The harmonized world soil database

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Abstract
For more than 30 years the FAO/Unesco Soil map of the World has been the only harmonized source of global soil information. Recent updates and release of new soil information in all regions of the globe was an incentive to tackle the harmonization and integration of the new soil data. The task was undertaken by a consortium of institutes and organizations and resulted in a product with 30 arc second resolution that includes for each soil unit estimates for fifteen top- and subsoil properties. The data come with a viewer, are GIS compatible and are freely available on-line.

Key Words
Soil databases, world soil map.

Background
Soil information, from global to local scale, has often been the one missing biophysical information layer which absence added to the uncertainties of predicting potentials and constraints for food and fiber production. The lack of reliable and harmonized soil data has hampered considerably land degradation assessments, environmental impact studies and adapted sustainable land management interventions. For more than 30 years the FAO/Unesco Soil Map of the World (FAO/UNESCO 1971-1981), based on soil surveys and information collected in the nineteen sixties, was the only harmonized soil map available at a scale of 1:5 Million. It was recognized that the soil information in this map was deficient in many areas and should be improved. At an international scale this was done for some regions since 1995 by FAO, ISRIC and UNEP under the SOTER programme (UNEP/ISSS/ISRIC/FAO 1993). However progress was slow and uneven. Soil information was also improved at national level in many countries, for instance in China (Shi et al. 2004); while a joint effort by USDA, the Dokuchaiev institute and the European Soil Bureau Network resulted in a harmonized Circumpolar Soil Map covering the Northern hemisphere up till 50°North (European Commission 2009). These recent updates and improvements justified this first attempt to harmonize this information in a unique product.

Recognizing the urgent need for improved soil information worldwide and its immediate requirement for the Global Agro-ecological Assessment study, the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA) took the initiative of combining the recently collected volumes of regional and national updates of soil information with the information already contained within the 1:5,000,000 scale FAO-UNESCO Digital Soil Map of the World (FAO/UNESCO 1995, 2003), into a new comprehensive Harmonized World Soil Database (HWSD). This work was undertaken with the International Soil Reference and Information Centre (ISRIC) that together with FAO, is responsible for the development of regional soil and terrain databases and the WISE soil profile database; and with the European Soil Bureau Network, which had recently completed a major update of soil information for Europe and northern Eurasia (Lambert *et al.* 2003), and the Institute of Soil Science, Chinese Academy of Sciences which provided the recent 1:1,000,000 scale Soil Map of China.

Characteristics of the harmonized world soil database
The HWSD contains soil information at scales that vary by region from 1:1 Million in most SOTER, ESBN and China products to 1:5 million in the Soil map of the world. The Harmonized World Soil Database is produced in a uniform raster format with a 30arcsec resolution (1km). The total number of pixels in the map is 15.

HWSD uses 4 distinct sources of data:
1. The European Soil Database (ESDB) extended with information of the Northern Circumpolar soil map at 1:1 M scale. This database is considered of moderate reliability with an adequate scale but often lacking soil profile information.
2. The new Soil Map of China at scale 1:1 Million produced by the Chinese Academy of Sciences. The database is considered of moderate reliability for the same reasons as the one above.
3. The SOTER databases mainly for Eastern, Central and Southern Africa, South America and the Caribbean and parts of Asia. This database is considered of moderate reliability in regions where the scale was smaller than 1:1 Million as is the case in South America and the Caribbean, Congo and Angola or where soil profiles were scarce such as in Mongolia, Egypt and Sudan. The database is considered of high reliability in areas where the scale of the original maps was 1:1 million or better and a complete soil profile database was available (Southern Africa, Central and Eastern Europe).
4. For the areas not covered by the above mainly West Africa, North America, South Asia, and Australia the "old" soil map of the world was re-interpreted. This part of the database is considered of low reliability.

Soil Unit Composition of each grid (classified according to the FAO Revised Legend (FAO 1990)) contains fifteen soil properties for topsoil (0-30cm) and subsoil (30-100cm) are automatically displayed and contained in the database / GIS layers based on legacy data and using simple taxon-transfer functions. This concerns the following parameters: Organic Carbon, pH(H2O), CECsoil, CECclay fraction, Total Exchangeable Bases (TEB), Base saturation %, ESP, Calcium carbonate, Gypsum, Sand fraction, Silt fraction, Clay fraction, ECe, USDA Texture, Reference Bulk Density, Soil Drainage, and Soil Phase information.

Additional information contained in the HWSD as separate layers with different lower resolution (5 arc minutes) are:
1. Land cover/land use shares. This information is classified in seven classes: rain-fed cultivated land, Irrigated cultivated land, Forest land, Pasture land, Barren/slightly vegetated land, Water, Urban land).
2. Terrain slope and aspect distributions within each grid. This information is derived from digital elevation data produced by the NASA Shuttle Radar Topographic Mission (SRTM) with a 90 meter resolution.
3. Soil qualities for agriculture including Nutrient availability, Nutrient retention capacity, Rooting conditions, Oxygen availability, Excess salts, Toxicity and Workability.
4. Rural and urban population distribution.
In addition a number of soil qualities can be derived using modeled relationships between soil properties. Examples are the organic carbon pool and the soil water holding capacity.(See Figure 2).

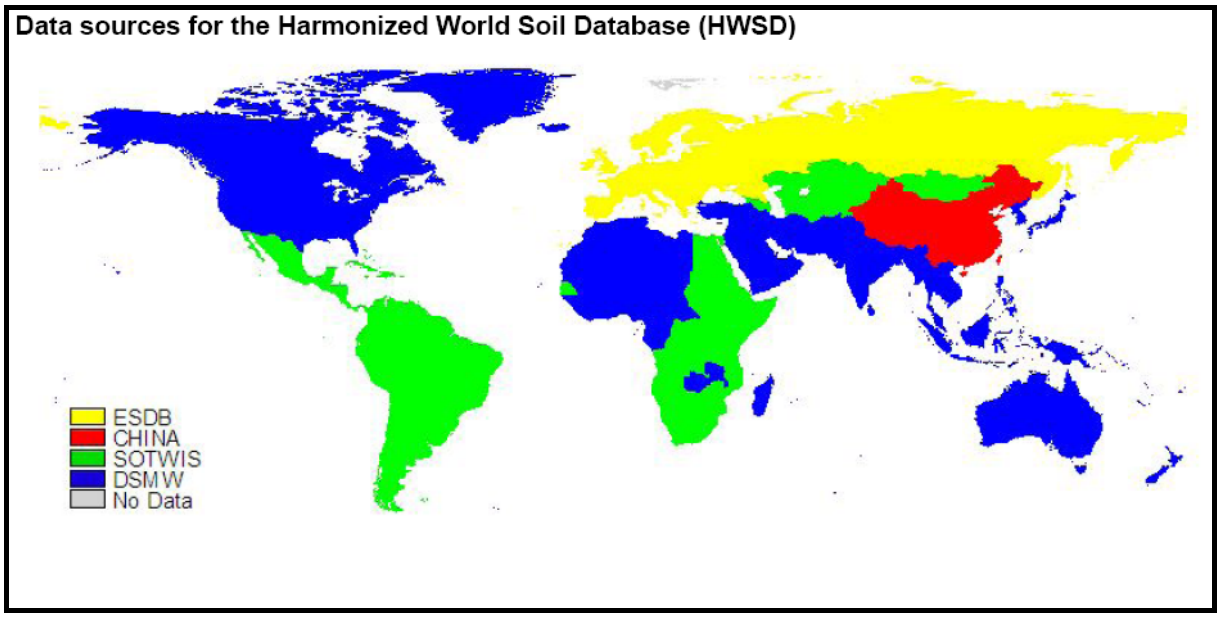

Figure 1. Sources of HWSD.

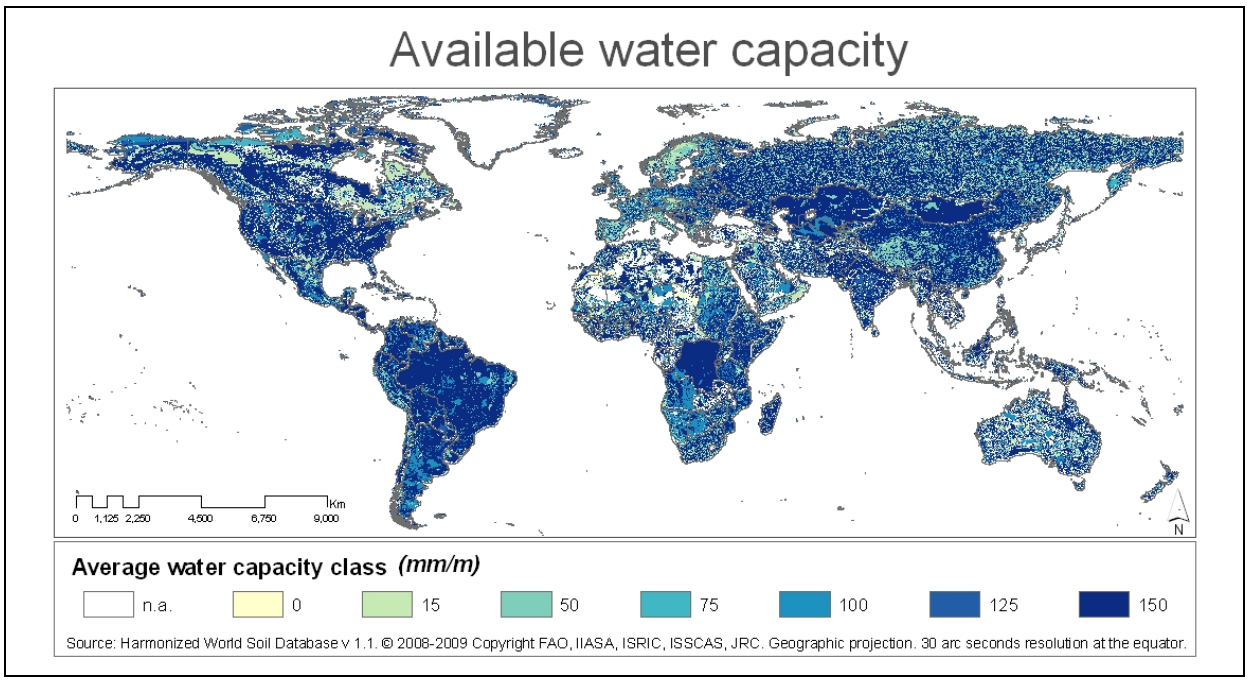

Figure 2. Soil moisture holding capacity derived from soil properties in HWSD.

Conclusions and recommendations

The completion of this comprehensive harmonized soil information will improve estimation of current and future land potential productivity, help identify land and water limitations, and enhance assessing risks of land degradation, particularly soil erosion. The HWSD contributes sound scientific knowledge for planning sustainable expansion of agricultural production and for guiding policies to address emerging land competition issues concerning food, energy and biodiversity. This is of critical importance for rational natural resource management and making progress towards achieving food security and sustainable agricultural development, especially with regard to the threats of global climate change and the need for adaptation and mitigation.

The HWSD constitutes improvements for about 60% of the land area as compared to the FAO/UNESCO Soil Map of the World. The GlobalSoilMap.net (Sanchez *et al.* 2009) digital soil mapping project that will provide the global information system of the future is in his first year and completion for Sub-Saharan Africa let alone the World is some time off. Readily available databases such as those present in Australia, Canada and the United States can easily be transformed in a similar 30 arc sec product. In other regions such as West Africa and South Asia many countries have the soil maps and soil profile databases available to contribute to an expanded HWSD. On going discussions in the framework of the Group on Earth Observations (GEO) aiming towards the development of a Global Soil Information System (GLOSIS) as a "system of systems of soil data and information" as part of the Global Earth Observation System of Systems (GEOSS) have already identified a possible improved HWSD as an intermediate product to be complete at short term, prior to the final release of the future GlobalSoilMap.net (GEO 2009-2011 Work plan 2009). It is therefore strongly recommended that an initiative is launched to complete the HWSD based on existing legacy information. This in turn will be a solid basis on which future global digital soil mapping can build.

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