The classification of Leptosols in the World Reference Base for Soil Resources

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Abstract
Mountain soils, often characterized by shallow soils on steep slopes, have received relatively little interest in soil science. The areas where they occur are thought to be sparsely populated and the soils themselves only suitable for marginal pastures and forests. They are often not sampled and this lack of knowledge is in stark contrast with their overall extent and their importance to provide a livelihood for 12 % of the Earth's population. The classification of Leptosols, the main mountain soils, on the contrary, has become more complex over the years. From three simple classes in the FAO Legend of 1974, the number of sub-classes has exponentially grown to at least 36 units in the World Reference Base for Soil Resources. It is highly recommended that this number be revised downward.

Key Words
Leptosols, mountain soils, soil classification, World Reference Base.

Introduction
Mountain soils, often characterized by shallow soils on steep slopes have received relatively little interest in soil science. The areas where they occur are often sparsely populated and the soils themselves only suitable for marginal pastures and forests. To illustrate this lack of interest Nachtergaele (1977) made a statistical analysis of soil surveys in the Philippines and found that the chance of a mountain soil being sampled was statistically very small and not in relation at all with the area extent of these soils. Likewise Batjes *et al.* (1997) while discussing soil parameters in the WISE database found very few examples among the soil profiles that could be associated with mountain soils (only five Leptosol profiles occur in the global soil profile database that contains more than 1000 soil profiles), this is in stark contrast with the fact that Leptosols are considered to be the most common soils in the world with an area extent estimated at 1655 Million ha (ISSS Working Group RB 1998) of which 545 Million ha occur in a mountainous environment. The most common soils in mountainous areas associated with Leptosols are Regosols and Cambisols, both are also characterized by their limited soil profile development. A special case of mountain soils are those in volcanic areas, many of which are Andosols. These are not discussed here. The importance of mountains as an important ecosystem for humans has been often underestimated. Around 720 million people (12% of the World's population) live in a mountain environment.

Leptosols
In soil classification, the shallow soils (characteristic for many mountain soils) in Soil Taxonomy (USDA 1999) are only recognized at (lithic) sub-group level, grouping together all soils that are less than 50 cm thick to hard rock. On the contrary FAO, in the inception of the Legend of the Soil Map of the World (1974), did recognize at the highest level of classification three major types of mountain soils: Lithosols, Rendzinas and Rankers. None of these Soil Groups had further subdivisions.

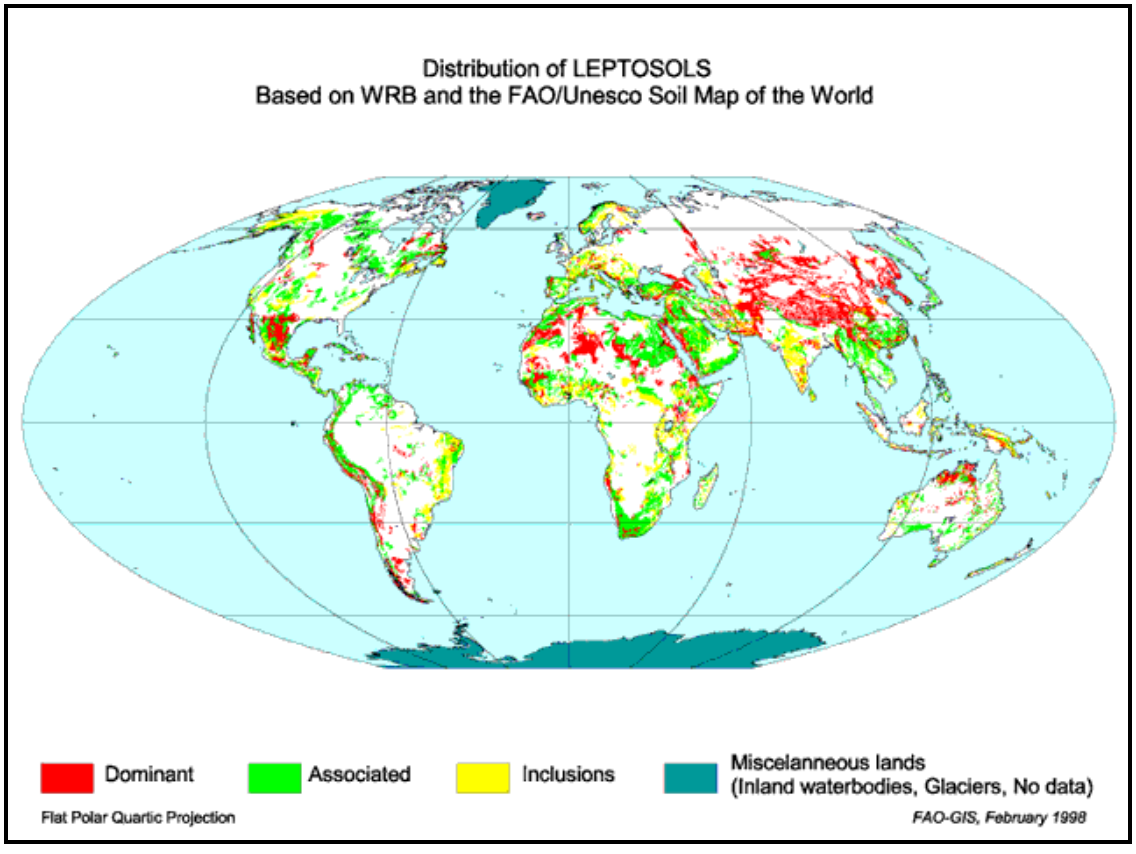
Lithosols were defined as: "soils other than Histosols that were limited in depth by continuous coherent and hard rock within 10 cm of the soil surface."
Rendzinas were defined as: "soils having a mollic A horizon which contains or immediately overlies calcareous material with a CaCO3 content of 40 percent or more."
Rankers were defined as: "soils having an umbric A horizon which is not more than 25 cm thick without other diagnostic horizons"

Consequent mapping of these soils at world scale revealed however that the latter two (Rendzinas and Rankers) had only a very limited extent and rarely could be mapped as dominant soils in a mapping unit, while the rather strict limit (10 cm to rock in Lithosols) was found to be too strict as a mapping criteria. Consequently in 1988, the Revised Legend of the soil map of the world introduced the concept of Leptosols which were defined as follows: "Soils that are limited in depth by continuous hard rock or highly calcareous material ($CaCO_3$> 40 percent) or a continuous cemented layer within 30 cm of the surface, or having less

than 20 percent fine earth over a depth of 75 cm from the surface; having no diagnostic horizons other than a mollic, umbric or ochric A horizon, or a petrocalcic horizon with or without a cambic horizon." Seven different soil units which were recognized within the Leptosols: Gelic (the cold ones), Lithic (less than 10 cm soil depth – the former Lithosols-), Rendzic Leptosols (those with high $CaCO_3$, the former Rendzinas), Umbric Leptosols (soils with an Umbric horizon, which group the more shallow of the former Rankers), Mollic Leptosols, Eutric and Dystric Leptosols.

When the work of the World Reference Base for Soil Resources working group of the IUSS took off, with the publication of the first official version (FAO/ISRIC/ISSS 1998) the basic FAO definition was retained, although some limits were adapted:
Leptosols were hence defined as: "soils which are either:
1. Limited in depth by continuous hard rock within 25 cm from the soil surface; or
2. overlying material with a calcium carbonate equivalent more than 40 percent within 25 cm of the soil surface; or
3. containing less than 10 percent (by weight) fine earth to a depth of 75 cm or more from the soil surface; and
4. having no diagnostic horizons other than a mollic, ochric, umbric, yermic or vertic horizon."

Differences with the earlier FAO (1988) definition were minor: a change in thickness of the soil layer from 30 to 25 cm, a decrease in amount of fine soil materials allowed (from 20 to 10 percent fine earth) in rocky/gravely soils. At the classification level of WRB which had a single list of "qualifiers", the introduction of a hyperskeletic is noted as a useful distinction of the rather different nature of these soils in contrast with the FAO (1988) which did not make this important distinction at this level.



The definition of Leptosols in the Key to WRB 2007 (IUSS Working Group WRB 2006, update 2007) was simplified:
Leptosols are other soils (excluding Histosols, Anthrosols, Technosols and Cryosols) having
1. one of the following:
a. limitation of depth by continuous rock within 25 cm of the soil surface; or
b. less than 20 percent (by volume) fine earth averaged over a depth of 75 cm from the soil surface or to continuous rock whichever is shallower; and
2. no calcic, gypsic, petrocalcic, petrogypsic or spodic horizon."

The introduction of the new RSG of Technosols before the Leptosols is noted; the reference to the Rendzina-like soils has been omitted (although the Rendzic qualifier has been maintained); the limits of the fine earth allowed have been set again at 20 percent, going back to the 1988 definition and also specifying the percentage by volume rather than by weight which should make identification easier in the field. Most diagnostic horizons are allowed with the exception of the calcic, gypsic, petrocalcic, petrogypsic and spodic horizon. "Hard Rock" traditionally classified as "non Soil" is considered as a specific type of Leptosol (Nudilithic qualifier). Unfortunately, at the same time the number of "qualifiers" foreseen in Leptosols skyrocketed to a total number of 36, which, given the fact that Leptosols are seldom mapped in any detail, is not justified.

Over the last 30 years soil classification has changed the groupings of the shallow and very gravely soils which are dominant in many mountain regions, but few new insights have been achieved, except perhaps perfecting definitions reflecting more correctly reality or facilitating mapping. The more recent development in the World Reference Base for Soil Resources where a great number of intergrades and extra-grades is allowed is however considered unhelpful and unpractical. From the original three FAO Soil Groups in 1974 we now have the choice of a single Reference Soil Group with 17 prefixes and 19 suffixes which allow, theoretically, for an infinite number of units by using all allowed combinations. It is proposed (IUSS Working Group WRB 2006/07) to limit the first level qualifiers in Leptosols to the following: Lithic (with Nudilithic as a subdivision of Lithic), Hyperskeletic, Rendzic, Organic (= Folic and Histic), Mollic, Umbric, Dystric and Eutric. All other qualifiers identified should be listed under the suffixes as they refer to local conditions, or can only be mapped at large scales.

Conclusions

Soils in mountains have received little attention in soil science, they are often not sampled and this lack of knowledge is in stark contrast with their overall extent and their importance to provide a livelihood for 12 % of the Earth's population. The classification of mountain soils on the contrary, has become more complex over the years. From 3 simple classes in the FAO Legend of 1974, the number of sub-classes has exponentially grown to at least 36 units in the World Reference Base for Soil Resources. It is highly recommended that this number is revised downward.

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