Soils of humid sub-tropics in south-east Asia with special emphasis on Acrisols.

For classifying world soils by the method of
"World Reference Base, the following web pages are very useful.

I advise you to visit the following sites by yourself and obtain the necessary information.

FAO SOILS PORTAL
http://www.fao.org/soils-portal/soil-survey/soil-classification/world-reference-base/en/

LECTURE NOTES ON THE MAJOR SOILS OF THE WORLD
http://www.fao.org/docrep/003/Y1899E/Y1899E00.HTM

Set #6Mineral Soils conditioned by a Wet (Sub)Tropical Climate
http://www.fao.org/docrep/003/Y1899E/y1899e08a.htm#P0_0

In the tropics, Ferralsols, Acrisols, Alisols, and Nitosols are common reference soil groups. Among them, Acrisols would be the most abundant soil in Myanmar.

For the convenience of my lecture, I summarize here the selected information on representative mineral soils under a wet sub-tropical climate. Plinthosols and Lixisols were not included in this summary.

Mineral Soils conditioned by a Wet (Sub)Tropical Climate

Major landforms in the (sub-)humid tropics
Plinthosols
Ferralsols
Alisols
Nitisols
Acrisols
Lixisols

FERRALSOLS (FR)

The Reference Soil Group of the Ferralsols holds the `classical', deeply weathered, red or yellow soils of the humid tropics. These soils have diffuse horizon boundaries, a clay assemblage dominated by low activity clays (mainly kaolinite) and a high content of sesquioxides. Local names usually refer to the colour of the soil. Internationally, Ferralsols are known as Oxisols (Soil Taxonomy, USA), Latosols (Brazil), Sols ferralitiques (France), Lateritic soils, Ferralitic soils (Russia) and Ferralsols (FAO).

Definition of Ferralsols#

Soils

1. having a *ferralic*@ horizon at some depth between 25 and 200 cm from the soil surface, and
2. lacking a *nitic*@ horizon within 100 cm from the soil surface, and
3. lacking an *argic*@ horizon that has 10 percent or more water-dispersible clay within 30 cm from its upper boundary unless the soil material has *geric*@ properties or contains more than 1.4 percent organic carbon.

Common soil units:

Gibbsic*, Geric*, Posic*, Histic*, Gleyic*, Andic*, Plinthic*, Mollic*, Acric*, Lixic*, Umbric*, Arenic*, Endostagnic*, Humic*, Ferric*, Vetic*, Alumic*, Hyperdystric*, Hypereutric*, Rhodic*, Xanthic*, Haplic*.

See Annex 1 for key to all Reference Soil Groups

@ Diagnostic horizon, property or material; see Annex 2 for full definition.

* Qualifier for naming soil units; see Annex 3 for full definition.

Summary description of Ferralsols

Connotation: red and yellow tropical soils with a high content of sesquioxides; from L. *ferrum*, iron and *aluminium*, alum.

Parent material: strongly weathered material on old, stable geomorphic surfaces; more in weathering material from basic rock than in siliceous material.

Environment: typically in level to undulating land of Pleistocene age or older; less common on younger, easily weathering rocks. Perhumid or humid tropics; minor occurrences elsewhere are considered to be relics from past eras with a wetter climate than today.

Profile development: ABC profiles. Deep and intensive weathering has resulted in a high concentration of residual, resistant primary minerals alongside sesquioxides and well-crystallized kaolinite. This mineralogy and the low pH explain the stable microstructure (pseudo-sand) and yellowish (goethite) or reddish (hematite) soil colours.

Use: Ferralsols have good physical properties but are chemically poor. Their low natural fertility and tendency to `fix' phosphates are serious limitations. In natural systems, the limited stock of plant nutrients is in a constant process of `cycling' with most nutrients contained in the biomass. Many Ferralsols are (still) used for shifting cultivation. Liming and full fertilisation are required for sustainable sedentary agriculture.

ALISOLS (AL)

The Reference Soil Group of the Alisols consists of strongly acid soils with accumulated high activity clays in their subsoils. They occur in humid (sub-)tropical and warm temperate regions, on parent materials that contain a substantial amount of unstable Al-bearing minerals. Ongoing hydrolysis of these minerals releases aluminium, which occupies more than half of the cation exchange sites. Hence, Alisols are unproductive soils under all but acid-tolerant crops. Internationally, Alisols correlate with `Red Yellow Podzolic Soils' that have high-activity clays (Brazil), `Ultisols' with high-activity clays (USA, Soil Taxonomy) and with `Fersialsols' and `sols fersiallitiques très lessivés (France).

Definition of Alisols#

Soils having

1. an *argic@* horizon, which has a cation exchange capacity (by 1 M NH4OAc at pH 7.0) of 24 cmol(+) kg-1 clay or more, either starting within 100 cm from the soil surface, or within 200 cm from the soil surface if the argic horizon is overlain by loamy sand or coarser textures throughout, and
2. *alic@* properties in most of the layer between 25 and 100 cm from the soil surface, and
3. no diagnostic horizons other than an *ochric@, umbric@, albic@, andic@, ferric@, nitic@, plinthic@* or *vertic@* horizon.

Common soil units:

Vertic*, Gleyic*, Andic*, Plinthic*, Nitic*, Umbric*, Arenic*, Stagnic*, Abruptic*, Humic*, Albic*, Profondic*, Lamellic*, Ferric*, Skeletic*, Hyperdystric*, Rhodic*, Chromic*, Haplic*.

See Annex 1 for key to all Reference Soil Groups

@ Diagnostic horizon, property or material; see Annex 2 for full definition.

* Qualifier for naming soil units; see Annex 3 for full definition.

Summary description of Alisols

Connotation: strongly acid soils with subsurface accumulation of high activity clays that have more than 50 percent Al3+ saturation; from L. *aluminium*, alum.

Parent material: Alisols can form in a wide variety of parent materials having high-activity clay minerals such as vermiculite or smectite. Most occurrences of Alisols reported so far are on weathering products of basic rocks.

Environment: most common in old land surfaces with a hilly or undulating topography, in humid (sub-)tropical and monsoon climates.

Profile development: ABtC profiles. Variations among Alisols are mostly related to truncation of A-horizons in eroded lands.

Use: Alisols contain low levels of plant nutrients (except for Mg2+ in some cases) whereas soluble inorganic Al is present in toxic quantities. If liming and full fertilization is no option, use of these soils is generally restricted to crops, which accommodate with low nutrient contents and tolerate high levels of free Al. Alisols are traditionally used in shifting cultivation and for low volume production of undemanding crops. In the past decades, Alisols have increasingly been planted to Al-tolerant estate crops such as tea and rubber, and also to oil palm.

NITISOLS (NT)

The Reference Soil Group of the Nitisols accommodates deep, well-drained, red, tropical soils with diffuse horizon boundaries and a subsurface horizon with more than 30 percent clay and moderate to strong angular blocky structure elements that easily fall apart into characteristic shiny, polyhedric (`nutty') elements. Nitisols are strongly weathered soils but far more productive than most other red tropical soils. Nitisols correlate with `Terra roxa estruturada' (Brazil), kandic groups of Alfisols and Ultisols (Soil Taxonomy, USA), `Sols Fersialitiques' or `Ferrisols' (France) and with the `Red Earths'.

Definition of Nitisols#

Soils,

1. having a *nitic@* horizon starting within 100 cm from the soil surface, and
2. having gradual to diffuse horizon boundaries, and
3. lacking a *ferric@*, *plinthic@* or *vertic@* horizon within 100 cm from the soil surface.

Common soil units:

Andic*, Ferralic*, Mollic*, Alic*, Umbric*, Humic*, Vetic*, Alumic*, Dystric*, Eutric*, Rhodic*, Haplic*.

See Annex 1 for key to all Reference Soil Groups

@ Diagnostic horizon, property or material; see Annex 2 for full definition.

* Qualifier for naming soil units; see Annex 3 for full definition.

Summary description of Nitisols

Connotation: deep, red, well-drained tropical soils with a clayey *`nitic'* subsurface horizon that has typical `nutty', polyhedric, blocky structure elements with shiny ped faces; from L. *nitidus*, shiny.

Parent material: finely textured weathering products of intermediate to basic parent rock, possibly rejuvenated by recent admixtures of volcanic ash. The clay assemblage of Nitisols is dominated by kaolinite/(meta)halloysite. Nitisols are rich in iron and have little water-dispersible (`natural') clay.

Environment: Nitisols are predominantly found in level to hilly land under tropical rain forest or savannah vegetation.

Profile development: AB(t)C-profiles. Red or reddish brown clayey soils with a *`nitic'* subsurface horizon of high aggregate stability.

Use: Nitisols are planted to farm and plantation crops. They are generally considered to be `fertile' soils in spite of their low level of `available' phosphorus and their normally low base status. Nitisols are deep, stable soils with favourable physical properties.

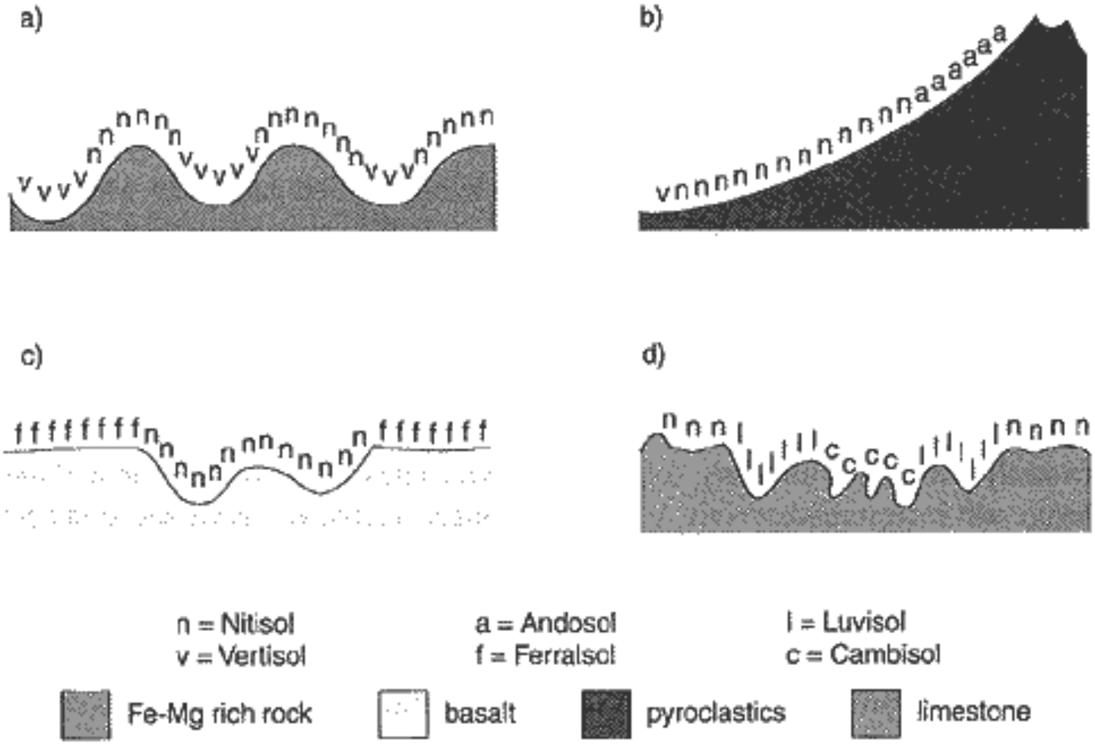
Associations with other Reference Soil Groups

Relationships between Nitisols and other Reference Soil Groups are quite diverse because they are conditioned by a score of (localized) factors. Figure 2 presents common lateral linkages.

1. In *undulating landscapes*, Nitisols are mostly found on basic and ultra-basic rock types in upper and middle slope positions; they grade into Vertisols or vertic units of other Reference Soil Groups towards lower slope sections and/or bottom lands.
2. In *volcanic landscapes,* Nitisols occur in mid-slope positions, between Andosols at higher elevation and more profoundly weathered `red tropical soils' on lower slope sections.
3. In *uplifted and dissected landscapes* on old surfaces, Nitisols are found on slopes in association with Ferralsols on flat and level plateaux.
4. In *landscapes on limestone,* Nitisols occur in pockets, in association with reddish soils such as Chromic Cambisols and Luvisols.

Figure 2

Some common lateral linkages between Nitisols and other Reference Soil Groups



ACRISOLS (AC)

The Reference Soil Group of the Acrisols holds soils that are characterized by accumulation of low activity clays in an *argic* subsurface horizon and by a low base saturation level. Acrisols correlate with `Red-Yellow Podzolic soils' (e.g. Indonesia), `Podzolicos vermelho-amarello distroficos a argila de atividade baixa' (Brazil), `Sols ferralitiques fortement ou moyennement désaturés' (France), `Red and Yellow Earths' and with several subgroups of Alfisols and Ultisols (Soil Taxonomy, USA).

Definition of Acrisols#

Soils,

1. having an *argic* horizon, which has a cation exchange capacity (in 1 *M* NH4OAc at pH 7.0) of less than 24 cmol(+) kg-1 clay in some part, either starting within 100 cm from the soil surface, or within 200 cm from the soil surface if the argic horizon is overlain by loamy sand or coarser textures throughout, and
2. having less than 50 percent base saturation (in 1M NH4OAc at pH 7.0) in the major part between 25 and 100 cm.

Common soil units:

Leptic*, Gleyic*, Vitric*, Andic*, Plinthic*, Umbric*, Arenic*, Stagnic*, Abruptic*, Geric*, Humic*, Albic*, Profondic*, Lamellic*, Ferric*, Hyperochric*, Skeletic*, Vetic*, Alumic*, Hyperdystric*, Rhodic*, Chromic*, Haplic*.

See Annex 1 for key to all Reference Soil Groups

@ Diagnostic horizon, property or material; see Annex 2 for full definition.

* Qualifier for naming soil units; see Annex 3 for full definition.

Summary description of Acrisols

Connotation: strongly weathered acid soils with low base saturation; from L. *acris*, very acid.

Parent material: most extensive on acid rock weathering, notably in strongly weathered clays, which are undergoing further degradation.

Environment: mostly old land surfaces with hilly or undulating topography, in regions with a wet tropical/monsoonal, subtropical or warm temperate climate. Light forest is the natural vegetation type.

Profile development: AEBtC-profiles. Variations in Acrisols will normally correlate with variations in terrain conditions (drainage, seepage). A shallow A-horizon with dark, raw and acid organic matter grades into a yellowish E-horizon. The underlying argic Bt-horizon has stronger reddish or yellowish colour than the E-horizon.

Use: a general paucity of plant nutrients, aluminium toxicity, strong phosphorus sorption, slaking/crusting and high susceptibility to erosion impose severe restrictions on arable land uses. Large areas of Acrisols are used for subsistence farming, partly in a system of shifting cultivation. By and large, Acrisols are not very productive soils; they perform best under undemanding, acidity-tolerant crops such as pineapple, cashew, oil palm or rubber.

Associations with other Reference Soil Groups

Acrisols are often the dominant soil group on old erosional or depositional surfaces and in piedmont areas in humic tropical regions where they are associated and alternating with *Nitisols, Ferralsols* and *Lixisols.* Acrisols are also well represented on ancient shield landscapes in the humid tropics, often alongside Ferralsols in less eroded, flatter areas or in areas that receive weathering material from adjacent uplands. A typical setting would have Acrisols on the eroding slopes of low hills and Ferralsols on nearby stable pediments or uplands. In mountain areas, Acrisols can be found on stable ridge tops, with *Regosols* and *Cambisols* on steeper and less stable slopes. In valleys, Acrisols are to be expected on the higher terraces with *Luvisols* or Cambisols on lower terraces. Old alluvial fans in the humid tropics may have Acrisols on higher parts with Plinthosols in adjacent depression areas.

Genesis of Acrisols

Acrisols are characterized by their argic B-horizon, dominance of stable low activity clays and general paucity of bases. Formation of an *argic* illuviation horizon involves

1. *clay dispersion*
2. *clay transport*, and
3. *clay accumulation* in a subsurface horizon.

These processes are discussed in some detail in the chapter on Luvisols. *Note that* some authors dismiss all clay illuviation horizons in highly weathered soils in the wet tropics as relics from a distant past.

The process of *`ferralitization'* by which sesquioxides accumulate in the soil profile as a result of advanced hydrolysis of weatherable primary minerals was discussed in the chapter on Ferralsols. Subsequent redistribution of iron compounds by *`cheluviation'* and *`chilluviation'* (see under Podzols) is accountable for colour differentiation directly under the A(h)-horizon where an eluviation horizon with yellowish colours overlies a more reddish coloured Bst-horizon (hence the name `Red-Yellow Podzolics' as used e.g. in southeast Asia).

Characteristics of Acrisols

Morphological characteristics

Most Acrisols have a thin, brown, *ochric* surface horizon, particularly in regions with pronounced dry seasons; darker colours are found where (periodic) waterlogging retards mineralization of soil organic matter. The underlying *albic* subsurface horizon has weakly developed structure elements and may even be massive; it is normally whitish to yellow and overlies a stronger coloured yellow to red *argic* subsurface horizon. The structure of this sesquioxide-rich illuviation horizon is more stable than that of the eluviation horizon. *Gleyic soil properties* and/or *plinthite* are common in Acrisols in low terrain positions.

Mineralogical characteristics

Acrisols have little weatherable minerals left. The contents of Fe-, Al- and Ti-oxides are comparable to those of Ferralsols or somewhat lower; the SiO_2/Al_2O_3 ratio is 2 or less. The clay fraction consists almost entirely of well-crystallized kaolinite and some gibbsite.

Hydrological characteristics

Acrisols under a protective forest cover have porous surface soils. If the forest is cleared, the valuable A-horizon degrades and slakes to form a hard surface crust. The crust allows insufficient penetration of water during rain showers with devastating surface erosion (low structure stability!) as an inevitable consequence. Many Acrisols in low landscape positions show signs of periodic water saturation; their surface horizons are almost black whereas matrix colours are close to white in the eluvial albic horizon.

Physical characteristics

Most Acrisols have weak microstructure and massive macrostructure, especially in the surface and shallow subsurface soil that have become depleted of sesquioxides. Bonding between sesquioxides and negatively charged low activity clays is less strong than in Ferralsols. Consequently, the ratio of water-dispersible *`natural clay'* over *`total clay'* (see under Ferralsols) is higher than in Ferralsols.

Chemical characteristics

Acrisols have poor chemical properties. Levels of plant nutrients are low and aluminium toxicity and P-sorption are strong limitations. As biological activity is low in Acrisols, natural regeneration, e.g. of surface soil that was degraded by mechanical operations, is very slow.

Management and use of Acrisols

Preservation of the surface soil with its all-important organic matter is a precondition for farming on Acrisols. Mechanical clearing of natural forest by extraction of root balls and filling of the holes with surrounding surface soil produces land that is largely sterile because toxic levels of aluminium (the former subsoil) kill any seedlings planted outside the filled-in spots.

Adapted cropping systems with complete fertilization and careful management are required if sedentary farming is to be practiced on Acrisols. The widely used `*slash and burn'* agriculture (`shifting cultivation') may seem primitive at first sight but is really a well adapted form of land use, developed over centuries of trial and error. If occupation periods are short (one or a few years only) and followed by a sufficiently long regeneration period (up to several decades), this system probably makes the best use of the limited resources of Acrisols.

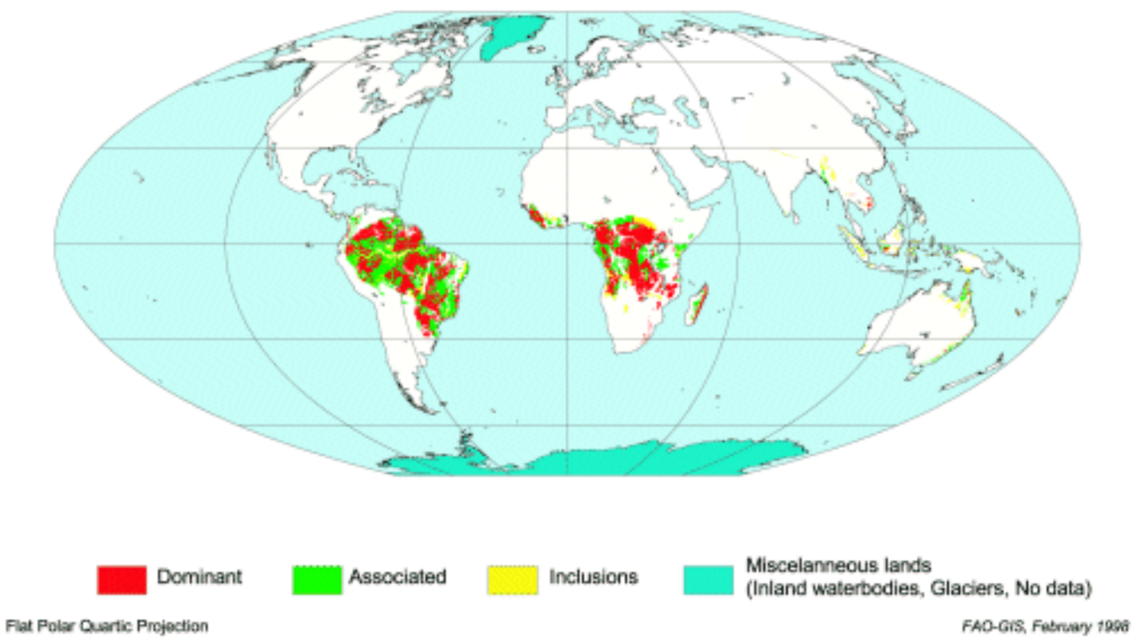
Low-input farming on Acrisols is not very rewarding. Undemanding, acidity-tolerant cash crops such as pineapple, cashew or rubber can be grown with some success. Increasing areas of Acrisols are planted to oil palm (e.g. in Malaysia and on Sumatra). Large areas of Acrisols are (still) under forest, ranging from high, dense rain forest to open woodland. Most of the tree roots are concentrated in the humous surface horizon with only few tap roots extending down into the subsoil. In South America, Acrisols are also found under savannah. Acrisols are suitable for production of rain-fed and irrigated crops only after liming and full fertilization. Rotation of annual crops with improved pasture maintains the organic matter content.

Regional distribution of Ferralsols (Fig. 1)

The worldwide extent of Ferralsols is estimated at some 750 million hectares, almost exclusively in the humid tropics on the continental shields of South America (Brazil) and Africa (Zaire, southern Central African Republic, Angola, Guinea and eastern Madagascar). Outside the continental shields, Ferralsols are restricted to regions with easily weathering basic rock and a hot and humid climate, e.g. in southeast Asia. See Figure 1.

The strong cohesion of (micro-)aggregates and rapid (re)flocculation of suspended particles complicate measurements of the particle size distribution of Ferralsol material. The clay content found after the removal of iron and addition of a dispersing chemical is known as the `*total clay*' content. The clay content found after shaking an aliquot of soil with distilled water (without removal of iron or addition of dispersion agents) is the `*natural clay*' content. The high degree of aggregation in ferralic subsurface horizons explains the low contents of natural clay (< 10 percent).

Figure 1. Ferralsols world-wide

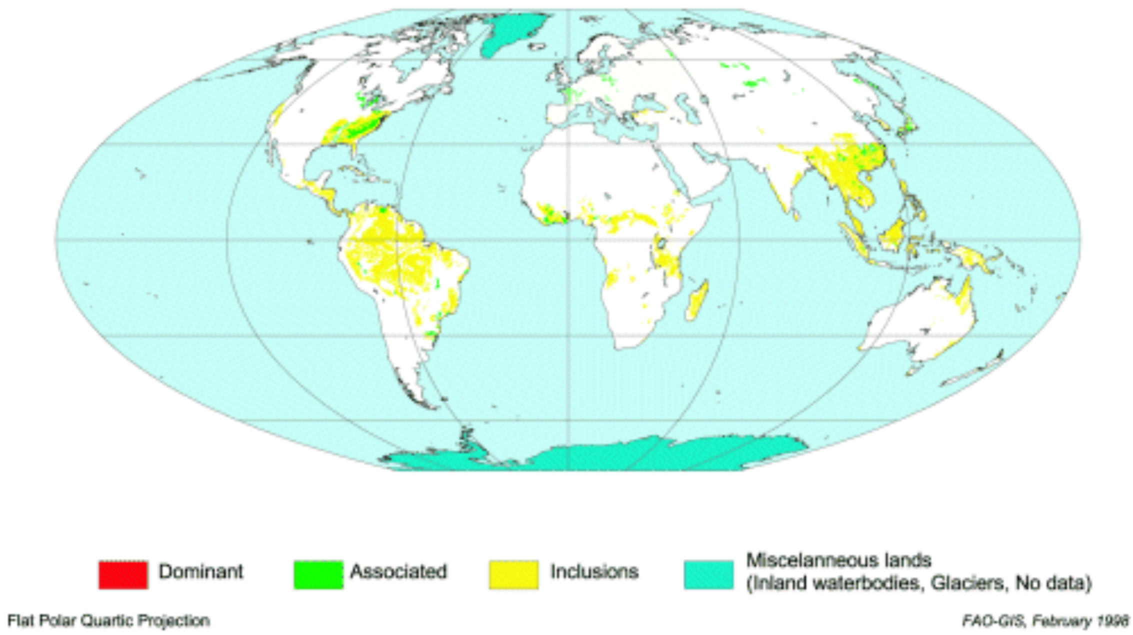


Regional distribution of Alisols (Fig. 2)

Major occurrences of Alisols are found in Latin America (Ecuador, Nicaragua, Venezuela, Colombia, Peru, Brazil), in the West Indies (Jamaica, Martinique, St. Lucia), in West Africa, the highlands of Eastern Africa, Madagascar and in southeast Asia and northern Australia. See Figure 1. Driessen and Dudal (1991) tentatively estimate that about 100 million ha of these soils are used for agriculture in the tropics.

Alisols occur also in subtropical and Mediterranean regions: they are found in China, Japan and the South Eastern USA and minor occurrences have been reported from around the Mediterranean Sea (Italy, France, and Greece).

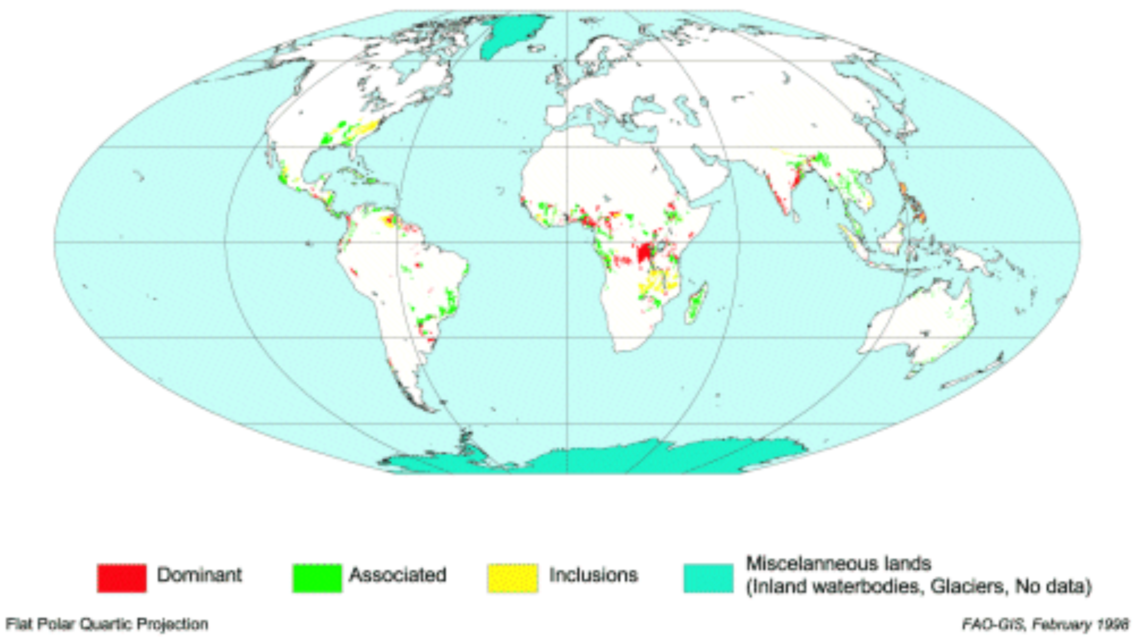
Figure 2. Alisols world-wide



Regional distribution of Nitisols (Fig. 3)

There are approximately 200 million hectares of Nitisols world-wide. More than half of all Nitisols are found in tropical Africa, notably in the highlands (>1000 m.) of Ethiopia, Kenya, Congo and Cameroon. Elsewhere, Nitisols are well represented at lower altitudes, e.g. in tropical Asia, South America, Central America and Australia. See Figure 3.

Figure 3. Nitisols world-wide



Regional distribution of Acrisols (Fig. 4)

Acrisols are found on acid rocks, mostly of Pleistocene age or older. They are most extensive in Southeast Asia, the southern fringes of the Amazon Basin, the southeastern USA and in both east and west Africa. There are approximately 1000 million hectares of Acrisols world-wide. See Figure 4.

Figure 4 Acrisols world-wide