Date: 27 June 2022

Dear Editor

Subject: Response to interactive comment on our manuscript entitled: Ali et al.: Reference Soil Groups Map of Ethiopia Based on Legacy Data and Machine Learning Technique: EthioSoilGrids 1.0

By Ashenafi Ali et al.

Dear Editor,

Below, the contents of community comment 1 (CC1) by Seleshi W Gudeta are provided in black text and our responses are marked in blue text.

Dear Seleshi W Gudeta,

Thank you for taking the time to review our manuscript. We will address the comments and revise the paper accordingly.

Dear Editor,

Comment 1. This is a very useful work and I congratulate the authors for taking the initiative.

Response 1: We are grateful for the positive comments indicating that the work is very useful.

Comment 2. I have the following concerns, which I believe the authors will address for this work to be useful.

(1) My main concern relates to the discrepancy between the map they produced in Figure 7 and the Soil Atlas of Africa (see Jones et al., 2013), which is currently the authoritative reference material. For their map to be useful, it is important to reconcile with the map and wherever discrepancies exist it will be helpful to explain.

Response 2: We thank Seleshi W Gudeata for the comments. The following are our responses:

We acknowledge that the Soil Atlas of Africa is still useful to provide harmonisation and improvement, however, it is too general for diverse soil information users at local levels. It is derived from the Harmonized World Soil Database (HWSD) with expert-based modifications. The HWSD for East Africa, including Ethiopia, combines existing data/maps from the Soil and Terrain (SOTER) and SOTER-based soil parameter estimates (SOTWIS), while the soil map in SOTER has the following limitations:

- it is based on qualitative (polygon) maps, which were based on the previous maps.
- the SOTER soil nomenclature doesn't meet the present demand since it is based on FAO 1974 and FAO soil map of the world revised legend 1988 (reprint FAO-1990).
- since it is on a smaller scale, it depicts the dominant soil types from a larger area coverage and masked important soil units which would have been reported if a larger scale had been used. For example, in the HWSD, in the delineation of a given soil type, only the major one is reported, while up to 9 soil types coexist in each delineation.

- the geographic location of the dominant and associated soil types is not defined as it is based on a qualitative approach

Conclusion: The existing spatial soil information of Ethiopia is based either on a conventional/traditional qualitative approach using the mental model for extrapolation or quantitative/ digital soil mapping with limited unevenly distributed profile observations. Currently, we do not have a consistent spatial soil types information for Ethiopia, which necessitated the development of EthioSoilGrids 1.0.

On the other hand, the development of the EthioSoilGrids 1.0 is based on the following state-of-the-art techniques and procedures:

- it is based on rigorous quantitative spatial predictive model (Machine learning) that combine information from soil observations with environmental variables/covariates and remote sensing products.
- the mapping of soil types is based on the quantitatively defined probability of occurrence of each reference soil group (RSGs) per modelling window (250 meters).
- it is based on a much larger number of soil profile observations than any other soil mapping initiatives layering Ethiopia.
- the process of its development involved soil profile-based harmonization and translation to IUSS WRB 2015.
- it followed a hybrid approach, i.e., a combination of digital soil mapping, and expert validation of the soil types and their spatial patterns for generating consistent and updatable national spatial SoilGrid.

Therefore, given the above differences, in the approaches followed, scale, data source, etc, one should expect the difference between the Soil Atlas of Africa and the EthioSoilGrids 1.0. In other words, the latter is developed not to match the former, but to come up with improved and quality soil information, an objective fully achieved. Consequently, we are not surprised that the two products do not coincide since that was the assumption when the work was initiated. By the way, this is not the first report on Ethiopian soils' information showing such discrepancies as compared to the global products; for example -the spatial soil grids layering Ethiopia based on digital soil mapping techniques (e.g., SoilGrids, 2017) a similar approach followed in the preparation of EthioSoilGrid 1.0, reflected differences in RSGs area coverage.

Comment: Below is some of the discrepancies:

Comment 2.1: Cambisols are represented by a small proportion of the area in isolated pockets of Ethiopia according to the Soil Atlas of Africa. On the other hand, in this manuscript, Cambisols are the top-ranked in Figure 8. The explanation given for this in the manuscript is unsatisfactory.

Response 2.1

Cambisols' most abundance is acceptable, because Cambisols are developed in areas where pedogenetic development is slow (i) because of continuous erosion, but is in equilibrium with the weathering process, or continuous erosion and depositional cycles are common. As the result, they covered significant parts of the highlands of Ethiopia at the foot-slopes of undulating mountainous or hilly terrains, where erosion and weathering processes are in equilibrium, or erosion and deposition cycles are common. (ii) because of low precipitation, or weathering-resistant parent materials. In this case, Cambisols occur in the large area of the lowlands of Ethiopia on weathering-resistant calcareous limestone, and on colluvial and alluvial deposits, where precipitation is low.

It is worth noting that the total number of profile observations per reference soil group (RSGs) in which Cambisols ranked third (with n=2219) following Luvisols (n= 2,229) and Vertisols (3,935). In fact, in some of the existing conventionally made country-wide legacy soil maps of Ethiopia, Cambisols were reported to cover e.g., 21% and 16% of the land mass of Ethiopia.

Comment 2.2: Areas bordering Djibouti and Eritrea that are predominantly covered by Leptosols (according to the Soil Atlas of Africa) are now covered by Fluvisols according to this manuscript. Many of these mountainous areas are not expected to have Fluvisols because Fluvisols naturally form in fluvial, lacustrine or marine deposits and periodically flooded areas.

Response 2.2. Yes, as noted by Seleshi W Gudeta, Pedogenetically Fluvisols are developed on flood plains, riverbanks, and lacustrine deposits. Since the areas bordering Djibouti and north-eastern lowlands (Afar and Somali lowlands) are under the influence of floods; where deposits from Awash, Wabishebele and Genale rivers are frequent, the predominance of Fluvisols is expected. Note that Leptosols are well represented on the volcanic mountains of Fantale, Boseti Guda and Ziqualla in the Awash valley, volcanic hills of the Afar lowlands, and the eastern escarpment of the central and northeastern rift valley, which are situated in these areas.

Comment 2.3: Areas in eastern and south-eastern Ethiopia bordering Somalia that are predominantly covered by Calcisols and Gypsisols (according to the Soil Atlas of Africa) have a continuous cover of Cambisols and some Fluvisols according to this manuscript. That cannot be possible.

Response 2.3: On comments about the formation and distribution of Cambisols and Fluvisols, we addressed the above in responses 2.1 and 2.2.

EthioGridSoil 1.0- is based on measured point observations collated from these areas after excluding RSGs with less than thirty observations including Gypsisols which had only 11 profiles. In this case, Gypsisols are excluded from mapping. Regarding Calcisols, as indicated by Seleshi W Gudeta, the probability of occurrence map (Figure C1 of Appendix C) depicts Calcisols dominantly occurring in eastern and south-eastern Ethiopia, bordering Somalia. However, when the relative abundance of RSGs per modelling window is assessed, Calcisols' area coverage as the dominant soil type as depicted in Figure 7, is the 7th most abundant soil in Ethiopia.

By the same token, in the polygon-based soil mapping like Soil Atlas of Africa, where a polygon is mapped as one soil unit does not mean that the polygon 100% represents that specific soil unit, but it also contains associations which are not depicted as dominant. Further, both the dominant and association geographic locations are not defined and hence do not directly indicate the specific location of each soil type.

Comment 2.4: Areas in north-western Ethiopia bordering Sudan that are predominantly covered by Nitisols, Luvisols and Alisols (according to the Soil Atlas of Africa) have almost a continuous cover of Vertisols according to this manuscript. That also does not make sense given that Vertisols form in depressions and level plains.

Response 2.4:

The north-western part of Ethiopia bordering Sudan from the Tekeze river (Humera area) down to the Baro basin is dominated by Vertisols while Luvisols and Nitisols intermingled before these two RSGs become dominant in relatively near distance/landscapes. The proportion of each soil type varies across the landscape. However, both the quantitative and qualitative assessments in those areas showed good agreement at this level of accuracy while the occurrence probability of each RSG is reported.

Comment 2.5: Andosols were shown in Eastern Ethiopia where they are not expected to occur (Andosols are formed from volcanic ejecta) and are common in the Rift Valley. Their occurrence outside is uncharacteristic.

Response 2.5:

Andosols are confirmed to occur outside the rift valley especially in the highland volcanic regions in the presence of organic matter. In Ethiopia, Andosols occur along the rift valley and on highlands for Examples on Bale mountains, Siemen Mountains (RasDashen), Choke Mountain, Abune Yosef Mountain and other mountains of the country. Below are some of the published references for confirmation:

Reference:

Assen, M., and Belay, T. 2008. Characteristics and classification of the soils of the plateau of simen mountains national park (smnp), Ethiopia.

Belay ,T.1995. Morphological, physical and chemical characteristics of Mollic Andosols of Tib Mountains, Central Ethiopian Highlands. SINET: Ethiop. J. Sci. 18 (2): 143–169.

Simane, B., Zaitchik, B.F, and Mutlu, O. 2013. Agroecosystem Analysis of the Choke Mountain Watersheds, Ethiopia" Sustainability 5, no. 2: 592-616. https://doi.org/10.3390/su5020592.

Gebrehiwot, K., Desalegn, T., Woldu, Z., Sebsebe, D., and Ermias, T.2018. Soil organic carbon stock in Abune Yosef afroalpine and sub-afroalpine vegetation, northern Ethiopia. Ecol Process 7, 6 (2018). https://doi.org/10.1186/s13717-018-0117-9.

In our study, the overall occurrence and the relative position of each of the reference soil groups along the topo sequence and its association with other RSGs agree with previous works and pedological expected/established schematic sequences. However, there were cases where the RSGs' position along the topo-sequence and association with other reference soil groups required further investigation, which was not adequately captured and explained in this study. This might be attributed to the positional accuracy of legacy point observations, modelling approach, and most importantly the level of details and scale/resolution of the environmental variables used in this study. For clarity, we will specify areas that require explanation arising from the above-stated likely reasons.

Comment 3: The colour coding in the map is confusing. For example, Acrisols, Cambisols and Leptosols were shown with colours that look alike. For this map to be useful it will be good if it is done with the same colour coding as the Soil Atlas of Africa and the Harmonisation of the soil map of Africa described in Dewitte.

Jones, A., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Dewitte, O., Hallett, S., Jones, R., Kilasara, M., Le Roux, P., Micheli, E., Montanarella, L., Spaargaren, O., Tahar, G., Thiombiano, L., Van Ranst, E., Yemefack, M. and Zougmore, R. (Eds.), (2013). *Soil Atlas of Africa. European Commission*, 176 pp., European Commission Luxembourg. DOI: 10.2788/52319

Dewitte, O., Jones, A., Spaargaren, O., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Gallali, T., Hallett, S., Jones, R., Kilasara, M., Le Roux, P., Michéli, E., Montanarella, L., Thiombiano, L., van Ranst, E., Yemefack, M. and Zougmore, R. (2013). Harmonisation of the soil map of Africa at the continental scale. *Geoderma* 212: 138-153. ODI: 10.1016/j.geoderma.2013.07.007.

Response 3:

As commented, we will address the colour coding and ensure distinct contrast among RSGs.

Comment 4: My appeal to the authors is to compare the soil profile data used for creating the map with the data used for the Soil Atlas of Africa.

Response 4:

See the preceding responses!

Comment 5: It is also important to check whether imbalances in sample sizes among soil types (e.g., preponderanc of vertisols and fewer Gypsisols) has influenced the analysis.

Response 5:

Kindly note that again Gypsisols are confirmed to occur based on the point profile observations but excluded from the modelling and not mapped in EthioSoilGrids version 1.0 product. However, as admitted in Line 441 to 444 of the manuscript, balanced datasets are ideal for modelling and mapping but the effect of datasets with uneven class along with various data treatment (pruning) techniques are recommended for future studies. The reason for this was that as we know there are different unbalanced categorical data treatment techniques targeting majority or minority classes leading to different predicted map accuracy and different overall, producers and users' accuracy.