2. Soil classifications
Between material facts and socio-ecological narratives

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2.1. Introduction

Local environmental knowledge and enhanced community participation in research and implementation have been used for a better understanding of the lack of new technology implementation in local communities - for example, for water management or agriculture. The benefits of local knowledge can be tapped by including farmers and their understandings of local needs in economic development. Local soil knowledge is "the knowledge of soil properties (...) possessed by people living in a particular environment for some period of time" (Winklerprins 1999: 151). This knowledge integrates various environmental (e.g. soil, climate) and social criteria (e.g. techniques or labour force availability) that influence soil productivity. Local soil typologies are the way soils are named and grouped, and they aim to describe the local environment in order to support people to fulfil local necessities, such as for steady food production under high rainfall variability (Barrera-Bassols et al. 2006). Integrating local soil typologies and technical knowledge - for example, provided by international soil classifications - as much as possible without losing the essence of one or the other aims to make local environmental knowledge accessible to outsiders. The integration of local and technical knowledge intends finally to improve agricultural management practices (Winklerprins 1999). The comparison and combination of these typologies require building an important body of knowledge that includes farmers' and scientific soil knowledge. However, the translation, simplification and codification of this new mixed knowledge is often found to be the cause of the failure to use local knowledge for development (Briggs 2013, Pottier et al. 2003). Although these

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processes are necessary to transfer explicit information to a wider audience (externalization), more sharing and a participatory research agenda are helpful.

The issues raised in using this mixed knowledge are that local soil knowledge is fragmentary and dynamic, and therefore difficult to translate into or combine with more centralized, international and static knowledge systems (Agrawal 1995, Rathwell et al. 2015, Sillitoe, 2010). Local soil types are not strictly defined and are described on a comparative basis (Sillitoe 1998), and can therefore vary from one village to another (Barrera-Bassols and Zinck 2003) depending on the socio-cultural context (Sillitoe 1998) and the local environmental conditions (Niemeijer and Mazzucato 2003). This flexibility and dynamism pose fundamental challenges to scientific endeavours focusing on the (more) strict, systematic and context-independent classification of objects (Ellen et al. 2000, Hobart 2002, Pottier et al. 2003).

In this article, we will spell out what it means to do environmental research in the interplay of local, implicit soil knowledge and international, explicit soil classification. We will contextualize the Oshikwanyama soil typology from north-central Namibia and its relation to international classification, and discuss the advantages of local knowledge for soil quality assessment. Thereafter we will reflect on issues regarding the collection, translation and selection of local soil knowledge. As a part of this, we will reflect on the experience of participatory approaches from the perspective of the first author, trained as a natural scientist.

2.1.1. Ohangwena region and villages

Ohangwena region in north-central Namibia is characterized by the endorheic Cuvelai drainage basin in the westernmost part and the Kalahari Sandveld in the central and eastern part (Figure 1). The climate is semi-arid and subtropical, with large inter- and intra-annual variability (Mendelsohn et al. 2000). Oshikwanyama-speaking communities immigrated into today's Ohangwena region during the late nineteenth century and moved eastwards during the first decades of the twentieth century (Kreike 2004). The Cuvelai drainage basin has to a large extent been converted into crop fields for small-scale (1-4 ha) non-commercial agriculture of rain-fed pearl millet (*Pennisetum glaucum*; Mendelsohn et al. 2000).

For our study, we selected three village areas in the western Ohangwena region, based on dialect homogeneity (Oshikwanyama) and environmental

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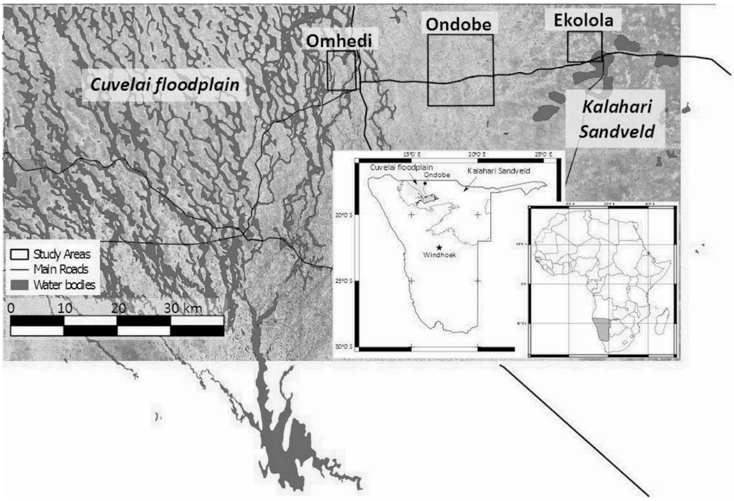
Figure 1: Overview of Africa, Namibia and north-central Namibia



Maps of Africa, Namibia and a satellite image (maps.google.com, retrieved in July 2016) of north-central Namibia with the Cuvelai floodplain (west), the Kalahari Sandveld (east) and location of the three study areas (squares). Water channels (*iishana*) and temporary ponds are in blue, vegetation and bare soil appear in green and in orange respectively.

heterogeneity, including vegetation and soils (Figure 1). These villages (Omhedi, Ondobe and Ekolola) are on a west-east gradient, representing edaphic and vegetation differences with decreasing influence of the Cuvelai River eastwards. Omhedi, the westernmost area, is situated in the Cuvelai drainage basin with active ephemeral water streams (*iishana*). Ondobe is located between the drainage basin (mostly inactive *iishana*) and the Kalahari Sandveld that lies east of Ondobe. Ekolola is characterized by the Kalahari Sandveld and is largely covered by deep loose sand deposits, forests and extended temporary pans (Mendelsohn et al. 2000).

2.1.2. Collecting local soil knowledge

The data collection for our study was carried out during various extended field stays between February 2013 and June 2014. We used semi-structured inter-

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views to construct a local soil typology and to understand local farmers'[1] soil quality perception. Most interviews were conducted in the farm homestead, promoting abstract discussion about soil types and definitions. This approach was chosen because it helped the researchers to create a local soil typology that can be extrapolated to a regional scale. However, some interviews were also conducted during transect walks through the field or in front of soil pits, both leading to discussions concerning micro-level soil transitions relevant for management practices, as suggested by Oudwater and Martin (2003).

In total, we conducted 87 interviews on 46 farms, mainly in Ondobe (50 interviews / 21 farms). From March to June 2014, we collected additional interviews from Omhedi (19 interviews / 15 farms) and Ekolola (18 interviews / 10 farms). In most cases, the head of the household (mostly men above the age of 60) was interviewed, as the family members within the households suggested this. Mostly, the interview language was Oshikwanyama and translation into English was provided by a translator from Ongwediva (Oshana region) without a background in soil science. This young woman was the translator for the entire duration of the data collection period. The continuous collaboration enabled the research team to build a common knowledge and language. The quality of the information collected improved during the period of study, given that both the researchers' knowledge concerning local soils and the interpreter's skills considerably increased (similar observation was done by, for example, Oudwater and Martin 2003).

All the interviews were audio-recorded and the English oral translation was transcribed. The most relevant parts of the interviews were transcribed in Oshikwanyama and translated into English. We used MAXQDA 11 (VERBI GmbH, 2014) to organize and classify the interviews.

2.1.3. Scientific soil description

We scientifically described 28 soil profiles in cultivated fields in Ondobe (21), Omhedi (3) and Ekolola (4). These profiles were classified by the farmers as *omutunda* (14), *ehenge* (4), *omufitu* (4), *elondo* (3) and *ehenene* (3). We selected more *omutunda* for the analysis given the high agricultural value of this local soil type and its prevalence in the cultivated area.

1 All informants involved in this study are called farmers, despite the fact that crop cultivation is not necessarily their main economic activity.

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We classified the described soils using two scientific soil classifications: the World Reference Base for Soil Resources 2014 (WRB; IUSS Working Group WRB 2014) and the Fertility Capability Soil Classification (FCC; Sanchez et al. 2003). Both require the analysis of various chemical and physical properties and exclude properties that reflect short-term changes. The WRB aims at identifying pedological structures and uses properties that are mostly the outcome of long-term soil evolution (aside from anthropogenic soil modifications). On the other hand, the FCC aims at highlighting limiting factors for crop production, specifically for tropical soils, and deals with properties "that are either dynamic at time scales of years or decades with management, as well as inherent ones that do not change in less than a century" (Sanchez et al. 2003: 157).

Both classifications present a hierarchical classification structure. The WRB's Reference Soil Groups are "differentiated mainly according to primary pedogenetic process[es]" (IUSS Working Group WRB 2014: 5) and the FCC's substrate reflects the soil type (texture).

2.1.4. The Oshikwanyama soil units

The body of mixed local-technical knowledge summarized in Table 1 is the result of previous studies (Hillyer et al. 2006, Newsham and Thomas 2011, Rigourd and Sappe 1999, Verlinden and Dayot 2005) and the interviews conducted during the current study. Interviewees described the local soil units mostly based on soil consistency (hard or soft) and colour shade (dark or light), as well as the sensitivity to waterlogging conditions.[2] These properties are related to soil suitability for cultivation - for instance, workability and fertility. Soil hydrology has a strong influence on agricultural suitability and therefore on local soil typology and, given the rainfall irregularity, both waterlogging and soil drought occur frequently during the rainy season. The five soil units described in Table 1 can be used as cornerstones for soil quality evaluation as they represent important soil processes and characteristics for crop cultivation (waterlogging risks, texture).

2 Waterlogging conditions indicate soil saturation with water and strongly inhibit roots' respiration.

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Table 1: List of local soil types

	Soil type attribute		
	Water related characteristics	**Consistence**	**Colour shade**
Omu-tunda	No waterlogging High water retention capacity Dries out quickly	Hard	Dark/black
Omu-fitu	No waterlogging Low water retention capacity	Loose	Dark or light
Elondo	No waterlogging	Intermediate	Intermediate
Ehenge	Waterlogging risk Dries out very slowly	Loose	Light/white
Ehenene	Waterlogging risk Low water retention capacity Dries out quickly	Hard	Light/white

2.1.5. Local soil types compared to international classifications

According to the WRB, the 28 soil profiles would be classified as arenosols (17), regosols (10) or calcisols (1) (Figure 2, left). These reference soil groups are almost exclusively determined by soil texture: sandy and loamy sand soils are classified as arenosols, while sandy loam and finer soils are regosols. The fertile soil (*omutunda*) has a loamy sand or sandy loam texture (<90% sand), while the other soil types have a sand texture (>90% sand), excluding *ehenene*.[3] This textural difference is significant for productivity and soil management strategies in north-central Namibia. Both the WRB and FCC classifications group all sand and loamy sand soil types into a single reference soil group (arenosols in WRB) or substrate (S in FCC) and describe these classes as having low chemical fertility. Farmers in the western Ohangwena region contradict this evaluation and consider loamy sand soils as good soils to grow pearl millet in north-central Namibia (i.e. *omutunda*). A better differentiation

3 Productivity in *ehenene* is limited by poor water infiltration, high pH and sodic conditions.

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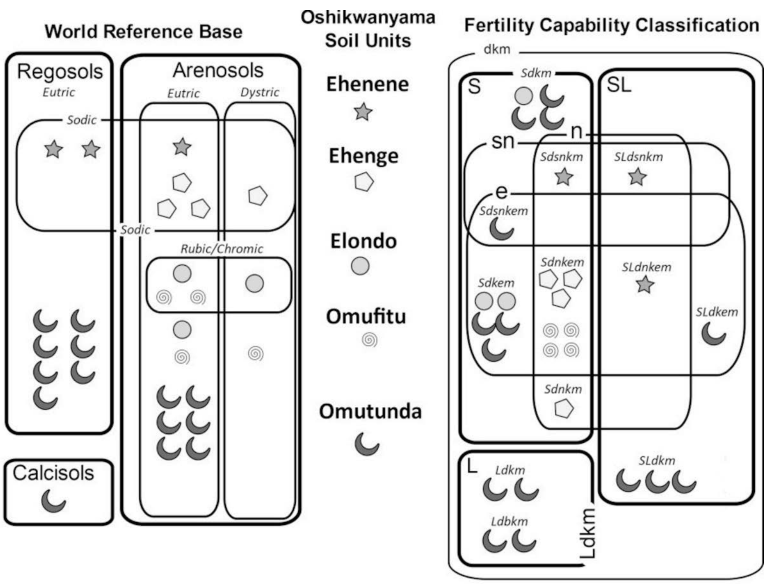
of the soils depends on the identification of other characteristics (e.g. base saturation, colour). Given the gently undulating landscape of the region, the spatial pattern of the distribution of local soil types is generally related to micro-topography (elevation differences of a maximum of a few metres), which results from the variable intensity of influence of the Cuvelai River. In contrast, the WRB classification is more driven by macro-topography. The lack of macro-topography in northern Namibia renders the linkage of local soil types' distribution to landforms (slope, plateau), and therefore to WRB classes, difficult.

Figure 2 gives an overview of the relation of the local soil typologies to the two scientific classification systems. This schematic representation highlights that soils are divided into different classification groups (e.g. distribution of *omutunda* symbols between regosols, arenosols and calcisols, or S, SL and L). It becomes clear that a simple translation of local soil types into WRB or FCC soil classes is not straightforward.

Figure 2: Schematic representation of the described soil profiles classified in WRB and FCC classifications



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Soil hydrology has a great influence on soil productivity, mostly in relation to rainfall variability. Indeed, both waterlogging and soil drought conditions, even for short periods of time (a few weeks) during the growing season, strongly reduce yields. The occurrence of these short events is not taken into consideration in either the WRB or the FCC.

Based on our findings, we argue that the translation of local soil types into international classifications is not relevant to evaluate soil quality in north-central Namibia. Indeed, the two selected international classifications use soil texture and soil hydraulic conductivity; both treat properties differently than farmers would, yet these properties are highly relevant in the local context and strongly influence soil productivity. Despite a seeming misfit, the local knowledge and the international soil classification complement each other. However, they are more likely to be of interest to researchers and experts than to the farmers themselves.

2.1.6. Advantages of combining local and scientific knowledges

Including farmers' knowledge and trying out a shared research arrangement helped us to highlight important limiting factors for agricultural production in the local context (e.g. soil water availability during the early growing stage) and soil characteristics that are difficult to detect during conventional soil surveys (waterlogging conditions, micro-scale soil heterogeneity). For these reasons, we support the use of local assessment as an entry point to understand and assess soil quality at the regional level. We suggest that stepping back from numerical and quantitative data - without excluding them - can improve soil fertility assessments on local scales. In comparison with natural science surveys, local soil knowledge presents many advantages. Firstly, it assesses quality based on needs; secondly, it requires no laboratory analysis; thirdly, it includes the most relevant characteristics locally - for example, soil water characteristics and humidity variability; and fourthly, it helps to reduce the number of variables that must be assessed for a locally relevant soil quality evaluation (in our case, for pearl millet cultivation) in a specific climate. Modern methods can, however, adequately complement the local soil knowledge by providing standardization (Niemeijer and Mazzucato 2003) and tools for extra-regional communication. Therefore, the two soil knowledge systems should be used in a complementary way.

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2.2. Issues regarding the participatory approach in natural sciences

By increasing our understanding of local soil knowledge we faced important difficulties. We supposed that similar issues came up in other studies that aimed to understand local soil knowledge and therefore reflected on our experiences against the literature. We tended to conclude that despite the usefulness of local soil typology for soil quality assessments, the use of local knowledge has limitations in the communication, which will be explained below using direct quotes from our interviews.

2.2.1. Translations of the concept of "soil"

For soil scientists, soils are vertical successions of horizons, which is a restricted concept that is not recognized in many cultures (Barrera-Bassols et al. 2009). The Oshikwanyama word *edu* [translation of the word "soil"] integrates broad concepts related to space, from landscape to sand. The range of meanings of *edu* led to misunderstandings and confusions about the spatial scale during many interviews. In particular, *omutunda* and *omufitu* were used to point to general landscapes as well as to specific soil types:

> "All over here, people are in *omufitu* area. The other side of the village is in *omutunda*. Mostly you find *ehenge* in *omutunda* area (LM, 80, Oipapakane).[4]
> But at *omufitu* is where you find *ehenge* (AA, 70, Oipapakane).
> All the parcel, like Martha, Kelly, Kalola, here, we are in *omutunda* area, but there are different soil types, like small *omahenene*, or *ehenge*. But in this *omutunda* area, you cannot find *efululu*"[5] (LS, 65, Ondobe).

These quotes show that there is a need to contextualize local knowledge and to acknowledge variation within specific soil types relevant for local users. For example, large areas like villages are referred to as *omutunda* (Ondobe village) or *omufitu* (Ekolola village), thereby considering and understanding these units as landscapes features. Within this context, *omufitu* was described as an "area that is not cleared [of trees] even a little" (KS, 65, Ohengobe). However, shortly after, when the focus shifted to soils, the same informant said: "If I

4 To keep the informants anonymous, we used a code that indicates: 1) a two-letter name; 2) the farmers' age; and 3) the study area of the farm.

5 *Efululu* mostly refers to a type of fine loose sand.

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cultivate on *omufitu*, the *edu* will look red", clearly referring to a soil. *Edu* also refers to soil layers and sand. In the expression, *edu li hapu*, which literally means "a lot of sand", *edu* takes the meaning of sand.

These examples illustrate the permanent differentiation between scales during discussions, while the scales of *edu* are integrated into one another (e.g. *omutunda* soil type in an *omufitu* landscape). Other authors point out the existence of a similar word, with a large range of meaning, in different African regions (Birmingham 2003, Lamers and Feil 1995, Niemeijer and Mazzucato 2003, Osbahr and Allan 2003). "Soil" in English or "terre" in French are two examples from Europe that also cover very large concepts related to space. These overlapping definitions increase the risk of confusion and misunderstandings. However, as used by Hillyer et al. (2006), these soil/landscape names have the advantage of including uncultivated lands, i.e. not ploughed.

From our observations, informants talked more about the landscape definition of *edu* when referring to abstract spatial concepts (e.g. villages) and focused on agricultural soil when referring to their fields. As an example, CH (65, Efidi) claimed that all his farm was in *omufitu*, but during transect walks it was possible to find *omutunda*, *ehenene* and most of the field was *ehenge*, while no *omufitu* was described.

The potential confusion regarding the concept of soil was mostly resolved by specifically improving the precision of communication between the translator and the researcher. Parts of the interviews were transcribed together to differentiate between these scales.

2.2.2. Intergrades

Local typology is highly adaptive to conditions and adjusts to changes - and even the interview context - by the extended use of combined soil names ("intergrades", after Krogh and Paarup-Laursen 1997). The intergrades are good indicators for land degradation or improvement in relation to, for example, land management techniques, and are a way to emphasize certain properties (Birmingham 2003). A soil might, for example, be related to *omutunda* to emphasize its good productivity but *omufitu* to emphasize its loose consistency in comparison to other locations.

> "This soil is a mixed soil of *ehenge* and *ehenene*, it's like a *ehenene-henge* (CH, 65, Efidi).

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> … because all where is *omutunda-henene* if it rains you can sink … (AA, 75, Oipapakane).
> Close to the fig tree and there, it is *ehenge*. In between, there is *omufitu* and it is *omufituhenge*" (KF, 65, Etomba).

During the first interviews at each farm, held in the house, these intergrades appeared only rarely. During transect walks, while trying to understand more details about local soil types, they appeared more frequently. Following the insistence of the interviewers to find the "real" *omutunda*, or the "real" *omufitu*, these intergrades appeared in high proportion.

2.2.3. Local experts

It proved to be very difficult to collect information concerning local soil types in Oshikwanyama from literate or schooled people. English speaking informants (local elite, ministry officer) explained the soil diversity in terms of three "soil" types, namely sandy soils, loamy soils and clay soils. We assume that these informants are aware of the soil diversity and local soil types, but it seemed clear that they considered the information learned in school as more valuable or more in line with the expectations of an outsider in comparison to the local knowledge.

2.2.4. Accuracy of descriptions

The accuracy of soil descriptions collected from the interviews depends on the local soil unit considered. This is related to the various values given to the soil for a specific unit. Verlinden and Dayot (2005) observed that depending on the indigenous land units, soil characteristics have various levels of importance. This explains that soils are more narrowly defined in soil units when used for cultivation.

2.2.4.1. *Omufitu* and the importance of soil versus vegetation information

Omufitu largely refers to areas where bushes are still present, and despite awareness of the scale issue (soil/landscape) of *omufitu*, it was difficult to get clear descriptions for *omufitu* as a soil type (e.g. soil colour; Table 1), mostly because soil characteristics are less important than vegetation in defining this unit.

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> "*Omufitu*, they are different. I think that an area is called *omufitu* if the area is not cleared from trees" (KS, 60, Ohengobe).
> "You can find *omufitu* that will give you good food […], but some of your neighbours with *omufitu* might not get anything from it" (NW, 70, Etomba).

In *omufitu*, soils did not matter much in a relatively recent past, as they were mostly kept for firewood and grazing. Therefore, soil characteristics are not important and soils have different qualities. However, *omufitu* is today increasingly cleared and cultivated, and the number of distinguished *omufitu* soil types may therefore grow with the rising cultivation rate (for a similar example in eastern Burkina Faso, see Niemeijer and Mazzucato 2003).

2.2.4.2. *Omutunda* and the relativity of soil quality in relation to the surrounding environment

In contrast to *omufitu*, soil characteristics are well defined for *omutunda* in the literature and during the interviews, because these soils have been largely turned into fields. This accuracy does not mean that all *omutunda* are similar, but they share a set of characteristics. Almost all informants described them as hard and dark soils.

The quality of a soil in a field is often compared with the other soils in one's own fields, however, and soils are defined comparatively, as observed by Birmingham (2003). Furthermore, it has been observed in various studies that soil quality ascriptions of local soil types may vary depending on various parameters such as individual perceptions (Barrera-Bassols et al. 2006), intended uses (e.g. agricultural versus housing; Gray and Morant 2003, Niemeijer and Mazzucato 2003) or specific environmental conditions in the surroundings (Gray and Morant 2003).

Omutunda was defined as the best soil for pearl millet by most informants.

> "There are different types of *omutunda*. At Tate S., *omutunda* is not good because there is stone; it will only be good soil when you add cow dung" (LN, 65, Omhedi).

Omutunda is "where you feed" (CK, 65, Ohandiba), and farmers tend to describe the most productive part of their land as *omutunda*. The *omutunda* described in or close to the Cuvelai drainage system (Omhedi and Ondobe) is finer and darker than the *omutunda* found in the Kalahari woodland biome (Ekolola). We can show this difference using technical parameters (pH, fine particles content, colour shade; Figure 3). This result indicates that the pro-

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ductivity potential of *omutunda* is lower in the woodland biome than in the floodplain environment, which was acknowledged by the farmers themselves:

> "The soil [*omutunda*] … inside the country [floodplain] breastfeeds on *iishana* … it is hard not like ours [Ekolola area]" (TN, 70, Ohandiba).

A farmer from Omhedi (eastern floodplain) used intergrades to illustrate similar soil quality difference:

> "… that is *omufitu-tunda* …Yes, because did you say it is at Eengonyo [Ekolola area]? *Omufitu-tunda* because that *omutunda* does not occupy a big area" (IS, 75, Omhedi).

In this example, the region (Eengonyo village) is important information to claim that the *omutunda* described is an intergrade between *omutunda* and *omufitu* (*omufitu-tunda)*, because *omutunda* "does not occupy a big area". Indeed, Eengonyo (in the Ekolola area) is situated in an area with a lot of deep sands and forest (*omufitu*).

2.2.4.3. Management and rainfall as influencing soil quality

Another aspect that needs to be taken into consideration is that actual soil quality (the yield achieved on a specific soil in a specific year) is strongly influenced by inputs (e.g. fertilizer, labour, rainfall). Even sandy soils can be productive if fertilizers (mostly manure) are used appropriately.

> "*Omutunda* and *omufitu* produce the same, but it strongly depends on manure availability" (LS, 65, Ondobe).

Consequently, the ongoing decline of livestock density in villages and/or the use of tractor ploughing is leading to a soil fertility decline in many areas. Land degradation was indicated by the transformation of *omutunda* soils (mostly) into other local soil types, which are, by definition, less fertile.

> "Originally our soil was *omutunda*, but then it became *ehenene*…" (CP, 40, Oilyateko).

Conversely, old homestead or kraal locations turn local soil into *omutunda*:

> "The field was just *ehenge*, but it has changed and it looks like *omutunda*, because when we shift the house or the kraal, or apply manure, it changes *ehenge* into something else" (VH, 45, Oilyateko).

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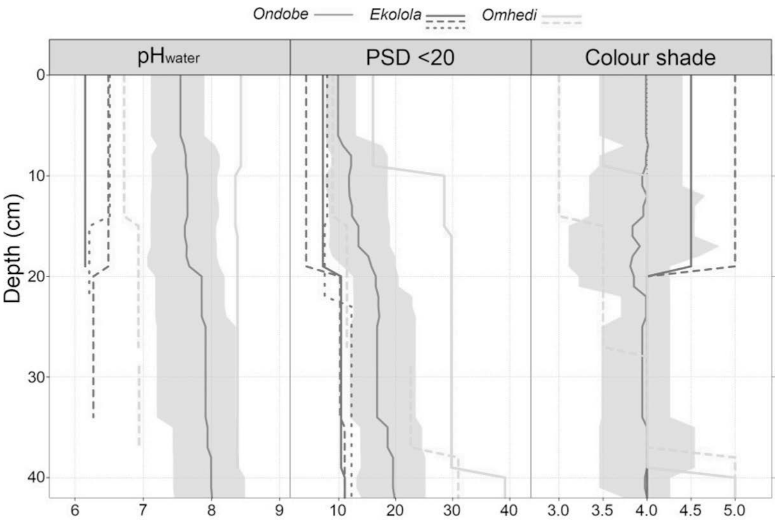
Figure 3: Regional variability of omutunda



The central line represents the median value of described omutunda in Ondobe, the shaded area represent 25 and 75 percentiles. Light grey lines represent the individual profiles of omutunda described in Omhedi and dark grey lines represent the individual profiles of omutunda described in Ekolola. The results indicate that omutunda from Ekolola has a lower pH, finer particle content (PSD <20), and is lighter (higher colour shade).

> "If you go and look at my crops there you will see how the cattle changed the soil. Now sand soil became *omutunda*" (MJ, 60, Omhedi).

Therefore, as soil quality can be altered rather fast through the application of manure or through over-exploitation, correspondingly the soil type can also change in a relatively short period. This highlights that labelling works with culturally built landscapes.

> "The availability of water in soil is the most limiting factor for agricultural productivity in north-central Namibia. Each soil type has a different productivity potential depending on rainfall scenarios (intensity, amount and distribution). Most obvious examples in north-central Namibia are the productivity of *omutunda* and *ehenge* [*Table 1*]. *Omutunda* is productive when rainfalls are frequent but has a poor yield if extended dry spells occur. On the other hand, *ehenge* is more productive during rainy seasons with below average

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> rains. During these years, it will not experience waterlogging conditions. [...] if it rains a lot, *omutunda* does not grow good millet. If there are short rains, then we will harvest at *ehenge*" (JP, 60, Omhedi B).

Consequently, *ehenge* is mainly cultivated to minimize the risk of crop failure during years of poor rainfall. In general, farmers will always plant on a mixture of different soils, not to aim for the best possible yield, but to reduce risks, as described in other studies (Briggs and Moyo 2012, Gray and Morant 2003, Krogh and Paarup-Laursen 1997, Niemeijer and Mazzucato 2003, Osbahr and Allan 2003). This behaviour is described by game theory as a minimax strategy (e.g. Lipton 1982).

2.3. Participatory research in natural sciences: reflections and challenges

2.3.1. Expectations and managing data

During this study, a young natural scientist collected local soil typologies and compared them to international classifications. Many farmers had some difficulties valuing their knowledge with regard to the white male scientist's knowledge. However, once they understood the goals of the study, they were very keen and proud to share their knowledge. Before starting the data collection, both interviewers (scientist and translator) had some expectations regarding the information that would and should be collected. Partly for that reason, early during the data collection period, we concluded that the main local soil types (*omutunda*, *omufitu*, *ehenge* and *ehenene*) can be defined using a limited amount of information. The information summarised in Table 1 is in line with the data collected during each interview, with few exceptions.

However, during the 87 interviews, a large quantity of information concerning soils was collected which did not correspond directly with our expectations. Thus, a continuous selection of information was necessary to do the analysis and to establish Table 1. The information that seemed to the scientist and the translator to be the most relevant information was selected, transcribed, codified and used for further analysis (comparing scientific and local soil knowledge, translation and classification). This led to a potentially biased or incomplete soil typology comparison, as the information which remained unclear, inconsistent or confusing was dismissed. The dismissed information

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might, however, have held important implicit local knowledge. For example, *ehenge* and *ehenene* are two different soil types described by most farmers and in the literature (Table 1), but two informants suggested that these soils are the same:

> "*Ehenge* is *ehenene*. Normally it is called *ehenge*, but it is *ehenene*. *Ehenge* is also *ehenene*, or vice-versa" (JD, 55, Omhedi).

Dismissed because it does not correspond to most opinions, this information may indicate that these two soils are very closely related to each other and differentiating them is irrelevant for some informants. This information highlighted the connection between these soils in relation to waterlogging probability and the presence of a hardened layer at various depths.

Another piece of evidence dismissed is that *omufitu* is considered either good or bad during droughts. Given the high permeability of this soil, we would favour the information that stipulates that *omufitu* is bad during droughts because it does not hold water. This was also the most commonly found information. However, we should not exclude that some *omufitu* might be good (or better) during droughts:

> "The entire field is the same soil [*omufitu*]. It is not suitable for millet ... *Omufitu* does not lose water moisture underground. So, with *omufitu*, people will have at least some millet this year [2013, drought]" (MH, 70, Ondobe).

2.3.2. Dealing with complexity

This information exclusion process was required to communicate and reduce the complexity of local knowledge. The information collected during the interviews can be divided into two levels of local knowledge: i) the local soil groups, with clearly defined characteristics; and ii) the information regarding specific locations, specific terms and incoherence highlighting soil processes. The information found on the first level can be transferred to and used by outsiders without many difficulties. It includes the most explicit information regarding land management (e.g. hardness, waterlogging risks). However, it should not be forgotten that summaries and externalization give only a glimpse into local knowledge and therefore need to be used carefully. The implicit information found in the second level of knowledge is more difficult to access and to make explicit to outsiders, as it varies from person to person. The set of information held in this body of knowledge cannot be codified, classified

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or generalized, and therefore needs to be collected directly (personalized) without any (or only limited) translation or intermediaries. Understanding all variations of this knowledge renders it difficult for outsiders to use. Through externalization to outsiders, a large proportion of this knowledge is lost and misinterpreted (or over-interpreted). It loses accuracy, but could be used in combination with other knowledge.

The summary table (Table 1) is the result of parallel processes of collection and selection performed by the translator and the authors. Identification of the key properties enabled them to use and communicate a simple soil typology that can thereafter be used, for example, in soil quality assessment (Prudat et al. 2018). This simplification often occurs when scientists categorize and communicate environmental and soil local knowledge to outsiders (Barrera-Bassols et al. 2006). However, as discussed above, the soil quality of local soil types is actually more complex than its presentation to readers.

Oudwater and Martin (2003) emphasize that social scientists do not have the necessary tools to understand soil typologies. Conversely, collecting farmers' soil knowledge is not as simple as visiting various farms and asking questions. The understanding of a local soil typology implies that soil scientists experience the local contexts for extended periods, but also to get acquainted with semi-structured interview methods and qualitative data analysis.

2.4. Conclusion and perspectives

The type of shared research we engaged in was to be open to local labelling of soils. We realized through this process that soil classes refer not only to general soil properties, but also to how soils are contextualized regarding the aim of production and the view on environmental factors, and they are set in relation to other areas observed in the neighbourhood.

We discussed the benefits and limitations of using the local soil typology to evaluate soil quality in regions with poorly developed and sandy soils. To collect farmers' knowledge about soils and evaluate their perception of soil quality, soil scientists need to engage with the local community. The explicit knowledge that can be collected and transferred (externalized) is a generalized and codified knowledge, while many implicit details mentioned by a few are excluded. The exclusion of a large proportion of the knowledge collected is criticized, but this process is necessary in order to remain usable to out-

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siders. It should be emphasized when externalizing this knowledge, however, that it does not represent the opinion of all members of the community and that the "local" knowledge has been de-localized and large proportions of implicit knowledge excluded. The possibility of collecting and understanding such knowledge during rapid appraisal should therefore be looked at critically, because local knowledge (e.g. of soils), is based on a comparative basis and changes over time and space.

The high variability and confusing answers collected were frustrating. However, the value of the knowledge accumulated should not be underestimated. We show with our understanding that the classification of natural objects (e.g. soils) is the result of a codification process performed by "experts" (elders, academics), and aims at simplifying the diversity of objects (e.g. *omutunda* defines fertile areas). This classification will vary between experts, and depends on the context in which the object exists and is used.

In general, the main advantage of using a participatory approach in natural sciences is commonly thought to be the involvement of communities in the research. We would argue the other way around, and that it works both ways, in that a participatory approach, by forcing researchers to invest time in the community, engages the researchers in the social context in which the soils are used, giving a broader perspective than the soil itself. In this way, research moves from participatory (including the community in the research) to observatory research (including the researcher in the community). Engaging in local knowledge together with local actors allows us to come to a view on shared knowledge which cannot be reached by rapid methods, but by participating and observing. This emic position opens new perspectives for further researches and further discussions with scientists in various fields of study.

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