,65	**36,15**±9,80	**49,80**±3,73	**31,96**±7,78	**46,50**±1,91	**27,12**±5,63	**49,89**±5,31	**31,74**±8,27

Table 2. Spearman correlation coefficient for soil parameters from the Sumapaz paramo, Colombia

Parameter		pH	P (ppm)	Al (meq/ 100g)	ρb (g/cm³)	Carbon (%)	CEC (meq/ 100g)	Sand (%)	Silt (%)	Clay((%)	VHC vol % 0,3 atm
P (ppm)	*sc*	0,14									
	p	0,45									
Al (meq/100g)	*sc*	**-0,44****	0,08								
	p	0,01	0,66								
ρb (g/cm3)	*sc*	**0,42***	0,09	-0,10							
	p	0,02	0,63	0,59							
Carbon (%)	*sc*	**-0,36***	-0,14	0,14	**-0,87****						
	p	0,04	0,43	0,43	0,00						
CEC (meq/100g)	*sc*	-0,15	**0,37***	**0,72****	0,10	-0,01					
	p	0,40	0,03	0,00	0,50	0,96					
Sand (%)	*sc*	0,12	**0,41***	0,24	0,30	**-0,44***	**0,44***				
	p	0,50	0,02	0,17	0,10	0,01	0,01				
Silt (%)	*sc*	-0,18	-0,15	-0,02	**-0,65****	**0,73****	-0,18	**-0,77****			
	p	0,33	0,42	0,93	0,00	0,00	0,31	0,00			
Clay (%)	*sc*	0,20	0,04	-0,12	**0,82****	**-0,84****	0,00	**0,48****	**-0,86****		
	p	0,26	0,84	0,51	0,00	0,00	0,99	0,01	0,00		
VHC % (0,3 atm)	*sc*	-0,34	0,03	0,11	**-0,85****	**0,88****	-0,03	**-0,37***	**0,71****	**-0,83****	
	p	0,06	0,86	0,53	0,00	0,00	0,89	0,03	0,00	0,00	
VHC % (15 atm)	*sc*	**-0,35***	0,00	0,12	**-,870****	**0,91****	-0,02	**-,371***	**0,681****	**-0,828****	**0,99****
	p	0,05	0,99	0,51	0,00	0,00	0,91	0,03	0,00	0,00	0,00

Abbreviations: mean ± STD, phosphorus (P), aluminum (Al), bulk density (ρb), cation interchange capacity (CEC), volumetric humidity percentage measured in atmospheres (VHC), numbers in bold are statistically significant at $p<0.05$* and $p<0,01$** ; Spearman's correlation coefficient (SC), level of significance (p).

(3.91%) was six times less than under natural vegetation soil (26%). Silt content was much higher under natural vegetation soil (97.5%) than under potato crop soil (64.20%). On the other hand, sand and clay content, were higher under potato crop soil than under natural vegetation soil. Volumetric humidity percentages, under pressures among 0.3 and 15.0 atmospheres were: 23% to 40% lower under potato crop soil than under natural vegetation soil (Figure 1). All of these parameters above mentioned, except pH, P, Al and CEC varied significantly among two soil uses.

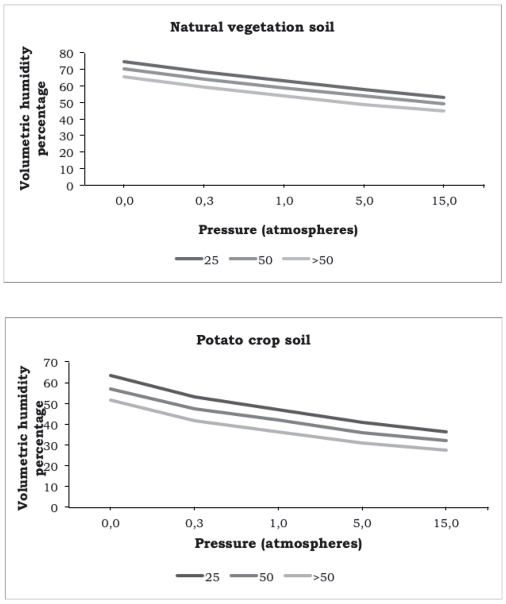

Figure 1. Comparison of humidity curves of soils under natural vegetation and soils under potato crop influence at 0-25 cm, 25-50 cm and > 50 cm soil depths in the Sumapaz paramo, Colombia.

The results of this research indicates that change in soil use from natural vegetation to potato crop establishment produces some variations in all soil parameters evaluated, except for Al and CEC. Soil under potato crop in this Andean ecosystem, loses silt, pH and consequently, phosphorus content increase and SOC decreases. These results are almost certainly, due to soil use in this Andean ecosystem. Higher phosphorus content and pH under potato crop soil, are consistent to the use of additives and fertilizers, which can increase retention of interchangeable cations (Hernández-Flores, Triana, & Daza-Torrez, 2011). Bulk density increases under potato crop soil and could be related to soil compression caused by grazing cattle and agricultural practices, such as soil tillage. Soil compaction diminishes the volume occupied by soil pores and soil aggregates, both saturated with water and unsaturated, within organic material (Daza- Torres, Flores & Triana, 2014). The same soil pattern had been found in the Chingaza paramo and Nevados National Natural Park, Colombia (Zúñiga-Escobar, Uribe, Torres-González, Cuero-Guependo, & Peña-Óspina, 2013). Soil texture also changes as the silt percentage decreases when soil use changes from natural vegetation soil cover to potato crop soil and cattle grazing. It is possible argue that elimination of natural vegetation followed by potato crop could pronounce silt losses within soil (Harrison-Kirk, Beare, Meenken, & Condron, 2014). Natural vegetation protects soil from direct sunlight and rainfall, consequently, soil availability to retain water, decreases when the natural vegetation is removed as shown by the lower volumetric humidity percentages found under potato crop in paramo ecosystem. In some stages, this is attributable in part to diminished SOC but may also be due, in part, to diminution of soil pore sizes at greater soil depths (Tonneijck et al., 2010).

Correlation among soil organic carbon and other edaphic parameters

Significant correlations were found among soil organic carbon with volumetric humidity percentages for 0.3 and 15 atmospheres (*sc*= 0.88, p= 0.00 and *sc* = 0.99; p=0.00, respectively) and silt (*sc* = 0.73, p=0.00). This could indicates that the increased amounts of SOC, increase the soil water retention capacity. This is probably due to the soil porosity of the soil organic matter in Sumapaz paramo, which allows high levels of water retained by the dominant capillary colloidal fraction. In contrast, SOC correlates negatively with clay content (*sc* = -0.84, p=0.00) (Wei, et al., 2014) and with sand percentage (*sc* = -0.44, p=0.01) (Harrison-Kirk, 2014). It is possible, that greatest clay and sand fractions could stimulate decomposition of soil organic matter by increasing the availability of substrata for microorganisms (Wei *et al.,* 2014). Similarly, the bivariate and opposite relationship among carbon sequestration and pH (*sc* = -0.36, p=0.04) (Mora, Guerra, Armas-Herrera, Arbelo, & Rodríguez-Rodríguez, 2014) can be explained by soil organic carbon accumulation as a result of microbial inhibition. However, this could be the result of low pH in the presence of Al-humus complexes (Tonneijck *et al.,* 2010). On the other hand, the negative relationship among SOC and ρb concentration (*sc* = -0.87, p=0.00) (Segnini *et al*., 2011) is probably due to organo-metallic complexes such as Al-humus that allows aggregation into the soil organic matter. This soil complex produces high levels of soil porosity and, consequently, low soil bulk density.

Vertical distribution of SOC

Vertical distribution of SOC could perform some variation for the soil uses and these features, are considered in Table 3. The mean SOC for every soil depth was twice as high under natural vegetation ($183 t.ha^{-1}$) than under influence of the potato crop soil ($91.2 t.ha^{-1}$). Comparisons of SOC among soil depth estimations within each soil use, revealed no significantly differences. Under the influence of both types of soil use, the SOC fractions, decreased slightly as the soil depth increased (Figure 2). Total sequestered SOC under natural vegetation influence was $550 t.ha^{-1}$ (0-25 cm: $188.2 t.ha^{-1}$; 25-50 cm: $183.4 t.ha^{-1}$; >50 cm: $178.4 t. ha^{-1}$). Total sequestered SOC under potato crop soil was $274 t.ha^{-1}$ (0-25 cm: $119.3 t.ha^{-1}$; 25-50 cm: $82.5 t.ha^{-1}$; >50 cm: $71.8 t.ha^{-1}$).

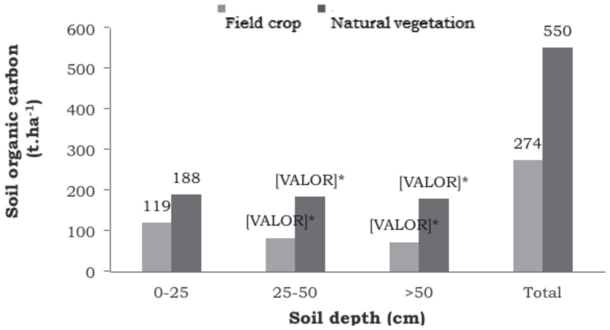

Figure 2. Soil organic carbon (SOC) distribution under natural vegetation (black) and under potato crop influence (grey) in the Sumapaz paramo, Colombia. * Significantly differences at $p<0.05$.

At all the soil depths evaluated, SOC content was higher under natural vegetation influence than under potato crop soil. Under natural vegetation, sequestered SOC proportions were almost the same at any soil depth. However, under the influence of potato crop soil, the highest proportion was found close to the surface soil layer (43%) and the proportion, decreased to 26% in the lowest soil layer sampled. The fact that no significantly differences were found among sequestered SOC levels in the surface soil layers of the two soil uses, could be related to similar climate conditions, which generate similar decomposition processes and carbon accumulation (Tonneijck *et al.,* 2010). The lowest levels of SOC sequestration under influence of the potato crop soil, could be due to several factors. The potato crop establishment and cattle grazing, may generate high soil organic carbon losses due of changes in soil use and soil management practices. When soil surface soil in the paramo ecosystem is under the tillage influence, it ruptures the soil aggregates, especially those larger than 250 mm. This increases the decomposition rate and the transformation of organic soil matter due to

Table 3. Mean and standard deviation and soil organic carbon comparison of mean in Sumapaz paramo, Colombia.

Natural vegetation	Potato crop	Natural vegetation	Potato crop	Natural vegetation	Potato crop	Natural vegetation	Potato crop
0-25 cm		25-50 cm		> 50 cm		Mean value	
188,2±41,2	119,3±62,3	**183,4**±36,9	**82,5**±38,5	**178,4±29,7**	**71,8**±22,8	**183,3**±33,8	**91,2**±46,1

oxidation process and reduces physical barriers that protect soil organic matter from microbial and enzymatic action (Zotarelli, Alves, Urquiaga, Boddey, & Six, 2007).

The fractions of sequestered SOC found under influence of natural vegetation and potato crop soil in this research in the paramo of Sumapaz, Colombia are in concordance with those found in other studies of paramos elsewhere in South America. In the paramo of Chingaza –Colombia, the surface SOC in undisturbed soil was 300 t.ha^{-1} and 158 t.ha^{-1} in an increased soil depth. In contrast, in a disturbed soil, the sequestered SOC in the surface soil layer was only 122 t.ha^{-1} (Zuñiga-Escobar *et al.,* 2013). Sequestered SOC in the surface layer of the paramo under influence of natural grasses in Manu National Park in Peru, in a 20 cm soil depth, was 123 t.ha^{-1} (Zimmermann *et al.,* 2010), but was only 119 t.ha^{-1} in sites that had suffered soil burned (Gibbon *et al.*, 2010). In the northern Andes in Ecuador, soils subject to burning and cattle grazing, performs SOC contents of 76.7 t.ha^{-1} at 0 to10 cm of soil depth, but this decreases as depth increases from 10-20 cm to 67.6 t.ha^{-1} (Farley, Bremer, Harden, & Hartsig, 2013).

Conclusions

The results of this research suggest that sequestered SOC in the paramo of Sumapaz, Colombia is performed within the range recorded for other paramo ecosystem elsewhere in South America. Sequestered SOC among 0 and more than 50 cm soil depth is 550 t.ha^{-1} under influence of natural vegetation and 274 t.ha^{-1} under potato crop soil. SOC does not performs a significantly variation among soil depths within either of the two soil uses evaluated, but it is strongly increased in the surface soil layer. This is possibly due to root density. These results indicates that the soil use influence, could generates significantly effects on almost all soil physical and chemical properties and soil parameters, except for Al and CEC. Sequestered SOC and volumetric humidity percentages, are decreased in a cultivated soil in the Sumapaz paramo, Colombia.

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