SET 3
ARENOSOLS
DEFINITION
SUMMARY
DISTRIBUTION
ASSOCIATIONS
GENESIS
CHARACTERISTICS
MANAGEMENT / USE
SAMPLE PROFILE
SLIDESHOW

ARENOSOLS (AR)

The Reference Soil Group of the Arenosols consists of sandy soils, both soils developed in residual sands, in situ after weathering of old, usually quartz-rich soil material or rock, and soils developed in recently deposited sands as occur in deserts and beach lands. Correlated soils in other classification systems include Psamments, Psammaquents of the USDA Soil Taxonomy. Deep sandy soils with an argic or a spodic horizon within 200 cm from the surface are accommodated as 'Grossarenic' subgroups within the Alfisol, Ultisol and Spodosol orders. In the French classification system (CPCS, 1967), Arenosols correlate with taxa within the "Classe des sols minéraux bruts" and the "Classe des sols peu évolués". Other international soil names are to indicate Arenosols are 'siliceous, earthy and calcareous sands' and various 'podsolic soils' (Australia), 'red and yellow sands' (Brazil) and the Arenosols of the FAO Soil Map of the World.

Definition of Arenosols

Soils

1 having a texture which is loamy sand or coarser either to a depth of at least 100 cm from the soil surface, or to a plinthic, petroplinthic or salic horizon between 50 and 100 cm from the soil surface; **and**

2 having less than 35 percent (by volume) of rock fragments or other coarse fragments within 100 cm of the soil surface; **and**

3 having no diagnostic horizons other than an ochric, yermic or albic horizon, or a plinthic, petro-plinthic or salic horizon below 50 cm from the soil surface.

Common soil units:

Gelic, Hyposalic, Gleyic, Hyperalbic, Plinthic, Hypoferralic, Hypoluvic, Tephric, Gypsiric, Calcaric, Albic, Lamellic, Fragic, Yermic, Aridic, Protic, Dystric, Eutric, Rubic, Haplic.

Summary description of Arenosols

Connotation: sandy soils; from L. arena, sand.

Parent material: unconsolidated, in places calcareous, translocated materials of sand texture; relatively small areas of Arenosols occur on residual sandstone or siliceous rock weathering.

Environment: from arid to (per)humid and from extremely cold to extremely hot; landforms vary from recent dunes, beach ridges and sandy plains under scattered (mostly grassy) vegetation, to very old plateaus under light forest.

Profile development: A(E)C-profiles. In the dry zone, an ochric surface horizon is the only diagnostic horizon. Arenosols in the perhumid tropics tend to develop thick albic eluviation horizons whereas most Arenosols of the humid temperate zone show signs of alteration or transport of humus, iron or clay, but too weak to be diagnostic.

Use: most Arenosols in the dry zone are used for little more than extensive grazing but they could be used for arable cropping if irrigated. Arenosols in temperate climate regions are used for mixed arable cropping and grazing but supplemental (sprinkler) irrigation is needed during dry spells. Arenosols in the perhumid tropics are chemically exhausted and highly sensitive to erosion. They are best left untouched.

SET 3
ARENOSOLS
DEFINITION
SUMMARY
DISTRIBUTION
ASSOCIATIONS
GENESIS
CHARACTERISTICS
MANAGEMENT / USE
SAMPLE PROFILE
SLIDESHOW

Regional distribution of Arenosols

Arenosols are one of the most extensive Reference Soil Groups in the world, covering about 900 million ha or 7 percent of the land surface. If shifting sands and active dunes ('non-soils') were included, the coverage would be about 10 percent. Vast expanses of deep eolian sands are found on the central African plateau between the equator and 30^{o} southern latitude. These 'Kalahari Sands' form the largest body of sands on earth. Other areas of Arenosols occur in the Sahelian region of Africa, various parts of the Sahara desert, central and western Australia, the Middle East and China. Sandy coastal plains and coastal dune areas are of smaller geographic extent. Although most Arenosols occur in arid and semi-arid regions, they are typical azonal soils; they are found in the widest possible range of climates, from very arid to very humid and from cold to hot. Arenosols are widespread in eolian landscapes but occur also in marine, littoral and lacustrine sands and in coarse-grained weathering mantles of siliceous rocks, mainly sandstone, quartzite and granite. There is no limitation as to age or period in which soil formation took place. Arenosols occur on very old surfaces as well as in very recent landforms, and may be associated with almost any type of vegetation.

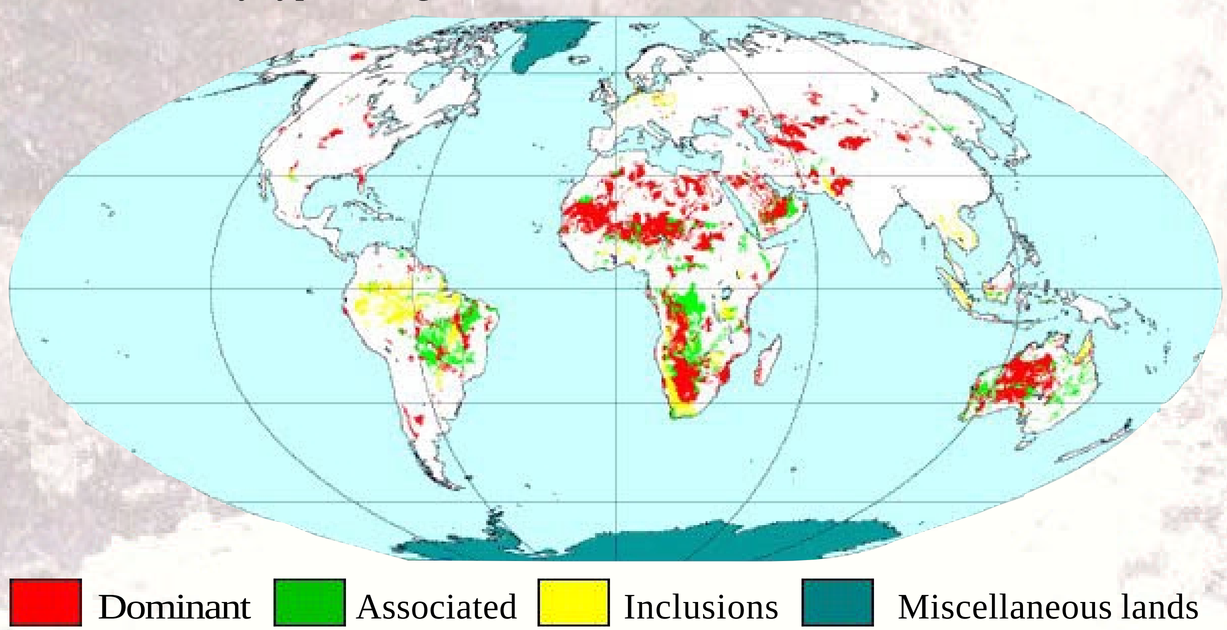

Figure 1. Arenosols worldwide.

Associations with other Reference Soil Groups

Arenosols have linkages with almost any other reference group. With some Reference Soil Groups such a linkage is rather theoretical and probably rare, with others the linkage is obvious and common. A broad division can be made between Arenic units of other reference groups and soil units of Arenosols.

Arenic units

The qualifier 'Arenic', indicating a texture of loamy sand or finer throughout the upper 50 cm of the soil (WRB, 1998), is recognised for all reference groups except Histosols, Cryosols, Leptosols, Vertisols, Solonchaks, Podzols, Plinthosols, Solonetz, Chernozems, Kastanozems, Phaeozems, Gypsisols, Calcisols, Nitisols and Cambisols. It is possible that Arenic units exist within these Reference Soil Groups but that they have not (yet) been sufficiently documented. If so, they are probably rare. Because of "opposed" textural requirements no linkage exists with Vertisols.

Most Podzols have a sandy texture and therefore it would not make sense to use the qualifier 'Arenic'; Leptosols are excluded because of the shallowness requirement.

Soil units of Arenosols

Soil units of the Arenosol reference group are linked with Cryosols (Gelic Arenosols), Solonchaks (Hyposalic Arenosols), Gleysols (Gleyic Arenosols), Andosols (Tephric Arenosols), Podzols (Albic or Hyperalbic Arenosols), Plinthosols (Plinthic Arenosols), Ferralsols (Hypoferralic Arenosols), Gypsisols (Gypsiric Arenosols), Durisols (Hypoduric Arenosols) and Calcisols (Calcaric Arenosols).

Special relationships exist with soils having thick sandy layers over an argic, ferralic or spodic subsurface horizon. In Alisols, Acrisols, Luvisols and Lixisols loamy sand or coarser textures are permitted if the argic horizon (by definition sandy loam or finer) occurs within 200 cm of the surface. In addition the qualifier "Hypoluvic" links Arenosols to Luvisols. Soils with a ferralic horizon starting within 170 cm of the surface qualify as Ferralsols, irrespective of the texture of the overlying horizons. Similarly, soils with a spodic horizon starting within 200 cm of the surface are Podzols. Planosols and Albeluvisols may have sandy textures in the upper part of the solum, but the presence of abrupt textural change or of an argic horizon within 100 cm excludes qualifiers linking these soils to Arenosols.

Genesis of Arenosols

The development of the Arenosols of the dry zone is distinctly different from that of Arenosols in the wet tropics. The former show minimal profile development because soil forming processes are at a standstill during long periods of drought and/or because the parent material is of young age. The latter formed in young sandy deposits or, the other extreme, constitute the thick albic E-horizon of a Giant Podzol and represent the ultimate in soil formation.

Arenosols of the dry zone

Most Arenosols in the dry zone are associated with areas of (shifting) sand dunes. Evidently, soil formation in such dune sand is minimal until the dune is colonized by vegetation and held in place. Then, some humus can accumulate in the surface soil and a shallow, ochric surface horizon can develop; Aridic Arenosols contain less than 0.2 percent organic carbon and show evidence of eolian activity. The sand grains of Arenosols in the dry zone may acquire a coating of (brownish) clay and/or carbonates or gypsum. In places, desert sand is deep red by coatings of goethite ('*ferrugination*', a relic feature according to some). Where the parent material is gravelly, sand is blown out of the surface layer and the coarser constituents remain behind at the soil surface as a '*desert pavement*' of polished pebbles and stones. Yermic Arenosols may be encountered in such situations. Depending on parent material and topographical situation, Gypsiric, Calcaric, Hyposalic and Hypoduric Arenosols, or combinations of these, occur as intergrades to Gypsisols, Calcisols, Solonchaks and Durisols. High permeability, low water storage capacity and low biological activity are all conducive to decalcification of the surface layer(s) of Arenosols in the dry zone, even though the annual precipitation sum is extremely low.

Arenosols of the temperate zone

Arenosols in the temperate zone show signs of more advanced soil formation than Arenosols in arid regions. They occur predominantly in fluvio-glacial, alluvial, lacustrine, marine or eolian quartzitic sands of very young to Tertiary age. In young fluvio-glacial or marine sandy deposits, pedogenesis would most likely proceed as follows: in geomorphologically stable conditions a plant cover establishes itself and calcareous sands are deeply decalcified. An ochric surface horizon forms, which contains humus of the 'moder' type, consisting for the greater part of excrements. Soluble organic substances produced in the ochric surface horizon percolate downwards while forming complexes with iron and aluminium (cheluviation, see under Podzols). At this stage the soils show signs of beginning *podzolization* with accumulation of Fe- and Al-humus complexes in thin lamellae. If the process continues until a true spodic subsurface horizon has formed, the soil has become a Podzol. In very poor sands (low in clay, silt and weatherable minerals), the incipient spodic horizon consists almost entirely of humus (Bh) whereas in richer materials it also contains amorphous, dispersible, humus-sequioxide complexes (Bhs). Human intervention can lead to the formation of an anthric horizon (e.g. plaggic horizon). Once the thickness of the anthric horizon reaches 50 cm or more the soil becomes an Anthrosol, otherwise the qualifier anthric (or plaggic) applies.

Lamellae may be of different origin and composition. Lamellae in geomorphologically unstable eolian or fluvio-glacial deposits are mere markers of short periods of stability and vegetative cover alternating with periods of wind erosion and deposition. In more stable situations, lamellae are formed by vertical transport, after decalcification, of fine components over short distances. Humus and/or humus-iron complexes precipitate as the ratio of sequioxides to organic carbon increases in the course of cheluviation or upon saturation upon evaporation at the depth of penetration of water (see the chapter on Podzols). Clay lamellae commonly follow visible stratification and are correlated with differences in pore size. Pores slightly larger than those in the next deeper layer cause water to 'hang' (unsaturated flow). If this water is withdrawn by plants or as vapor, any suspended clay is left behind and the difference in size of pores is accentuated. Thus, once the process has begun, clay continues to accumulate in the same place. The process may take place at several depths. Once the combined thickness of clay lamellae exceeds 15 cm within 100 cm from the surface, the qualifier 'lamellic' applies. The effect of lamellae on the water-holding capacity can be significant because water hangs in each lamella.

SET 3
ARENOSOLS
DEFINITION
SUMMARY
DISTRIBUTION
ASSOCIATIONS
GENESIS
CHARACTERISTICS
MANAGEMENT / USE
SAMPLE PROFILE
SLIDESHOW

Biological homogenization may counteract the transport of metal-humus complexes or of suspended clay in loamy sands that are relatively rich and deep: homogeneous, brown or reddish profiles develop. Many have an orange-red colour under the ochric surface horizon, indicative of thin ($<10^{-5}$ m) iron coatings on the sand grains.

Arenosols of the humid tropics

Arenosols in the humid tropics are either young soils in coarsely textured alluvial, lacustrine or eolian deposits, or they are very old soils in residual acid rock weathering that lost all primary minerals other than (coarse grained) quartz in the course of an impressive pedogenetic history.

The *young* Arenosols of beach ridges and coastal plains, are azonal soils; they merely have a thin brown ochric surface horizon over a deep subsoil that may have gleyic properties and/or show signs of beginning horizon differentiation that are taxonomically insignificant.

The *old* (albic) Arenosols constitute the deep, bleached surface soils of Giant Podzols the albic horizon of which extends downward to a depth below 100 cm from the surface (hyperalbic). If the underlying spodic horizon starts within 200 cm, the soil is classified as a Podzol but where the spodic horizon has occurs beyond the taxonomic control section (200 cm), the soil is back among the Arenosols. These Arenosols are zonal soils; they result from intense and prolonged dissociation of weatherable minerals and translocation of the weathering products. Figure 2 shows an Albic Arenosol developed in sandstone weathering in Queensland, Australia.

SET 3
ARENOSOLS
DEFINITION
SUMMARY
DISTRIBUTION
ASSOCIATIONS
GENESIS
CHARACTERISTICS
MANAGEMENT / USE
SAMPLE PROFILE
SLIDESHOW

Figure 2. Albic Arenosols in the deep eluvial horizon of a Giant Podzol in Queensland, Australia. Photo by courtesy of R. Miedema, Wageningen.

SET 3
ARENOSOLS
DEFINITION
SUMMARY
DISTRIBUTION
ASSOCIATIONS
GENESIS
CHARACTERISTICS
MANAGEMENT / USE
SAMPLE PROFILE
SLIDESHOW

Characteristics of Arenosols

Morphological characteristics

Arenosols in the arid zone have a beginning A-horizon with weak single grain or crumb structure over a massive C-horizon. Arenosols in the temperate zone have better developed but still ochric surface horizons over a substratum that may have thin iron coatings throughout, or contain lamellae of illuviated humus, clay or iron compounds that are too thin, too few or contain too little humus to qualify as a diagnostic B-horizon. Young tropical Arenosols are morphologically not very different from those of the temperate zone. Old tropical Arenosols under forest on residual quartzitic rock weathering or sandy deposits have a dark brown O-horizon over a shallow greyish brown A horizon that tops a deep, grey to white, coarse sandy E-horizon (e.g. “Giant Podzols”). A shallow mini-Podzol may form in the A-horizon; it remains intact because biological activity is virtually absent.

Hydrological characteristics:

Coarsely textured soils hold a much greater proportion of their ‘available’ water at low suctions than finer soils. Since most of the pores are relatively large, much of the retained moisture is lost at a soil suction of only 100 kPa. Depending on the grain size distribution and organic matter content, the ‘Available Water (storage) Capacity’ (AWC) may be as low as 3 to 4 percent or as high as 15 to 17 percent.

Arenosols are permeable to water; saturated hydraulic conductivity varies with the packing density of the sand and can assume any value between 300 and 30,000 cm/day. Infiltration of water in sandy soils varies between 2.5 and 25 cm/hour and may be 250 times faster than in clay soils (0.01 – 0.1 cm/hr). Note that under unsaturated flow conditions water moves more slowly in sandy soils than in clayey soils on account of their lower moisture content and lower unsaturated hydraulic conductivity. Understanding these relations is important for proper irrigation and drainage practices.

SET 3
ARENOSOLS
DEFINITION
SUMMARY
DISTRIBUTION
ASSOCIATIONS
GENESIS
CHARACTERISTICS
MANAGEMENT / USE
SAMPLE PROFILE
SLIDESHOW

Mineralogical characteristics

The principal minerals found in the sand and silt fractions of Arenosols are quartz and feldspars and, to a lesser extent, micas, ferromagnesian minerals (pyroxenes, amphiboles, olivines) and 'heavy' minerals (zircon, garnet, tourmaline, ilmenite, magnetite, rutile, etc). The nature of the clay fraction is conditioned by weathering conditions and parent rock. Certain clay minerals (e.g. vermiculites, chlorites and cemented kaolin) may sometimes be large enough to belong to the sand or silt fraction of the soil.

Physical characteristics

Arenosols have relatively high bulk density values that are typically between 1.5 and 1.7 kg $dm^{-3;}$ somewhat lower or higher values are not uncommon. With the specific gravity of quartz close to 2.65 g dm^{-3}, the calculated total porosity of Arenosols amounts to 36 to 46 volume-percent, less than that of most finely textured soils. Arenosols have a high proportion of large pores that account for their good aeration, rapid drainage and low moisture holding capacity.

Most sands and loamy sands are non-coherent, 'single grain' materials, especially in the ab-sence of organic matter or other cementing agents. Arenosols are predominantly 'structureless'; they are 'non-sticky' and 'non-plastic' when wet and 'loose' when dry. A cemented or indurated layer may occur at some depth. Static loads produce very little compaction of Arenosols but vibration does; fine sand in a loose state and saturated with water is a very unstable material, especially in embankments.

Chemical characteristics

- Most Arenosols in *humid temperate* or *tropical* regions are deeply leached and decalcified soils with a low capacity to store bases. Their A-horizons are shallow and/or contain little or poorly decomposed organic matter. The natural (forest) vegetation survives on cycling nutrients and roots almost exclusively in the O-horizon and in a shallow A-horizon.
- Rooting is deeper and nutrient cycling less vital to the vegetation in Arenosols in *temperate* regions, particularly those in loamy sands. The organic carbon content of well-drained Are-nosols is normally less than 1 percent; 2 to 3 percent may be present in the upper 10 to 20 cm of soil. The CEC is typically low except in the upper 10 to 20 cm layer. The effective CEC (ECEC) is normally less than 4 cmol(+) kg^{-1} soil but may reach somewhat higher values in the topsoil.

SET 3
ARENOSOLS
DEFINITION
SUMMARY
DISTRIBUTION
ASSOCIATIONS
GENESIS
CHARACTERISTICS
MANAGEMENT / USE
SAMPLE PROFILE
SLIDESHOW

- Arenosols in *dry* regions are normally rich in bases. Moderate leaching and shallow decalci-fication may still occur. The organic carbon contents of most surface horizons are normally less than 0.5 percent (less than 0.2 percent in the subsoil). CEC and ECEC values are not as low as one might have expected in view of the low organic carbon content; this is explained by a higher proportion of smectitic (and/or vermiculitic and chloritic) clay minerals than are found in Arenosols in humid areas.

SET 3
ARENOSOLS
DEFINITION
SUMMARY
DISTRIBUTION
ASSOCIATIONS
GENESIS
CHARACTERISTICS
MANAGEMENT / USE
SAMPLE PROFILE
SLIDESHOW

Management and use of Arenosols

Arenosols occur in vastly different environments and possibilities to use them for agriculture vary accordingly. All Arenosols have a coarse texture, accountable for the generally high permeability and low water and nutrient storage capacity. Arenosols are further marked by ease of cultivation, rooting and harvesting of root and tuber crops.

- Arenosols in *arid lands*, where the annual rainfall sum is less than 300 mm, are predominantly used for extensive (nomadic) grazing. Dry farming is possible where the annual rainfall sum exceeds 300 mm. Low coherence, low nutrient storage capacity and high sen-sitivity to erosion are serious limitations of Areno-sols in the dry zone. Good yields of small grains, melons, pulses and fodder crops have been realized on irrigated Arenosols but high percola-tion losses may make surface irrigation impracticable. Drip or trickle irrigation, combined with careful dosage of fertilizers, may remedy the situation. Many areas with Arenosols in the Sahelian zone (300 to 600 mm rainfall per annum) are transitional to the Sahara desert; their soils are covered with sparse vegetation. Uncontrolled grazing and clearing for cultiva-tion without appropriate soil conservation measures can easily make these soils unstable and revert the land to shifting dune areas.
- Arenosols in the *(sub)humid temperate* zone have similar limitations as the Arenosols of the dry zone albeit that drought is a less serious constraint. In some instances, e.g. in horticulture, the low water storage of Arenosols is considered advantageous because the soils warm up early in the season. In (much more common) mixed farming systems with cereals, fodder crops and grassland, supplemental sprinkler irrigation is applied to prevent drought stress during dry spells. A large part of the Arenosols of the temperate zone are under forest, either production forest or 'natural' stands in carefully managed 'nature' reserves.
- Arenosols in the *humid tropics* are best left under their natural vegetation, particularly so the deeply weathered Albic Arenosols. As nutrient elements are all concentrated in the biomass and in the top 20 cm of the soil, removal of the vegetation inevitably results in infertile badlands without ecological or economic value. Under forest, the land can still pro-duce some timber (e.g. *Agathis spp*.) and wood for the pulp and paper in-dustry. Permanent cultivation of annual crops would require management inputs that are usually not economically justificable.

SET 3
ARENOSOLS
DEFINITION
SUMMARY
DISTRIBUTION
ASSOCIATIONS
GENESIS
CHARACTERISTICS
MANAGEMENT / USE
SAMPLE PROFILE
SLIDESHOW

In places, Arenosols have been planted to perennial crops such as rubber and pepper; coastal sands are widely planted to estate crops such as coconut, cashew, casuarina and pine, especially where good quality groundwater is within reach of the root system. Root and tuber crops benefit from the ease of harvesting, notably cassava, with its tolerance of low nutrient levels. Groundnut and bambara groundnut can be found on the better soils.