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CALCISOLS (CL)

The Reference Soil Group of the Calcisols accommodates soils in which there is substantial secondary accumulation of lime. Calcisols are common in highly calcareous parent materials and widespread in arid and semi-arid environments. Formerly used international soil names for Calcisols include 'Desert soils' and 'Takyrs'.

Definition of Calcisols

Soils

1 having a calcic or petrocalcic horizon within 100 cm of the surface; **and**

2 having no diagnostic horizons other than an ochric or cambic horizon, an argic horizon which is calcareous, a vertic horizon, or a gypsic horizon

Common soil units:

Petric, Hypercalcic, Leptic, Vertic, Endosalic, Gleyic, Luvic, Takyric, Yermic, Aridic, Hyperochric, Skeletic, Sodic, Haplic.

Summary description of Calcisols

Connotation: soils with substantial secondary accumulation of lime; from L. calcarius, calcareous

Parent material: mostly alluvial, colluvial and eolian deposits of base-rich weathering material.

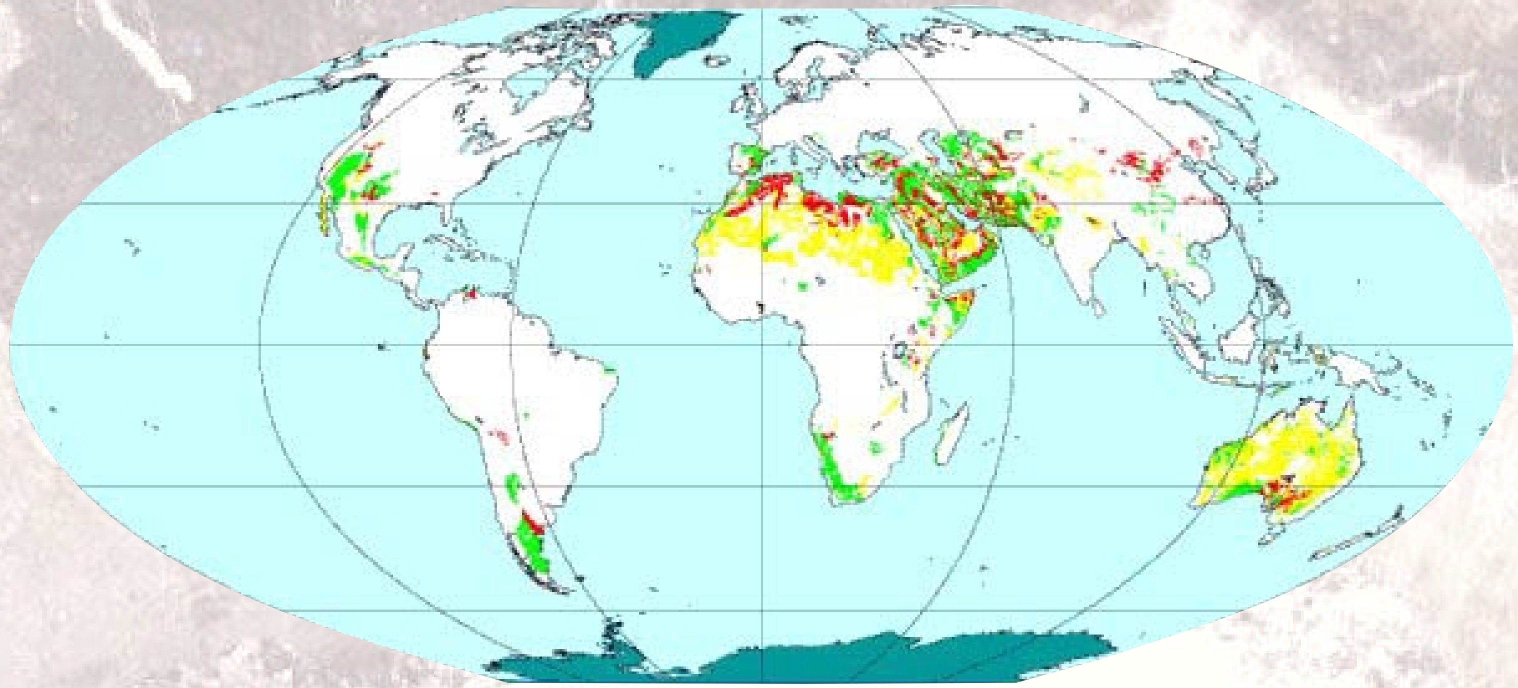
Environment: level to hilly land in arid and semi-arid regions. The natural vegetation is sparse and dominated by xerophytic shrubs and trees and/or ephemeral grasses.

Profile development: typical Calcisols have ABC- or AB(t)C-profiles with a pale brown ochric surface horizon over a cambic or argic subsurface horizon. Finely textured subsurface horizons tend to develop some or all of the characteristics of a vertic horizon. Substantial secondary accumulation of lime occurs within 100 cm from the surface.

Use: dryness, and in places also stoniness and/or the presence of a shallow petrocalcic horizon, limit the suitability of Calcisols for agriculture. If irrigated, drained (to prevent salinization) and fertilized, Calcisols can be highly productive under a wide variety of crops. Hilly areas with Calcisols are predominantly used for low volume grazing of cattle, sheep and goats.

Regional distribution of Calcisols

It is difficult to quantify the worldwide extent of Calcisols with any measure of accuracy. Many Calcisols occur together with Solonchaks that are actually salt-affected Calcisols and/or with other soils with secondary accumulation of lime that do not key out as Calcisols. The total Calcisol area may well amount to some 1 billion hectares, nearly all of it in the arid and semi-arid (sub)tropics of both hemispheres. Figure 1 gives an indication of the regional distribution of Calcisols.



Dominant Associated Inclusions Miscellaneous lands

Figure 1. Calcisols worldwide.

Associations with other Reference Soil Groups

Calcisols can occur in association with a variety of soils, many of them showing signs of secondary re-distribution of lime. Lateral transitions in the field are primarily associated with differences in the expression of the redistributed lime that normally correlate with differences in relief, climate and/or geology. Cross-sections through landscapes with Calcisols frequently show a gradual transition from shallow soils with rather diffuse signs of lime redistribution (at the highest parts) to deeper soils that are also richer in calcium carbonate. There is great variation in the expression of lime redistribution; common forms include filled-in pores that show up as 'pseudomycelia', pockets of soft lime, soft and hard nodules, and layered, platy or compact, consolidated 'calcrete'. Studies on the redistribution of the calcic horizon in space and time suggest that both lateral and vertical redistribution of lime have occurred and that lateral movement of lime is not without significance. Soils found in association with Calcisols range from shallow Leptosols (at the highest parts of the landscape) to Vertisols at the lower end of slopes and in bottomlands. Calcisols in depression areas are frequently associated with Solonchaks and Gleysols. (Piedmont) plains with Calcisols in semi-arid subtropical regions may grade into areas with Chernozems, Kastanozems or Phaeozems with a deep groundwater table.

Genesis of Calcisols

Many Calcisols are old soils if counted in years but their development was slowed down by recurrent periods of drought in which such important soil forming processes as chemical weathering, accumulation of organic matter and translocation of clay came to a virtual standstill. As a result, only an ochric surface horizon could develop and the modification of subsoil layers did not advance beyond the formation of a cambic subsurface horizon. Many Calcisols are '*polygenetic*': their formation took different courses during different geologic eras with different climates. The argic subsurface horizon of many Calcisols is widely considered a relic from eras with a more humid climate than at present.

The most prominent soil forming process in Calcisols - the process from which the soils derived their name - is the translocation of calcium carbonate from the surface horizon to an accumulation layer at some depth. Under certain conditions, e.g. in eroding land or in land that is intensively homogenized by burrowing animals, lime concretions occur right at the surface of the soil. However, it is more common to find the surface horizon wholly or partly de-calcified.

Dissolution of calcite ($CaCO_3$) and subsequent accumulation in a calcic or petrocalcic horizon is governed by two factors:

1 the *CO_2-pressure* of the soil air, and
2 the *concentrations of dissolved ions* in the soil moisture.

The following equilibria are involved (the pH-ranges over which the equilibria are in operation are shown in Figure 2):

$$CO_2 + H_2O = H_2CO_3$$

$$H_2CO_3 = HCO_3- + H^+$$

$$HCO_3^- = CO_3^{2-} + H^+$$

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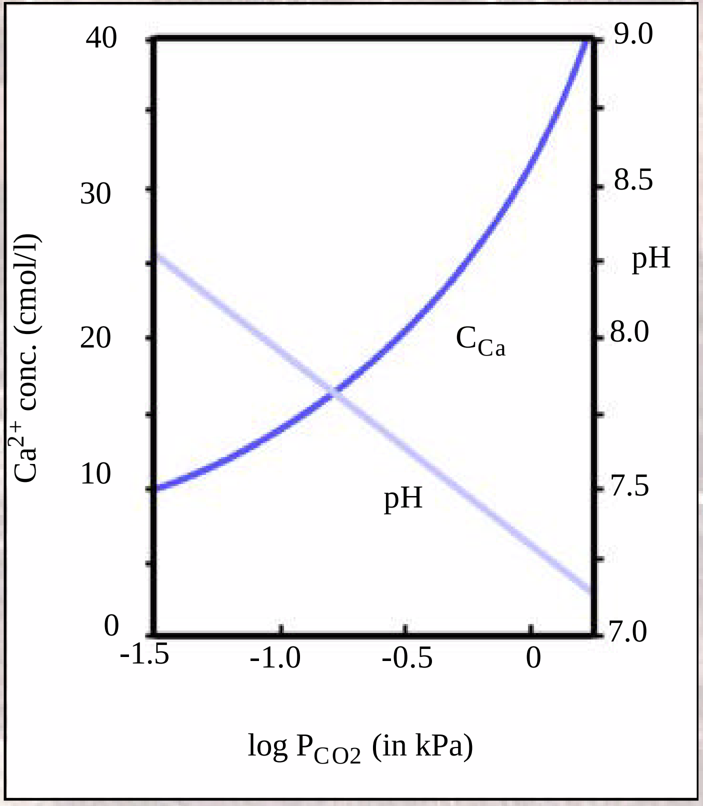

Figure 2. Solubility of calcite at different CO_2-pressures and corresponding pH-values.
Source: Bolt & Bruggenwert, 1979.

For all practical purposes, the dissolution and precipitation of calcite in soils (pH <9) can be viewed as follows:

$$CaCO_3 + H_2CO_3 = Ca^{2+} + 2\ HCO_3^-$$

An increase in the CO_2-content of the soil-air drives the reaction to the right: calcite dissolves and the concentrations of Ca^{2+}- and HCO_3^--ions in the soil solution rise. Alternatively, calcite dissolves if (rain) water with a low Ca^{2+}-concentration flushes the soil.

Precipitation of calcite occurs if the reaction is driven to the left, e.g. by a lowering of the CO_2-pressure (with a consequent rise in pH), or by an increase in ion concentrations to the point where the solubility product of dissolved calcium carbonate is exceeded.

The formation of a calcic horizon is now easily understood: the partial CO_2-pressure of the soil-air is normally highest in the A-horizon where root activity and respiration by micro-organisms cause CO_2 contents to be 10 to 100 times higher than in the atmospheric air. As a consequence, calcite dissolves and Ca^{2+}- and HCO_3^--ions move downward with percolating soil moisture, particularly during and directly after a rain shower. The water may take up more dissolved calcite on its way down.
Evaporation of water and a decrease in partial CO_2-pressure deeper in the profile (fewer roots and less soil organic matter and microorganisms) cause saturation of the soil solution and precipitation of calcite. The precipitated calcite is not or only partly transported back with ascending water because much of this water moves in the vapour phase. (The water table in Calcisols is normally deep; where there is capillary rise to the solum, calcite accumulates at the depth where the capillary water evaporates.)

Calcite precipitation is not (always) evenly distributed over the soil matrix. Root channels and wormholes that are connected with the outside air act as ventilation shafts in which the partial CO_2-pressure is much less than in the soil around it. When $Ca(HCO_3)_2$-containing soil moisture reaches such a channel, it loses CO_2 and calcite precipitates along the walls. Where narrow root channels become filled with calcite, so-called 'pseudomycelium' forms. Other characteristic forms of calcium carbonate accumulation in Calcisols are nodules of soft or hard lime ('calcrete'), platy or continous layers of calcrete and calcite 'pendants' or 'beards' below pebbles.

High soil temperature and high soil-pH enhance dissolution of silica from feldspars, ferromagnesian minerals, etc. Where there is (or was) sufficient moisture in some period of the year to enable translocation of dissolved silica, this may have furthered the hardening of the layer with calcite accumulation. However, cementation of a petrocalcic horizon is in first instance by calcium and magnesium carbonates.

Characteristics of Calcisols

Morphological characteristics

Most Calcisols have a thin (=<10 cm), brown or pale brown surface horizon over a slightly darker subsurface horizon and/or a yellowish brown subsoil that is speckled with white calcite mottles. The organic matter content of the surface soil is low, in line with the sparse vegetation and rapid decomposition of vegetal debris. The surface soil is crumb or granular, but platy structures can occur as well, possibly enhanced by a high percentage of adsorbed magnesium. Most subsurface soils have a blocky structure; the structure elements are coarser, stronger and often more reddish in colour in an argic horizon than in subsurface soils without clay accumulation.

The highest calcite concentration is normally found in the deeper subsurface soil and in the subsoil. Burrowing animals homogenize the soil and bring hardened carbonate nodules to the surface; their filled-in burrows ('krotovinas') may extend deep into the subsoil.

Hydrological characteristics

Most Calcisols are well drained and are wet only in part of the (short) rainy season when there is just enough downward percolation to flush soluble salts to the deep subsoil. One reason why Calcisols as a taxonomic unit have good drainage properties is that carbonate-rich soils in wet positions (depressions, seepage areas) quickly develop a salic horizon (long dry summers!) and key out as Solonchaks.

Physical characteristics

Most Calcisols have a medium or fine texture and good water holding properties. Slaking and crust formation may hinder the infiltration of rain and irrigation water, particularly where surface soils are silty. Surface run-off over the bare soil causes sheet wash and gully erosion and, in places, exposure of a petrocalcic horizon.

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Chemical characteristics

Most Calcisols contain only 1 or 2 percent organic matter but many are rich in plant nutrients. The $pH_{(H_2O;1:1)}$ is near-neutral in the surface soil and slightly higher at a depth of 80 to 100 cm where the carbonate content may be 25 percent or more. The nominal cation exchange capacity of typical Calcisols is highest in the surface soil (10 to 25 cmol(+)/kg) and slightly less at some depth. The exchange complex is completely saturated with bases; Ca^{2+} and Mg^{2+} make up more than 90 percent of all adsorbed cations.

Management and use of Calcisols

Vast areas of 'natural' Calcisols are under shrubs, grasses and herbs and are used for extensive grazing. Drought-tolerant crops such as sunflower might be grown rain-fed, preferably after one or a few fallow years, but Calcisols reach their full productive capacity only when carefully irrigated. Extensive areas of Calcisols are used for production of irrigated winter wheat, melons, and cotton in the Mediterranean zone. Fodder crops such as 'el sabeem' *(sorghum bicolor)*, Rhodes grass and alfalfa, are tolerant of high calcium levels. A score of vegetable crops have successfully been grown on irrigated Calcisols fertilized with nitrogen, phosphorus and trace elements (Fe, Zn).

Furrow irrigation is superior to basin irrigation on *slaking* Calcisols because it reduces surface crusting/caking and seedling mortality; pulse crops in particular are very vulnerable in the seedling stage. In places, arable farming is hindered by stoniness of the surface soil and/or a petrocalcic horizon at shallow depth. Citrus is reportedly sensitive to high levels of 'active $CaCO_3$' i.e. finely divided calcium carbonate particles in the soil matrix.