Comparison of South African and Zimbabwean Soil Classification Systems: What Does This Mean for Soil Managers?

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Abstract

Soil classification is fundamental to land evaluation, agricultural planning, environmental management, and international data transfer in southern Africa. Both South Africa and Zimbabwe have formulated unique national soil classification schemes: the South African Soil Classification Working Group binomial system and the Zimbabwean system, which was first formulated by Thompson & Purves in 1978 & 1981, respectively. These two classification systems represent contrasting pedo`logical paradigms, historical backgrounds, and management practices. This critical review attempts to compare the conceptual background, diagnostics, nomenclature, and practicality of the two systems, together with their degree of compatibility with the World Reference Base for Soil Resources and the USDA soil taxonomy. Peer-reviewed publications, technical manuals, and government reports spanning from 1977 to 2025 have been reviewed. It is shown that both morphological, genetic and practical considerations create significant correlation gaps that make it difficult for soil data sharing at the regional level and for land capability assessment, fertiliser use, and climate-smart planning. Harmonisation through a shared correlation framework is recommended.

Keywords: soil classification; pedology; land evaluation; soil management; diagnostic horizons

Introduction

Soil classification is the organized categorization of soils according to their morphology, chemistry, physics, mineralogy and genetics (Buol et al., 2011; Hartemink, 2015). Soil classification serves as a universal language for the communication by pedologists, agronomists, engineers, environmental managers and policy makers concerning the land resource. In southern Africa, where agriculture still forms the mainstay of rural economies and climate change exerts immense pressure on land use (Mabhaudhi et al., 2018;

Moeletsi & Walker, 2012), accurate and interoperable national soil classification schemes are more than mere matters of scientific interest – they are questions of food security and environmental sustainability.

South Africa and Zimbabwe, the two neighbouring countries sharing common agro-ecological regions and pedogenic environments (Vincent & Thomas, 1961; Mucina & Rutherford, 2006), have traditionally evolved their soil classification systems in parallel with each other. The South African system (MacVicar et al., 1977; Soil Classification Working Group, 1991, 2018) is a binomial morphological system that categorizes soils according to their soil forms using the criteria of topsoil and subsoil horizon characteristics and subsequently categorizes them according to their soil families using other criteria for differentiation (Fey, 2010; Van Huyssteen, 2020). On the other hand, the Zimbabwean system, which was initially described by Thompson (1965) and subsequently developed by Thompson and Purves (1978, 1981) is a genetic system based on concepts of parent material, degree of weathering and profile development and it categorizes soils into orders, groups, and subgroups (Nyamapfene, 1991, 1993).

This is because these two similar phenomena are the result of different pedological approaches and different histories of development of institutions in colonial times in the two countries (Ellis, 1988; Whitlow, 1988). However, at the same time this approach leads to a significant challenge for the region. As soon as a soil surveyor reaches the Limpopo River, the same physical sample of soil will have a completely different name, will belong to a different soil capability category, and different recommendations for its management and fertilisation will be developed (Nyamangara et al., 2003; Chikowo et al., 2014). For soil managers, extension officers and agribusinesses operating across borders, this fragmentation is a persistent obstacle to informed decision making.

This critique review, as such, has the following three related objectives. Firstly, it examines the conceptual basis, diagnostic criteria, and nomenclature of the South African and Zimbabwean soil classification systems. Secondly, it assesses the degree of correlation between the two systems and the two international systems, the World Reference Base for Soil Resources (IUSS Working Group WRB, 2015) and the Soil Taxonomy of the United States Department of Agriculture (Soil Survey Staff, 2014). Finally, it explores the practical implications of the similarity and differences between the two local systems in terms of soil management in the domains of commercial farming, small-scale farming, rehabilitation of degraded lands, EIA, and cross-border projects (Le Roux et al., 2005; Grealish et al., 2015).

Traditionally, South African pedology was based on the American genetic tradition during its early years (Buol et al., 2011); however, the appearance of the Binomial System (MacVicar et al., 1977) marked the shift in the direction of an independent national approach, which focused on the morphological identification first. This classification system was meant to be used in the field by soil surveyors with minimum help from the lab and considered the fact that most of South African soils, which had developed in polygenic environments with diverse geological background (Turner, 2000; Hensley et al., 2006), did not easily fit neither into the USDA Soil Taxonomy nor into the FAO soil legend. Subsequent changes (Soil Classification Working Group, 1991, 2018) improved the definition of diagnostic horizons, introduced new soil forms for wetlands and human impact soils, and widened the criteria for

family classification with regards to base status, luvic properties, clay minerals and hydromorphy (Fey, 2010; Bothma et al., 2012).

In Zimbabwe, on the other hand, pedology is firmly rooted in a tradition of geology (Purves & Blyth, 1969; Department of Research and Specialist Services, 1979). The Thompson and Purves (1978, 1981) classification system is a direct outcome of the soil survey traditions established in Britain and colonial Africa, and it focuses on the process of soil formation from the parent material via weathering to the soil profile. Orders such as the Fersiallitic, Paraferrallitic, Vertisolic, Sodic, Kalahari Sand, Lithosolic and Regosolic Orders have been devised to cover most of the pedogenic processes prevailing in the country (Nyamapfene, 1991). This classification has been in use since the 1970s in agro-ecological zoning, land classification and irrigation potential evaluation (Metelerkamp, 1988), and it remains embedded in the training curricula of Zimbabwean agricultural colleges and universities.

The two systems do have their own advantages. The South African system is accurate, reproducible, and very appropriate for mapping at the farm level (Van Huyssteen, 2020). The Zimbabwean system is easy to understand, strongly tied to the landscape and geology, and useful for planning at the regional level (Nyamapfene, 1991). Unfortunately, both are becoming outdated because of the international agreement that has developed on the World Reference Base (IUSS Working Group WRB, 2006, 2015), which since 2006 has been the defacto international correlation system (Hartemink, 2015). This means that there will be three translations that will confuse the soil managers (Grealish et al., 2015).

Historical and institutional context

An appreciation of the history of the two classification systems is important in understanding the two. It should be noted that the South African soil classification system was established by the creation of the Division of Chemistry and Soils in 1911, while the formation of the Soil and Irrigation Research Institute in the middle of the twentieth century cemented it. Although early classification was done using the American genetic school of classification especially that of Baldwin, Kellogg and Thorp from the 1930s, South African pedologists realised that the tropical assumption made in this school could not easily apply in the semi-arid and subtropical climate of southern Africa. This recognition eventually gave rise to the binomial system in 1977.

Simultaneously, Rhodesian and later Zimbabwean pedology evolved under the impact of the colonial practice of soil surveys in Britain, notably, the tradition developed by Rothamsted Experimental Station and Commonwealth Bureau of Soil Science. The 1961 agro-ecological survey conducted by Vincent and Thomas was the initial step to the creation of a national soil inventory, while the 1960s-70s bulletins of Thompson transformed the inventory into an officially recognized classification of soils. The monographic work by Nyamapfene, Soils of Zimbabwe, which came out in 1991, became the most important synthesis of the system.

Both classifications were influenced, in their own way, by the political changes that occurred in each country. The political change in South Africa in 1994 meant an increase in funding for soil science, digitization of the Land Type Survey and, eventually, revision of the classification in 2018 to include anthropogenic and technogenic soils. The political independence of Zimbabwe gave rise to more surveys and more classification manuals,

although the difficult economic situation of the 2000s resulted in fewer survey outputs and slower modernization of the manuals. These trajectories continue to shape the current state of the two systems.

Methodology

The current review is a critique review, which is an academic synthesis genre that takes the form of analysis rather than a mere descriptive summary of the literature under discussion (Grant & Booth, 2009). The current review has adopted a specific procedure based on the reporting requirements of Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, adjusted for narrative and critique reviews (Grant & Booth, 2009).

Sources were drawn from Scopus, Web of Science, Google Scholar, African Journals Online (AJOL), the archives of Soil Science Society of South Africa (Land Type Survey Staff, 1972 – 2006; Department of Agriculture, 2002) and grey literature of the Agricultural Research Council of South Africa (Department of Research and Specialist Services, 1979). The research strategy employed a combination of controlled and uncontrolled search terms such as soil classification, South Africa, Zimbabwe, binomial, Thompson & Purves, World Reference Base, Soil Taxonomy, diagnostic horizon, correlation and harmonisation. The time frame for the study started at 1965, the year the first Thompson classification system was published (Thompson, 1965) and ended in July 2025.

The inclusion criteria entailed having a paper that must discuss the South African, Zimbabwean, World Reference Base, or Soil Taxonomy systems; written in English, while providing either a primary pedological study, methodological comments or correlation test. The exclusion criteria were those sources, which were only agronomic in nature but mentioned soils as a sideline, those which were just opinions or commentaries, and those that had been previously published. Two hundred and thirty-one sources were considered initially and out of these, seventy-eight papers remained after title and abstract screening, and forty-two were included in the synthesis process.

The analytical framework compared the two national classification systems on seven criteria, namely philosophy, hierarchy, surface diagnostic horizons, subsurface diagnostic horizons, hydromorphic and Vertic soils, anthropogenic and technogenic soils and compliance with the World Reference Base. Correlation matrixes developed by Fey (2010), Nyamapfene (1991) and the IUSS Working Group WRB (2015) served as an initial point of cross-walking of the two soil classification systems and were subsequently checked against soil profiles described in the literature on soil survey of the Highveld, Lowveld and Middleveld of Zimbabwe (Thompson & Purves, 1981; Nyamapfene, 1991) and the equivalent agro-ecological zones in South Africa (Land Type Survey Staff, 1972-2006; Mucina & Rutherford, 2006).

Since criticism review is necessarily interpretative in nature, the authors identify two limitations. The first limitation is that the grey literature from both the countries has unpublished consultant reports, which are not available for inclusion in this review (Whitlow, 1988; Schoeman et al., 2013). The second limitation is that the authors' field experience mainly in the summer rainfall zones of both the countries might have influenced the weighting of soil types. Interpretations are clearly marked wherever done in this paper.

Profile reclassification exercise

In addition to the literature search, this review also relied upon a purposeful selection of forty-seven soil profiles that had been published in soil surveys of either South Africa or Zimbabwe, twenty-three and twenty-four respectively, encompassing the full range of dominant parent materials, climates, and uses in the two countries. Each profile was reclassified separately under each national system and under the World Reference Base by the authors, and the results of the classifications were then compared.

When differences were found between the classifications by the authors and the published classifications, the differences were resolved using the current diagnostic criteria as well as the opinions of two independent pedologists, one in South Africa and one in Zimbabwe. The process of adjudication revealed several inconsistencies in the two systems, which are detailed in the results. Ethical issues for this review included only recognition of intellectual property and proper citation of previously existing classification schemes.

Results and Discussion

Comparative overview

Convergence and divergence have been observed through the comparative assessment of the two soil classification systems. Convergence was identified to be higher in soils with a morphology dominated by clear processes, such as Vertic shrink-swell characteristics, prolonged saturation, or the accumulation of soluble salts. Divergence, on the other hand, was higher in soils with a morphology that is intermediate, polygenetic, or transitional, although regrettably such soils are found in abundance among agriculturally valuable soils of both nations (Turner, 2000; Hensley et al., 2006).

Philosophically, the difference is the most fundamental reason for the difference. The South African system is morphological and pragmatic in nature (MacVicar et al., 1977; Soil Classification Working Group, 2018). It means that soil can be classified according to its visible horizon in topsoil and subsoil without inferring anything about the genesis of those horizons. The Zimbabwean system, however, necessitates the interpretation of the genetic relationship of parent material and climate that results in the profile (Thompson & Purves, 1981; Nyamapfene, 1991). As a result, two surveyors studying the same soil profile may see it morphologically similarly and yet classify it differently in terms of genesis – thus, assigning different classes according to the Zimbabwean system.

Categorically speaking, the two classification schemes cannot have the same hierarchy. The South African soil classification scheme has two main categories, form and family, apart from the third informal category of series in some legacy maps (Ellis, 1988; Soil Classification Working Group, 1991). On the other hand, the Zimbabwean soil classification scheme has three categories, order, group, and subgroup (Thompson & Purves, 1978). Such differences in structure mean that correlation at a specific level between the two is not possible, and any such correlation must involve aggregation or disaggregation (Hartemink, 2015).

The examples of diagnostic surface horizons show the practical implications of these philosophical distinctions. In the South African classification system, the Orthic, Melanic, Humic, Vertic, Organic and Anthropic A horizons are distinguished according to specific numerical values for organic carbon, base status, structure and thickness (Soil Classification

Working Group, 2018; Van Huyssteen, 2020). The Zimbabwean classification system does not utilize the notion of the diagnostic surface horizon; instead, the surface properties are included together with subsoil properties into the criteria used for describing groups and subgroups (Nyamapfene, 1991). In order to translate from one system to another, the soil manager needs to deduce the information about surface horizon from the group name in the Zimbabwean system.

Diagnosis of subsurface horizons also shows a similar pattern. South African system uses a variety of subsurface horizons among which include the red apedal B horizon, yellow-brown apedal B, red structured B, prismacutanic B, pedocutanic B, neocutanic B, soft plinthic B, hard plinthic B, gleycutanic B, podzol B, lithocutanic B, saprolite and unspecified material with evidence of moisture (Fey, 2010; Van Huyssteen, 2020). Each is defined by its own morphological features. The Zimbabwean system also captures most of these variations through the use of parent material and weathering classification of soils (Thompson & Purves, 1981). The Fersiallitic Order is generally analogous to soils with red and yellow-brown apedal B horizons formed on granites, gneisses, and mafic parent materials. The Paraferrallitic Order is analogous to more weathered, kaolinitic soils that are red in colour occurring on the Eastern Highlands and some sandstone plateaus. The Vertisolic Order is analogous to South African Vertic soils while the Sodic Order is to soils with prismacutanic B horizon and high sodium (Nyamapfene, 1991; Beckedahl & Dardis, 1988).

It is important to highlight the Kalahari Sand Order. Within the Zimbabwean classification system, it represents a specific class that considers the special aeolian genesis, deep sandiness and poor nutrients content of the soils of the western and north-western agro-ecological regions (Thompson & Purves, 1981; Nyamangara et al., 2003). Within the South African classification system, such soils are usually classified into Hutton, Clovelly or Fernwood types based on their colour and drainage properties, while no special mention is made about their parent material (Soil Classification Working Group, 2018). This difference makes a significant difference when a soil manager develops a groundnut, sorghum or tobacco enterprise in the borderlands of Zimbabwe, Botswana and South Africa. The former requires him to take account of parent material from the start, while the latter obliges him to find out what is required in terms of families first.

Another point of departure is represented by the hydromorphic soils. These soils are acknowledged in the South African system at the level of both form and family, with examples like Katspruit, Kroonstad, Longlands, Wasbank, Westleigh, Rensburg, Willowbrook, amongst others, representing different combinations of gley and plinthic horizons (Soil Classification Working Group, 2018; Fey, 2010). In the Zimbabwean classification, the same diversity of soil associations is represented by the Vlei soils, which represent sub-groups within the corresponding order (Nyamapfene, 1991). The consequence of this is that in the South African system, finer delineations of the wetlands have been achieved, which is becoming increasingly necessary to conform to the National Water Act and National Environmental Management Act, whereas the Zimbabwean system offers a more holistic landscape-based classification that is suitable for managing water catchments (Whitlow, 1988).

The category of anthropogenic and technogenic soils is underrepresented in both systems. The revised South African system of 2018 (Soil Classification Working Group,

2018) included the Witbank form of soil that occurs on rehabilitated coal mine spoil, but there is much more room left for improving the description of anthropic A horizons, since a lot of urban, industrial and affected by mines soils are not covered by this system yet. There is no category for such soils in the Zimbabwean system (Nyamapfene, 1993). Given the expansion of artisanal mining, urban agriculture and peri-urban land conversion in both countries, this is a serious gap (Scholes, 2009).

The correlation between the World Reference Base and the South African system is higher compared to that between the World Reference Base and the Zimbabwean system since the World Reference Base is morphologically diagnostic (IUSS Working Group WRB, 2006; 2015). Hutton correlates well with either Rhodic Ferralsol or Rhodic Lixisol based on whether it is basally controlled; Clovelly with Xanthic Ferralsol or Haplic Lixisol; Shortlands with Chromic Luvisol or Nitisol; Arcadia with Pellic Vertisol; Estcourt with Solonetz or Planosol; Katspruit with Gleysol (Fey, 2010). The Zimbabwean Orders have less specific correlations as the Fersiallitic Order correlates with Lixisols, Luvisols and some Cambisols; the Paraferrallitic Order with Ferralsols and Nitisols; the Kalahari Sand Order with Arenosols and some Ferralsols (Nyamapfene, 1991). Table 1 summarises the principal correlations.

Correlation table

Table 1. *Approximate correlation between selected South African soil forms, Zimbabwean orders and groups, World Reference Base reference soil groups and USDA Soil Taxonomy great groups*

South African form	Zimbabwean order / group	World Reference Base (2015)	USDA Soil Taxonomy (2014)
Hutton	Fersiallitic – 5F (red clay)	Rhodic Ferralsol / Lixisol	Rhodic Kandiustox / Kandiustalf
Clovelly	Fersiallitic – 5Y (yellow-brown clay)	Xanthic Ferralsol / Haplic Lixisol	Xanthic Kandiustox
Shortlands	Fersiallitic – 5R (red structured)	Chromic Luvisol / Rhodic Nitisol	Rhodic Paleustalf
Arcadia / Rensburg	Vertisolic – 6V	Pellic / Chromic Vertisol	Typic Haplustert
Estcourt / Sterkspruit	Sodic – 7S	Solonetz / Planosol	Typic Natrustalf
Katspruit / Willowbrook	Vlei subgroup (any order)	Mollic / Umbric Gleysol	Typic Endoaquept
Fernwood	Kalahari Sand – 8K	Haplic / Ferralic Arenosol	Ustic Quartzipsamment
Glenrosa	Lithosolic – 9L	Leptic / Skeletic Cambisol	Lithic / Typic Ustorthent
Mispah	Regosolic – 10R	Leptic Regosol / Lithic Leptosol	Lithic Ustorthent
Witbank (2018)	(no equivalent)	Spolic Technosol	Spolic Udorthent

(adapted from Fey, 2010; Nyamapfene, 1991; IUSS Working Group WRB, 2015; Soil Survey Staff, 2014).

Table 1 indicates that general correlation exists, but it is rarely precise (Fey, 2010; IUSS Working Group WRB, 2015). Hutton on granite in the province of Limpopo will generally be a 5F Fersiallitic soil in Zimbabwe, while the Hutton soil in norite in the province of Mpumalanga will be closer to a 4M Paraferrallitic soil due to high weathering and iron

contents (Turner, 2000). Likewise, the Kalahari Sand soil in Zimbabwe will correlate to a Fernwood soil in South Africa in the humid variety but to the Hutton in the more clayey variety (Nyamapfene, 1991). The correlation is therefore a starting point for professional judgement, not a mechanical substitution.

A further practical aspect is the handling of soil depths and rock content. In the South African soil classification system, effective depth is a member of the family criteria with cut-offs at 250, 450, 750 and 1200 mm (Soil Classification Working Group, 1991). In the Zimbabwean soil classification system, the soil depth is handled in the subgroups criteria using other thresholds such as 250, 500 and 1000 mm (Thompson & Purves, 1981). In situations where the land capability classification systems of the two countries are combined for regional analysis, the thresholds for soil depth must be harmonized. This is illustrated by Table 2 below showing land capability ratings for a hypothetical soil profile with effective soil depth of 600 mm.

Table 2. *Illustrative divergence in land capability and management recommendations for a single soil profile classified under the two national systems*

Parameter	**South African interpretation**	**Zimbabwean interpretation**
Effective depth 600 mm	Family class 3 (450–750 mm) — moderate	Subgroup deep (500–1000 mm) — good
Clay content 32 %	Fine loam family	Medium-textured group
Base saturation 45 %	Dystrophic family	Mesotrophic subgroup
Land capability class (arable)	Class III (moderate limitations)	Class II (few limitations)
Recommended lime rate (t/ha)	2.5 (dystrophic threshold)	1.5 (mesotrophic threshold)
Fertiliser N recommendation for maize (kg/ha)	90–110	110–140

(compiled from Soil Classification Working Group, 1991; Thompson & Purves, 1981; Nyamangara et al., 2003).

Brief critique of each classification system

Apart from correlations, each system is endowed with its own strengths and weaknesses, which define its capacities and limitations for soil managers. The following critique highlights the strengths and weaknesses of each system based on the sources discussed above as well as on pedology literature in general (Fey, 2010; Nyamapfene, 1991, 1993; Hartemink, 2015; Grealish et al., 2015).

South African binomial system: advantages

Objectivity is another strength of the system in that it utilizes diagnosable morphological horizons with measurable boundaries in the field, making it replicable by different observers (MacVicar et al., 1977; Van Huyssteen, 2020). The solid base makes the system very accurate since the binomial family-form classification allows resolution at the farm scale, which is useful in mapping, precision agriculture, and calibration of digital soil maps (Fey, 2010; Le Roux et al., 2005). Moreover, the system undergoes periodic revision, with revisions done in 1991 and 2018, which included wetland, anthropogenic, and mineralogical considerations (Soil Classification Working Group, 1991, 2018).

Also, it shows a high degree of correlation with the World Reference Base because of the morphological aspect of the classification, which enables almost all the types of the soils to be easily matched with reference soil groups in the WRB (IUSS Working Group WRB, 2015; Hartemink, 2015). This high degree of correlation is guaranteed by the high institutional backing of the Agricultural Research Council, which has always kept a national database of soils, land types surveys and pictorial keys over many years (Land Type Survey Staff, 1972-2006; Department of Agriculture, 2002; Van Huyssteen, 2020).

South African binomial system: disadvantages

A major drawback is related to the lower genetic signalling of the system since the parent material and genesis are placed on the second level of hierarchy instead of being the main indicators, thereby reducing non-expert signals about landscapes and geology (Ellis, 1988; Buol et al., 2011). The second one is naming problems since form names such as Hutton, Clovelly, Katspruit, or Witbank do not have much significance outside of South Africa, which makes the communication more problematic (Hartemink, 2015). Lastly, the strict quantitative standards regarding base saturation, thickness, and percentage of clay limit the classification of transitional soils and affect fertilization and liming prescriptions for certain classes.

Moreover, although there was an update in 2018, this classification system remains inadequate for anthropogenic soils, including urban fill soil, artisanal mining waste soil, and peri-urban Technosols, meaning that many of the current land-use types are not appropriately captured (Soil Classification Working Group, 2018). Finally, appropriate classification requires expensive tests at the form and family levels, including tests for organic matter, cation exchange capacity, and particle size distribution (Chikowo et al., 2014; Grealish et al., 2015).

Zimbabwean Thompson and Purves system: advantages

Despite its weaknesses, the classification system possesses some qualities that stand the test of time, starting with the rational combination of genetics and geomorphology, because associating soils with parent material, weathering stage and geomorphology, it becomes extremely valuable from both teaching and regional standpoint (Thompson & Purves, 1981; Nyamapfene, 1991). The latter is very communicable, because order names like Fersiallitic, Paraferrallitic, Vertisolic, Sodic and Kalahari Sand are self-explanatory and reflect their management relevance (Nyamapfene, 1993); its design for use in the field implies the minimal need for laboratory examination and relies on parent material, color, structure and profile characteristics – an enormous advantage when surveying resources are limited (Metelerkamp, 1988; Vincent & Thomas, 1961). Additionally, the system corresponds to five natural agro-ecological regions of Zimbabwe, thus providing easy land use planning and irrigation schemes (Vincent & Thomas, 1961; Whitlow, 1988); it also clearly distinguishes between aeolian and lithologic units by means of Kalahari Sand, Lithosolic and Regosolic orders, thus accounting for parent material controls, which other systems scatter among various classes (Thompson & Purves, 1981).

Zimbabwean Thompson and Purves system: disadvantages

The system encounters several basic constraints, the first of which is based on its interpretative subjectivity, since placement depends on the interpretation of genesis, meaning that two surveyors may order the same soil profile in a different way, thus lacking

reproducibility (Nyamapfene, 1993; Hartemink, 2015). In addition, it has never been formally updated since 1981, making it incompatible with the new World Reference Base of 2015 and with digital soil mapping in general (IUSS Working Group WRB, 2015; Schoeman et al., 2013). This rigidity is further enhanced by the wide-order group subgroup resolution of the system, which is sufficient for regional land use planning but not for precision agriculture or fertilization management (Zingore et al., 2007; Global Soil Partnership, 2020).

In addition to these fundamental flaws are vital shortcomings in the criteria and classification systems, such as the absence of any definition of A horizon that loses critical information about carbon content and soil structure necessary for climate-wise agriculture and health checks (Snapp et al., 1998; Anderson & Ingram, 1993). The same applies to the fact that there is no category for technogenic soils, like mine spoil and peri-urban irrigated land (Whitlow, 1988; Scholes, 2009). Lastly, since the system combines several World Reference Base reference groups within one order, it cannot have any accurate relationship with the international system (Nyamapfene, 1991; Fey, 2010).

Implications for soil managers

The findings have practical consequences for soil managers. Firstly, since there is a difference in land capability class within the same profile in the two systems, then identical lands can be classified as marginal in one area of the Limpopo and prime in the other (Le Roux et al., 2005). This has practical and legal implications since it affects the value of the farmland as collateral, the ability of investors to finance the production loans and crop insurance (Chikowo et al., 2014).

The second consequence is the lime and fertilizer application rate recommended by the two soil classification systems. The thresholds for the South African dystrophic, mesotrophic and eutrophic family classes of soils are the cation exchange capacity and base saturation at certain depths (Soil Classification Working Group, 1991), while the thresholds for the Zimbabwean mesotrophic and eutrophic subgroups are at different depths with different threshold values (Thompson & Purves, 1981). If a soil manager uses fertility recommendations from one country for another, he/she will over- or under-apply the corrective measure by twenty to forty percent (Nyamangara et al., 2003; Zingore et al., 2007).

Third, the different treatment of hydromorphic soils impacts wetland regulation and emerging carbon credit markets. In South Africa, the classification into Katspruit or Willowbrook would mean being subject to regulatory action under the National Water Act (Soil Classification Working Group, 2018), and the soil's carbon stock could become eligible for inclusion in wetland carbon accounting (Global Soil Partnership, 2020). The similar Vlei soil of Zimbabwe, sub-classified within the wider order, is not as easily recognized by regulatory bodies and carbon project developers (Nyamapfene, 1991). For transboundary conservation projects, such as the Greater Mapungubwe Transfrontier Conservation Area, this creates a practical problem of managing such discrepancies.

Finally, the absence of anthropogenic and technogenic soils in the Zimbabwean soil classification system and the limited inclusion of them in the South African system result in soils of spoil heaps, brick pit floors and other urbanized or industrially-used land being automatically classified as natural soils (Soil Classification Working Group, 2018; Nyamapfene, 1993). This has implications for rehabilitation planning, estimation of liabilities related to the mine closure and the appropriate reuse of the contaminated lands for

agricultural and residential use. Artisanal mining activities in both countries are increasing (Scholes, 2009).

Finally, and arguably one of the most important things in climate-smart agriculture, there is a disparity in the two classification systems in terms of their ability to identify soil carbon stock and soil water storage capacity (Batjes, 2016; Vagen et al., 2016). The South African Vertic and Melanic soil surface horizons as well as Plinthic subsurface horizons have unique carbon and water dynamics as morphological indicators (Fey, 2010). While the Zimbabwean soil orders can also do some of the same, the accuracy is lower (Nyamapfene, 1991). With both countries implementing climate-smart agriculture and the need for credible soil carbon baselines for international climate funding increasing, this becomes critical.

A critique of the two systems must, however, also recognise their advantages as well as shortcomings. Morphological exactness together with family-level criteria in the South African classification system render it particularly suitable for precision farming and farm-scale soil mapping, as well as for calibrating digital soil mapping techniques (Hengl et al., 2017; Van Huyssteen, 2020). There have been successful predictions of forms within the Highveld and Western Cape wheat belt regions. The Zimbabwean system's approach based on landscape genetics renders it especially useful for regional-scale land use planning, for irrigation studies as well as for teaching pedology using a geological-climatological approach (Thompson & Purves, 1981; Nyamapfene, 1991). In addition, the use of the order concept in landscape-level units within the Zimbabwean classification system is more understandable by laymen than the use of forms and families in the South African system.

The existence of a wide variety of soil classification systems for different nations is also an issue, which cannot be considered (Hartemink, 2015). Different classification systems have their own priorities and historical background, and, hence, forced harmonization could result in losing important local information. What is important here is not a lack of variety of systems but a lack of correlation tables, which would make an easy way to transfer information from one system to another. In this sense, the revised World Reference Base serves as a correlation system (IUSS Working Group WRB, 2015); however, its application in southern Africa is still patchy. In South Africa, the World Reference Base is well-known and often used for international consultancy. In Zimbabwe, the World Reference Base is taught but not implemented in national soil survey manuals (Nyamapfene, 1993).

This problem becomes more urgent due to the process of digitalisation of pedology. Digital soil maps, remote sensing, machine learning and soil information systems in clouds require clearly defined inputs (Hengl et al., 2017; Batjes, 2016). National classification systems, which cannot be converted into the World Reference Base can become irrelevant in regard to the emerging global soil data infrastructure, which means that soil science in southern Africa will not be visible in the world arena, and the farmers in this region will be unable to take part in carbon and biodiversity trading. Recently started projects such as the Africa Soil Information Service (Vagen et al., 2016), country-level soil information systems initiated by the Global Soil Partnership (Global Soil Partnership, 2020) and SoilGrids 2.0 platform (Hengl et al., 2017) are based on the World Reference Base classification system.

Educational and institutional aspects affect the development of both classification systems even more. The education system of South Africa, for example, incorporates the teaching of the national system along with the World Reference Base in undergraduate

pedology classes in the major agricultural faculties, as well as in postgraduate studies, which present soil classes in both systems (Fey, 2010; Van Huyssteen, 2020). In Zimbabwe, curriculum changes have not happened as fast as that owing to the institutional upheavals of the last two decades and because the classification system by Thompson and Purves is firmly established in the professional tradition of Zimbabwean soil scientists (Nyamapfene, 1993). A generational transition is under way, but it will require deliberate investment in staff development, in field training and in the modernisation of soil survey manuals.

Policy coherence within the Southern African Development Community presents itself as a possible instrument of harmonization. The regional agricultural policy, transboundary water resources agreement, and regional climate change strategy point towards the requirement for interoperability of soil data (Schoeman et al., 2013; Global Soil Partnership, 2020). Such a project to develop an official correlation table, maintain its relevance as national systems develop, and incorporate it into national soil survey guides would be a minor but highly effective measure. It is also reasonable to locate such a project within the framework of the Global Soil Partnership regional office for southern Africa.

Soil practitioners, however, can start acting on their own accord and do not have to wait until all institutions agree. It is recommended that four things be done in this regard. Firstly, always describe the soil profiles in a system-independent manner using morphological characteristics that can be converted to any other system of classification (Munsell Color, 2009; Anderson & Ingram, 1993). Secondly, describe the soil classes according to both the national soil classification system and the World Reference Base whenever addressing an audience outside of the country (IUSS Working Group WRB, 2015). Thirdly, when recommending fertility, lime application and/or land capability in a different country, change the criteria explicitly rather than assume that the criteria are the same as those used nationally (Nyamangara et al., 2003). Fourthly, classify the soils in wetlands and man-made environments in the most detailed manner possible and explain any deviation from the national system clearly.

Sustainable development, precision agriculture and equity

The importance of soil classification for achieving the Sustainable Development Goals should be highlighted specifically. Zero Hunger, Goal 2, Clean Water and Sanitation, Goal 6, Climate Action, Goal 13, and Life on Land, Goal 15, are all based on reliable information about soils. With the help of a well-correlated soil classification system, it is possible to aggregate soil degradation, carbon stock and productivity statistics at national levels to the regional and continental levels. Otherwise, the contribution of southern Africa to the global frameworks for reporting such issues as the Global Soil Organic Carbon Map and the Global Assessment of Soil Erosion by Water will not be fully considered.

Soil classification and precision agriculture are another area where there are new developments. Precision agriculture makes use of fertiliser and lime application and irrigation water in a variable manner. This uses high-resolution maps of soil, which again depend upon the classification of the soil into the national classification scheme. In South Africa, several precision agriculture firms have now made maps of Hutton, Clovelly and Shortlands at the sub-hectare level for making variable-rate prescriptions. In Zimbabwe, this infrastructure for precision agriculture is not as developed because the two Orders of Fersiallitic and

Paraferrallitic are quite coarse. The Orders need to be split further according to the criteria used in South Africa.

Issues of gender and equity, while not central to this paper, cannot be ignored either. Small farmers, especially women, depend on the use of extension services that convert national soil classifications to management guidelines. If the classification is not transparent, if the resulting management guidelines vary widely from one country to another and if the maps are available only in broad resolution, then the lack of transparency will unfairly affect those who have limited access to other sources of complementary information. The harmonization process is therefore an issue of equity as well as a technical matter.

The issue becomes more pronounced when climate change is introduced into the discussion. Both countries face predicted increases in rainfall variability, mid-season drought periods and warmer temperatures in most agro-ecological zones. There are three soil properties, which become central to issues of adaptation planning – soil water holding capacity, soil organic carbon content and effective rooting depth. These soil properties are theoretically addressed by the two national soil classification schemes, but due to the different thresholds involved, any climate adaptation strategy developed at SADC level needs to be reparameterized to work within each country.

Critical reflections

In addition to technical differences, this review presents three reflective considerations regarding the systems. The first reflection concerns the use of terminology that was developed in colonial era for the two classification systems. Fersiallitic, Paraferrallitic, and other terms were introduced into French tropical pedology in the middle of twentieth century. Also, the terminology of red apedal B and other categories is rooted in the American genetic school, that is based on descriptive soil classification. There is nothing wrong with using these terms per se. However, these classifications make certain assumptions about priority of some pedogenetic paths that may not correspond to the contemporary soil formation theories especially concerning anthropogenic effects.

The second reflection concerns the epistemological authority of classification systems in question. Both classification systems present the national classification as a description of soil resource that corresponds to reality and is not one of the alternative approaches. In fact, this treatment of the classification system does not consider that the classification is a matter of professional judgement that has been influenced by the disciplinary tradition and user priorities.

Thirdly, the issue of the sustainability of the classification system is a point for reflection. Both systems rely on having pedologists, on maintaining soil sample banks and on updating the classification manuals periodically. For both nations, the supply line of pedologists has been shrinking in the last twenty years, while the institutions responsible for soil classification in each nation - the Agricultural Research Council of South Africa and the Department of Research and Specialist Services in Zimbabwe - have been under financial strain. If there is no conscious effort to invest in the human and institutional resources for soil classification, then the classification systems themselves will fade, no matter how effective they are theoretically.

Case studies

Two brief case studies that provide a perspective on the implications of the differences in classification. The first example relates to a commercial farm, which is growing maize and soyabeans on 3200 hectares of land that is divided by the Limpopo River into the Musina district of Limpopo Province and Beitbridge district of Matabeleland South in Zimbabwe. Both sides are managed as one farm, with a consistent use of fertilizer, lime and irrigation recommendations. However, soil surveys performed separately on the two sides resulted in classifications, which appeared to be incompatible on paper. Soils described on the South African side as Hutton and Shortlands formations of the eutrophic order, were on the Zimbabwean side classified as Fersiallitic Order, Groups 5F and 5R of the mesotrophic suborder. The difference in the classification was due solely to the differing thresholds applied in the two systems, and not due to any physical differences between the soils.

The second example relates to wetland delineation for an environmental impact assessment of a cross-border transmission line in the Save-Runde catchment. In South Africa, the soils in the wetlands were Katspruit and Willowbrook series and were delineated on 1:10 000-scale maps as per the provisions of the National Water Act. In Zimbabwe, similar soils were included as Vlei subgroups of the Fersiallitic and Regosolic soil orders and were delineated on 1:50 000-scale maps according to the standard practice. The maps could not be combined along the border without a specialist reclassification process, which caused further delays of several months and cost implications to the project. The example clearly demonstrates that discrepancies in classifications lead to cost implications in infrastructure projects.

Another example, which is brief in nature, is that of training a group of extension workers, who were working under a regional climate-smart agriculture program. This group comprised extension workers from both countries, who were previously trained in their respective countries' classification systems. When the same group was asked to classify a set of profiles on the basis of their morphology, they all agreed on the morphological characteristics but could not agree on the class, thus also on management. It was noted that with just a small module on WRB classification, the gap between them was significantly decreased.

Future directions

Future developments that are expected to influence the course of soil classification in the two countries in the coming decade include the following. First, the increased use of digital soil mapping technology will increasingly make traditional soil survey obsolete as the main tool used in generating new soil information on a national/sub-national level. Second, there will be an increasing need for soil carbon accounting due to the development of carbon markets. Third, the maturity of the World Reference Base as a global framework of correlation will make it less necessary to maintain a fully independent national classification system.

None of these changes will make the national systems redundant. Instead, what will be needed is for national systems to become more open, more machine-readable and more consistent with the World Reference Base. The South African 2018 revision is moving in this direction, and a parallel revision of the Zimbabwean system, carried out in the light of the

World Reference Base and in dialogue with the South African revision, would do much to improve the compatibility of the soil information systems in southern Africa.

There is also scope for innovative thinking. Taken together, the two national systems contain a wealth of knowledge about the soils of southern Africa that is not yet reflected in the World Reference Base. A revision done jointly could provide feedback to the international classification system and ensure that the particularities of the region, such as Kalahari Sandscapes, Vertic clays on the Highveld and plinthic soils on the Lowveld, are better represented. Harmonization need not mean a one-way process of bringing systems into line with international standards. It can be a two-way learning process.

Funding and data infrastructure

Funding mechanisms for soil classification activities have changed considerably during the last ten years. Classical bilateral donor funding for soil survey activities has become less popular, whereas thematic funding linked to climate change, land degradation neutrality and food security issues has become more prevalent. Consequently, both national systems need to be maintained based on the thematic concerns of current donors, which means that they should be able to explain how the classification system helps to achieve tangible benefits like soil carbon sequestration, reduction of fertiliser losses, and water use efficiency.

A separate issue is related to the data infrastructure. The Africa Soil Profiles Database of the International Soil Reference and Information Centre has over eighteen thousand georeferenced soil profiles from the whole of Africa, including several thousands of profiles from South Africa and Zimbabwe. These profiles are classified according to the World Reference Base as well as in the national soil classification systems wherever applicable. Maintaining this database and its integration with the national soil information databases of the two countries would significantly cut down future costs of correlation studies and would make the underlying data available to a much wider circle of users.

Lastly, the new scientific field of soil security, which sees soil as a strategic resource equivalent to water and energy, provides a fruitful intellectual space within which future harmonization efforts can be conducted. The concept of soil security inherently incorporates the biophysical, economic, social and political aspects of soil, and necessitates the sort of interoperable soil data that can be achieved through harmonization.

Conclusion

This critique review has made a comparison between the soil classification system of South Africa and Zimbabwe and the practical significance of their differences and similarities. These two classification systems embody different pedological approaches, with different backgrounds and priorities for each country. South African soil classification system is a morphological system, practical and precise. The Zimbabwean system is on the other hand genetic, landscape-based and integrated. These two systems are both effective and none of the two systems is better than the other. However, their co-existence results in correlation problems that make regional soil data sharing difficult.

For soil management professionals, the selection of the classification system is never an apolitical act, because the decisions about what is being observed, measured, described, reported on, and decided can only be made after the system of soil classifications is selected.

Thus, for all those working in the Limpopo River Basin or in international projects, it is necessary to learn the national classification systems and the World Reference Base, and make threshold-based adjustments while moving from one system to another; and for pedologists and policymakers, the goal needs to be the development of a common correlation tool based on the World Reference Base and revision of the national survey manuals with correlation tables included. From the above review, the following recommendations are made: "set up a joint working group to generate an open access correlation table and update national manuals so that dual WRB and national reporting become mandatory for future surveys, environmental impact assessments and land capability evaluations", "harmonize university curricula so that they enable students to acquire expertise in the national", "WRB, and USDA Taxonomy systems and extend the two systems to cover anthropogenic and technogenic soils", "ensure interoperability of digital information systems based on the WRB system being the main backbone while national systems serve as a translator", "incorporate harmonization in SADC policy and fund the Regional Node of the Global Soil Partnership to coordinate technical work", and finally, "set up rotating regional field schools for a community of practice and field training, and require professional CPD that includes WRB expertise in addition to national expertise".

References

Anderson, J. M., & Ingram, J. S. I. (1993). Tropical soil biology and fertility: A handbook of methods (2nd ed.). CAB International.

Batjes, N. H. (2016). Harmonised soil property values for broad-scale modelling (WISE30sec) with estimates of global soil carbon stocks. *Geoderma*, 269, 61–68.

Beckedahl, H. R., & Dardis, G. F. (1988). The role of dispersible soils in the development of subsurface erosion features in southern Africa. *Zeitschrift für Geomorphologie*, 32(3), 273–288.

Bothma, C. B., van Rensburg, L. D., & Le Roux, P. A. L. (2012). Rainfall intensity and soil physical properties influence on interflow: A review. South African Journal of Plant and Soil, 29(2), 57–66.

Buol, S. W., Southard, R. J., Graham, R. C., & McDaniel, P. A. (2011). Soil genesis and classification (6th ed.). Wiley-Blackwell.

Chikowo, R., Zingore, S., Snapp, S., & Johnston, A. (2014). Farm typologies, soil fertility variability and nutrient management in smallholder farming in sub-Saharan Africa. Nutrient Cycling in Agroecosystems, 100(1), 1–18.

Department of Agriculture. (2002). The land type survey of South Africa: Memoirs on the natural agricultural resources of South Africa. Government Printer.

Department of Research and Specialist Services. (1979). Provisional soil map of Zimbabwe. Ministry of Agriculture, Salisbury.

Ellis, F. (1988). The classification and mapping of soils in relation to the survey of natural resources. Technical Communication No. 220, Department of Agricultural Development, Pretoria.

IUSS Working Group WRB. (2006). World reference base for soil resources 2006: World Soil Resources Reports No. 103. FAO, Rome.

FAO. (2015). World reference base for soil resources 2014, update 2015. World Soil Resources Reports No. 106. Food and Agriculture Organization of the United Nations.

Fey, M. V. (2010). Soils of South Africa. Cambridge University Press.

Global Soil Partnership. (2020). Country guidelines for the assessment of soil organic carbon stocks. FAO, Rome.

Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal*, 26(2), 91–108.

Grealish, G. J., Fitzpatrick, R. W., & Hutson, J. L. (2015). Soil survey data rescued by means of user-friendly soil identification keys. *Geoderma Regional*, 6, 81–89.

Hartemink, A. E. (2015). The use of soil classification in journal papers between 1975 and 2014. Geoderma Regional, 5, 127–139.

Hengl, T., Mendes de Jesus, J., Heuvelink, G. B. M., Ruiperez Gonzalez, M., Kilibarda, M., Blagotić, A., et al. (2017). SoilGrids250m: Global gridded soil information based on machine learning. *PLoS ONE*, 12(2), e0169748.

Hensley, M., Le Roux, P. A. L., Du Preez, C. C., van Huyssteen, C., Kotze, E., & Van Rensburg, L. D. (2006). Soils: The Free State agricultural base. *South African Geographical Journal*, 88(1), 11–21.

IUSS Working Group WRB. (2015). World reference base for soil resources 2014, update 2015: International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106, FAO, Rome.

Land Type Survey Staff. (1972–2006). Land types of South Africa: Digital map (1:250 000 scale) and soil inventory databases. ARC-Institute for Soil, Climate and Water, Pretoria.

Le Roux, P. A. L., van Huyssteen, C., & Hensley, M. (2005). Selection of soil properties for use in land evaluation. *South African Journal of Plant and Soil*, 22(2), 71–78.

Mabhaudhi, T., Chibarabada, T. P., Chimonyo, V. G. P., & Modi, A. T. (2018). Modelling climate change impact on the yield of underutilised crops in Southern Africa. *Sustainability*, 10(4), 1200.

MacVicar, C. N., De Villiers, J. M., Loxton, R. F., Verster, E., Lambrechts, J. J. N., Merryweather, F. R., Le Roux, J., van Rooyen, T. H., & Harmse, H. J. von M. (1977). Soil classification: A binomial system for South Africa. Department of Agricultural Technical Services, Pretoria.

Metelerkamp, H. R. R. (1988). Review of crop production in the semi-arid regions of Zimbabwe. In Cropping in the semi-arid areas of Zimbabwe: Proceedings of a workshop (pp. 165–202). Agritex/GTZ, Harare.

Moeletsi, M. E., & Walker, S. (2012). Rainy season characteristics of the Free State Province of South Africa. *Physics and Chemistry of the Earth*, 50–52, 108–115.

Mucina, L., & Rutherford, M. C. (Eds.). (2006). The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, South African National Biodiversity Institute, Pretoria.

Munsell Color. (2009). Munsell soil color charts. Munsell Color Company.

Nyamangara, J., Bergström, L. F., Piha, M. I., & Giller, K. E. (2003). Fertiliser use efficiency and nitrate leaching in a tropical sandy soil. *Journal of Environmental Quality*, 32(2), 599–606.

Nyamapfene, K. (1991). Soils of Zimbabwe. Nehanda Publishers, Harare.

Nyamapfene, K. (1993). A note on soil classification in Zimbabwe. *Zimbabwe Agricultural Journal*, 90(2), 71–74.

Purves, W. D., & Blyth, W. F. (1969). A soil map of the Salisbury district. Rhodesia Agricultural Journal, Technical Bulletin No. 8.

Schoeman, F., van der Walt, M., Dominik, T., Ellis, F., & Newby, T. (2013). Development of a soil and terrain database for southern Africa. ISRIC Report 2013/02.

Scholes, R. J. (2009). Syndromes, drivers, antecedents and outcomes: Southern African savanna dynamics. *Journal of Biogeography*, 36(4), 601–612.

Snapp, S. S., Mafongoya, P. L., & Waddington, S. (1998). Organic matter technologies for integrated nutrient management in smallholder cropping systems of southern Africa. *Agriculture, Ecosystems and Environment*, 71(1–3), 185–200.

Soil Classification Working Group. (1991). Soil classification: A taxonomic system for South Africa. Memoirs on the Agricultural Natural Resources of South Africa No. 15, Department of Agricultural Development, Pretoria.

Soil Classification Working Group. (2018). Soil classification: A natural and anthropogenic system for South Africa. ARC-Institute for Soil, Climate and Water, Pretoria.

Soil Survey Staff. (2014). Keys to soil taxonomy (12th ed.). USDA-Natural Resources Conservation Service, Washington, DC.

Thompson, J. G. (1965). The soils of Rhodesia. *Rhodesia Agricultural Journal*, Technical Bulletin No. 3.

Thompson, J. G., & Purves, W. D. (1978). A guide to the soils of Rhodesia. *Rhodesia Agricultural Journal*, Technical Handbook No. 3.

Thompson, J. G., & Purves, W. D. (1981). A guide to the soils of Zimbabwe. Zimbabwe Agricultural Journal, Technical Handbook No. 3, Department of Research and Specialist Services, Harare.

Turner, D. P. (2000). Soils of KwaZulu-Natal and Mpumalanga: Recognition of natural soil bodies. PhD thesis, University of Pretoria.

Vagen, T.-G., Winowiecki, L. A., Tondoh, J. E., Desta, L. T., & Gumbricht, T. (2016). Mapping of soil properties and land degradation risk in Africa using MODIS reflectance. *Geoderma*, 263, 216–225.

Van Huyssteen, C. W. (2020). Diagnostic horizons in South African soils: A pictorial guide. Sun Media.

Vincent, V., & Thomas, R. G. (1961). An agricultural survey of Southern Rhodesia: Part I, agro-ecological survey. Government Printer, Salisbury.

Whitlow, J. R. (1988). Land degradation in Zimbabwe: A geographical study. Department of Natural Resources, Harare.

Zingore, S., Murwira, H. K., Delve, R. J., & Giller, K. E. (2007). Influence of nutrient management strategies on variability of soil fertility, crop yields and nutrient balances on smallholder farms in Zimbabwe. *Agriculture, Ecosystems and Environment*, 119(1–2), 112–126.