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Interactive comment on "Soil andic properties as powerful factors explaining deep soil organic carbon stocks distribution: the case of a coffee agroforestry plantation on Andosols in Costa Rica" *by* Tiphaine Chevallier et al.

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This study nicely relates the pedogenic development of volcanic soils totheir capacity to store OC not only in the topsoil or top 1 meter, but down to 2 m depth, and shows that the mineralogy (i.e. halloysitic vs. short range order) plays a key role in OC stabilization and storage down to 2 m depth. This in itself warrants publication.

Answer: Thank a lot for your encouragements. We highlighted the interest of our study in the introduction, see comment 1 in answers to the reviewer 1.

Comment 1 The English is generally comprehensible, but would strongly benefit from revision (with the help of a native speaking soil scientist)

Answer: A English native speaker read our paper and improved English grammar and syntax. See all the Ms and figure caption (on demand)

Comment 2 The abstract currently does not include any results or conclusions. The study has produced many interesting results, and the authors definitely should include the main results and conclusions in the abstract

Answer: The abstract was re-written see the comment 1 to reviewer 1.

Comment 3 The term "andic properties" is not used correctly throughout the manuscript (incl. title, abstract, and esp. in lines 165-175).Andic properties are clearly defined in US soil taxonomy and WRB, and these definitions should be used when claiming that a certain horizon has andic properties or not. The authors have analysed several properties that are specifically important for Andosols (e.g. Alp or Sio or (Alo-Alp)/Sio) but are not "andic properties" per se nor are they requirements for the classification of "andic properties". The authors are advised to be very rigorous in their use of clearly defined terms such as "andic properties", as a misuse of such terms may spread and perpetuate in literature.

Answer: The term of "andic properties" was changed as it was misused for all the analysis of Alp, (Alo-Alp)/Sio etc. . . We replaced this term by andic soil materials, some characteristics of andic soils, extractable Al, Si, Fe contents or short-range-order constituents content according the context. Note that the title was thus modified to "Short-range-order constituents as powerful factors explaining deep soil organic carbon stocks distribution: the case of a coffee agroforestry plantation on Andosols in Costa Rica"

Comment 4 The accuracy of the developed prediction models was determined by LOO-cross validation using the whole dataset, if I understood it correctly. While LOO-cross validation is a valid approach for a data set of independent samples, there may be issues when depth samples of the same profiles (in this study up to 10 depth samples per profile) are included in the dataset. The validation would be much more convincing if it was truly out-of-sample, i.e. using different profiles for calibration and validation, respectively. One way around this could be to perform "LOO-cross validation" leaving out not only one horizon but one entire profile at a time. Alternatively, 75% of the studied profiles could be used for calibration and 25% for validation. Still, the samples of this study originate from a very small (0.9km2) watershed; the authors need to be aware that even if their models yield accurate predictions for this study area, this may be an indication that similar approaches might work elsewhere, but the parameterized models cannot necessarily be applied directly to other volcanic soils.

Answer: See comment 3 to reviewer 1. We did not assume that our parameterized model could be applied directly to other volcanic soils. MIRS is used to predict SOC contents, bulk density and SOC stocks for a set of volcanic soils. The new result in our study is not a parameterized model. The new result is to show that the MIRS approach could be an appropriate tool to classify andic from non-andic soil material directly from the soil spectra.

We added a sentence in the text (§3.1.1): MIR spectroscopy seems to be a promising tool for predicting contents of extractable Al, Si, and Fe in volcanic soils, providing that the specific prediction models are based upon conventional analyses of a large set of representative samples.

Additional comments L 198 : correct was replaced by accurate L 199 we deleted the reference to table 1 L 204-205 we deleted Fe to the sentence

L. 225 To my understanding, Alp/Alo ratios of 1 and higher indicate that (almost) all of the amorphous Al is in the form of organic complexes; but still the authors find 16% allophane in these soils. How can this discrepancy be explained?

Answer: We agreed that when allophane content is high, Alp:Alo ratio was small. But our results still show some allophane content ranged from 2 % to up to 10 % for Alp:Alo

about 2. (see supplementary)

Changes in the Ms §3.1.2, L. 277: Surprisingly, and especially in the surface soil, ratios of Alp to Alo are greater than 1, and Allophane contents are high (from 5 to 20 g allophane per 100 g soil). Those results indicate a co-existence of allophane and Al-organo complexes in this ALL material; which may be due to some combination of the soil pH (approximately 5; i.e. near the boundary between allophane and Al/Fe-organo complexes) and the regular inputs of organic materials and ashes from the surface (Mizota and Van Reewijk, 1989).

L. 234 Did the authors observe nano-spherule structures? If yes, how?

Answer: We did not observe nano-spherule structures. We made it clearer in the sentence.

Changes in the Ms §3.1.2, L. 274.The literature (Levard et al., 2012) notes that SRO constituents like Al-rich allophanes, proto-imogolite, and imogolite predominate in volcanic-ash soils with Alo+0.5Feo » 2% and high (»2) Al:Si ratios, such as in the andic-material rich soils in the ALL cluster (Tab. 3). Filimonova et al. (2016) found that the SRO constituents in soils of this type form nano-spherule structures.

L. 367. Absorption was replaced by adsorption. L371-378: Rephrase for more clarity. Which are results of this study, which are general statements based on references?

Answer: We rephrase for more clarity which results came from our study: in last sentence of §3.2.2. Our results showed that deep-soil carbon contents as well as surface-soil carbon contents were essentially driven by the type of soil material and contents of SRO constituents. The combination of soil development and mineralogy was a powerful factor for explaining SOC content, regardless of the soil depth.

L405-410: If OC stocks are compared to other studies, the depth to which OC stocks were analysed in those other studies needs to be listed, and the comparisons need to address potential differences in depth.

Answer: We added the depth of the soil studies cited in the text. Changes in §3.3.2, L. 466. The SOC stocks in this watershed's ALL soil profiles were much larger than the global average reported by Batjes (2014) for Andosols (35.3 kgC m-2, in the upper 2 m of soil, with a high coefficient of variation of 61%). However, larger SOC stocks were also measured in deep, homogeneous volcanic-ash soils of Andean ecosystems in Ecuador under upper montane forest and high altitude paramo (87 $\pm$ 12 kgC m-2 within the 0-200 cm depth, Tonneijck et al., 2010), as well as in young Hydric Andosols derived from recent volcanic ash (Poulenard et al., 2003).

L439: "thickness of the young andic A horizon" or "thickness of andic properties"?

Answer: we specified in §3.3.2, L. 486. The thickness of the andic-soil material layer was a better predictor of SOC stock in 0-200 cm than the SOC stocks in the topsoil (Figure 8b).

Fig. 2, 3 and 4 were combined; See Figure 1

Fig. 6 has now a legend. We kept the figure as it shows the variability of the thickness of the andic-soil material layer. It is now the Figure 4

Fig. 8d It seems that there are 2 populations with very different slopes, (roughly) corresponding to the 2 mineralogical groups (halloysitic vs. short range or-der). Could the different slopes be related to different Fe forms (with different capacityto stabilize OM) in these two types of materials?

Answer: We agreed that it seems that there are 2 populations with very different slopes in Fig 8d but could not conclude on the different from of Feo. We added a sentence to notice that result in Section 3.2.2, L. 388: In addition, the relation between SOC content and Feo content appeared to have a threshold near 1.3 g Feo 100g-1 soil. Beyond that threshold, all soil samples were in the ALL cluster. More specifically, the SOC contents were generally high (> 30 gC kg-1 soil) and very sensitive to small variations in Feo content (SOC content = 82 Feo – 66, r2= 0.73). In contrast, SOC contents of soils

below that threshold were lower and less sensitive to Feo content (SOC content = 24 Feo – 5, r2= 0.85).

Fig. 10a we have changed the abbreviations as requested. It is now the Figure 8

Tables 5, 7 et 8 : Please explicitly state in the caption if these tables show statistics of the predicted or measured values(I assume the latter). In Tables 7 and 8, please add the number of replicates (n).

Answer: We explicitly wrote that the tables showed predicted values. The correlations between the measured values were also shown in supplementary materials. The numbers of samples were added in the table.

Modifications: Table 5. Descriptive statistics (predictive data) for SOC contents of all soil samples with depth, and with their spectral cluster (ALL and H); p-value expresses results from t-test between samples from the two spectra cluster classes (Welsh, two sided alternative). For a given cluster, means followed by the same letters do not differ significantly at p=0.05.

Table 7. Descriptive statistics (predictive data) for bulk densities with depth and with their spectral cluster. P-value express results from t-test between samples from the two cluster classes (Welsh, two sided alternative). For a given cluster, means followed by the same letters do not differ significantly at p=0.05.

Table 8. Descriptive statistics (predictive data) for SOC stocks with depth and with their spectral cluster. P-value express results from t-test between samples from the two cluster classes (Welsh, two sided alternative). For a given cluster, means followed by the same letters do not differ significantly at p=0.05.

End of section 2.6.2. Measured data and correlations among laboratory-measured variables (SOC content and the characteristics of andic soils presented above) can be found in the supplementary materials for this article (S1, S2, S3).

Tables and figures were numbered in the order of their appearance.

Please also note the supplement to this comment:
https://www.soil-discuss.net/soil-2019-14/soil-2019-14-AC2-supplement.pdf

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Interactive comment on SOIL Discuss., https://doi.org/10.5194/soil-2019-14, 2019.

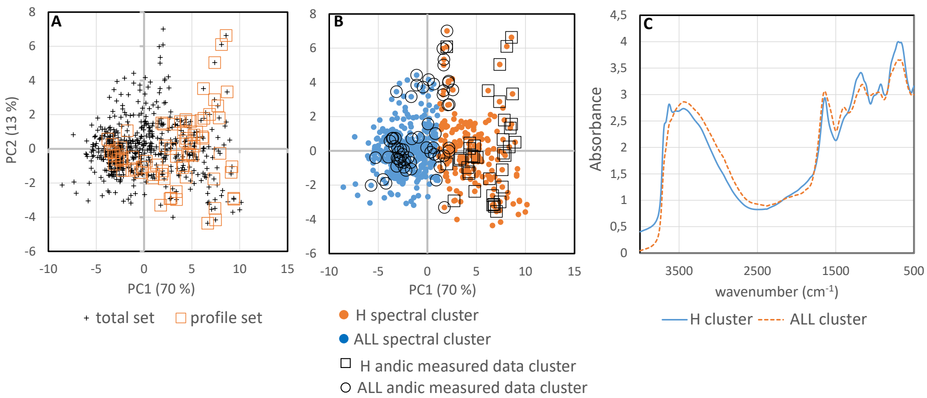

Fig. 1. Figure 1. Map of the study site: a 1-km2 micro-watershed. "X" symbols mark the 69 sampling locations. The seven squares show where pits were dug down to a depth of 2 m for bulk-density measurements. T

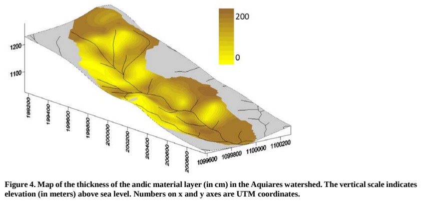

Fig. 2. Figure 4. Map of the thickness of the andic material layer (in cm) in the Aquiares watershed. The vertical scale indicates elevation (in meters) above sea level. Numbers on x and y axes are UTM coordi

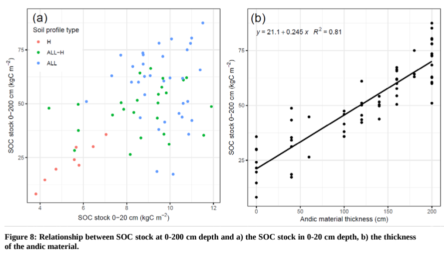

Fig. 3. Figure 8: Relationship between SOC stock at 0-200 cm depth and a) the SOC stock in 0-20 cm depth, b) the thickness of the andic material.

Table 5 Descriptive statistics for SOC contents of all soil samples with depth, and with their spectral cluster (*ALL* and *H*); p-value expresses results from t-test between samples from the two spectra cluster classes (Welsh, two sided alternative). For a given cluster, means followed by the same letters do not differ significantly at p=0.05.

SOC **g kg^{-1}soil**	All soil samples			*ALL* cluster (398 samples)			*H* cluster (199 samples)			p-value
	Mean	std	n	Mean	Std	n	Mean	std	n	
0-20	68.0	22.5	68	75.1 f	16.8	57	31.2 d	5.2	11	<0.0001
20-40	58.5	21.6	69	67.3 ef	14.9	54	26.8 cd	7.8	15	<0.0001
40-60	49.8	21.3	66	59.9 de	14.1	49	20.9 bc	6.5	17	<0.0001
60-80	45.4	21	67	54.9 cd	14.7	50	17.5 ab	7.3	17	<0.0001
80-100	41.2	20.9	67	51.8 bd	14.8	47	16.2 ab	6.6	20	<0.0001
100-120	35.8	20.2	62	46.0 abc	15.7	42	14.3 ab	7.6	20	<0.0001
120-140	34	21.1	55	46.8 abc	15.9	34	13.3 a	7.5	21	<0.0001
140-160	28.6	19.6	53	45.6 abc	14.2	25	13.5 a	7.5	28	<0.0001
160-180	24.4	17.9	48	39.5 a	14.9	22	11.6 a	6.7	26	<0.0001
180-200	24.1	17.4	42	41.1 ab	12.5	18	11.3 a	5.1	24	<0.0001

Table 7 Descriptive statistics for bulk densities with depth and with their spectral cluster. P-value express results from t-test between samples from the two cluster classes (Welsh, two sided alternative). For a given cluster, means followed by the same letters do not differ significantly at p=0.05.

Bd **g cm^{-3}**	All soil samples		*ALL* Cluster (398 soil samples)		*H* Cluster (199 soil samples)		p-value
	Mean	Sd	Mean	Sd	Mean	Sd	
0-20	0.68 f	0.14	0.65 a	0.11	0.87 c	0.11	<0.0001
20-40	0.70 ef	0.15	0.65 de	0.12	0.87 bc	0.12	<0.0001
40-60	0.72 ef	0.16	0.66 de	0.12	0.88 bc	0.15	<0.0001
60-80	0.74 de	0.15	0.69 cd	0.12	0.89 bc	0.13	<0.0001
80-100	0.77 cd	0.17	0.71 bc	0.13	0.93 abc	0.14	<0.0001
100-120	0.80 abc	0.16	0.73 ab	0.11	0.94 abc	0.15	<0.0001
120-140	0.81 abc	0.16	0.73 ab	0.12	0.93 ab	0.13	<0.0001
140-160	0.82 bc	0.16	0.72 ab	0.10	0.91 abc	0.14	<0.0001
160-180	0.87 ab	0.15	0.76 a	0.11	0.96 a	0.12	<0.0001
180-200	0.88 a	0.15	0.75 ab	0.11	0.98 a	0.09	<0.0001

Table 8. Descriptive statistics (predictive data) for SOC stocks with depth and with their spectral cluster. P-value express results from t-test between samples from the two cluster classes (Welsh, two sided alternative). For a given cluster, means followed by the same letters do not differ significantly at p=0.05.

SOC **kgC m^{-2}**	All soil samples		*ALL* Cluster (398 soil samples)		*H* Cluster (199 soil samples)		p-value
	Mean	Sd	Mean	Sd	Mean	Sd	
0-20	8.8 a	2.0	9.4 a	1.3	5.4 a	1.0	<0.0001
20-40	7.6 b	2.0	8.5 b	1.1	4.6 b	1.4	<0.0001
40-60	6.6 c	2.1	7.6 c	1.0	3.7 c	1.3	<0.0001
60-80	6.2 cd	2.1	7.2 c	1.1	3.2 cd	1.5	<0.0001
80-100	5.8 de	2.2	7.0 cd	1.1	3.0 d	1.3	<0.0001
100-120	5.3 ef	2.4	6.5 de	1.7	2.7 de	1.4	<0.0001
120-140	5.0 efg	2.4	6.5 de	1.4	2.5 ef	1.4	<0.0001
140-160	4.2 fg	2.3	6.3 e	1.2	2.3 ef	1.3	<0.0001
160-180	3.8 g	2.3	5.8 e	1.7	2.2 f	1.2	<0.0001
180-200	3.8 g	2.2	6.0 e	1.3	2.1 f	0.9	<0.0001

Fig. 4. Tables 5, 7, 8