

## ***Interactive comment on “Local soil quality assessment of north-central Namibia: integrating farmers’ and technical knowledge” by Brice Prudat et al.***

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We are very excited to have been given the opportunity to revise our manuscript and are very thankful for the number and pertinence of the comments.

Herein, we explain how we answer those comments and suggest how we would revise the paper.

Reviewer’s comment: On page 3, the technical knowledge is highlighted because it facilitates international communication. Keeping this in mind, I wonder, why the authors do not try to present some information about the soil classification (reference groups

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and qualifier) according to FAO of the studied soils. The system is applied in Namibia and thus, from my perspective, this seems to be necessary.

Author’s answer and suggestions: We agree with this concern and we would add few soil descriptions, including pictures and FAO names. A short chapter following 3.2 “Technical analysis of farmers’ field experiences” will be added to explain the major results regarding the WRB (reference soil groups, qualifiers). Add in Chapter 3.5.1 “Importance of a soil quality evaluation toolbox”: “Soil classification based on the FAO is used by Namibian institutions and is used to draw the Namibian soil map. Therefore, it could be appropriate to use for international and scientific communication. However, this classification system does not bring additional information that would benefit this paper and was therefore not discussed. FAO classification is orientated towards representing “primary pedogenetic process[es]” and does not aim at detecting soil differences at micro-scale, neither spatial nor temporal” (IUSS Working Group WRB, 2014). Therefore, the use of this classification is not relevant to highlight SQ differences at small-scale. Moreover, the classification of the described soils in the WRB is poorly informative given the low prevalence of diagnostic properties and horizons leading to poorly informative nomenclature.”

Reviewer’s comment: Both variables in the SQ toolbox (sand content and colour shade) are not independent and are known by the local farmers in its indicative value.

Author’s answer and suggestions: It is true that sand content and colour shade are not independent variables. Despite the dependency between these variables, we can use both to evaluate SQ because meaningful variability remains. The indicative value of these properties is known by the farmers. As explained in the introduction, farmers’ knowledge is valuable but lack of standardisation, which can be brought by technical assessment.

Reviewer’s comment: Although SOC is undoubtedly a very relevant variable for SQ, the direct link to colour shade with one unit discriminating between the qualifier + and – is

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an over-interpretation of the possibilities of soil colour interpretation. As given in figure 3, there is a significant overlap of SOC between neighbouring colour shade classes. Thus, in the field very slight differences in colour divide between the qualifier + and –, if the evaluator cannot decide, the qualifier becomes 0.

Author's answer and suggestions: It must be emphasized that this toolbox is a suggestion that would require further developments. In §3.4.4 "Outcome of toolbox application": "The developed toolbox is and remains a suggestion for evaluating SQ and for prioritising SQ-improvement practices." Considering the comment and the low accuracy of Munsell colour evaluation, we would modify the colour shade classes defined in the toolbox (Fig 4b) to include more soil colour shade values in the 0 class. This would result in more soils classified into this class; 1) avoiding an overinterpretation of SQ evaluation and 2) corresponding better to the farmers SQ evaluation. The values are then adapted to avoid over-interpretation of field data collected.

Reviewer's comment: The Munsell Soil Color Charts do not present colours (also not figure 3) for the broken classes as given in figure 4.

Author's answer and suggestions: The broken classes suggested in Fig. 4 are defined based on theoretically-calculated optimal SOC and colour shade values.

Reviewer's comment: The combination of the variables fine particles and colour is relevant, however, it is not promising to distinguish between 29 classes, as has been proposed in the toolbox by the authors.

Author's answer and suggestions: It leads indeed to 29 classes possible. However, this classification is constructed as a combination of 5 KwsUs, 4 texture classes and 3 colour classes. Each level has a specific meaning and can be evaluated without the other (e.g. "-" for colour value indicates a need for organic fertilisers, no regards with KwsU or texture. In §3.4.4, we would add a comment considering this high number of classes and emphasize that all classification levels can be used separately.

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Reviewer's comment: The general problem of smallholder agriculture in the studied region is: i) Soils best suitable for cropping become scarce, thus expansion in the pristine woodlands will become increasingly restricted. ii) In the consequence, also those soils are cultivated, of which the farmers know their lower productivity. iii) the ongoing crop production is especially restricted by the lack of nutrient inputs, here N and P, and – off course – years with low rainfall.

Author's answer and suggestions: Known to be limiting nutrients in most agricultural land, particularly in sub-Saharan Africa, nitrogen and phosphor availability are most likely significant for plant growth. However, given the high connection between these nutrients and the soil short-term fertilisation, we decided to not include these analysis in our analysis as our work aim to understand and follow longer-term soil fertility discussion. In §2.3.2 Laboratory analyses: add "Known to be limiting nutrients in most agricultural land and in sub-Saharan Africa, nitrogen and phosphor availability are most likely significant for plant growth. However, given the high connection between these nutrients and the soil short-term fertilisation, we decided to not include these analysis in our analysis as our work aim to understand and follow longer-term soil fertility discussion."

Reviewer's comment: The future challenge is i) to concentrate crop production on the best suitable soils and ii) to improve nutrient inputs on these areas in an intensity, that yields are just water or management controlled and iii) to develop sustainable LU management techniques (e.g. conservation agriculture). This development needs help by the agriculture extension services.

Author's answer and suggestions: This issue would need to be discussed. However, it does not relate directly with the objectives of the current paper, which do not aim at suggesting management techniques to improve SQ. The aim is to suggest a SQ toolbox that helps to evaluate the conditions of a soil, regarding its potential.

Reviewer's comment: The mapping of the best suitable soils should be oriented to

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technical knowledge for its comparability, however should include farmers views. The general objective of the paper just moves to the right direction, the presented toolbox however needs improvement (reduction in units).

Author's answer and suggestions: Our objective is not to create a map or tools to map, it is to enable the farmers to optimise their SQ evaluation. However, for mapping purposes, each criterion used can be mapped separately, which presents the advantage to evaluate the various issues separately (organic matter availability, erosion, soil types).

Reviewer's comment: P3, Table 1, L pH: I suggest, that doing numerous measurements on soil pH is cheaper by application of the sensor technique instead of the Hellige test kit

Author's answer and suggestions: We accept this proposition and add this method in the Table 1.

Reviewer's comment: P4, Table 2: add a row with information, for which sort of soils (types, region) and land use the soil quality indicators were proposed

Author's answer and suggestions: Very relevant, we decided to ignore this information to facilitate the reading of the Table. We would then modify Table 2 by adding this information.

Reviewer's comment: P6 L31: what is meant with colour shade? The standardized MUNSELL soil colour charts are composed by the variables hue, value and chroma. Is shade identical with value? Please explain.

Author's answer and suggestions: Colour shade in common language would refer to "colour value" in the Munsell colour system. We use both to separate the perception of shade (dark or light) against the numeric evaluation of darkness (colour value).

Reviewer's comment: P7 L12: "two sample rings": defined volume? calculation of bulk density possible? please explain or reformulate

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Author's answer and suggestions: "Two 100 cm<sup>3</sup>-sampling rings were collected from each described horizon. Dried-samples were weighted to calculate bulk density, sieved (2 mm) and used for further analysis."

Reviewer's comment: P9 Table 4: hardness is an often-mentioned indicator for soil quality. I suggest, that the hardness is related to the condition of the soil in the (almost) dry state, perhaps for that time of the year, when ploughing is done. Please add some explanations on the local farmers intention.

Author's answer and suggestions: The consistence, or the concept of hardness, is in relation to the hardness of dry soil, which impacts importantly the difficulty of ploughing. Add a clarification of the meaning of hardness at the beginning of the chapter 3 "Results and Discussion": The consistence, or the concept of hardness, is in relation to the hardness of dry soil, which impacts importantly the difficulty of ploughing.

Reviewer's comment: P10 L21: values of pH (8.4 to 10.1) are not existing in Table 5!

Author's answer and suggestions: These pH values are pH in water, while in Table 5 the values are pH in CaCl<sub>2</sub>. We would clarify this difference in the text.

Reviewer's comment: P11 Table 5 and P12 Table 6: Row <20 μm sub data of sand are given and in row sand – sub data of < 20 μm are given. Check all data and compare with data in respective chapters.

Author's answer and suggestions: Some errors are in the Table 5 and 6. We will modify the Table 5 and 6 to clarify the particle size content.

Reviewer's comment: P11 Table 5: Add row with WRB classification

Author's answer and suggestions: We don't think that WRB names for all soils would help the discussion because of the presence of very limited number of diagnostic horizon, properties or materials, which leads to very limiting meaning of WRB names. We would add few soil descriptions, including pictures and FAO names. A short chapter following 3.2 "Technical analysis of farmers' field experiences" will be added to explain the

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most important characteristics regarding the WRB (reference soil groups, qualifiers).

Reviewer's comment: P12 L6: acc. to tab. 6 the coefficient of variation is large for TOC, moist color value, < 20  $\mu\text{m}$  fraction but not for pH (in both depth intervals CV < 0.2).

Author's answer and suggestions: This error comes from a calculation mistake. To calculate CV of pH, we should not use the pH values but the H<sup>+</sup> concentrations. Using these values, we find a CV of 1.2

Reviewer's comment: P13 Fig2: This graph pretends a precise depth distribution which was not analysed. Additionally, this graph is redundant, please delete.

Author's answer and suggestions: This remark is relevant, and we will delete this table.

Reviewer's comment: P13 L8: fragipan: delete term because of its vague definition

Author's answer and suggestions: Fragipan is the most accurate concept that describe this soil layer. We would add the definition of fragipan suggested by Soil Survey Staff (1999): "Fragipans are compacted layers that result from various processes (freezing-thawing, pressure, swelling-drying), excluding ploughing pan."

Reviewer's comment: P14 L8: "large variety of soils" -> large variety of soil properties

Author's answer and suggestions: Accept the change to "soil properties".

Reviewer's comment: P14 L9: "standardize the assessment of the SQ at a specific location and time". Why time? Soil quality assessments always results in a potential for intended land use. Different climatic conditions may be included in the potential. Thus, the results are irrespective of time, however may be altered by changes in soil properties due to land use.

Author's answer and suggestions: SQ represents the potential regarding various climatic conditions, but is also the consequence of various soil degradation or improvements techniques. Therefore, the notion of time is important. The SQ of a specific site

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can change through agricultural activities.

Reviewer's comment: P14 L9: What is meant with location in this context: Three villages were studied, should the SQ assessment by different for each village?

Author's answer and suggestions: Not in this context. The assessment would be done following the same method in all villages. What we mean is that it is important to evaluate SQ at various location (points) and to compare the results between these locations. The comparison is important to evaluate the potential that can be reached in specific regions (villages). There is no need to explain that a soil in Ekolola (woodland) is bad and in Omhedi (Oshana) it is good. It is more useful to differentiate between various location in a same village, to evaluate the potentials.

Reviewer's comment: P14 L16: harder in dry conditions (?)

Author's answer and suggestions: Add "in dry condition" after harder.

Reviewer's comment: P14 L21: This increase in <20  $\mu\text{m}$  can only be marginal.

Author's answer and suggestions: The increase in fine particle content can be significant by mining riverbeds for example, following researches from Kreike (2013), as already explained in the manuscript (P13 L14).

Reviewer's comment: P15 L12: Data presented by Blume et al 2011 cannot be transferred to Namibian soils.

Author's answer and suggestions: It is a relevant comment given the origin of the soils used in Blume 2011, difficult to compare to the Namibian context. However, we did not find similar relations adapted to tropical soils. Moreover, the results indicate a relatively well-balanced repartition of SOC status in our soils, which therefore helps to analyse the SQ status of a soil in relation to other soils of the same region.

Reviewer's comment: P16 L8: "indicates important degradation". Relevant forms of degradation (acidification, salinization, decline in nutrients, compaction) do not include

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the shift to more coarse particles.

Author's answer and suggestions: Processes that can remove fine particles from the top soil are 1) eluviation related to dispersive salts; 2) overland flow erosion, 3) wind erosion. Add suggestions of processes leading to soil texture coarsening.

Reviewer's comment: P16 L8: Thus, if farmers classify soils as Elondo and field tests show, that sand content is > 90 %, this means. that farmers needed to shift to less suitable soils.

Author's answer and suggestions: This was observed with people who moved to the eastern areas (Woodlands), where they described omutunda that was not as fertile as the omutunda found in the western areas (Oshana). However, farmers who moved to or extended their fields to less fertile land will not necessarily classify this new land as a fertile Kwsu. A sentence summarising this issue would be added in §“3.4.4 Outcome of toolbox application”.

Reviewer's comment: P16 L9: major soil improvements”: see above.

Author's answer and suggestions: The increase in fine particle content can be significant, following researches from Kreike (2013) (P13 L14).

We want to extend our appreciation for taking the time and effort necessary to provide such insightful guidance.

We hope that the answers and the suggested revisions improve the paper.

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