http://www.fao.org/ag/agl/agll/prosoil/psintro.htm

Acid soils

In the context of agricultural problem soils, acid soils are soils in which acidity dominates the problems related to agricultural land use. They are characterized by a pH which is strongly (5.5-4.5) to extremely acid (<4.5), a low cation-exchange capacity and a low base saturation. In the World Reference Base (WRB) soil classification system acid soils (as agricultural problem soils) may mainly occur in the following Reference Soil Groups: Acrisols, Arenosols, Cambisols, Histosols, Ferralsols, Luvisols, Planosols, Podzols and Fluvisols. However, the Reference Soil Groups with the widest distribution of acid soils are Acrisols, Ferralsols and Podzols.

Acid soils occur in the tropics and subtropics as well as in moderate climates. Their formation depends on specific conditions of climate, topography, vegetation, parent material and time for soil formation. Acrisols and Ferralsols are most common in old land surfaces in humid tropical climates. Acid sulphate soils occur in the tropics, in low-lying coastal land formerly occupied by mangrove swamps. Podzols are typical soils of the northern coniferous forests but may occur in the tropics, too.

The types of acid soils vary considerably due to different factors in soil formation, especially differences in climate, parent material and vegetation. Acid soils place major difficulties for agricultural use but can be very productive if lime and nutrients are constantly applied and appropriate soil management is practised.

Special management implications are caused by the occurrence of aluminium toxicity. In general soils with pH (H_2O) <5 and >60% Al saturation of the cation exchange capacity (CEC) may suffer from Al toxicity. High concentrations of Al affect root growth, uptake and translocation of nutrients (especially immobilization of phosphorus in the roots), cell division, respiration, nitrogen mobilization and glucose phosphorylation of plants. Therefore, in the context of agricultural problem soils, it is necessary to make a distinction between acid soils with Al toxicity and soils without Al toxicity because of the differing management implications for these soils.

A special case of acid soils with aluminium toxicity are Thionic Fluvisols (acid sulphate soils) which have a sulfuric horizon in the upper soil horizons. If these soils are drained sulphuric acid is produced by oxidisation processes resulting in extremely acid soil conditions.

Strongly acid soils with aluminium toxicity (pH < 5)

Strong soil acidity considerably effects physical, chemical and biological properties of soils. The low calcium concentrations in the soil solution of acid soils restrict biological activity and soil structure stability. The major production constraint on strongly acid mineral soils is, however, the possible occurrence of high aluminium concentrations in the soil solution which are toxic to plants. Especially many tropical soils which are extremely weathered contain high amounts of exchangeable aluminium due to advanced soil formation processes. The first effects of aluminium toxicity to be observed are a shortening and thickening of the roots. Roots become brown in colour and branching is reduced. The symptoms of aluminium toxicity are similar to phosphorus or calcium deficiency. If aluminium toxicity further progresses various plant metabolic processes are affected such as uptake and translocation of nutrients (especially immobilization of phosphorus in the roots), cell division, respiration, nitrogen mobilization and glucose phosphorylation of plants. The tolerable aluminium concentration varies from plant species to plant species. But there are few crops such as tea which may accumulate greater amounts of aluminium without negative effects on plant growth. Tolerance of plants may depend on different factors such as differences in root morphology, ability to increase the pH of the root zone, mechanisms to reduce translocation of aluminium from the roots to the shoots, accumulation of aluminium in the shoots without affecting plant metabolism and mechanisms for not inhibiting nutrient uptake (Ca, Mg, P) despite the presence of aluminium. Lime application is a common means for increasing soil pH and consequently reducing the amount of aluminium in the soil solution. However, in many tropical areas lime is in short supply. Therefore the breeding of aluminium tolerant crop varieties is of specific importance for tropical agriculture. There are tolerant varieties of various crops available. Especially varieties of upland rice, cassava, mango, cashew, citrus, pineapple and cowpeas may be suitable for arable production on these soils. Also various grasses (Brachiaria decumbens, Paspalum plicatulum, Pueraria lobata, Melinis minutiflora, Hyparrhenia rufa) and legumes (Stylosanthes ssp., Desmodium ssp, Centrosema ssp.) can be productively used on these soils

Reference Soil Groups which may contain acid soils with aluminium toxicity are:
- **Acrisols and Ferralsols**
- **Podzols**

Moderately acid soils without aluminium toxicity (pH >5 and <6.5)

In moderately acid soils there are no principal differences with regard to the pH demands of crops if aluminium toxicity is excluded. Even crops which are known to demand more neutral soil conditions such as sugar beet, barley and wheat may give reasonable yields on moderate acid soils if appropriate nutrient and water supply and favourable rooting conditions are ensured. The negative effects of soil acidity on physical and chemical soil conditions can be partly compensated by a high organic matter content. The lower the soil pH, the higher should be the organic matter content of the soil. A high organic matter content helps to achieve favourable tillage conditions, good aggregate stability and soil aeration. Consequently appropriate attention has to be given to increase the organic matter content in moderate acid soils. This can be achieved, for instant, by mulching or no-tillage systems.

Reference Soil Groups which mainly contain acid soils are:
- **Acrisols and Ferralsols**
- **Podzols**

Acrisols and Ferralsols

Definition

Acrisols are characterized by a clay accumulation horizon, the argic horizon, in combination with the occurrence of low activity clays (cation exchange capacity of <24cmolckg^{-1}) and a low base saturation (i.e. <50%).

Ferralsols are soils that have a ferralic horizon at some depth between 30 and 200 cm from the soil surface. A ferralic horizon is a fine textured horizon which has been formed by strong weathering and leaching over a long period of time resulting in the accumulation of stable sesquioxides of iron and aluminium.

Further description

Acrisols and Ferralsols are tropical and subtropical soils of old landscapes under high rainfall conditions. They are usually very deep, yellowish to reddish coloured, extremely weathered and leached. Most of the soils are characterized by a high percentage of low-activity clay minerals such as kaolinite and sesquioxides (goethite, gibbsite, haematite). Hydrolysis of the silicate minerals, combined with rapid removal of weathering products leads to a low pH and low concentrations of weathered products in the soil solution.

General environment

Acrisols and Ferralsols are most common in old land surfaces in humid tropical climates. They occur on gently undulating Tertiary and early Pleistocene erosion surfaces upon which repeated cycles of weathering, erosion and deposition have taken place.

Global extent and location

Acrisols cover about 1 billion hectares (see Table), mainly in the equatorial tropics on old deeply weathered land surfaces in Southeast Asia, West Africa and the central part of South America. Ferralsols occur almost on 745 million hectares worldwide (see Table), concentrated in the humid tropics. They are mainly situated on the continental shields of South America and Central Africa. Outside the continental shields, Ferralsols are restricted to regions with easily weatherable basic rock and a hot and humid climate, e.g. in Southeast Asia and on some Pacific Islands.

Table. Extent ('000s ha) of soil groups by continent

	Africa	Australasia	Europe	North America	North and C. Asia	South and C. America	South and SE Asia	Total
Acrisols	92728	32482	4170	114813	148241	341161	263005	996600
Arenosols	462401	193233	3806	25512	3436	118967	94530	901885
Calcisols	171237	113905	56657	114720	95264	24318	220068	796169
Ferralsols	319247	0	0	0	0	423353	0	742600
Histosols	12270	1167	32824	93462	99451	9245	24829	273248
Leptosols	381531	48789	64836	83303	710863	246588	48789	1655318
Podzols	11331	8459	213624	220770	21825	5522	5982	487513
Solonchaks	48574	16565	2308	127	46895	24344	48512	187325
Solonetz	13800	38099	7906	10748	30062	34652	0	135267
Vertisols	106126	90019	5856	9120	11797	38076	76328	337322

Land use

Acrisols and Ferralsols are naturally covered by tropical rainforests. For agriculture, Acrisols and Ferralsols can be used as pasture or arable land but their sustainable use highly depends on appropriate land management. Large areas of Acrisols and Ferralsols are used for subsistence farming, partly under shifting cultivation.

Main production constraints

Acrisols and Ferralsols are extremely nutrient deficient and acid, often with toxic levels of exchangeable aluminium. The high amounts of exchangeable aluminium may act as firm barrier to deep rooting of the plants, leading to physiological drought of crops at dry spells within the rainy season. Acrisols and Ferralsols are also characterized by low availability of phosphorus due to a high capacity for phosphorus fixation. Thus lime, macro-nutrients and often micro-nutrients (e.g. molybdenum) have to be added for crop production. The exchange capacity of the organic matter in these soils is very important because of the low cation-exchange capacity of the clay minerals; however the organic matter is rapidly mineralized under the hot tropical conditions.

Summary

Acrisols and Ferralsols are tropical and subtropical soils which are extremely weathered and leached. These soils are generally of low fertility because of both macro- and micro-nutrient deficiencies often combined with aluminium toxicity and soil acidity. In addition they are highly susceptible to erosion if used for arable cultivation. For sustainable agricultural use a careful soil fertility management in combination with conservation practices have to be applied.

Podzols

Definition

Podzols are soils characterized by the presence of a spodic horizon containing an accumulation of organic matter, iron and aluminium within 200 cm of the soil surface. The process of translocation and accumulation is usually shown by the occurrence of an albic horizon underlain by the spodic horizon.

Further description

A cover layer of acid organic litter (under the original vegetation) is followed by a marked bleached (albic) horizon due to the leaching out of iron, aluminium and humus. Strong leaching, with highly acidic conditions, provide conditions where a mor humus develops and clay minerals are broken down. In association with the organic breakdown products, iron and aluminium are transported from the eluvial horizons to the spodic horizon.

General environment

Podzols develop on sandy substrates and are soils of the northern cool temperate areas with coniferous forests. Podzols may also occur in many parts of the tropics where they develop in deposits of almost pure quartz sand (see sandy soils).

Global extent and location

Podzols cover an estimated 487 million hectares worldwide (see Table), mainly in the temperate and boreal regions of the northern hemisphere. Tropical Podzols total not more than 32 million hectares, important occurrences are along the Rio Negro and in the Guyanas of South America, in the Malesian region (Kalimantan, Sumatra, Irian) and in northern Australia. There, they mainly occur in residual sandstone weathering in perhumid regions and in old, alluvial quartz sands.

Land use

Low nutrient status, sandy texture and low pH value make Podzols infertile soils. Therefore the agricultural use of Podzols is limited. They are normally reserved for coniferous forestry, low intensity grazing or are left fallow. However, if fertilizers, liming and irrigation are practised reasonable yields of arable crops may be achieved.

Main production constraints

Podzols are very sandy, acid and nutrient deficient. Aluminium toxicity, restriction of nitrification and phosphorus deficiency are major problems encountered when growing crops on Podzols. Furthermore, the leaching out of iron and subsequent accumulation in lower horizons may lead to a thin iron pan which is impervious. They may then have hydromorphic properties. Podzols are inherently infertile for arable crops. Before crops can be grown, these soils must be limed, fertilized and cultivated; if formed the iron pan must be broken to improve their drainage. Then Podzols can be productive, provided that constant additions of lime and fertilizers are applied.

Summary

Podzols are the principal soils of the northern coniferous forest. They have an extremely low potential for agriculture since they need heavy applications of lime and fertilizers but they have proved to be productive in some parts of Europe and North America if the respective inputs are applied. They are often used for coniferous forest or low volume grazing.

Sandy Soils

Definition

In the context of agricultural problem soils, sandy soils are soils in which a coarse texture dominates the problems related to agricultural land use. Sandy soils are characterized by less than 18% clay and more than 65% sand in the first 100 cm of the solum. In the World Reference Base (WRB) soil classification system sandy soils may occur in the following Reference Soil Groups: Arenosols, Regosols, Leptosols and Fluvisols. In the following the focus is laid on the consideration of Arenosols as the main Reference Group for actual "sandy" soils.

Further description

Sandy soils are weakly developed soils with only weak profile horizon formation because of the slow chemical weathering in these normally dry and hot soils. Physical weathering predominates in response to extreme variations in temperature. Wind erosion is dominant. The A-horizon is only weakly developed and can hardly be seen in a desert sandy soil, but becomes more distinct in the semi-arid sandy soils. Soil structure is very weak and unstable. Absence of vegetation cover results in an extremely low production of organic material which leads to the very low organic matter contents of sandy soils. However, the actual soil moisture content of the sandy soils determines the rate and duration of the chemical reactions, the production of organic matter and biological activity.

General environment

Regions of sandy soils can be divided in two broad categories: residual sands, formed upon weathering of old, usually quartz-rich soil material or rock (normally under tropical conditions) and shifting or only recently deposited sands, e.g. in deserts and beach lands where sand accumulates by the selective action of wind and water. Arenosols may occur from arid to (per)humid and from extremely cold to extremely hot climates; related land forms vary from recent dunes, beach ridges and sandy plains under a scattered (mostly grassy) vegetation to very old plateaux under a light forest.

Global extent and location

Arenosols cover some 900 million hectares (see Table), mainly in the dry zone, i.e. in the southern Sahara, Southwest Africa and western Australia. Several million hectares of highly leached Arenosols are found in the perhumid tropics, notably in South America and in parts of Southeast Asia. Small areas of (young) Arenosols may occur in all parts of the world.

Land use

Many sandy soils are non-used wastelands. Sandy soils in the dry zone may be used for extensive grazing but with irrigation also arable cropping is possible. In temperate areas mixed arable cropping and grazing is practised but often supplemental (sprinkler) irrigation is needed during dry spells. In the perhumid tropics sandy soils are chemically exhausted and highly sensitive to erosion and therefore demand cautious management if used for agriculture.

Main production constraints

The course texture of sandy soils causes a low water holding capacity and high infiltration rate which represent the main production constraints. Nutrients contents and nutrient retention are normally low, thus causing a low inherent fertility status for agricultural production. Nutrients are easily leached out of the solum. The poor soil structure makes the soils very susceptible to wind erosion. However, sandy soils can be very productive when appropriate management is applied and water is available for crop cultivation by means of irrigation or because of a shallow water table.

Summary

The agricultural potential of sandy soils depends on the availability of sufficient water for crop cultivation and the provision of nutrients. If appropriately managed sandy soils can be highly productive.

Last update: August 2000