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The use of soil classification in journal papers between 1975 and 2014

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ABSTRACT

We classify soils to group our knowledge, increase our understanding, and communicate results. I have analyzed how soil classification and factor and soil property naming have been used in journal papers between 1975 and 2014. There is an exponential increase in the use of *Taxonomy* and *WRB* but the increase in the number of soil science papers is much faster than the use of *Soil Taxonomy* and *WRB*. The percentage of papers with soil classification information was highest in *Geoderma* (34%). The soil biology journals had soil classification in only 6% of their papers. *Soil Taxonomy* seems to be more frequently included particularly in journals from the USA, whereas *FAO-Unesco* and *WRB* are more frequently used in European journals. Soils in dry areas (Aridisols, Calcisols, Gypsisols) seem to be under-researched, whereas Spodosols (Podzols), Vertisols, Anthrosols, Chernozems, and Luvisols seem over-represented. Soil factor and property naming (e.g. "agricultural soil", "sandy soil") increase faster than the use of *Soil Taxonomy* and *WRB*. Temperate and boreal soil is commonly used in *Soil Biology and Biochemistry* which also tops the number of papers with forest soil, "agricultural soil", "upland soil", "wetland soil", and "valley soil". The more geologically oriented journals use parent material terms like "alluvial soils" and "granite soils". Color soil naming is common in some Chinese (black soil, red soil) and Canadian journals (Brown soil). Problems of soil classification are related to technical issues of soil classification, the adoption of the system, and the lack of instructions in soil science journals. A lack of soil classification in our papers makes transfer of information, data and results difficult.

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"The only thing that will redeem mankind is cooperation."
[Bertrand Russell (1954)]

1. Introduction

Many elements of the natural world are named and classified using systems developed in the 18th century. Carl Linnaeus developed taxonomic classifications of plants and animals and almost all living organisms. Rock classification followed pioneering work of James Hutton and Charles Lyell in the 18th and early 19th centuries. Systematic classification of soils started in the mid-1800s — initially focussing on geologic concepts and parent materials (e.g. Morton, 1843; Senft, 1857; Ramann, 1893) and then with an emphasis on climate and vegetation (Dokuchaev, 1883; Sibirtsev, 1900). Since that time, a bewildering number of classification systems have been developed. Systems have focused on, for example, chromatic aspects, soil age and development (Kubiëna, 1950), textural differentiation (Chamberlin, 1882; Whitney, 1909), maturatal — based on age (Wolfanger, 1930; van Wambeke, 1962) or zonal and azonal groupings (Marbut, 1927). There has been wide discussion on whether systems should be genetic or morphometric (Cline, 1949; Beckmann, 1984; Bockheim et al., 2005). As Leeper (1952) summarized it: we are slowly coming to agree to classify soils-as-they-are, and not to classify them according to guesses about their origin.

Soil classification leaped in the early 1950s (Eswaran, 1999) but the 1960 World Congress of Soil Science in Madison, USA, was pivotal. At the congress, the "7th Approximation" of the USDA was presented there (Soil Survey Staff, 1960). This system was presented as a conceptual change to the factorial-genetic concepts that dominated USA soil classification during the 1920s to 1950s (Bockheim et al., 2014). The "7th Approximation" was modified and published in 1975 as *Soil Taxonomy: a Basic System of Soil Classification for Making and Interpreting Soil Surveys* (Soil Survey Staff, 1975). *Soil Taxonomy* has undergone two editions (1975, 1990) and 12 classification keys of which the most recent was published in 2014 (Soil Survey Staff, 2014). Secondly, at the World Congress in 1960 a decision was made to prepare a World Soil Map (Hartemink et al., 2013). The World Soil Map's legend was turned into the *FAO-Unesco* soil classification, that in 1998 was published as the *World Reference Base for Soil Resources* (*WRB*), with the latest edition published in 2014 (IUSS Working Group WRB, 2014). In addition to these two soil classification systems, there are many national soil classification systems of which an overview was given by Krasilnikov et al. (2009).

There are other ways that soils have been classified including folk classification systems (Barrera-Bassols and Zinck, 2003), numerical approaches (e.g. Bautista et al., 2005; Hughes et al., 2014), capability classification systems (e.g. Helms, 1997; Sanchez et al., 2003), or diagnostic

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horizon classifications (FitzPatrick, 1980). Both *Soil Taxonomy* and *WRB* have been endorsed by the *International Union of Soil Sciences* (IUSS) as the internationally accepted soil classification systems. The *WRB* was endorsed at the World Congress of Soil Science in 1998 and *Soil Taxonomy* at the World Congress of soil Science in 2014.

There are many reasons why soils are classified and these have been fairly well defined by *Soil Taxonomy* and *WRB* (Soil Survey Staff, 1999; IUSS Working Group WRB, 2014). Firstly, the importance of soil classification stems from the need to bring systematics to the study of soil, as without classification the knowledge would be factual chaos that is difficult to retain and impossible to understand (Hallberg, 1984). Classification enables us to see relationships among and between soils and their environment, to formulate principles of prediction value, to establish groups at various levels, for the proper use of experience, and to extend the results of research (Soil Survey Staff, 1951; Beinroth et al., 1980; Beckmann, 1984).

It has been more than 40 years since the two international soil classification systems have been established, so it can be assumed that soil classification is grounded in the soil science community and other disciplines. Here, I analyze how soil classification is used in scientific journal papers in the past 40 years. As a punter of soil scientific publications (for research and as editor and reviewer), I have noticed that in many papers soil classification was absent or vague terms like “sandy soil” or “agricultural soil” were used. This prompted me to try to quantify the current use of soil classification and investigate possible trends over time. The analysis was restricted to the two international used soil classification systems: *Soil Taxonomy* and *World Reference Base for Soil Resources* as well as its predecessor *FAO-Unesco*. Data were extracted from the Scopus database (Elsevier) which metrics are slightly higher than that of the Web of Science (Minasny et al., 2013).

2. *Soil Taxonomy*

The number of papers in Scopus that contain *Soil Taxonomy* soil order information (e.g. Alfisols, Ultisols) is presented in Table 1. The numbers represent the papers with soil order information so that suborder (e.g. Ustults) or great groups (e.g. Haplusterts) information was not included in the analysis. Over the period 1975–2014, there were over 6000 papers containing information on the order Oxisols. The number of papers with Alfisols, Ultisols and Vertisols was around 4000 whereas the rest of the orders were mentioned in less than 2000 papers. Aridisols was mentioned in less than 200 papers, and there were less than 40 papers on Gelisols, which is not surprising given that this order was only established in 1999. Overall, there was a sharp increase in the number of papers containing *Soil Taxonomy* soil order information from less than 200 in the decade 1975–1984 to over 18,000 papers in the 2005–2014 decade. The number of papers mentioning specific soil orders has tripled in the past two decades.

Fig. 1 presents a count of papers in *Geoderma* and *Soil Survey Horizons* that included *Soil Taxonomy* orders as well as suborder or great group levels. For *Geoderma*, this is based on 2079 papers published between 1967 and 2001 (Hartemink et al., 2001). In the 1980s, most attention was given to Alfisols and Inceptisols, but in the late 1990s there was a steady rise in research conducted on Spodosols, Entisols and Mollisols. Alfisols and Inceptisols accounted for almost 20% of all papers in *Geoderma*, and Spodosols were the subject of about 7% of all papers. Oxisols and Ultisols have been researched in less than 7% of the papers; Histosols have received minimal attention.

We also classified all 1080 contributions published in *Soil Survey Horizons* (now named *Soil Horizons*) between 1960 and 2009. Since 1975, references to all soil orders increased and peaked for most orders in the mid and late 1990s. This includes reference to suborder or great group levels. Almost half of all contributions in *Soil Survey Horizons* included a reference to a soil order. Alfisols, Entisols, Inceptisols and Mollisols were most represented in contributions to *Soil Survey Horizons* (Hartemink et al., 2012). From the 1980s onwards, the majority of the contributions were from midwestern USA and about 17% of the soils discussed were Mollisols. The number of papers on Gelisols (introduced in 1999) was lowest along with Oxisols. Whereas Gelisols account for 8.7% of the soils in the USA, Oxisols comprise only 0.02% (Soil Survey Staff, 1999).

Comparing the distribution of *Soil Taxonomy* soil orders as found in Scopus, *Geoderma* and *Soil Survey Horizons* to the global extent of each order there seem to be some striking differences. It appears that the number of papers on Aridisols is much lower than their relative global extent (Fig. 1). The same applies to Gelisols. The Scopus database shows a large relative volume of paper on Oxisols compared to their global extent, whereas Spodosols are overrepresented in and Entisols underrepresented. There are a relatively large number of papers on Vertisols in Scopus and *Soil Survey Horizons* compared to its global extent.

Table 1
Papers with one or more *Soil Taxonomy* order in any text field over the period 1975–2014. Soil orders in bold were already in the first edition of *Soil Taxonomy* (Soil Survey Staff, 1975); Gelisols and Andisols were added in 1999 (Soil Survey Staff, 1999). Data extracted from Scopus.

Soil order	Number of papers			
	1975–1984	1985–1994	1995–2004	2005–2014
Alfisol	50	243	1057	2508
Andisols	0	0	266	1108
Aridisols	3	12	59	117
Entisols	12	30	181	538
Gelisols	0	0	14	22
Histosols	4	18	134	388
Inceptisols	11	35	177	924
Mollisols	9	52	361	1127
Oxisols	30	188	1377	4624
Spodosols	11	115	877	1088
Ultisols	20	144	940	2857
Vertisols	27	170	1167	2964
Total	178	1034	6610	18,265

3. *FAO-Unesco* and *WRB*

The number of papers containing *FAO-Unesco* or *WRB* soil groups in the past 40 years is presented in Table 2. As opposed to the soil order information of Table 1, this is probably a more accurate account as the names do not change at lower levels of classification. The legend to the 1:5 million World Soil Map was introduced in 1974 and Major Soil Groupings (also called soil units, reference soil groups, soil groups) have been added and discarded between 1974 (FAO-Unesco, 1974) and the *WRB* report of 2006 (IUSS Working Group WRB, 2006). Some soil groups have had a steady flow of papers like Cambisols, Chernozems, Ferralsols, Luvisols, Podzols and Vertisols. Other soil groups saw less increase over time. It seems that no paper has yet been published on Durisols. Overall, there were 19,440 papers that contained *FAO-Unesco* or *WRB* soil group information between 1975 and 2014, which is twice the amount of papers containing soil classification in the previous decade.

The total number of papers with soil-group information between 1975 and 2014 is presented in Fig. 2 that also shows the percentage of global land area for each group based on the 2006 version of *WRB* (IUSS Working Group WRB, 2006). Some soil groups have received less attention than their relative extent would warrant (underrepresentation) whereas other soil groups have received more attention that their relative extent (overrepresentation). Soils that are seemingly underrepresented are Acrisols, Arenosols, Calcisols, Cryosols, Ferralsols, Gleysols, Gypsisols, Kastanozems, and Leptosols, whereas soils that are overrepresented include Anthrosols, Chernozems, Luvisols, Podzols and Vertisols.