Development of a harmonized soil profile analytical database for Europe: A resource for supporting regional soil management

The authors are grateful for the comments provided on the manuscript by two anonymous referees, to which we propose the following replies (in red):

Anonymous referee #1

Abstract and elsewhere: Avoid using 'demonstrated', rather use shown or illustrated – noted and amended throughout

88: but (change to) → in which data from Europe are extracted from . . . - done

150: Hannam et al (2009) refers to an unpublished report. Should at least add

the URL: - thank you for this. URL added to reference

156-157: undertook a scrutiny → assessed the . . . - done

Comment 5:

197: URL does not work. Similarly, the EU SPADE 14 database does not seem to be accessible (https://ec.europa.eu/knowledge4policy/dataset/jrc-esdac-114 and https://data.europa.eu/euodp/data/dataset/jrc-esdac-114), but its availability may be considered a prerequisite for publishing this manuscript. Similarly, the landing page for the dataset is non-operational (https://esdac.jrc.ec.europa.eu/content/spade-14)

Response: URL and landing page on ESDAC updated and now operational. Also available on EU Data Portral. URL in text modified to reflect access point in ESDAC.

Comment 6:

199: 'stakeholder passivity', probably true, but should this be phrased as such in this manuscript?

Response: phrase removed

Comment 7:

200: The manuscript would benefit from a succinct description of these guidelines/or predefined equations.

Response: Description of guidelines and equations are provided in subsequent text. For example, see 212

Comment 8:

211: ‘before publication’, according to the website these are ‘provisional data’ and the associated URL does not work (see above).

Response: Final data now available through url

Comment 9:

233: Add abbreviations for texture classes in text (as used in 242-249), e.g. <2um (TEXT2) etc. Alternatively, do these functions need to be defined here at all?

Response: abbreviations added

Comment 10:

264: publishing SPADE-14 database. As indicated, not accessible online at the time of this review. 265-270:.

Response: Now accessible online

Comment 11:

274: The number of 1831 profiles for SPADE 18 is not consistent with Table 2 (1819). Based on a rough calculation, this would amount to some 0.4 profile per 1000 km2.

289: Please explain how this would lead to 'a substantial improvement in the accuracy of . . .'. How would this be quantified?

Response: sentence redrafted to remove the issue of accuracy

Comment 12:

295: See comment. Database in preparation still?

Response: unclear. Full Level 2 database is still being developed. Is comment referring to work of GSP and open access? If so, see edits to conclusion.

Comment 13:

342-354: This calculation gives a capacity, but does not consider whether there are any physical or chemical constraints for growth of specific crops, which would limit the effective 'capacity' (see e.g. https://doi.org/10.1016/j.geoderma.2018.02.046).

Response: No, physical and chemical constraints were not considered – this is simply an example to show how the SPADE database can be used, in this case just for the root zone capacity.

Comment 14:

360: Commonly, a correction for the occurrence of coarse fragments (> 2mm) is considered in such calculations (https://www.soil-journal.net/3/61/2017/soil-3-61-2017.pdf).

Is this the case for line 371-372.

Response: It was not, thanks for pointing this out. It is now corrected.

Comment 15:

396: This confirms the need to consider the full map unit (STMU) composition in such types of assessments.

Response: Agree

Comment 16:

417: Should add http://dx.doi.org/10.1371/journal.pone.0169748.

Response: Hengl 2017 added as reference.

Comment 17:

421: Actually, it has: http://dx.doi.org/10.1371/journal.pone.0169748.

Response: Text amended

Comment 18:

243: At global level, using pedotransfer rules (interim update to HWSD), see http://dx.doi.org/10.1016/j.geoderma.2016.01.034

Response: The reference to Batjes (2016) is now added.

Comment 19:

424-430: Not correct as written; should rephrase this. GSM and SoilGrids (now at 250m see above) are not related to the development of the HWSD, rather initiated in realisation of the need to improve on “conventional soil maps” using automated dsm procedures. Response: Thanks for this clarification. Text rephrased.

Comment 20:

430: Not really possible as written. HWSD v1.2 was published in 2012. As such it cannot be based on the 'SPADE dataset described in this' manuscript.

Response: Text amended to make reference to original HWSD

Comment 21:

444, 446, 450: replace demonstrated by shown or illustrated.

Response: done

Comment 22:

454: Alternatively, the increasing predictive capability and accuracy of digital soil mapping approaches should be indicated. Possibly, also make a reference to soil data collection /monitoring efforts such as LUCAS. Consideration of proximally derived soil data in future work other recent developments re. pedology-based and digital soil mapping (https://doi.org/10.1111/ejss.12790).

Response: Text added to recognise the contribution of LUCAS and precision farming. Reference to LUCAS Soil added.

Comment 23:

Figure 1. See 2018, SPADE 18 this paper. The dataset does not seem to be available from JRC ESDAC (https://esdac.jrc.ec.europa.eu/resource-type/soil-point-data); searching for 'SPADE 18' gives not results at al.

Response: Data now online.

Comment 24:

As such, the conclusions could be couched in terms of‘ desirability of gaining free access (CC-BY) to profile data collected using public funds’. –: In my view, some discussion on ‘data sharing’, and desirability of open access (CC-BY) to profiles collated using public money, should be included in the discussions as a ‘way forward’. See also: http://dx.doi.org/10.5194/essd-9-1-2017 and https://doi.org/10.1016/j.grj.2017.06.001. Possible synergies with the work of the GSP P4 & P5?

Response: New section added to conclusion addressing these issues

Comment 25:

Remove the PTF regressions.

Response: we prefer to maintain the regression equations in 242-250

Anonymous referee #2

General comments:

This MS is informative on how SPADE was developed and evolved

over the years. Unfortunately, the descriptions are not detailed enough so that potential

users are convinced to use SPADE for their research endeavors. Many questions

that raised my mind are mentioned below. The two examples for application of the

SPADE 18 at EU level were not very convincing. Regarding the Root zone capacity

I presume an error in the equation applied (hopefully it is just a typing error so that

calculated results are all right) and for the SOC stock estimation no coarse fragments are taken into account, not even mentioned. More references could have been made to recent papers and studies and to the applied methods. Over all, this MS can be still be improved substantially, starting by considering my suggestions and corrections seriously. I look forward to a next revision and a proper answer to my questions.

Response: Thanks for the overall positive reception of our manuscript and for the helpful suggestions for improvements. We hope our answers are satisfactory.

Specific comments:

Comment 1:

L36-37. In the lack of systematic cross-European soil analysis schemes, . . . Several cross and pan-European soil analysis schemes exist already for decades. Examples are the UN-ECE ICP Forests soil manual with sampling schemes for forest soils in the systematic 16x16 km Level I forest soil network. Freely accessible though this link. For agricultural soils mainly, a manual and sampling scheme was developed for the LUCAS monitoring grid. Reference: Fernández-Ugalde O., Orgiazzi A., Jones A., Lugato E., Panagos P., LUCAS 2018 – SOIL COMPONENT: Sampling Instructions for Surveyors, EUR 28501 EN, doi 10.2760/023673. Strange it is not mentioned in this manuscript, since different coauthors are involved. Also in World Reference Base, soil analytical methods required for soil description and classification are well described (see IUSS Working Group WRB (2014) among other FAO reports)

Response: By “scheme” we meant “programme” or “plan” for actually going to the field and collecting soil samples systematically, rather than a formalised sampling protocol. We have changed “scheme” to “programme” to avoid this misunderstanding. Further, we have added a

reference to the LUCAS soil collection programme, as suggested. Text has been amended in line 36-39 and 449-458.

Comment 2:

L55-57. A recent assessment . . . This phrase is unclear and difficult to understand, unless you read the referenced article. Please rephrase

Response: Done

Comment 3:

L64-L66. I expect some critical evaluation in this MS concerning the mapping-unit approach, especially the practical problems in GIS processing since soil-types are not spatially explicit defined this way. Maybe state some alternative (better) soil mapping approaches from literature.

Response: Considering the mapping scale (1:1 mio.) for Europe, it (still) makes good sense to work with STUs grouped into SMUs containing soil associations and inclusions, because at that scale it would not be feasible to delineate the STUs. Therefore, the European Soil Database still uses the soil mapping unit (SMU) as the spatial unit on the soil map, but King et al.(1994) give a clear description of how this relates to soil types (STU). This work was done in the 'manual map drawing' era. However, without a massive new survey programme to increase the density of sampling points, it will not be possible to increase true spatial accuracy. To date, no Soil Survey organisation anywhere in Europe has provided sufficient resources to map the STUs spatially within each SMU. None of the DSM or pedometric approaches can overcome this problem. Thus, at the present time, the pedometric approach can only increase spurious spatial accuracy. Should the EU decide to improve the current soil map by taking it to a more detailed level, for example based on disaggregation of the existing soil by machine learning methods (see Møller et al. 2019), it might be appropriate to consider a cell-based data representation instead (similar to

WISE30sec or SoilGrids), but that is, of course, to be decided among the experts involved. We have now added a discussion on this in the text (line 459-470).

Møller, A.B., Malone, B., Odgers, N.P., Beucher, A., Iversen, B.V., Greve, M.H. & Minasny, B. (2019): Improved disaggregation of conventional soil maps. Geoderma, 341, pp.148-160.

Comment 4:

L87-96. Overall, this section is not very clear in describing the various database products and how they are linked to each other, and what they effectively contain (which countries, number of soil profiles, measured vs. estimated/derived profile data, etc).

I suggest to use Table 2 earlier in the text to describe the SPADE versions and their evolution.

Response: The intension here was not to give an overview of the SPADE-databases, but rather why it is such a cornerstone in the ESDAC (other widely used databases extract data from it), and to introduce how this paper is structured. We have rephrased a bit to, hopefully, make this clearer.

Comment 5:

L98. I would replace “Root zone capacity” here with “volumetric water content” since the first term is not used frequently and should be defined first along with a proper reference.

Response: We prefer to stick to root zone capacity, although we recognise that in certain soil-water disciplines other terms may be more common. We have now added a short explanation and some examples in line 246-7, and a reference to Jensen et al (1998).

Comment 6:

L106. Why “preferable on arable land” ? Would have been more logical to provide analytical data for the dominant STU and for the dominant land-use in each SMU in Level 1, while in Level 3 you then have the differentiation among land-uses fo all soiltypes.

Response: When the principles were developed during the 80-90s, it was with the primary aim to provide data for modellers to solve agricultural problems. SPADE as the entire EUSIS was driven by the need to provide data for the agricultural crop forecasting system operated by MARS, known as Crop Growth Monitoring System (CGMS).

Comment 7:

L115. What do you exactly mean by “established analytical procedures” ? Do you refer to international procedures like ISO methods, EN, etc ? Or do you mean specific ‘established manuals’ ?

Response: By “established” procedures, we mean analytical methods that are widely accepted, but not necessarily directly comparable. This could for example be CEC measured at different pH values. Therefore, Proforma I was established at the same time to have a dataset with estimated mean values based on the same methods. See Breuning-Madsen and Jones (1995) for further description of the standard methods. We have rephrased to make this clearer.

Comment 8:

L115-116. I would expect the inverse: established procedures (understood as internationally accepted conventional methods) are more comparable across country borders than national methods (Proforma I).

Response: See answer to Comment 8

Comment 9:

L122-123. Why is the database limited to assessments of agricultural land management if one-third of the EU land area are forests ? Considering also that soil profiles under forest are well suited as a reference and to better evaluate the impact of agricultural management on soil development and quality.

Response: This should not be understood as if the database is limited to agricultural application, but rather that this was the primary objective at its establishment. We have now added a reference to Breuning-Madsen et al (1989), where the principles were originally defined.

Comment 10:

L132-133. Can you provide any reason explaining the limited response from national stakeholders ? Was there any questionnaire or evaluation study dealing with this issue ?

Response: There was no questionnaire but the feedback we received was that essentially national soil survey organizations were lacking the resources to engage or that data were not available to third parties. We have added a short comment on this, and a section in the discussion (453-8).

Comment 11:

L144. Was there any information on coarse fragments (stoniness) in each horizon ?

Response: Yes, there was. This has now been added to the text.

Comment 12:

L149&L151. Versioning for SPADE databases is quite confusing. So you have SPADE2v11 (11th version of SPADE 2 ?), but also a SPADE version released in 2014,

being SPADE14. I presume there is some simplification possible here ?

Response: We agree that the versioning of the SPADE databases are quite confusing and inconsistent – some were named after the year they were released, some after their relative chronology, and some again after the year finalisation was initialised. We debated whether we should make a simpler nomenclature for the purpose of this publication, but decided that it might introduce further confusion. Instead, we decided to include the timeline in Figure 1 to hopefully make it the chronology clearer. We have added extra references to this figure in the text.

Comment 13:

L167-168. If implausible values were adjusted, was this documented in the database.

If so, how ?

Response: This was done with a standardised set of colour codes in the reports and country subsets of the database sent to the national stakeholders according to Koue et al (2008). From the stakeholders we corresponded with after we sent the evaluation reports and country-specific databases for approval, none of them mentioned any confusion related to this, so we believe our colour codes were clear and unambiguous.

Comment 14:

L168-179. It seems that response of stakeholders for reviewing SPADE databases was repeatedly low or absent. Could it be that EC asked for responses and reviews on a voluntary basis, while only by (co) financing serious and adequate expert responses may be expected ? In this MS it seems that often the national stakeholders are blamed. Maybe the approach and strategy of responsible institutions like DG JRC is inadequate and does not promote fruitful cooperation between EC and member states on European soil databases?

Response: We do not intend any blame to the national stakeholders. We have now added some text on this (line 139, lines 453-8). Partly, as a consequence of the inadequate engagement by member states the EC recently set up its own data collection system (LUCAS SOIL COMPONENT), as you mentioned in comment 1.

Comment 15:

L192. Matching of similar soil types in neighbouring countries is quite tricky. Thorough validation and evaluation of such a process is needed to avoid systematical bias in the SPADE database. Estimated records need a clear flag in the database so that they can be omitted by evaluators if they do not trust the estimated/imputed records.

Response: The estimated values were clearly flagged in the databases sent to the national stakeholders for evaluation (see Breuning-Madsen et al. 2015).

Comment 16:

L196. Replace 'final' by 'resulting'. Is there any further versioning of the SPADE14 database ?

Response: "Final" replaced by "Resulting". SPADE 14 is the final level 1 database, named after the year it was finalised (2014). SPADE 18 is the level 2 database, currently named after the year it was initiated (2018).

Comment 17:

L199. 'passivity' – There might be several reasons for not cooperating. See comment for L168-179

Response: We have now added a small phrase on this. See response to comment 14.

Comment 18:

L201-L203. This all seems tricky to me. Is this process clearly documented and traceable

? Please inform the reader on this.

Response: Yes, it is clearly traceable. Individual datasheets for each country documenting the process were sent to each stakeholder during the 2014-15 evaluation. An additional reference was added to Breuning-Madsen et al (2015) (line 204-5), where it is all described in detail.

Comment 19:

L206-208. Please provide a reference or URL to such a detailed description of the

methodology

Response: Reference added

Comment 20:

L210-211. Can you inform the reader how many stakeholders responded and how their

response was processed before publication ?

Response: We could, but it is probably not very informative about the engagement, as they were only requested to respond if they had any objections, questions or wanted to change our suggested corrections.

Comment 21:

L214 “weredeveloped” add space between words

Response: done

Comment 22:

L218. SPADE 2 (table 1), . . . please add “depending on their OM content and depth”

Response: done

Comment 23:

L223. BD estimated a value in the range 1.1-1.2 g cm-3. Why not using 1.15 g cm-3,

making gap filling more reproducible ?

Response: In practice, we used 1.15 g cm3 unless the over-/underlying horizons gave us strong reason to believe it should differ. We have used a sentence stating that the OM range was also included in the assessment.

Comment 24:

L229. Root zone capacities. Please refer to a definition or paper for this term (e.g.

Jensen et al. 1998)

Response: See response to comment 5

Comment 25:

L233. Why using 50µ in 20-50 µm and 50-200µm fractions while 63µ is recommended

by FAO and USDA soil texture classes ?

Response: In the early 1970s, there were discussions at international level, mostly between American and European soil scientists on the definitions of soil particle sizes and how these relate to soil texture classes. The USDA texture classes were based on silt defined as 2-50um whereas the MIT size grade for silt used in civil-engineering is 2-63um. After in –depth discussion with the USDA and other European experts in the early 1970s, the Soil Survey of England & Wales (SSEW) adopted the MIT size grades for soil particle size and texture analysis.

The relationship between 2-50um and 2-63um size fractions was developed for the conversion of historic data (Jones, 1975). But USDA still uses 2-50um as the particle size limits for silt and FAO only adopted the 2-63um size limit for silt much later (ie FAO 2006, p27). For the SPADE databases therefore, the original 2-50um size grade for silt has been retained, also because much of the national soil data from European soil institutes was collected several decades ago.

References:

FAO 2006. Guidelines for Soil Description, Fourth edition (97pp) – for particle size grades see p27.

Hodgson, J M (ed) 1997. Soil survey field handbook. Soil Survey Technical Monograph No.5, Silsoe (116pp) - for particle size grades see p29.

Jones, R J A. 1975. Soils in Staffordshire II, Soil Survey Record No.31 (158pp) –

particle size conversion: [%(2-60um) = %(2-50um)+%(50-100um)0.26].

Schoeneberger, P J, Wysocki, D A, Benham, E.C. and Broderson, W D. 1998. Field book for describing and sampling of soils. Natural Resources Conservation Service, USDA, National Soil Survey Center, Lincoln, NE.

Comment 26:

L234. “Complete estimated datasets” Does it mean completed using estimated data ?

So, for instance estimated bulk density using PTF functions instead of measured bulk

density ?

Response: “estimated” was erased, as it is indeed confusing. We meant complete datasets in the Proforma I database

Comment 27:

L240 VWC1000 not mentioned in line 231. VWC1500 in stead ?

Response: Yes, thanks for finding this error. It is now corrected to 1500

Comment 28:

L243 In all these equations BD is used twice, so this is a high impact predictor. Is only measured BD applied here or also predicted BD ?

Response: These are all measured values, as only countries with complete datasets were used to derive these equations.

Comment 29:

L250 please explain predictors in the regression equations: “where TEXT2 = 0-2 µm fraction in mass %, . . .

Response: Yes, you are correct. We have now added further explanation.

Comment 30:

L261-262. Again, when adjusted, how is this documented in the database ?

Response: These adjustments were also part of the colour coding system developed for the 2015-scrutiny (Breuning-Madsen et al. 2015).

Comment 31:

L274-275. It would be helpful to provide an EU map showing the profile locations of SPADE 14 and SPADE 18 across Europe, so that the geographical distribution across Europe may be evaluated

Response: This is unfortunately not available due to the database structure with STUs and SMUs rather than individual soil profiles with coordinates.

Comment 32:

L288. . . . assigned by estimated analytical data

Response: rephrased

Comment 33:

L322 will be published. . . so without any national validation then. Is it indicated in the

SPADE 18 database if the data has been nationally validated or not ?

Response: This has not yet been sent out for validation, but we will keep a record of this, once it is sent off.

Comment 34:

L326 currently only the SPADE 14 can be downloaded through this link; and also

SPADE/M and SPADE/M2 but these are not explained in this manuscript

Response: National stakeholders have not yet validated SPADE18, therefore, it is not publically available.

Comment 35:

L314& L345. Can you provide a reference for this equation ? It seems to me that

VWC100i, which needs to be VWC at Field capacity is far too high at -100 kPa. Conventionally it should be for FC between -10, -20 or -32 kPa depending on soil texture,

respectively sand, silt or clayey soils. Can you check this ?

Response: Correct, this is a typo. FC should have been VWC10. It is now corrected. Thanks for pointing out this rather embarrassing mistake.

Comment 36:

L350. I presume there is also a fraction 200-300mm considered “High”

Response: Correct, this is now added.

Comment 37:

L360. For the SOC stock estimation volumetric proportion of coarse fragments are not taken into account while these are usually considered for accurate SOC stock estimation (see De Vos et al. 2015 you are referring to) ? Why is this ? Because SPADE has no coarse fragments data ? Neglecting coarse fragments content will lead to an overestimation of the SOC stock.

Response: We have now corrected the equation to subtract the coarse fragments before calculating the SOC. This reduce the estimate a bit, and with the adjustment of the estimate by Lugato et al (2014) you kindly suggest below, we are getting rather close to previous estimates of European SOC stocks. This has now been incorporated in the text.

Comment 38:

L379-380. You cannot simply sum the estimates by De Vos et al. 2015 and Lugato et al. 2014 because the latter is only the 0-30 cm stock. According to the first referene, assuming a 60% proportion of SOC in the upper 30 cm, the total 1-m SOC stock in EU27 agricultural and forest soils would amount to 51.3 Gt, which is about 68% of the SPADE 18 estimated stock. As said before, since coarse fragments are neglected

in the calculation the SPADE 18 estimate is presumably an over-estimate. Recently the GSOC map was developed by the Global soil partnership. Please compare these results for Europe also with the SPADE 18 data, if necessary only for 0-30 cm topsoil SOC stocks.

Response: Thanks for this excellent suggestion. See response to comment 37

Comment 39:

L402. Indeed. This is a very important factor. Carbon hotspots are often smaller SMU's and often underrepresented in soil databases or masked by generalization of soil maps.

Response: Thanks. We agree, this is an often underappreciated point.

Comment 40:

L436. Refer to figure please for Danish-German border example. . .

Response: Done