Geo Factsheet

Number 70

The Effect of Agriculture on Soils

Humans have been changing soils by cultivating, draining, liming and adding dung for thousands of years. More recently - within the last 100 years - farmers have been able to add chemical fertilisers and pesticides.

Farmers influence many soil characteristics - aeration, drainage, structure, nutrient content, pH etc, and in turn these affect the properties of the soil, particularly its fertility and its stability. Whilst farmers may try to increase stability and fertility, very often their activities have resulted in precisely the opposite, i.e. fertility and stability have decreased and soils have become degraded and eroded.

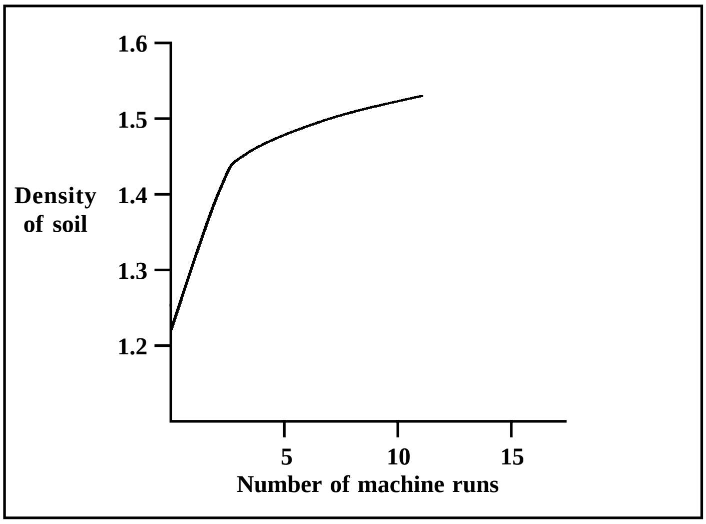
Soil is an extremely complex medium. When farmers attempt to change one soil characteristic, e.g. pH, they almost always influence several others. The soil characteristics and processes interact and it is essential to understand some of these interactions. However, before considering some of the complexities, it is necessary to summarise the individual ways in which agriculture influences soils.

1. Cultivation

The aim of cultivation is to improve the physical condition of the soil, so that seed germination and crop growth are improved. Cultivation mixes the surface horizon and brings previously buried organic matter - decomposing roots, dead leaves, etc - to the surface, accelerating its oxidation.

Cultivation also affects the drainage characteristics and hence the moisture content of soils. Wet soils may become compacted by heavy machinery (Fig 1).

Fig 1. Effect of heavy machinery on soil compaction



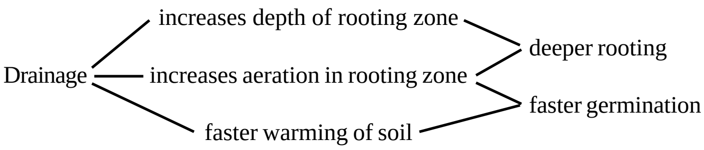
Compaction blocks drainage channels, leading to a build-up of surface water.

2. Drainage

Plant roots cannot grow in saturated soil. Roots penetrate soils by growing in through air spaces. In saturated soils, these air spaces are filled with water. This means roots cannot obtain the oxygen they need to absorb minerals. Thus, plant growth declines and plant death may quickly follow.

The many benefits of drains laid below ploughing depth, which carry water away from the field, are summarised in Fig 2.

Fig 2. Advantages of drainage



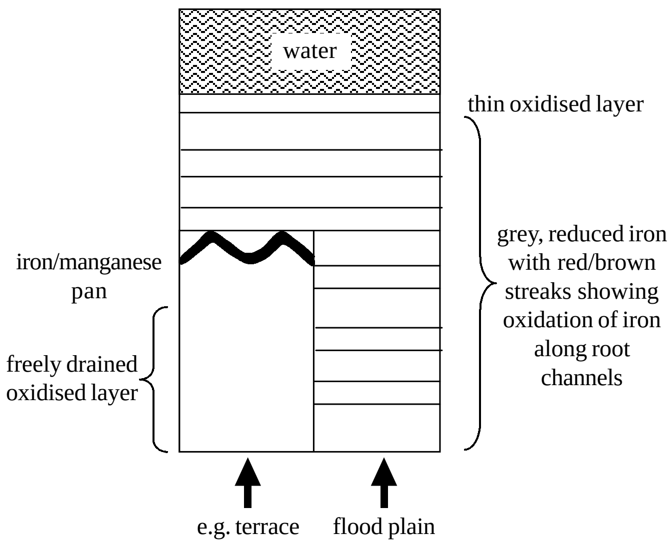
Poor drainage may result from:

1. Soil overlying impermeable material, e.g. rock or clay
2. Presence of high water table
3. Soil receiving run-off from adjacent areas
4. Destruction of or damage to surface layer, preventing infiltration, e.g. compaction - which is most likely in wet soils
5. Damage to subsoil layers, e.g. by development of a paddy

Paddy soils

Approximately 115 million hectares of land is used to grow rice in paddy conditions, i.e. soils which are flooded during the growing season. Most of these are soils on alluvial parent material, but hillside terraces are also used. The structure of a typical paddy soil is shown in Fig 3.

Fig 3. Paddy soils



Typical Exam Questions

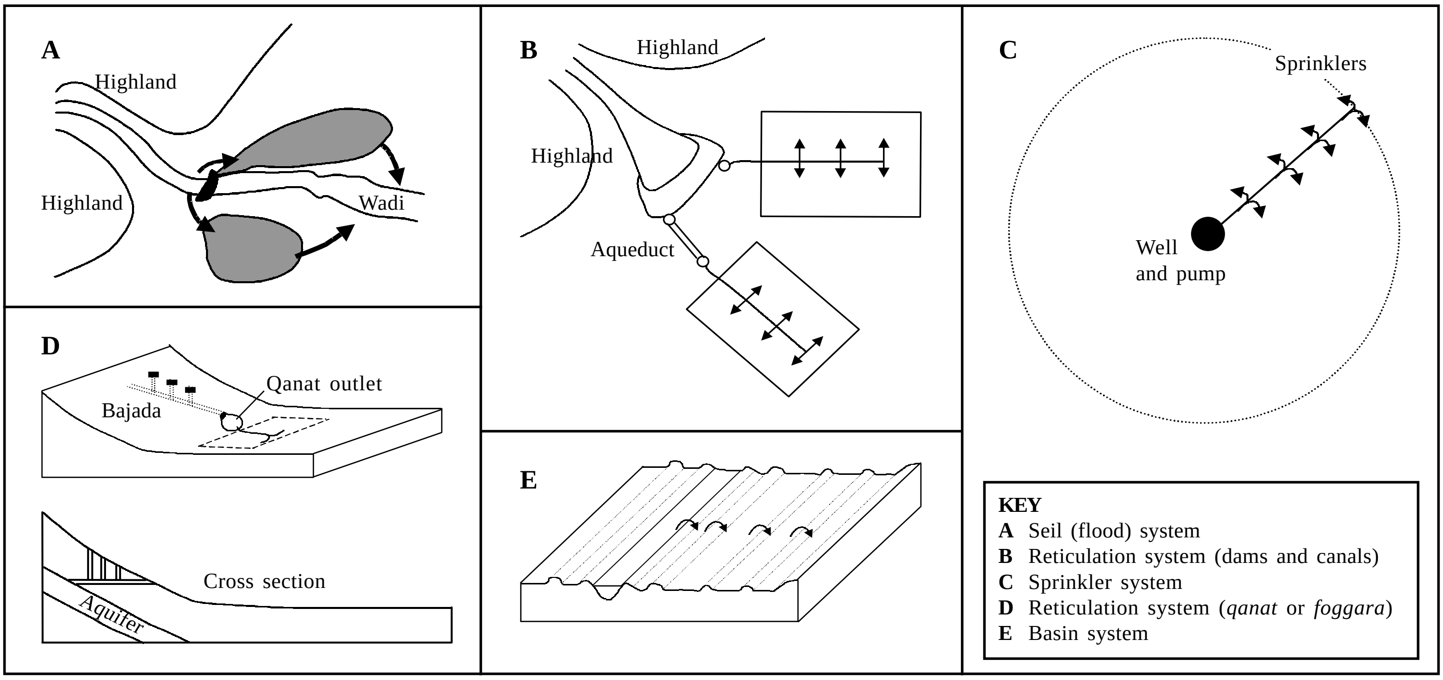
This is a topic on which examiners can test candidates' ability to apply their knowledge of soil processes in unfamiliar situations. Thus, it is essential that candidates understand the principals of processes such as illuviation, elluviation and podsolisation. A good way of revising this topic is to draw flow charts linking agricultural practices with soil processes and characteristics.

Constructed soils

Soils may be artificially thickened by successive additions of soil, turves or animal manure.

The poor, sandy soils of north-west Europe, known as **plaggen** soils, have been raised by up to 1m by successive additions of turves which have been cut from heaths and forests and used as animal bedding before being laid onto the land.
In a process known as **warping**, river floodwaters have been carefully directed to deposit fertile silts in several areas around the Humber estuary. The fluvial deposits have been built up over decades and, through cultivation, have resulted in 30cm thick, homogenised fertile topsoils.

Fig 4. Irrigation systems



3. Irrigation

There are many different ways of supplying irrigation water (Fig 4).

Surface or gravity irrigation involves flooding the land and allowing it to be distributed according to relief. Land levelling is often necessary and problems such as puddling, soil erosion, excessive evaporation and salinisation are common.

Sprinkler irrigation systems force water through pipes and sprinklers, mimicing rainfall. This allows greater control of the rate/volume applied, reducing soil erosion but increasing problems of leaf scorch and fungal diseases.

Trickle irrigation is the most efficient system. Water is distributed through plastic pipes with narrow holes above or around the individual plants and this minimises problems.

The greatest problem caused by irrigation is **salinisation**. Evaporation of the water on and in the soil leaves salt deposits (chlorides and sulphates) behind. These salts become concentrated around the rooting zone, drawing water out of plant roots, killing the plants. In addition, specific ions, such as chloride, sodium and borate, may be directly toxic. Saline soils are effectively ruined for agriculture. The salinisation can be prevented by ensuring that drainage is adequate to wash out salts.

Salts may also accumulate if excess irrigation water raises the level of the water table, drawing salts up from depth. If the amount of sodium and bicarbonate increases, the soil may suffer **alkalinisation**. When pH rises above 8.5, sodium has a deflocculating effect, i.e. it causes clay particles to disintegrate, soil structure deteriorates and soil permeability decreases.

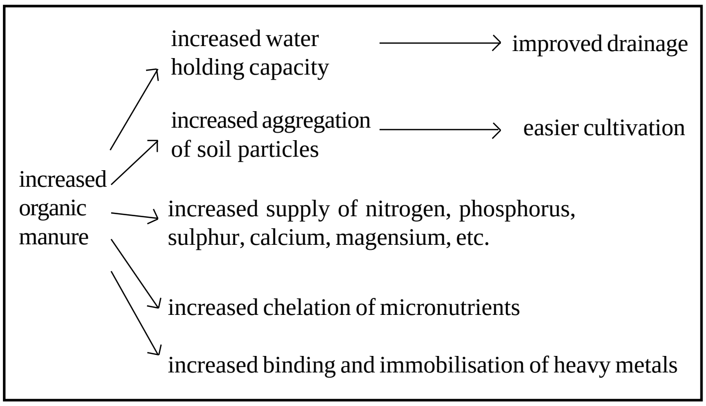
The broken up clay particles may leach downwards to form an impermeable B-horizon. Organic matter also breaks down into a structureless black scum. Such soils are described as black-alkali soils or **solonetz.**

4. Fertility changes

Repeated cropping of soils, without the addition of natural or artificial fertiliser or without fallow (rest) periods, will lead to nutrient deficiencies. Soils beneath cleared rainforests are often very nutrient poor, because most of the nutrients were stored in the above-ground biomass. Peasant farmers have found that such soils may support only two or three years' crop growth before becoming exhausted. Overgrazing can lead to the same effect.

Whilst artificial fertilisers, e.g. ammonium sulphate, supply nutrients (in this case nitrogen and sulphur) to the soil, they do nothing to improve soil structure. Organic manure and crop residues, on the other hand, have a profound effect on overall soil fertility (Fig 5).

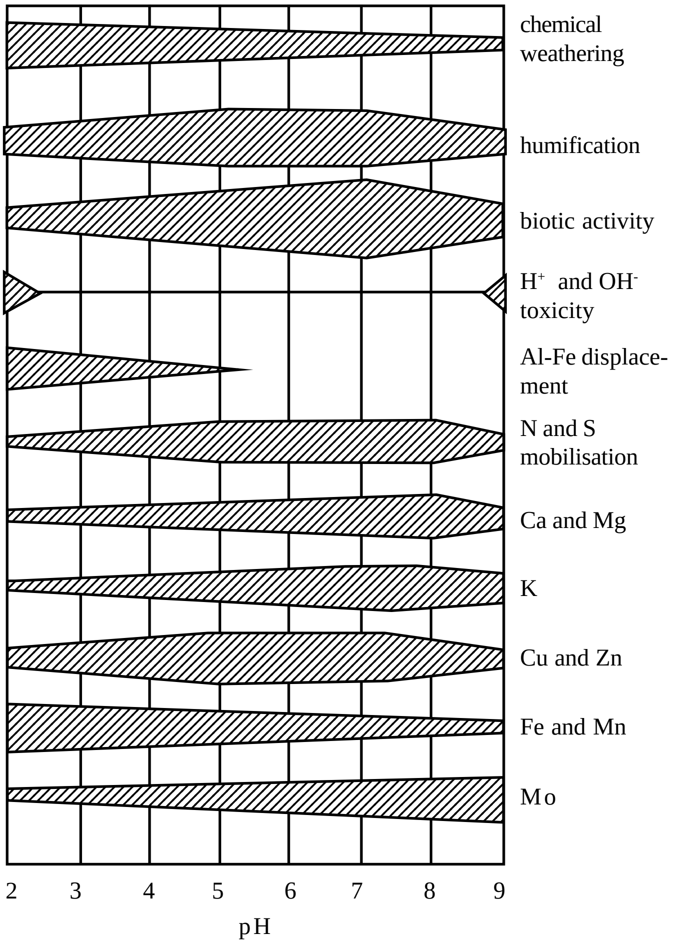
Fig 5. Organic matter and soil fertility



5. pH changes

Nutrient availability in soils is heavily influenced by soil pH (Fig 6).

Fig 6. Influence of soil pH on soil processes and mineral availability



The wider the band, the more available the nutrient is or the greater the rate of the process or activity. Thus, biotic activity e.g. activity of earthworms is greatest at pH7. Potassium (K) is most available between pH 7-8 but becomes less available as pH decreases.

In simple terms, different nutrients become available at different pHs. The farmer has to try to maintain soil pH so that just the right amount of essential nutrients are made available. The most common technique is to attempt to increase soil pH by adding lime. Lime improves soil structure, neutralises potentially toxic acidic elements and increases the availability of calcium ions – essential for plant growth.

However, acid rain – a natural phenomenon made worse by human-generated emissions of nitrogen dioxide and sulphur dioxide – has increased soil acidification. This problem has mainly affected soils with low buffering capacity, i.e. those which are on acid strata. Soil acidification affects plant growth directly (by damaging root hairs) and indirectly, by changing the availability of nutrients (Fig 6).

6. Soil erosion

The key factors which affect soil erosion are:

1. The erosivity of rainfall (the potential of rainfall to cause erosion)
2. The erodibility of the soil (how easy or difficult it is to remove the soil)
3. The slope of the land
4. The nature of the plant cover on the land.

All of these are incorporated into the Universal Soil-Loss Equation (Fig 7)

Fig 7. Universal Soil-Loss Equation

$$A = R \times K \times LS \times P \times C$$

KEY
A Average annual soil loss
R Erosivity
K Erodibility (structure)
LS Length and angle of slope
P Land practice factor
C Crop management factor

Agriculture practices should ensure that K, LS, P and C are considered at every stage. Ploughing a loosely compacted soil in a sloping field which contains no vegetation during the rainy season will inevitably lead to rapid soil erosion. The effects of the most important factors are summarised in Table 1.

Table 1. Factors effecting soil erosion

Erosivity (rain and wind)	- Rainfall – a function of intensity and duration and mass, diameter and velocity of raindrops - Wind – a function of velocity and duration
Erodibility	- a function of soil texture, stability of soil aggregates, shear strength, infiltration capacity, organic content, chemical content. Silts and fen sands are highly erodible
Slope	- a function of steepness and length which affect velocity and volume of surface runoff. The effect of slope is particularly important when rainfall intensity is high. However, as overland flow increases in depth, the underlying soil may be protected from raindrop impact so that overall erosion rates may decrease.
Plant cover	- Plants may reduce soil erosion because they: 1. Intercept rainfall, reducing its velocity, hence erosivity 2. Decrease the volume of water which reaches the soil 3. Provide organic matter which improves soil structure 4. Bind the soil via roots However raindrops from canopies may be more erosive because the average droplet size is greater than normal rain and if the canopy is more than 7m above the ground, the drops attain 90% of their terminal velocity anyway.

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