Sustainable Soil Management

Soil management plays an important role in sustainable agriculture as it can contribute to both, water and land conservation. Soil management usually includes soil fertility management, soil conservation and soil cultivation. This note only covers soil fertility management and soil cultivation on agricultural land, as soil conservation specifically addresses measures relating to watershed and rangeland management.

Understanding the soil

For a comprehensive understanding of soil management it is important to know the soil and its different properties. The basic components of soil are water (25%), air (25%), soil minerals (45%), soil organisms and soil organic matter (5%) which are described in more detail in the following section.
(http://www.physicalgeography.net)

Soil texture

The **soil mineral** section is further divided into three classes by particle size: sand, silt and clay. The relative proportion of sand, silt or clay in a soil is known as soil texture. A soil that has a relatively even mixture of sand, silt and clay, and exhibits the properties from each, is called "loam". (FiBL, 2011) Soils in Afghanistan are mostly clay loams and sandy loams, presented in Figure 1. (USDA&UC Davis, 2013)

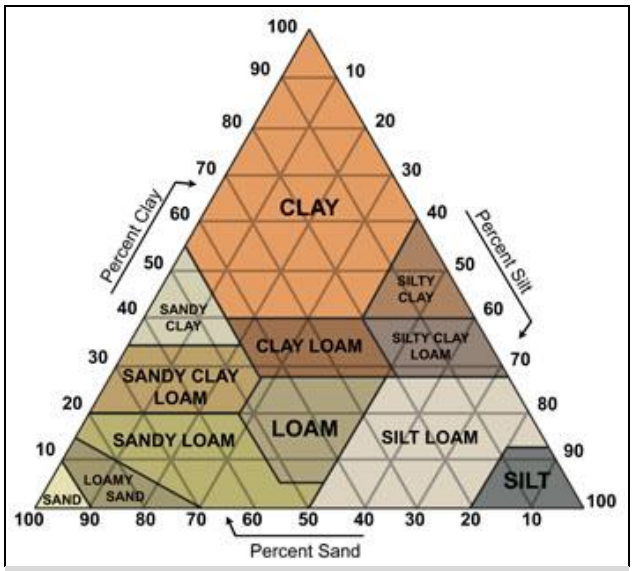

Figure 1: The soil texture triangle shows the major soil texture classes and their relative proportion of sand, silt and clay (http://www.soilsensor.com/)

Soil profile

A soil consists of several distinct layers, all of which have their own characteristics. All the soil layers (or soil horizons) taken together form a distinct soil profile. We distinguish between five soil layers (Figure 2):

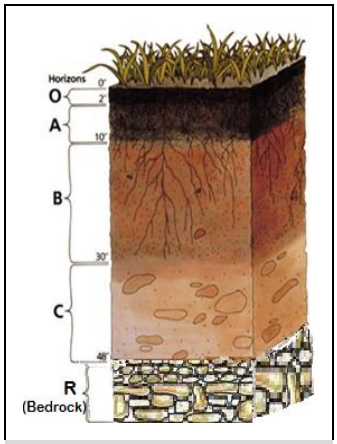

Figure 2: A soil profile showing the distinct soil layers (FiBL, 2011)

O Superficial deposit of plant residues
A Surface soil
B Subsoil
C Parent rock
R Bedrock

The most important layer for plant growth is A, the surface soil, where soil organic matter is concentrated (FiBL, 2011).

Seasonality

Soils undergo seasonal changes. In a cool and dry climate such as the one in the Central Highlands of Afghanistan, light, temperature and frost play an important role. The soil absorbs heat from the sun (light), which allows sufficiently high temperatures for germination and plant growth. However, cold temperatures reduce the activity of soil organisms and also affect the air–water interplay. Frost also has a considerable impact on plant growth.

Soil fertility and pH

Soil fertility is defined by the soil´s ability to provide all essential nutrients in adequate quantities and in the proper balance for plant growth – independently of direct application of nutrients – when other growth factors like light, temperature and water are favourable. This ability doesn't only depend on the content of nutrients,

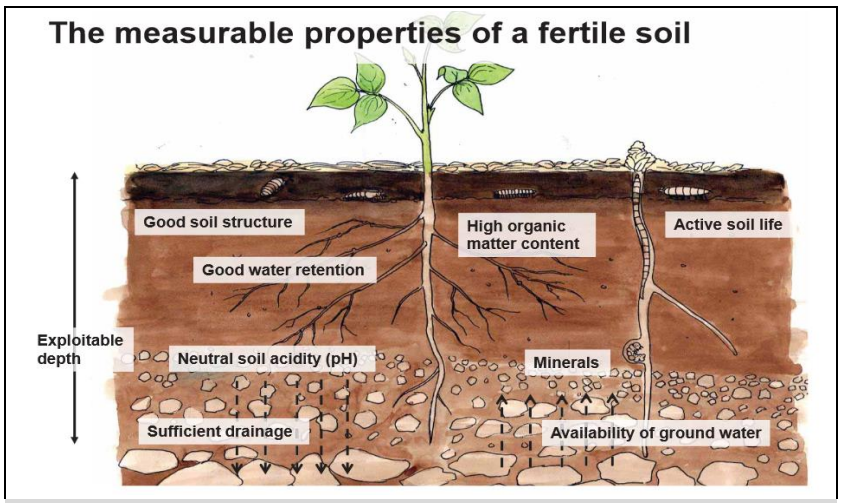

Figure 3: The parameters of soil fertility (FiBL, 2011)

Box 1: A fertile soil

- is rich in **nutrients** necessary for plant growth
- contains an appropriate amount of **soil organic matter**
- has a **pH** in a suitable range for crop production (between 6.0 and 6.8)
- has good **water retention** and supply qualities
- has crumbly structure and is biologically active

Source: FiBL, 2011

but on its efficiency at transforming nutrients within the soil´s nutrient cycle. (FiBL, 2011) Soil fertility is key in sustainable agriculture. The main idea is to promote a healthy soil by feeding the soil (improving soil fertility) rather than by feeding the plants.

Soil pH is defined as the soil´s acidity or alkalinity. Soil pH is highly relevant to how readily available nutrients become in the soil - known as the solubility of nutrients - and whether plant roots can take up these nutrients. (FiBL, 2011) Apart from the effect of pH, other factors such as nitrogen fixation, the C/N quotient and potassium fixation also contribute to soil-induced nutrient deficiencies, while little air (compact soil) or too much water lead to plant roots being unable to take up the nutrients.

Soil organic matter

Soil organic matter is the decomposed plant material and animal manure in the soil. Soil organisms mineralise organic material to soil organic matter.
Soil organic matter usually takes up only a small proportion of the soil and is mainly present in the top layer of the soil (A). The quality of soil organic matter has a fundamental impact on plant growth. **Humus** is well-decomposed soil organic matter and highly stable organic material. (FiBL, 2011)

Box 2: Soil organic matter

- can **hold water** up to five times of its own weight
- has a great capacity to **retain nutrients** and releases them continuously to plants
- gives the soil a good structure
- provides food for soil organisms
- prevents soils from becoming too acidic

Source: FiBL, 2011

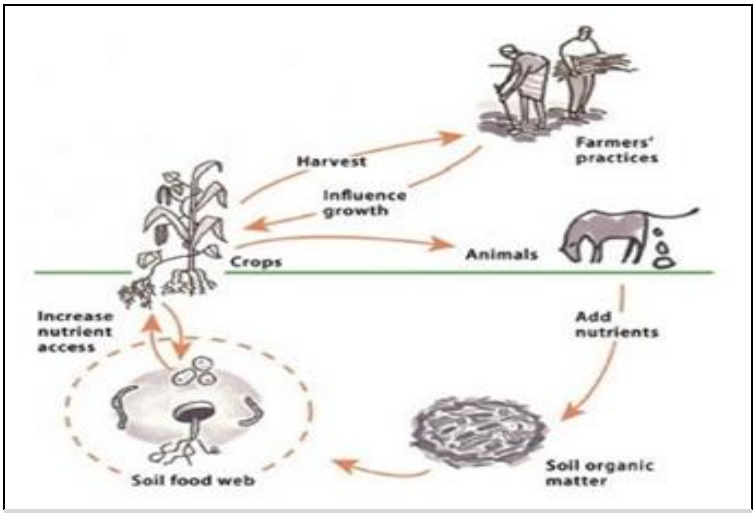

Figure 4: Cycle of soil organic matter. Plant material and animal manure are decomposed to soil organic matter (ILEIA, 2010).

In Afghanistan soil pH is high, whereas soil organic matter content is rather low, ranging from 0.2 to 2.5%, as is water-holding capacity. This stresses the importance of improving soil organic matter content, which will also increase the soil's water-retention capacity (USDA&UC Davis, 2013).
Improving soil organic matter content is a long-term process, and its results generally only become visible after a few years.

Sustainable practices

There are many ways to improve soil organic matter, but most take a long time to have a significant effect. The amount and quality of organic materials applied influence the content of soil organic matter. A regular supply produces the best conditions for maintaining good soil organic matter levels. The following measures contribute to improving soil organic matter (FiBL, 2011 and ILEIA, 2010):

Green manure: This involves so-called cover crops, which are grown specifically to improve soil conditions. Green manure often includes nitrogen-fixing leguminous plant species. Normally, a fast-growing cover crop is ploughed under the soil when mature. Green manure also contributes to preventing soil erosion, as it keeps the soil covered (for instance during winter). Green manure can be easily integrated into an existing farming system - in crop rotation, as an intercrop or as part of an agroforestry system (leguminous trees). Winter rye or varieties of vetch are typically used in winter, while clover or mustard feature in summer.

Compost: Compost is a process of controlled decomposition of plant material and animal manure. The product is of high quality, and its main value is its long-term improvement of soil fertility. Compost increases the pool of nutrients in the soil, and its capacity to retain water. Composting usually makes use of materials that are available on-farm. However, it does require careful management and is labour-intensive. **Small compost enterprises** involving a farmer producing compost as an income opportunity can present a sustainable approach to the on-farm labour deficit for composting.

Mulching: Any fresh or dried plant or woody material can be used for mulching. Some additional advantages of mulching are a reduction in evaporation, the suppression of weeds, insulation against extreme heat and cold, water retention, and prevention of soil compaction and soil erosion.

Figure 5: Challenges to the adoption of sustainable soil management practices such as green manure, compost and mulching by farmers in Afghanistan (HELVETAS Swiss Intercooperation, 2014)

These methods have shown a substantial increase in soil organic matter and plant yields in various countries, though challenges continue to hinder their adoption. Figure 5 shows the remaining challenges to farmers' application of these practices. Some challenges, such as knowledge and awareness, can be tackled by providing capacity building for farmers, yet others, such as lack of capital (land, biomass) and the fuel problem, are more difficult to overcome.

The gender aspect has to be considered when addressing sustainable soil management. There are often gender discrepancies with regards to soil fertility, as women are often involved in producing staple foods on poor soils, whereas men grow cash crops on the most fertile land. When promoting sustainable practices to improve soil organic matter (e.g. green manures, compost and mulching) it is important to consider whose workload will increase and when. Moreover, as these practices are very knowledge-intensive, capacity-building and training must always target the performer of the activity, i.e. men *and* women in many cases.

Soil preparation

The main aim in sustainable agriculture is to maintain soil fertility and conserve soil water. One method that aims to achieve these objectives is **conservation agriculture**. Conservation agriculture has three basic principles:

1. Minimise soil disturbance (by reduced tillage)
2. Keep the soil covered as much as possible
3. Mix and rotate crops

Box 3: Conservation agriculture in semi-arid climates

- Retains water in the soil (soil moisture)
- Keeps the soil temperature constant
- Protects the land from erosion

Source: Biovision, 2012

Reduced tillage

Tillage is the basic crop production operation. Tillage operations include ploughing, harrowing, mechanical destruction of weeds, and many more. However, every time land is tilled the land is exposed to erosion, water loss through evapotranspiration and decomposition of soil organic matter. It is therefore best to reduce soil disturbance, for example through reduced tillage. (Biovision, 2012)

Table 1: Advantages and disadvantages of reduced tillage (Biovision, 2012)

Advantages	Disadvantages
• Less labour due to less operations • Reduction of erosion • Conservation of soil moisture • Improves soil organic matter • Reduction of compacting, better rooting of plants • Reduces CO_2 emissions	• Takes a long time to establish • Weed control is critical • Knowledge and mindset • Non-availability of equipment for reduced tillage

Author(s): Tina Roner, April 2014

Further reading and references

- Biovison, 2012: Infonet - Biovison, available at: http://www.infonet-biovision.org/
- FibL, 2011: African Organic Training Manual, Module 2, Soil fertility management, available at http://www.organic-africa.net/1311.html?&L=0
- Fundamentals of Physical Geography, 2nd Edition, available at: http://www.physicalgeography.net/fundamentals/contents.html
- Hudson, N.W., 1987: Soil and water conservation in semi-arid areas, Soil Resources, FAO, Rome
- ILEIA, 2010: Learning AgriCultures Module 2, Soil and water systems, available at: http://www.agriculturesnetwork.org/resources/learning/mod2
- SSMP Notes, ICIMOD 2008, available at: http://www.icimod.org/?q=10300
- USDA&UC Davis, 2013: Afghan Agriculture Portal, online on: http://afghanag.ucdavis.edu/

This publication has been made possible through financial support of Swiss Agency for Development and Cooperation SDC. The content, however, is the sole responsibility of HELVETAS Swiss Intercooperation.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Agency for Development and Cooperation SDC