Soil classification (SAES-7105)

Soil classification

Systematic grouping and arrangement of soils into different groups or categories on the basis of their distinguished characteristics is known as soil classification.

Soil classification system

All the rules and regulations that govern the grouping into different categories is known as soil classification system.

Soil taxonomy

Soil classification system is known as soil taxonomy.

Technically speaking, soil taxonomy is the branch of soil science which deals with discovering, characterizing, classifying and naming the soils as to understand the relationships between them and with the factors of environment.

Need for soil classification

Soil is a natural media capable to support plant growth. A soil is a product of parent material have been changed over time by climate and living organisms and modified by topography. Soils vary widely in their nature and properties depending upon soil farming factors. For example the soils that have been developed from sand stone are sandier and inherently less productive compare to the soils developed from limestone. Likewise, the properties of that developed on steep slope are entirely different from the soil developed on flat or depressed topography. Similarly, the nature and properties of soils farmed & developed in temperate region are quite different from the soils developed in tropical climate. It indicates that some soils are naturally productive and respond well to different management practices while others are relatively less productive and respondent to cultural practices. Likewise, some soils drain very rapidly and need frequent irrigation while others retain much water but require good aeration.

In order to make profitable and sustainable use of soil we cannot handle all types of soils in the same way. Therefore scientists, study these variations in nature and properties of soil and setup a classification system that recognize large number of soils each with distinguished characters. The knowledge of kinds and properties of soil around the world is critical to humanity struggle for survival and well being. A soil classification system is equally important if we want to use the knowledge of soil properties gained at one location to solve the problems at another location where similarly classed soils are found. In short, soil classification system provides a base for efficient and sustainable use of soil on profitable basis.

Objectives of soil classification

Soil classification is important not only for scientific research in soil sciences themselves but also for social, economic, natural, cultural and technical sciences. The main contribution of soil classification is to allow for defining off cluster of different soil characteristics relevant in space & time to the specific research needs in the respective field of sciences.

Soil classification plays a central role in categorizing the large body of information being assembled during soil survey. The main objectives of soil classification are:

1. To give an identity to soil to study their nature and properties precisely.
2. It serves as a frame work for organizing our knowledge of soils and provides the means of communication among scientists and between scientists and the users of the land.
3. To establish various groups and subgroups of soils in order to predict their behavior and identify their best uses and productivity.
4. To highlight and understand relationship among different classes to each other and to the environment.
5. To provide appropriate objects and units for research and experimentation.
6. To study the soil intelligently at different locations on the earth surface and to communicate information about genesis and characteristics of soil.
7. Classification provides a way to organize information regarding soil into a pattern so that we can recognize and use soil more efficiently and effectively.

Evolution of soil classification system

Soil taxonomy is a soil classification system. Throughout the history, humans have used some kind of system to name and classify the soil. From the time, when crops were first cultivated the people observed some differences in soil with respect to their productivity. And they classified the soils as good soils and bad soils. The early Chinese, Egyptian and Roman civilization, acknowledge the differences in soils as natural media for plant growth. Such recognition is also common today as soils are recognized as good cotton soils, wheat, maize, and rice or sugarcane soils. The earliest documented attempt at formal classification of soils based on the productivity of the soils seemed to occur in china. The Chinese system included 9 classes of soil based on the productivity of soils. The evidences suggested that Chinese soil classification system was used to impose taxes on the farmers based on the productivity of soils. Later on, Roman scientist develops a classification system based on farming utility. This system was comprised of 9 classes and 21 subclasses and this system was designed for guidance to make decisions about the use and care of land for the production of food and fiber.

In 1882 Russian Government deputed their scientist to design program for classification and mapping of soils as a basis for tax assessment. These Russian scientists promoted the description of soils as natural bodies rather than considering soils simply as materials of weathered rocks.

They studied some relationships among climate, vegetation and soils. They gave the idea of pedon from which data can be collected and compared. The size of pedon varies from 1-10m^2 depending upon the variability in soils. But due to poor classification facilities, this idea could not be promoted to USA up to earlier parts of 20th century. In 1927 US department of agriculture used this idea of natural body and develop a classification scheme. This scheme was further improved in 1935 & 1938. By the survey department in USA this classification scheme was named as soil taxonomy and it has been implemented in USA as well as 45 other countries since 1965. This scheme was also followed in Pakistan.

Principles of soil taxonomy

Soil taxonomy is based on following principles:

1) Equity

Each category in the system should provide a place for all soils in a landscape or have the capability to provide such a place without distortion of the system.

2) Transparency

The categories of the system must have unambiguous definitions and clearly stated functions. Knowledgeable persons equipped with some information must arrive at the same classification.

3) Science based

The system should not prejudice future applications. This is ensured by adhering to logical scientific rules and minimizing the use of biases, popular feelings and traditional approaches. However, this historical information may be used but must be continually validated for its relevance and acceptance.

4) Architecture and linkage

The designs of classification should facilitate its use in digital processing system, and where possible with easy linkage to other natural resource classification system.

5) Ecosystem links

As soils are a component of any ecosystem, ecosystem parameters should be valid to use as criteria for defining categories particularly at higher categories.

6) Flexibility

To serve its intended purpose and to reduce subjectivity (biasness) in application of the system, flexibility should not result in distortion of the system integrity.

Features of soil classification

It must be comprehensive i.e. it must be capable of accumulating all of the soil found in the country.

1. Class definition must be clear, vigorous, and mutually exclusive and based on factual statements of soil properties.
2. Only those soil properties that are easy to measure and verifiable by others should be used as criteria for soil classification.
3. Classification system must be well structured so that similarities and differences among soils can easily be understood.
4. Unique nomenclature should be employed which gives definite connotation of the major characteristics of soil e.g. vertisol.

Categories of soil taxonomy

A category of soil taxonomy is a set of classes that are defined approximately at the same level of generalization and that include all soils. Soil taxonomy has six categories these are from top to bottom, order, suborder, great group, sub group, family and series. The highest category has lowest classes and criteria separating the classes while lowest categories have most classes and criteria.

1) Order

This is the most generalized category of soil taxonomy. There are 12 soil orders. These are differentiated on the basis of presence or absence of diagnostic horizons or features that reflect soil farming processes. Mostly the criteria include properties that reflect major differences in the genesis of soil. The soil properties are the consequences of a variety of process acting on parent material over time. Distinction among soil orders help in understanding soils and remembering them on grand scale.

Soil properties that can be measured quantitatively are used in this classification system – they include: depth, moisture, temperature, texture, structure, cation exchange capacity, base saturation, clay mineralogy, organic matter content and salt content.

The distinction made in classifying soils cannot be based on processes themselves because new knowledge is certain to change our ideas about the process but features of the process are the facts that cannot be observed and measured and used as basis for distinction. Thus, distinguishing between the orders is based on the markers left by process that are dominant forces in shaping the characters of soil. There are twelve soil orders. However, these orders are not only the possible orders in soil taxonomy. The hierarchy is flexible and other adhocorders may be defined to emphasize properties not considered in 12 orders.

2) Sub orders

A suborder category is the sub division of an order with in which genetic homogeneity is emphasized. Soil characteristics used to distinguish sub orders with in orders vary from order to order. However, soil moisture regimes, temperature regimes and soil properties derived from differences between soil moisture and temperature are considered important criteria to differentiate sub order within an order. Sixty four suborders are currently recognized.

3) Great groups

It is sub division of suborder. There are more than three hundred great groups. Soil within great group is identified by the kind of sequence of soil horizon.

4) Sub group

It is the subdivision of great group. In sub groups classes are identify on the basis of horizon nature and arrangement as well as soil temperature and moisture regimes. There are three kinds of sub groups, typic, inter grade and extra grade.

I. Typic sub group

A typic subgroup represents the basic concept of great group from which it derives.

II. Inter grade sub group

Inter grade sub group contains soil of grade group but also have soil containing same properties and characters of another great groups.

III. Extra grade

Soil has properties that do not inter grade or match to any soil of known great group.

5) Family

A soil family is a group of soil with in a sub group that has similar physical and chemical properties of soil. The principle characteristics used to differentiate soil texture, structure, mineralogy, temperature, cation exchange capacity, soil thickness, and presence of soil coatings, cracks or any other property which is important from the plant growth point of view.

6) Soil series

The series is the longest category in soil taxonomy. Soil series are the sub division of soil family based upon relatively detailed properties of the pedon within the depth of control section. The range of variability of differentiating characteristics is narrower than for families. The properties such as the nature of horizons, which includes the mineralogy, texture, structure, rupture, resistance, moisture and temperature regimes and degree of horizon thickness contrast between horizon and the nature of horizon boundary.

Nomenclature of soil classification

1) Order

The name of the order can be recognized as such because the name of each order ends at “sol”. Sol is a Latin word derived from solum (soil) with a connecting vowel “O” for Greeks routs and “I” for other routes e.g. Spodosol or Entisol. Each name of an order contains a formative element that begins with vowel e.g. in Entisol “Ent” formative element.

Order name	Formative element
Entisol	Ent
Inceptisol	Ept
Alfisols	Alf
Aridisol	Ardi
Gelisol	El
Histosol	Ist
Mollisol	Oll
Oxisol	Ox
Spodosol	Od
Ultisols	Ult
Vertisol	Ert
Andisol	

i. Entisol

Entisol derived from a Latin word “ent” means meaningless or recent and sol means soil. Entisols are those soils which are immature and lack of vertical development of horizons. These soils are oftenly associated with recently deposited sediments by the action of wind, water, ice and gravity. The unique feature of the soil is the dominance of the mineral soil material (sand, silt and clay) and absence of marks of any pedogenic process. The absence of distinct pedogenic development in entisol is due to following reasons.

ii. Inceptisol

The word inceptisol is derived from a Latin word “Inceptum” meaning beginning or start. These are weekly developed soils with ochric or umbric epipedon.

- **Ochric epipedon**

  A surface horizon too light in color, very low in organic matter and very thin in thickness is called ochric epipedon.

- **Umbric epipedon**

  Surface horizon having base saturation percentage less than 50% is called umbric epipedon.

Profile development of inceptisol is more advanced than entisol (poorly developed) but less than all other orders. The lack of profile development in Inceptisol may be due to following reasons:

- Deposits may be recent, the interaction between soil farming factors such as parent material with climate and living organisms continued for short period of time that is not enough for the development of soil profile.
- Erosion may be first enough to remove the developing soil before strong horizon can be develop.
- Climatic conditions are not very conducive for the development of soil profile.
- Parent material may be inert.

iii. Mollisol

Mollisol is derived from a Latin word "Mollus" mollus mean soft. Mollisols are characterized by mollic epipedon which is thick in depth, dark in color and has more than 50% base saturation percentage, mostly Ca and have soft consistence.

Mollic epipedon

"A surface horizon having organic matter less than 1%, relatively dark in color, almost 18cm thick and does not have any hard structure. It has more than 50% base saturation percentage and less than 250mg/kg P_2O_5 soluble in 1% citric acid."

Mollisols are some of the most fertile soil inherently and some can produce optimum yield without fertilizer. Mollisols are characteristically developed under grass in the climate that has moderate to pronounced seasonal moisture stress. Some Mollisols develops under forest ecosystem and some in marshes under humic conditions. Mollisols have largest number of sub orders that indicates the diverse nature of these soils. Sub order names indicate the wide distribution of Mollisols in cold, temperate, humid and semiarid climatic conditions.

iv. Aridisols

Aridisol derives from a Latin word "Aridus" Aridus mean dry or arid. These soils are developed in very dry environment. Aridisol have no available water during most of the time. Aridisol tends to be light in color because of limited humus addition from vegetations. Since Aridisols develop under low soil moisture and have little or no water for leaching, consequently soil profile in Aridisols has following features:

- Lime layer
- Accumulation of gypsum or other salts
- Low organic matter accumulation
- Calcareousness
- Development of hard pane

v. Alfisols

The word alfisols derives from pedalfer, ped mean soil, al mean aluminum, fer mean ferric.

The unique character of alfisols is the translocation of clay, aluminum and iron and their subsequent accumulation into the B horizon. Alfisols are developed under forest vegetation, where parent material has gone under significant weathering. The distinguished characters of alfisols are:

- Translocation of clay, aluminium and iron into B- horizon
- Medium to high base saturation
- Light color

vi. Ultisols

Ultisols derived from a Latin word "Ultimus" ultimus mean last or highly leached soil. Ultisols have marks of clay translocation and intensive leaching. Ultisols are humid area soils and have following characters:

- Clay accumulation in B-horizon
- CEC is moderate to low
- pH will be moderately to strongly acidic
- Surface horizon dark with humus
- Intensive weathering
- Kaolinites dominates the clay fraction of most Ultisols, although appreciate able quantity of primary minerals such as quarts, mica and feldspar arestill present

vii. Vertisols

Vertisol derived from a Latin word "Verto" verto mean turn.

Vertisols are characterized by high content (>30%) of swelling and shrinking type clays (smectite, montmorillonite and vermiculite) to the depth of 1m. these swelling clays swell on wetting while contract on drying. Alternate swelling and contracting of these minerals develop deep and wide cracks making them difficult to cultivate and nearly impossible to use for supporting roads, buildings and other infrastructures. The unique characteristics of Vertisols are the high content of swelling clays, pronounced changes in volume with change in moisture contents, crack that open and close periodically and the evidence of soil movement such as slicken sides (polished and grooved soil surfaces that develop when one soil mass slides over other).

In Vertisols significant amount of material from the upper part of soil profile may be slough off into cracks giving raise a partial inversion of soil. Hence, these soils are known as Vertisols. Cation exchange capacity is more than 30meq/100g of soil, evidence of vertical and horizontal movement of soil material.

viii. Oxisols

Oxisols derived from a French word "oxide" means highly oxidized throughout the profile. The oxisols are more intensively weathered soil in the classification system. Weathering is accelerated by high temperature and moisture, so the highly weathered oxisols typically occur in hot and humid, tropical and sub tropical area. The unique feature of an oxisols is the presence of oxic epipedon and often plinthite. These have lost much of their silica and are rich in iron and aluminium oxide. Weather able minerals in oxisols are either absent or present in trace amount. There is no translocation of clay in oxisols. These soils are highly permeable and have low permeability.

ix. Spodosols

Spodosols derived from Greek word "Spodos" mean wood ash. These soils are grey in color. The unique features of spodosols are highly acidic, well leached and ashy white Albic epipedon and a sub surface horizon with an accumulation of organic matter and oxides of aluminium with or without iron oxides known as spodic endopedon, B-horizon consisting of an accumulation of radish or black amorphous material with high cation exchange capacity. Spodosols form mostly on coarse textured acidic parent material subjected to ready leaching. These occur only in moist to wet climate under forest vegetation.

x. Histosols

Histosols derived from Greek word "Histos" histos mean tissue. Histosols are characterized by very high content of organic matter (>20%) in upper 80cm of soil. Most histosols are peat or muck soils, which contains more or less decomposed plant residues.

Peat

Unconsolidated soil material consisting largely of undecomposed or slightly decomposed organic matter accumulated under the conditions of excessive moisture.

Peat soil

An organic soil containing more than 50% organic matter which is undecomposed or slightly decomposed is called peat soil.

Muck

Soil material consisting of largely, highly decomposed organic material in which original plant parts are not recognizable is called muck.

Muck soil

Soil containing 20-50% organic matter which is well decomposed is known muck soil.

Histosol have high cation exchange capacity and low bulk density.

xi. Andisols

Modified from a Japanese word "Ando" ando mean dark volcanic ash, the unique property of Andisols is the dominance of aluminium and humus complexes that results from weathering and mineral transformation with minimum translocation.

These soils have high phosphorus retention available water capacity and cation exchange capacity.

xii. Gelisols

Gelisols derived from a Latin word “Gelare” gelare means to freeze, unique property of gelisols is the presence of permafrost (where temperature is always below freezing point) and soil features that are associated with freezing and thawing. These features include irregular broken horizon and incorporation of organic material into the lower horizon. Freezing and thawing producing granular and platy structure in the surface and sub surface horizon. The increasing in soil volume on freezing is the major soil farming process in gelisols. These soils are confined at high altitude or elevation. These soils makes up about 13% soils in the world second only to Aridisols.

2) Sub order

Name of sub order have two syllables. The 1st syllable indicates or represents the diagnostic property of soil or soil moisture regime and 2nd is the formative element from the name of order. Thirty formative elements are used with twelve formative elements from the name of orders, to make the name of the 64 sub orders e.g. Aquent is the suborder of entisol having aquic moisture regime.

Formative elements in the name of sub orders in soil taxonomy

Formative element	Derivation	Connotation/ Representation
Alb	L. Aibus (white)	Albic horizon
Anth	G. Anthropos (humans)	Modified by humans
Aqu	L. Aquq (water)	Aquic conditions
Ar	L. Arare (to plough)	Mixed horizon
Arg	L. Argilla (white clay)	Argilic horizon
Cal	L. Calcis (lime)	Calcic horizon
Cam	L.Cambiare(to exchange)	Cambic horizon
Dur	L. Durus (hard)	Duripan
Fibr	L. Fibra (fiber)	Least decomposed stage
Fluv	L. Fluvius(river)	Flood plains
Fol	L. Folia(leaves)	Mass of leaves
Gyps	L. Gypsum	Presence of gypsic horizon
Hapl	G. Haplus(simple)	Minimum horizon development
Hem	G. Hemi(half)	Intermediate stage of decomposition
Hist	G.Histus(tissue)	Presence of organic material

Hum	L. Humus	Presence of organic matter
Ochr	G. Ochrus(color)	Ochric horizon
Per	L. Per(throughout)	Per udic moisture regime
Psamm	G. Psammos (sand)	Sandy texture
Rend	Rendrina	High carbonate content
Sal	L. Sal(salt)	Presence of salic horizon
Sapr	G. Sapros(rotten)	Most decomposed stage
Torr	L.Torridus(hot dry)	Torric moisture regime
Turb	L. Turbidis(disturbance)	Presence of cryoturbation
Ud	L. Udus (moist)	Udic moisture regime
Umbr	L. Umbera(shade)	Umbric horizon
Ust	L. ustus(burnt)	Ustic moisture regime
Vitr	L. Vitrum (glass)	Presence of glass
Xer	G. Xros(dry)	Xeric moisture regime

Soil characteristics used to distinguish sub orders within an order vary from order to order. For example, soil moisture and temperature regimes are important factors that differentiate sub orders in certain orders like alfisols. The presence of argilic horizon is used to place sub orders within the order Aridisols. However, sub orders within a soil order differentiated largely on the basis of soil properties and horizons resulting from difference in soil moisture and temperature regimes.

Sub orders within soil orders are discussed below:

Order

Entisol

Suborders

i. Aquents
ii. Fluvents
iii. Orthents
iv. Psamments
v. Arents

i. Aquents (unfavorable ecological conditions)

Derived from a Latin word “Aqua” means saturated. This suborder include those soils that have aquic conditions (aquic soil moisture regimes) or (reducing soil conditions for sometime). These are the soils in the areas of marshes. These soils are often saturated with water and have blue or green on the surface these are called mottles (patches of different color). If more than 10% soil is colored then it is called mottled soil.

ii. Fluvents (insufficient time)

This sub order includes the soils that are not wet and consist of recent illuvium which is generally stratified. This sub order contains soils that are very young and poorly developed. The poor development (poor development) in these soils is mainly due to continuous deposition of new sediments which consequently have in sufficient time for development.

iii. Orthents

This sub order includes soils of recently eroded slopes. The rate of erosion is greater than the rate of development. Consequently the horizon development is poor. This sub order includes those soils which are kept young due to removal of soil material at a rate that is more rapid than horizon development.

iv. Psamments

It is derived from Greek word"Psammos" means sand. This sub order includes sand that is too inert to develop soil horizon. Consequently these soils have poor structure development, low soil fertility, poor water holding capacity, high susceptibility to erosion and high hydraulic conductivity.

v. Arents

Arents derived from a Latin word "Arare" means to plough. It includes those soils in which horizon have been mixed by deep ploughing or other human activities that have destroyed pedogenic horizon.

Order

Inceptisol

Sub orders

i. Anthrepts
ii. Aquepts
iii. Cryepts
iv. Udepts
v. Ustepts
vi. Xerepts

i. Anthrepts

These are more or less freely drained inceptisol that have an anthropic or plaggic epipedon. Most of these soils have been used in crop land or as sites for man occupation for many years.

ii. Aquepts

These are wet inceptisols. The natural drainage is poor or very poor and if the soil has not been artificially drained ground water is at or near the soil surface for sometime during the year but not during the whole season.

iii. Cryepts

Cryepts are old inceptisols of high mountains or high latitude. The vegetation is mostly conifers. These soils mostly develop from loess (large deposits) and have brownish ochric epipedon.

iv. Udepts

Udepts have udic moisture regimes. These are formed on nearly level to steep surfaces. Most of these soils support forest vegetation and usually have ochric or umbric epipedon.

v. Ustepts

These are more or less freely drained inceptisols that have an ustic moisture regime. These soils dominantly received summer precipitation and have isomesic, hyper thermal or warmer temperature regime. Most ustepts have an ochric epipedon and many have calcic horizon. The native vegetation commonly are grasses but some soils may support forest.

vi. Xerepts

Xerepts are inceptisols that have xeric moisture regime. These have frigid or mesic temperature regime but in some cases thermic temperature regime are also present. The native vegetation is commonly coniferous forest.

Order

Aridisols

Sub orders

i. Argids
ii. Calcids
iii. Cambids
iv. Cryids
v. Druids
vi. Gypsids
vii. Salid

i. Argids

These are Aridisols that have an argilic or natric horizon. The low water flux or availability and high accumulation of salts in many Aridisols usually hinder the crop productivity.

ii. Calcids

Calcids are the Aridisols with high concentration of calcium carbonates that was either in parent material or added externally as dust. Precipitation is insufficient to leach or even move carbonates to greater depth. The upper boundary of calcic or petrocalcic horizon is normally within 50cm of soil surface. If soils are not irrigated or cultivated, micronutrients deficiencies are common. These have temperature regime warmer than cryic.

iii. Cambids

These are the Aridisols with least soil development. These soils have cambic horizon within 100cm of soil surface. These may have other diagnostic horizons such as petrocalcic, gypsic or calcic horizon but the upper boundary of these horizons must below 100cm of depth.

iv. Cryids

Cryids are the Aridisols of cold deserts, short growing season combined with arid conditions limit the use of these soils, and Cryids sub order may have a duripan, Argillic, calcic, gypsic, Natric, petrocalcic, petrogypsic or salic horizon. These horizons are the basis for great groups. Some cryids may have ustic or xeric soil moisture regime which is also used as criteria for placing soils in different great groups.

v. Druids

Druids are the Aridisols that have duripan in many areas. The duripan is within 50cm of soil surface. These soils occur dominantly on gentle slopes. The soils commonly have $CaCO_3$. The duripan is barrier to both water infiltration and root penetration.

vi. Gypsids

Gypsids are the Aridisols that have a gypsic or petrogypsic horizon within 100cm of soil surface. Accumulation of gypsum takes place initially as crystal aggregates in the voids of soil but then deposits in the form of layer. When gypsic horizon occurs as cemented impermeable layer, it is referred as petrogypsic horizon that may restrict the movement of water and plant roots.

vii. Salids

The concept of salids represents the accumulation of excessive amount of salts that are more soluble than gypsum. Salids must have EC $30dsm^{-}$ in1:1 soil extract and the product of EC and thickness should be at least 900. Under arid environment and hot temperature, accumulation of salts commonly occur when there is a supply of salts and net upward movement of salts. In some areas salic horizon formation may be due to salty parent material. The most common form of salts is NaCl but sulfates and other salts may also be present.

Order

Mollisols

Sub orders

i. Albolls
ii. Aquolls
iii. Cryolls
iv. Rendolls
v. Udolls
vi. Ustolls
vii. Xerolls

i. Albolls

Albolls are the Mollisols that have an Albic horizon and fluctuating ground water. Most of these soils are saturated with water to or near the soil surface, at sometime during winter season, however in summer ground water is not commonly within a depth of 200cm. below Albic horizon, there is either an Argillic or less commonly Natric horizon. These soils developed mostly on broad nearly level to sloppy ridges, on back slopes (slope which is opposite to sun) or in closed depression. Most Albolls developed under grass vegetation. However in early stages of development some are thought to support vegetations that were replaced by grasses.

ii. Aquolls

Aquolls are the Mollisols that are wet and have reduced conditions. Aquolls have aquic soil moisture regime and need artificial drainage. These soils commonly develop in low lying areas, where water collects and stands for long time. Most of soils have grass vegetation but few soils may support forests.

iii. Cryolls

Cryolls are cool and more or less freely drainedMollisols. Cryolls have cryic temperatureregimes and udic or ustic and xeric moisture regime.

iv. Rendolls

These are the Mollisols developed in highly calcareous parent material such as limestone or chalk. These soils have mollic epipedonthat rest on cambic horizon which is rich in carbonates. These are formed mostly under forest vegetation but may develop under grass and shrubs.

v. Udolls

Udolls are more or less freely drained Mollisols of humid climate in addition to mollic epipedon, these soils have cambic, Natric, calcic or Argillic horizon. These have udic moisture regime while temperature regime is frigid or warmer. Where slops are not too steep, these soils are cultivated. Maize and sorghum are major crops grown on these soils.

vi. Ustolls

Ustolls are the Mollisols having ustic soil moisture regime. In these soils, drought is common and may be severe. During drought soil bellowing becomes a problem without irrigation the low supply of moisture usually limits crop yield. In addition to mollic epipedon most ustolls have B_k horizon (k represent the accumulation of calcium carbonate) that have identifiable secondary carbonates or calcic horizon. Ustolls may also have cambic, Argillic, Natric, petrocalcic horizon. The presence or absence of these horizons is used as basis for defining great groups of ustolls.

vii. Xerolls

These are the Mollisols having xeric soil moisture regime. Xerolls are dry for extended periods in summer but moisture retain and move through most of soils in winter characteristically are relatively thick mollic epipedon, cambic or Argillic horizons and accumulation of carbonate in the lower part of B horizon.

Order

Alfisols

Suborders

i. Aqualf
ii. Cryalf
iii. Udalf
iv. Ustalf
v. Xeralf

i. Aqualf

Aqualf are the alfisols that have aquic soil moisture regime during some part of the year. The wetness of aqualf may be due to shallow water table, poor hydraulic conductivity, seepage from any water source or heavy rainfall. These soils required artificial drainage for cultivation of crops. Rice is the most important crop of these soils.

ii. Cryalf

Cryalf are more or less freely drained alfisols of cold region. These soils have cryic temperature regime and mostly udic moisture regime. These soils are generally used for coniferous forests.

iii. Udalf

These soils have udic soil moisture regime and frigid or warm temperature regime. These soils mostly support forest vegetation. Normally the undisturbed soil has a thin a horizon which is darkened by the accumulation of humus. These soils may have Natric horizon.

iv. Ustalf

Ustalf are the alfisols of sub humid to semiarid region. These soils have ustic moisture regime. Moisture moves through most of these soils to deeper layer only in occasional years. If carbonates are present in parent material or added to soil surface as dust. These soils have Bk horizons.

v. Xeralf

Xeralf have xeric moisture regime. These are dry for extended period in summer but in winter sufficient moisture is available for leaching in occasional years. If irrigation water is available these soils are suitable for variety of crops.

Order

Andisol

Suborders

i. Aquand

ii. Cryand
iii. Torrand
iv. Udand
v. Ustand
vi. Xerand
vii. Vitrand

i. Aquand

Aquand are the Andisols with aquic soil moisture regime. These soils have dark colored surface horizons that meet the requirement of histic or mollic epipedon. These soils normally occur in lower land scape and generally support forest vegetation.

ii. Cryand

Cryand are the Andisols that have cryic temperature regime. These soils generally support coniferous forest.

iii. Torrand

These soils haveTorric (aridic) moisture regime. These soils mostly develop under grass or shrub and have ochric or mollic epipedon. Some of these soils may have duripan or petrocalcic horizons.

iv. Udand

Udand are the Andisols that have udic soil moisture regime. These soils generally developed under forest vegetation and have umbric epipedon.

v. Ustand

These soils have ustic soil moisture regime and frigid or warmer soil temperature regime. These soils have an ochric or mollic epipedon.

vi. Xerand

Andisol that have xeric moisture regime is called Xerand. Most Xerand have a frigid or mesic temperature regime and develop under coniferous vegetation.

vii. Vitrand

These are relatively young soils that occur near volcanoes. These are normally well drained soils having coarse texture.

Order

Gelisols

Suborders

i. Histell
ii. Orthell
iii. Turbel

i. Histell

These are the gelisols with large amount of carbon that commonly accumulate under anaerobic condition. Cold temperature contributes to the accumulation of organic matter.

ii. Orthell

Orthells are the gelisols that show the evidence of cryoturbation (profile development through wetting and drying, freezing and thawing). These soils occur primarily within the zone of permafrost where parent material is mostly coarse textured.

iii. Turbel

These are the gelisols having a layer of organic matter accumulation on the top of permafrost layer. These soils have also the evidence of cryoturbation.

Order

Histosol

Suborders

i. Fibrist
ii. Hemist
iii. Saprist
iv. Folist

i. Fibrist

Fibrists are the histosols in which organic matter is slightly decomposed. The botanic origin of organic matter can be readily identified. The bulk density is less than $0.1g/cm^3$.

ii. Hemist

These are the histosols in which organic materials are moderately decomposed. The source of organic matter cannot be readily identified. The bulk density is commonly between $0.1\text{-}0.2g/cm^3$. Ground water is at very close to soil surface, unless artificially drained.

iii. Saprist

These are the histosols in which organic materials are well decomposed. The botanic origin of organic material is very difficult to identify. Most of these soils have a bulk density more than $0.2g/cm^3$. These soils commonly occur in areas where ground water fluctuates.

iv. Folist

These are the histosols that have organic horizon commonly derived from leaf litter or branches resting on rocks or on fragmental material that consists of gravels, stones or bolders in which cavities are filled with organic materials and plants are grown on these organic materials. These soils are commonly present in humid climates particularaly at high latitudes.

Order

Oxisol

Suborders

i. Aquox
ii. Torrox
iii. Udox
iv. Ustox

i. Aquox

These are wet oxisols developed in shallow depressions and in seepage areas. These soils accumulate iron in the form of nodules or concretions. These soils constitute small areas.

ii. Torrox

These are the oxisols of arid regions. These have an aridic or Torric moisture regime and have high base saturation percentage compare to other oxisols.

iii. Udox

Udox are well drained oxisols with udic soil moisture regime. These soils have considerable moisture content but may be dry in some parts for less than 90 days.

iv. Ustox

These are the oxisols that have an ustic moisture regime. These soils are moist for at least 90 days, that period is long enough for one rain fed crop.

Order

Spodosols

Suborders

i. Aquod
ii. Cryod
iii. Humod
iv. Orthod

i. Aquod

Aquod are the spodosols of wet regions, these are characterized either by shallow fluctuating water table or an extremely humid climate. These soils mostly developed in sandy parent material and may have any temperature regime.

ii. Cryod

Cryod are the spodosols that have cryic temperature regime and mostly developed at high latitudes. Many cryods are formed in volcanic ash or glacial drift. However, some farmed or developed in colluvial parent material at the base of mountain slope. These soils have very thin organic horizon.

iii. Humod

Humods are relatively freely drained spodosols that have a large accumulation of organic material in spodic horizon. These soils generally support forest vegetation.

iv. Orthod

Orthod are relatively freely drained spodosols with a layer containing Al or Fe and organic carbon. The moisture regime of orthods is predominantly udic but a few may have xeric moisture regime.

Order

Ultisols

Suborders

i. Aquult
ii. Humult
iii. Udult
iv. Ustult
v. Xerult

i. Aquult

These are the Ultisols having aquic soil moisture regime. High moisture content in these soils is mainly due to shallow water table. These soils mostly support forest vegetation.

ii. Humult

Humults are the Ultisols which are rich in humus. These soils mostly develop in mountainous areas that have high rainfall. The natural vegetation consists of coniferous forest.

iii. Udult

These are humus poor Ultisols having udic moisture regime. Most soils have light colored upper horizon commonly grey in color that rest on yellowish brown to redishargilic horizon. These soils have well distributed rainfall.

iv. Ustult

These are the Ultisols that have an ustic soil moisture regime and relatively low contents of organic matter. These occur in the regions where rainfall is moderately low and evapotranspiration usually exceeds precipitation.

v. Xerult

These soils have xeric moisture regime and small amount of organic matter. These soils mostly develop on generally sloppy to very steep areas. Natural vegetation mostly consists of coniferous forests.

Order

Vertisol

Suborders

i. Aquert
ii. Cryert
iii. Torrert
iv. Udert
v. Ustert
vi. Xererts

i. Aquert

Aquerts are the wet Vertisols. These have aquic condition at or near the soil surface for extended period during the year. But these soils are also dry for the period long enough for cracks to open.

ii. Cryerts

Cryerts are the Vertisols having cryic temperature regime. These soils are fine textured, develop in cold temperature, periodically shrink and swell farming diagnostic characteristics of Vertisols.

iii. Torret

Torrert are the Vertisols having Torric soil moisture regime. The cracks of Torrert commonly stay open for most of the year. These soils are further subdivided into different great groups by the presence or absence of salts gypsum or carbonates.

iv. Udert

These are the Vertisols having udic moisture regime. These soils have cracks that open and close depending upon the amount of precipitation. In some years cracks may not open completely.

v. Ustert

These are the Vertisols having ustic soil moisture regime, cracks open and close once or twice during the year. Many of these soils farmed in gently sloping areas of fine textured alluvial deposits.

vi. Xererts

Xererts are Vertisols having xeric moisture regime. Due to fluctuation in soil moisture these soils have cracks that open and close regularly and may damage soil structure.

3) Great group

The name of great group consists of the name of suborder and a prefix that reflects some unique features of that group.

Examples

Dur Argids.

In “Dur Argids” Dur is prefix, arg represents the sub order and ids represents the name of order.

Fluvents is the sub order of entisol developed from fluvial parent material and torri fluvents is the great group having Torric moisture regime.

4) Sub group

i. Typic
ii. Intergrade
iii. Extra grade

The name of sub group consists of the name of the great group modified by one or more adjectives e.g. typic torri fluvents, typic indicates the sub group, torri great group while fluvents indicates the sub order and order name.

5) Family

The family names consist of the name of the sub group and descriptive term generally three or more to indicate particle size, the mineralogy, the CEC, the calcareousness, temperature, soil depth and rupture resistance.

Examples

Fine, montmorillonitic, thermic, typic torri fluvents
Fine loamy, mixed, hyper thermic, typic dur Argids

6) Series

The name of series is generally taken from a place where soil series has discovered or recognized first. It may be the name of town or country or some local features e.g. Gujranwala fine loamy, mixed, hyper thermic, calcareous, typic dur Argids.

Criteria for soil classification in soil taxonomy

i. Presence and absence of diagnostic horizon
ii. Soil moisture regimes
iii. Soil temperature regimes
iv. Soil properties important from agriculture
v. Soil profile development

Diagnostic horizon

Diagnostic horizons are those horizons which are used to differentiate a soil among different order, sub order, great group, sub group, families and series. A layer of soil approximately parallel to soil surface different in soil characteristics from adjacent genetically similar layer present above or below it. The diagnostic horizons are of two types

1) Diagnostic epipedon

The word epi is derived from Greek origin meaning above. Those diagnostic horizons which are developed at the soil surface are known as diagnostic epipedon.

i. Mollic epipedon
ii. Umbric epipedon
iii. Anthropic epipedon
iv. Plaggin epipedon
v. Ochric epipedon
vi. Histic epipedon
vii. Melanic epipedon

Out of these epipedon two epipedon mollic and ochric are present in Pakistan.

i. Mollic epipedon

A surface horizon darker in color and contain more than 1% organic matter, it is 18cm thick and does not have any hard or massive structure. It has more than 50% base saturation percentage and less than 250mg/kg P_2O_5 in 1% citric acid.

ii. Umbric epipedon

Surface horizon similar to mollic epipedon but have less than 50% base saturation percentage.

iii. Ochric epipedon

Surface horizon too light in color, too low in organic matter, too thin in thickness to be mollic or umbric epipedon is known as ochric epipedon.

iv. Anthropic epipedon

Surface horizon developed during the use of soil by people for long period of time as home sites for growing irrigated crops. It contains more than 250mg/kg of P_2O_5 soluble in 1% citric acid.

v. Plaggin epipedon

Man made surface horizon developed by long and continuous manuring. It is generally more than 30cm thick. Its color and organic “C” contents depends upon the source of material used for manuring.

vi. Melanic epipedon

Thick black horizon at the surface with high contamination of organic carbon associated with aluminium- humus complexes. The intense black color is associated with accumulation of organic matter. It has low bulk density and high phosphate retention.

vii. Histic horizon

Surface horizon high in organic matter and saturated with water at least far apart during the year, unless artificially drained. It is generally 20-30cm thick and should contain more than 30 % organic matter.

2) Diagnostic endopedon

Diagnostic horizon which is developed below the soil surface horizon as diagnostic endopedon is known as diagnostic endopedon.

i. Agric endopedon
ii. Argillic endopedon
iii. Natric endopedon
iv. Spodic endopedon
v. Sombric endopedon
vi. Albic endopedon
vii. Oxi endopedon

i. Agric endopedon

A sub surface horizon that have farmed under the plough layer by movement of silicate clay and humus into voids (these are created by worms, wetting and drying or by capillary pores).

ii. Argillic endopedon

It is an illuvial horizon developed by the deposition or accumulation of silicate clays. It is at least 15cm thick.

iii. Natric endopedon

Natric endopedon derived from Latin word natrium means sodium. It is the sub surface horizon containing 15% or more exchangeable sodium.

iv. Spodic horizon

Sub surface horizon in which organic matter and compounds of aluminium and iron are accumulated. The active material has high CEC, large surface area and high water holding capacity. It is usually developed in humid climate.

v. Sombric endopedon

A sub surface horizon farmed or developed in well drained mineral soil containing illuvial humus. Its base saturation percentage is less than 50%.

vi. Oxi endopedon

Sub surface horizon containing mixture of kaolinite, hydrated iron and aluminium oxides, quartz and other primary minerals.

vii. Albic endopedon

It is a sub surface horizon from which clay and iron oxide have been removed, as a result of this color depends upon sand and its particles.

Horizons developed through the accumulation of solublized materials:

i. Calcic horizon

ii. Gypsic horizon
iii. Salic horizon
iv. Sulfuric horizon

i. Calcic horizon

It is a horizon developed by the accumulation of calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$). It is generally present in C horizon. It is more than 15cm thick and contains at least 5% more carbonates than C horizon, where it is present.

ii. Gypsic horizon

Horizon that developed by the accumulation of gypsum. The gypsum content should be at least 5% more than the horizon where it is present. The product of its thickness in cm and gypsum percentage should be 150 or more.

iii. Salic horizon

A horizon having the accumulation of salts more soluble in cold water than gypsum is called salic horizon. The product of its thickness in cm and gypsum percentage should be 60 or more.

iv. Sulfuric horizon

A horizon rich in sulfide mineral or high in surface organic matter, that when drained, oxidized to sulfuric acid. Under oxidized conditions such soils have pH less than 3.5, therefore these soils are toxic o many plants.

Hard horizons

i. Duripan
ii. Fragipan
iii. Petrocalcic horizon
iv. Petrogypsic horizon
v. Placic horizon

i. Duripan

A sub surface horizon that is strongly cemented by silica is called duripan. Although carbonates may be present, duripans do not slack during prolonged soaking in water or 8% HCl. However, it is disintegrates in hot concentrated KOH solution.

ii. Fragipan

A natural sub surface horizon with high bulk density relative to the master horizon where it is present is called Fragipan. It is slowly permeable to water and usually shows cracks on repeated wetting and drying.

iii. Petrocalcic horizon

A sub surface horizon cemented by carbonates (CO_3^{-2}) and not penetrable by spade or auger is called petrocalcic horizon. Dry fragments do not slack in water. It is at least 2.5cm thick.

iv. Petrogypsic horizon

A subsurface horizon that is cemented by gypsum so strongly that dry fragments do not slack in water and cementation usually restricts root penetration is called petrogypsic horizon.

v. Placic horizon

A sub surface horizon cemented by iron manganese or iron humus complexes is called Placic horizon. It is usually present in humid region. It restricts root penetration and water infiltration.

Other diagnostic features used in soil taxonomy:

i. Slicken sides
ii. Plinthite
iii. Permafrost
iv. Lithic contact
v. Durinodes

i. Slicken sides

Polished and grooved surfaces produced by sliding of one soil mass over other. These surfaces are usually present in soils having high content of swelling clays (smectite) and marked seasonal changes in moisture content.

ii. Plinthite

A mixture of iron and aluminium oxide clays, quartz and other material that commonly occur as red soil mottles (patches of different color other than that soil), Plinthite changes irreversibly to iron stone or exposure to repeated cycles of wetting and drying with heat from the sun.

iii. Permafrost

A layer of soil where temperature is either 0^0C or below zero throughout the year is known as permafrost.

iv. Lithic contact

A contact or boundary between the soil and underlying coherent or consolidated material which is usually sufficiently hard to make and digging with spade practically impossible, however it can be chipped or scrapped.

v. Durinodes

It is weekly cemented nodules, the cementation is usually by silica oxides, and these nodules usually do not slack into water.

N-value

It refers to the relation between percentage of water under field conditions and percentage of clay and humus. A simple field test is used to estimate the n-value by squeezing the moist soil in hand. If the soil flows freely between fingers the n-value will be more than 1, but if the soil flows with difficulty the n-value is between 0.7-1.

COLE (coefficient of linear extensibility)

The ratio between difference of moist length and dry length of clod to its dry length, It can be estimated from shrinkage of sample packed at field capacity into a mold and than dry.

$$COLE= Lm-Ld/Ld$$

Soil moisture regimes

Soil moisture regimes refer to relative amount of water in soil control section. Soil control section is the depth of soil used to measure soil moisture regimes. The soil control section ranges from 10-30cm when soil is fine loamy, coarse silty, fine silty and clayey, 20-60cm when soil is coarse loamy and 60-90cm when soil is sandy. Soil moisture regimes range from those where ground water remains on the soil surface for a part of year to those containing only unavailable water for much of the year. Soil moisture regimes indicate the soil moisture condition that combine many water related features such as runoff, climate, seepage, drainage and slope direction. The regimes are based mostly on the length of time (consecutive days) for which soil control section is moist to permanent wetting percentage. Following are soil moisture regimes:

1. Aquic soil moisture regime

The word aquic derived from Latin word aqua, aqua mean water. Aquic moisture regime is a reducing regime in soil that is completely free of dissolved oxygen. It is not known how long soil must be saturated with water before it is set to have an aquic moisture regime but duration must be at least a few days to deplete dissolved oxygen completely. When soil is completely saturated with water, the dissolved oxygen is consumed by plant roots, microorganisms and soil fauna resulting in reducing conditions in soil. When soil remains saturated with water for sufficiently long period of time to deplete the oxygen completely. Consequently soil is not suitable for the cultivation of crops because of anaerobic conditions.

2. Udic moisture regime

The word udic derived from Latin word Udus, Udus mean humid; at this moisture regime soil moisture control section is not dry in any part for 90 cumulative days in a year. At this moisture regime adequate moisture is available for growing plants for most of the year. Udic moisture regime is common to the soils of humid climates that have well distributed rainfall, which is approximately equal or exceeds the evapotranspiration requirements.

3. **Ustic moisture regime**

   The word ustic derived from Latin word ustus, ustus means dryness. At this moisture regime soils contains considerable but inadequate plant available water. The soil moisture control section may dry in any part for more than 90 but less than 180 cumulative daysper year. However, soil moisture control section is not dry for 45 consecutive days in four growing months from June 21- October 20.

4. **Xeric moisture regime**

   The word xeric derived from a Greek word xeros, xeros mean dry. Xeric moisture regime is a typical moisture regime in areas where winter is moist and cool while summer is hot and dry. Xeric moisture regime contains moisture which is particularly effective for leaching during winter months when evapotranspiration is minimum. In the areas of xeric moisture regimesoil moisture control section is dry in all parts for at least 45 consecutive days in four growing months June 21- October 20. However, soil moisture control section is moist for half of the time per year.

5. **Aridic/ Torric soil moisture regime**

   The word aridic derived from Latin word Aridus, Aridus mean dry while Torric derived from a Latin word torridus, torridus mean hot and dry. These terms are used for some moisture regimes but in different categories of soil taxonomy. In aridic or Torric soil moisture regime soil moisture control section is dry in all parts for more than half of the year, and the soil temperature at the depth of 50cm from the soil surface is above 5C^o. soil moisture control section is moist in some or all parts for less than 90 consecutive days. Soils that have aridic or Torric moisture regimes normally occur in arid climate. There is little or no leaching in the moisture regime and soluble salts may accumulate in soil if there is any source of salt.

Soil temperature regimes

Soil temperature regimes are defined in term of soil temperature measured at 50cm soil depth and the difference between mean annual summer and mean annual winter temperature. Soil temperature regimes are used to define soil classes at various catabolic levels in soil taxonomy. There are ten soil temperature regimes:

1. **Pergelic temperature regime**

   Temperature regime is said to be Pergelic when mean soil annual temperature is below 0C^o (permafrost).

2. **Cryic temperature regime**

   Soils in this temperature regime have mean annual temperature 0-8C^o but do not have permafrost.

3. **Frigid temperature regime**

A soil with frigid temperature regime is warmer in summer than a soil with cryic temperature regime. Mean annual soil temperature is 0-8C^{o} and the difference between mean summer and mean winter temperature is more than 5C^{o}.

4. **Iso frigid temperature regime**

If the name of soil temperature regime has prefix Iso, it means that mean summer and mean winter temperature differs by less than 5C^{o} at the depth of 50cm or at Lithic contact. At this temperature regime soils have mean annual temperature 0-8C^{o} but the difference between mean summer and mean winter temperature is less than 5C^{o}.

5. **Mesic temperature regime**

The mean annual soil temperature ranges from 8-15C^{o} and the difference between mean summer and mean winter temperature is more than 5C^{o} at the depth of 50cm from soil surface.

6. **Iso-mesic temperature regime**

The mean annual soil temperature is 8-15C^{o} and the difference between mean summer and mean winter temperature is less than 5C^{o} at the depth of 50cm.

7. **Thermic temperature regime**

At this temperature regime mean annual soil temperature is 15-22C^{o} and difference between mean summer and mean winter temperature is more than 5C^{o}.

8. **Iso-thermic temperature regime**

The mean annual soil temperature is 15-22C^{o} and the difference between mean summer and mean winter temperature is less than 5C^{o}.

9. **Hyper thermic temperature regime**

At this soil temperature regime mean annual soil temperature is more than 22C^{o}and the difference between mean summer and mean winter is more than 5C^{o}.

10. **Iso-hyper thermic**

The mean annual soil temperature is greater than 22C^{o} and the difference between mean summer and mean winter temperature is less than 5C^{o}.