Soil Qualities for Crop Production

On the basis of soil parameters provided by HWSD seven key soil qualities important for crop production have been derived, namely: nutrient availability, nutrient retention capacity, rooting conditions, oxygen availability to roots, excess salts, toxicities, and workability. Soil qualities are related to the agricultural use of the soil and more specifically to specific crop requirements and tolerances. For the illustration of soil qualities, maize was selected as reference crop because of its global importance and wide geographical distribution.

**TABLE 1: Soil qualities and related soil characteristics**

|  |  |  |
| --- | --- | --- |
|  | Soil Qualities | Soil Characteristics |
| SQ1 | Nutrient availability | Soil texture, soil organic carbon, soil pH, total exchangeable bases |
| SQ2 | Nutrient retention capacity | Soil Organic carbon, Soil texture, base saturation, cation exchange capacity of soil and of clay fraction |
| SQ3 | Rooting conditions | Soil textures, bulk density, coarse fragments, vertic soil properties and soil phases affecting root penetration and soil depth and soil volume |
| SQ4 | Oxygen availability to roots | Soil drainage and soil phases affecting soil drainage |
| SQ5 | Excess salts. | Soil salinity, soil sodicity and soil phases influencing salt conditions |
| SQ6 | Toxicity | Calcium carbonate and gypsum |
| SQ7 | Workability (constraining field management) | Soil texture, effective soil depth/volume, and soil phases constraining soil management (soil depth, rock outcrop, stoniness, gravel/concretions and hardpans) |

Soil qualities have been estimated for the sequence 1 soils in each grid cell with as reference crop maize. The derived maps for the individual soil qualities represent therefore the qualities of ‘main soils’ only.

Details of estimation procedures for the individual soil qualities from soil characteristics in HWSD are:

Nutrient availability (SQ1)

This soil quality is decisive for successful low level input farming and to some extent also for intermediate input levels. Diagnostics related to nutrient availability are manifold. Important soil characteristics of the topsoil (0-30 cm) are: Texture/Structure, Organic Carbon (OC), pH and Total Exchangeable Bases (TEB). For the subsoil (30-100 cm), the most important characteristics considered are: Texture/Structure, pH and TEB.

The soil characteristics relevant to soil nutrient availability are to some extent correlated. For this reason, the most limiting soil characteristic is combined in the evaluation with the average of the remaining less limiting soil characteristics to represent soil quality SQ1.

Nutrient retention capacity (SQ2)

Nutrient retention capacity is of particular importance for the effectiveness of fertilizer applications and is therefore of special relevance for intermediate and high input level cropping conditions.  
Nutrient retention capacity refers to the capacity of the soil to retain added nutrients against losses caused by leaching. Plant nutrients are held in the soil on the exchange sites provided by the clay fraction, organic matter and the clay-humus complex. Losses vary with the intensity of leaching which is determined by the rate of drainage of soil moisture through the soil profile. Soil texture affects nutrient retention capacity in two ways, through its effects on available exchange sites on the clay minerals and by soil permeability.  
The soil characteristics used for topsoil are respectively: Organic Carbon (OC), Soil Texture (Text), Base Saturation (BS), Cation Exchange Capacity of soil (CECsoil), pH, and Cation Exchange Capacity of clay fraction (CECclay). Soil pH serves as indicator for aluminum toxicity and for micro-nutrient deficiencies.  
The most limitingof these soil characteristic is combined with the average of the remaining less limiting soil characteristics to estimate nutrient retention capacity SQ2.

Rooting conditions (SQ3)

Rooting conditions include effective soil depth (cm) and effective soil volume (vol. %) related to presence of gravel and stoniness. Rooting conditions may be affected by the presence of a soil phase either limiting the effective rooting depth or decreasing the effective volume accessible for root penetration. Rooting conditions address various relations between soil conditions of the rooting zone and crop growth. The following factors are considered in the evaluation:

1. Adequacy of foothold, i.e., sufficient soil depth for the crop for anchoring;
2. available soil volume and penetrability of the soil for roots to extract nutrients;
3. space for root and tuber crops for expansion and economic yield in the soil; and
4. absence of shrinking and swelling properties (vertic) affecting root and tuber crops.

Soil depth/volume limitations affect root penetration and may constrain yield formation (roots and tubers). Relevant soil properties considered are: soil depth, soil texture/structure, vertic properties, gelic properties, petric properties and presence of coarse fragments. This soil quality is estimated by multiplying of the soil depth limitation with the most limiting soil or soil phase property

Soil phases that relevant for rooting conditions vary somewhat with source of soil map and soil classification used. In the HWSD these are:

1. FAO 74 soil phases: stony, lithic, petric, petrocalcic, petrogypsic, petroferric, fragipan and duripan.
2. FAO 90 soil phases: rudic, lithic, pertroferric, placic, skeletic, fragipan and duripan.
3. ESB soil phases and other soil depth/volume related characteristics: stony, lithic, petrocalcic, petroferric, fragipan and duripan, and presence of gravel or concretions, obstacles to roots (6 classes), and impermeable layers (4 classes).

Oxygen availability (SQ4)

Oxygen availability in soils is largely defined by drainage characteristics of soils. The determination of soil drainage classes is based on procedures developed at FAO (FAO 1995). These procedures take into account soil type, soil texture, soil phases and terrain slope.

Apart from drainage characteristics, the soil quality of oxygen availability may be influenced by soil and terrain characteristics that are defined through the occurrence of specific soil phases. These include for the FAO ‘74 classification soil phases indicating phreatic conditions, and for the FAO ’90 classification soil phases indicating respectively phreatic, anthraquic, inundic, or placic conditions.

Excess salts (SQ5)

Accumulation of salts may cause salinity. Excess of free salts referred to as soil salinity is measured as Electric Conductivity (EC in dS/m) or as saturation of the exchange complex with sodium ions, which is referred to as sodicity or sodium alkalinity and is measured as Exchangeable Sodium Percentage (ESP).

Salinity affects crops through inhibiting the uptake of water. Moderate salinity affects growth and reduces yields; high salinity levels may kill the crop. Sodicity causes sodium toxicity and affects soil structure leading to massive or coarse columnar structure with low permeability. Apart from soil salinity and sodicity, conditions indicated by saline (salic) and sodic soil phases may affect crop growth and yields.

In case of simultaneous occurrence of saline (salic) and sodic soils the limitations are combined. The most limiting of the combined soil salinity and/or sodicity conditions and occurrence of saline (salic) and/or sodic soil phase is selected.

3.2.6    Toxicities (SQ.6)

Low pH leads to acidity related toxicities, e.g., aluminum, iron, manganese toxicities, and to various deficiencies, e.g., of phosphorus and molybdenum. Calcareous soils exhibit generally micronutrient deficiencies, for instance of iron, manganese, and zinc and in some cases toxicity of molybdenum. Gypsum strongly limits available soil moisture. Tolerance of crops to calcium carbonate and gypsum varies widely (FAO, 1990; Sys, 1993).

Low pH and high calcium carbonate and gypsum are mutually exclusive. Acidity related toxicities such as aluminum toxicities and micro-nutrient deficiencies are accounted for respectively in SQ1, nutrient availability, and in SQ2, nutrient retention capacity. This soil quality SQ6 is therefore only including calcium carbonate and gypsum related toxicities. The most limiting of the combination of excess calcium carbonate and gypsum in the soil, and occurrence of petrocalcic and petrogypsic soil phases is selected for the quantification of SQ6.

Workability (SQ7)

Diagnostic characteristics to indicate soil workability vary by type of management applied. Workability or ease of tillage depends on interrelated soil characteristics such as texture, structure, organic matter content, soil consistence/bulk density, the occurrence of gravel or stones in the profile or at the soil surface, and the presence of continuous hard rock at shallow depth as well as rock outcrops. Some soils are easy to work independent of moisture conditions, other soils are only manageable at an adequate moisture status, in particular for manual cultivation or light machinery. Irregular soil depth, gravel and stones in the profile and rock outcrops, might prevent the use of heavy farm machinery. The soil constraints related to soil texture and soil structure are particularly affecting low and intermediate input farming LUTs, while the constraints related to irregular soil depth and stony and rocky soil conditions are foremost affecting mechanized land preparation and harvesting operations, of high-level input mechanized farming LUTs. Workability constraints are therefore handled differently for low/intermediate and high inputs.

The workability soil quality SQ7 includes physical hindrance to cultivation, and limitations to cultivation imposed by texture/clay mineralogy. The soil quality SQ7 is derived by combining the most limiting soil/soil phase attribute with the average of the remaining attribute coditions. Soil phases considered in the quantification of SQ7 are stony, lithic, petric, petrocalcic, petroferric, fragipan and duripan (FAO ‘74), and lithic, petroferric, rudic, skeletic, duripan and fragipan (FAO’90).

Data Citation:  
Fischer, G., F. Nachtergaele, S. Prieler, H.T. van Velthuizen, L. Verelst, D. Wiberg, 2008. *Global Agro-ecological Zones Assessment for Agriculture (GAEZ 2008)*. IIASA, Laxenburg, Austria and FAO, Rome, Italy.