UCAM & UNAH

Fieldwork & Laboratory

Soils Manual

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2026

Soils Handbook

Contents

Appendix

Soils Handbook

This introductory section provides the pedological and regional context for soil sampling in the Ayacucho region. It introduces the major soil-forming factors, USDA Soil Taxonomy, and the principal soil orders and subgroups relevant to the Huanta area. The aim is to help field teams understand why sampling design must account for differences in parent material, altitude, moisture regime, landform, and land use.

1. INTRODUCTION

Soils are often seen as being nothing more than a layer of undifferentiated material covering much of the earth's surface. In reality, they are dynamic biodiverse systems critical to all life on earth. Soil may be defined as a '*natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment'*. This is the standard definition adopted by the US Department of Agriculture.

The role of soils is fundamental to the integrity of many ecosystem services and natural resources, providing humans with food and water. Soils and soil systems are highly complex and varied and require careful management to ensure their critical properties are not degraded or lost. Soil processes are closely linked to climatic variables and have a direct bearing on agriculture as well as biodiversity and the wider environment. Land-use systems and climate change provide two significant pressures on soil resources that bring about systematic changes, directly impacting their essential functions. It is important that soil systems are better understood to ensure that essential natural resources are properly maintained.

Soil ecosystem services and functions may be subdivided as follows:

A. Supporting ecosystem services - include primary production and biodiversity, soil formation and nutrient cycling.

B. Provisioning ecosystem services - include refugia, water storage, food & water supply, biodiversity, etc.

C. Regulatory ecosystem services - include water filtration, flood control, atmospheric gas regulation, climatic regulation, erosion control, etc.

All of these are critical for maintaining the conditions for life on Earth. Soil erosion, the decline of soil organic matter, salinization, desertification, soil compaction, landslides and contamination all represent the degradation of this 'natural capital'. Ecosystem services derived from natural capital stocks are critical to the functioning of the Earth's life-support system.

2. SOIL IDENTIFICATION

2.1. Global Soil classification

In determining a system for classifying soils, the initial objective is to establish a hierarchy of types that allows for a clear understanding as to the relation between soil types and the variables that determine their character. The USDA soil taxonomy strives to give priority to those properties that are important to plant growth and that result from or influence soil development. Determining the similarities between soils is not simple. For example, there may be similarity in particle-size distribution between two soils and base status between one of these and another soil. The most important property must be identified for the development of a taxonomy that suits the needs of the user. Specific uses of soils, usually relating to plant growth, under specified systems of soil management are the principal concerns of comparing and analysing soil types.

Soil taxonomy, as with all taxonomies, reduces reality to types while recognising the clines that naturally exist between them. The USDA soil classification taxonomy is the most widely adopted. In the highest category, all kinds of soil are sorted into a small number of classes, which are small enough in number to be easily remembered and the distinctions between them readily understood.

In this way soils have been organised into **Orders,** which is followed by the **Suborders, Great Groups, Subgroups, Families** and, lastly, **Series** as follows:

ORDER: the highest taxonomic level. Names end with the suffix sol. Geological links.

SUB-ORDER: the second taxonomic level. Climatic determination.

GREAT GROUP: the third taxonomic level. Soil horizon character determination.

SUB-GROUP: the fourth taxonomic level. Three types: typic, intergrade and extra-grade. Typic subgroup is that which is representative of Great group character.

FAMILY: the fifth taxonomic level. Physical and chemical property determination: texture, mineralogy, pH, permeability, structure, consistency, precipitation pattern and soil temperature.

SERIES: the sixth taxonomic level. These are based on type locality data and named after prominent local features.

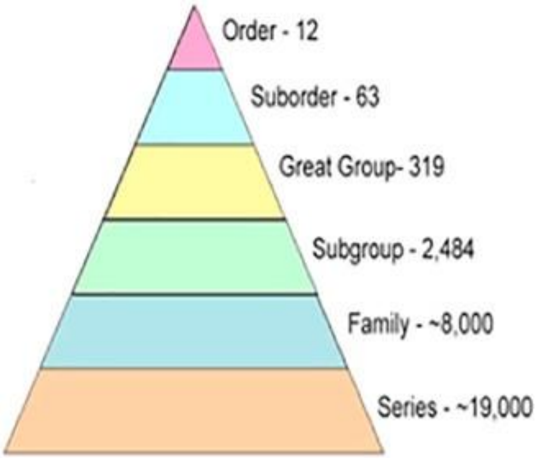


Figure 1 - Mineral Soil Categories of Soil Taxonomy and approximate numbers of units in each Category (after Brady and Weil, 2014).

2.1.1 Soil Orders

There are **twelve** soil **orders**, differentiated by the diagnostic horizons and features that reflect soil forming processes. Soils from different groups will, most likely, have distinct developmental processes. Soil properties are the consequences of a variety of processes acting on parent materials over time.

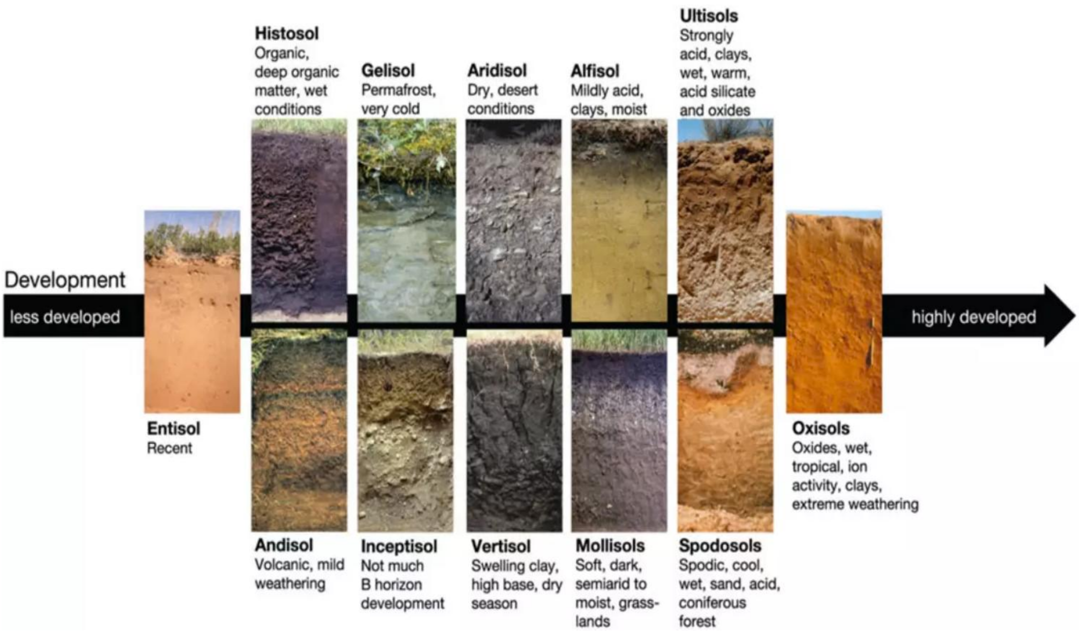


Figure 2 - Soil orders diagram.
(https://serc.carleton.edu/kskl_educator/soil_classification/chap_5_explore.html)

Alfisols: These soils develop in semi-arid to humid areas. They have a clay-enriched subsoil and relatively high native fertility. "Alf" refers to aluminium (Al) and iron (Fe). Alfisols are one of the more important soil orders for food and fiber production. The properties of Alfisols are a combination of an ochric or umbric epipedon, an argillic or natric horizon, a medium to high supply of bases in the soils, and water available to mesophytic plants for at least 6 months or more than 3 consecutive months during a warm season.

Andisols: most Andisols are formed in volcanic ejecta or volcaniclastic materials and are defined as soils containing high proportions of silica and amorphous colloidal materials, including allophane, imogolite and ferrihydrite. Andisols are generally young, typically fertile (except where phosphorus is easily fixed). They typically support intensive cropping, such as in south-east Asia to grow rice. A unique property of Andisols is the dominance of the Al humus-complex, resulting from weathering and mineral transformation. Andisols are typified by high phosphorus retention, available water capacity, and cation-exchange capacity. This is the dominant soil type in the lower river Cachi from Huanta to Huamanga.

Aridisols: are predominantly soils of xeric environments and occupy nearly a third of the Earth's land surface. The vegetation in many areas consists of scattered ephemeral grasses and forbs, cacti, and xerophytic shrubs. Aridisols have a very low concentration of organic matter, reflecting vegetative production in arid regions and water scarcity. Leaching and weathering processes in Aridisols often produces one or more subsurface soil horizons in which minerals have accumulated: silicate clays, sodium, calcium carbonate, gypsum or soluble salts. The unique properties common to Aridisols are a combination of a lack of water available to mesophytic plants for very extended periods, one or more pedogenic horizons, a surface horizon or horizons not significantly darkened by humus, and absence of deep, wide cracks.

Entisols: are soils that show little or no distinct pedogenic horizons, except for a limited A-horizon. As such they are characterised by having no diagnostic horizons, and reflect very largely their parent materials, which could be sediments or bedrock. Entisols are widespread and cover nearly one fifth of the earth's ice-free land. Entisols are dominated by mineral materials and are soils in that they support plants, but can be associated with any climate or vegetation. The absence of pedogenic horizons may result from factors such as inert parent material, hard parent rock, immaturity, location on highly eroded slopes, churning of superficial layers by animals or ploughing.

Gelisols: the unique property of Gelisols is the presence of permafrost and soil features and properties associated with freezing and thawing. These features include irregular or broken horizons and the incorporation of organic materials in the lower horizons, especially along the top of the permafrost table. Freezing and thawing produce granular, platy, and vesicular structures in surface and subsurface horizons. The increases in soil volume on freezing are considered a major soil-forming process in Gelisols. These soils are confined to the higher latitudes or high elevations, but they make up about 13% of the soils in the world, second only to Aridisols.

Histosols: uniquely, Histosols exhibit a very high organic content in the upper horizons to at least 80 cm and have no permafrost. The accumulated carbon is from 20-30% in this layer. Most Histosols are peats, formed under waterlogged conditions in which plant remains accumulate. These form under either minerotrophic or ombrotrophic conditions to give fen or bog environments. They are the most important edaphic mechanism for carbon storage. These are soils of particular significance in Andean landscapes for water resource related ecosystem services. They are the soils strongly associated with bofedales and wet meadows throughout the Andes.

Inceptisols: are soils of relatively new origin, characterized by minimal horizon development. They are highly variable and develop in a wide variety of humid and sub-humid regions. They exhibit horizons that have lost bases or iron and aluminum but retain some weatherable minerals. These soils lack an illuvial horizon enriched with silicate clay or an amorphous mixture of aluminum and organic carbon. Inceptisols can have various diagnostic horizons, but not argillic, natric, kandic, spodic, and oxic. They are the most abundant soil order on Earth, covering almost 22% of ice-free land. These soils are the dominant in Ayacucho throughout the mid-catchment.

Mollisols: the unique properties of Mollisols are a combination of a very dark brown to black surface A and B horizons (mollic epipedon) that is more than 25 cm thick, with a dominance of calcium in those horizons. Mollisols characteristically form under grass in climates that have a moderate to pronounced seasonal moisture deficit. Some Mollisols form under forest ecosystems, and a few formed in marshes. Mollisols are extensive steppic soils in Eurasia and throughout the Americas. In our area of study these soils have formed principally under the dry forests and valley grasslands in the headwater subcatchments of the rivers Cachi, Mantaro, Pampas and Apurimac.

Oxisols: are characterised by extreme mineral weathering, except quartz, inactive clay fraction, and a loamy or clayey texture. They characteristically developed in humid tropical or subtropical regions, on land surfaces that have been stable for a long time (early Pleistocene or older). As they have developed over long periods of time they can be found in arid regions.

Spodosols: also known as podosols, podzols, or espodosolos, are the typical soils of coniferous or boreal forests and also the typical soils of eucalyptus forests. In Western Europe, Spodosols develop on heathland, which is often a construct of human interference through grazing and burning. Spodosols uniquely have a B horizon consisting of accumulated black or reddish materials that have a high cation-exchange capacity. This horizon is the spodic horizon. These soils can develop on almost any parent material, but generally derive from either quartz-rich sands and sandstone or sedimentary debris from magmatic rocks, provided there is high precipitation. Spodosols are generally poor for agriculture due to the sandy portion, resulting in a low level of moisture and nutrients. A low pH further compounds issues, along with phosphate deficiencies and aluminum toxicity. The best agricultural use of Spodosols is for grazing, although well-drained loamy types can be very productive for crops if lime and fertilizer are used.

Ultisols: are often thought of as the final product of continuous weathering of minerals in a humid, temperate climate without new soil formation via glaciation. They are defined as mineral soils which contain no calcareous (calcium carbonate containing) material anywhere within the soil, have less than 10% weatherable minerals in the extreme top layer of soil, and have less than 35% base saturation throughout the soil. Ultisols occur in humid temperate or tropical regions. They are found in regions of Africa, Asia, Australia, South America and the southern United States. The soils in the lower Apurimac are primarily Ultisols, reflecting the more humid conditions of the subtropical and tropical environments of the east flank of the Andes.

Vertisols: Vertisols typically develop on basic rock, such as basalt, in climates that are seasonally humid or subject to erratic droughts and floods. The shrinking and swelling of Vertisols can damage buildings and roads, leading to extensive subsidence. Depending on the parent material and the climate, they can range from grey or red to the more familiar deep black. Vertisols are found nearer the equator. Areas where Vertisols are dominant are eastern Australia, the Deccan Plateau of India, and the lower Paraná river basin in South America. The natural vegetation of Vertisols is grassland, savanna, or grassy woodland. The heavy texture and unstable behaviour of the soil makes it difficult for many tree species to grow in them.

2.1.2. Soil Suborders

The soil **orders** are further divided into **suborders**. These are differentiated in accordance with the presence or absence of specific soil horizons. Looking at two soil orders provides a useful illustration of the means by which the classification system operates.

Entisols: are characterised by little or no development of horizons. This order has **five suborders**:

-wet or waterlogged soils with an aquic character with a blue/green coloration near the surface.

-stratified alluvial soils that are young and are undergoing continuous superficial deposition.

-soils on eroding slopes. These soils show little or no evidence of horizons owing to the continuous removal of materials.

-sands, in which horizons have not developed due to a lack of moisture or soil forming materials.

-soils that have been ploughed deeply or are impacted by other anthropogenic activity that arrests pedogenic processes.

Alfisols: this **order** has **five suborders** -

-grey coloured wet soils.

-cold soils with a short growing season.

-soils with a *udic* moisture regime with continuous water availability for plant growth.

-soils with a *ustic* moisture regime with extended periods in which water is not continuously available for plant growth.

-soils with a *xeric* moisture regime.

In these examples, it can be seen that the conditions and processes that differentiate soil suborders relate to water availability and movement of soil materials and which then impact upon plant growth. The nomenclature of the suborders is composed of two soil features. The first syllable identifies the diagnostic property of the soil and the second is the formative component of the soil order. Combining these elements gives sixty four suborders derived from the twelve soil orders.

Using the **Entisol** example, aquic conditions gives ’**Fluvents**’, with ‘***fluv***’ from the Latin word *fluvius* for river, and ’***ents***’ from the order Entisols.

MOIST → **DRY**

SATURATED	MOIST	LIMITED MOISTURE IN SOIL			LOW MOISTURE
AQUIC	UDIC	USTIC (Tropical)		XERIC (Mediterranean)	ARIDIC
		*Hyperthermic *'iso'*	*Thermic 'Non *iso*'		
• Soils periodically water saturated.	• Well distributed rainfall • Rainfall + stored moisture exceeds evaporation.	• Moisture more than Aridic but less than Udic. • Available at times when conditions are suitable for plant growth.		• Climate with cool, moist winters and warm, dry summers.	• Soils of Arid climate (both cold and hot).
▪ Reduced conditions. ▪ Less dissolved Oxygen.	▪ Not dry ≥ 90 days in an year. ▪ Not dry >45 days after summer.	▪ Dry ≥ 90 days but moist >180 days and at least 90 days consecutively.	▪ Dry ≥ 90 days but moist >180 days cumulative or ≥ 90 days consecutively . ▪ Not dry consecutive 45 days after summer. ▪ Moist 45 or more consecutive days after winter.	▪ Dry > 45 days consecutively after summer months. ▪ Moist ≥ 45 consecutive days after winter.	▪ Not moist > 90 consecutive days.

** Soil Temperature Regime (STR)*

Figure 4 - Soil moisture regime (after S.Kumar Singh, 2025)

2.1.3. Great Groups

The **suborders,** in accordance with dichotomous formative elements, are divided up into **Great Groups.** The name of a **Great group** has a prefix to the suborder name. Thus, the Fluvents may be named Cryofluvents, after the Greek ’*kryo*s’ for cold and the fluvent suborder. Conversely, Fluvents may be named Torrifluvents, after the Latin ’*toridus*’ for hot and dry.

Formative elements and nomenclature of the Great Groups -

- Acr. Modified from Gr.arkos, at the end. Extreme weathering.
- Al. Modified from aluminum. High aluminum, low iron.
- Alb. L.albus, white. Presence of an albic horizon.
- Anhy. Gr.anydros, waterless. Very dry.
- Anthr. Modified from Gr.anthropos, human. An anthropic epipedon.
- Aqu. L.aqua, water. Aquic conditions.
- Argi. Argillic horizon; L.argilla, white clay. Argillic horizon.
- Calci, calc. L.calcis, lime. A calcic horizon.
- Cry. Gr.kryos, icy cold. Cold.
- Dur. L.durus, hard. A duripan.

- Dystr.dys. Modified from Gr. dys, ill. Low base saturation.
- Endo. Gr.endon, endo, within. Implying a ground water table.
- Epi. Gr.epi, on, above. Implying a perched water table.
- Eutr. Modified from Gr. eu, good, fertile. High base saturation.
- Ferr. L.ferrum, iron. Presence of iron.
- Fibr. L.fibra, fiber. Least decomposed stage.
- Fluv. L.fluvius, river. Flood plain.
- Fol. L.folia, leaf. Mass of leaves.
- Fragi. Modified from L.fragilis, brittle. Presence of a fragipan.
- Fragloss. Compound of fra(g) and gloss.
- Fulv. L.fulvus, dull brownish yellow. Presence of organic carbon.
- Glac. L.glacialis, icy. Ice lenses or wedges.
- Gyps. L.gypsum, gypsum. Presence of a gypsic horizon.
- Gloss. Gr.glossa, tongue. Presence of a glossic horizon.
- Hal. Gr.hals, salt. Salty.
- Hapl. Gr.haplous, simple. Minimum horizon development.
- Hem. Gr.hemi, half. Intermediate stage of decomposition.
- Hist. Gr.histos, tissue. Presence of organic materials.
- Hum. L.humus, earth. Presence of organic matter.
- Hydr. Gr.hydor, water. Presence of water.
- Kand, kan. Modified from kandite. 1:1 layer silicate clays.
- Luv. Gr.louo, to wash. Illuvial.
- Melan. Gr.melasanos, black. Black, presence of organic carbon.
- Moll. L.mollis, soft. Presence of a mollic epipedon.
- Natr. Modified from natrium, sodium. Presence of a natric horizon.
- Pale. Gr.paleos, old. Excessive development.
- Petr. Gr.comb. form of petra, rock. A cemented horizon.
- Plac. Gr.base of plax, flat stone. Presence of a thin pan.
- Plagg. Ger.plaggen, sod. Presence of a plaggen epipedon.
- Plinth. Gr.plinthos, brick. Presence of plinthite.
- Psamm. Gr.psammos, sand. Sandy texture.
- Quartz. Ger.quarz, quartz. High quartz content.
- Rhod. Gr.base of rhodon, rose. Dark red color.
- Sal. L.base of sal, salt. Presence of a salic horizon.
- Sapr. Gr.saprose, rotten. Most decomposed stage.
- Somb. F.sombre, dark. Presence of a sombric horizon.
- Sphagn. Gr.sphagnos, bog. Presence of sphagnum.
- Sulf. L.sulfur, sulfur. Presence of sulfides.
- Torr. L.torridus, hot and dry. Torric moisture regime.
- Ud. L.udus, humid. Udic moisture regime.
- Umbr. L.umbra, shade. Presence of an umbric epipedon.
- Ust. L.ustus, burnt. Ustic moisture regime.
- Verm. L.base of vermes, worms. Wormy or mixed by animals.
- Vitr. L.vitrum, glass. Presence of glass.
- Xer. Gr.xeros, dry. Xeric moisture regime.

Temperature usually plays a less significant role in soil development than precipitation levels but can still be important as mentioned above with respect to certain soils.

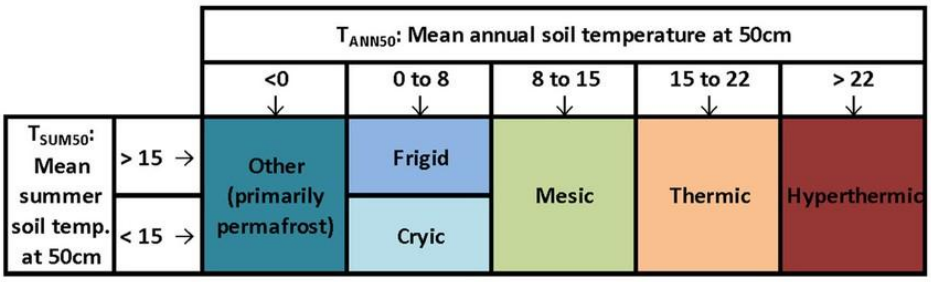


Figure 5 - Soil temperature regime (DOI: 10.3389/fevo.2019.00358)

2.1.4. Soil Subgroups

The naming of **Subgroups** is arranged with the name of the **Great group** with a modified prefix. These are as follows:

Aridic: soils that experience dry conditions and / or seasonality.

Lithic: soil of its type with rock fragments.

Typic: soil typical of its type.

Vermic: evidence of earthworm activity.

It is the sub-group that is often the mapped soil type. The soil family and soil series present field sample location detail.

2.1.5. Soil Families

At this level in the taxonomy, the principles governing differentiation relates to the physical and chemical properties that determine their response to land management.

The following apply to identify mineral soils with restricted ranges in:

- Particle-size classes in horizons of major biologic activity below plough depth.
- Mineralogy classes in the same horizons that are considered in naming particle-size classes.
- Cation-exchange activity classes of certain particle-size and mineralogy classes in the same horizons that are considered in naming particle-size classes.
- Calcareous and reaction classes in horizons directly below plough depth.
- Soil temperature classes.
- Thickness of the soil penetrable by roots.
- Classes of coatings, cracks, and rupture resistance used in defining some families to produce the needed homogeneity. These factors affect aeration as well as the movement and retention of water, both of which affect the growth of plants and engineering uses.

Soil Families are polynomial. Each consists of the name of a **Subgroup** and descriptive terms, generally three or more:

- Particle-size class (or combinations thereof, if strongly contrasting).
- Mineralogy (26 classes).
- Cation-exchange activity (4 classes).
- Calcareous and reaction class (4 classes).
- Temperature (8 classes).
- Depth of the soil (3 classes).
- Rupture resistance (2 classes).
- Classes of coatings and classes of cracks (3 classes).

2.1.6. Soil Series

In the USDA soil classification system **Soil series** is the most finely defined category, with more than 19,000 having been recognized in the United States alone. As a general rule the names are place names from whence the soil samples were collected.

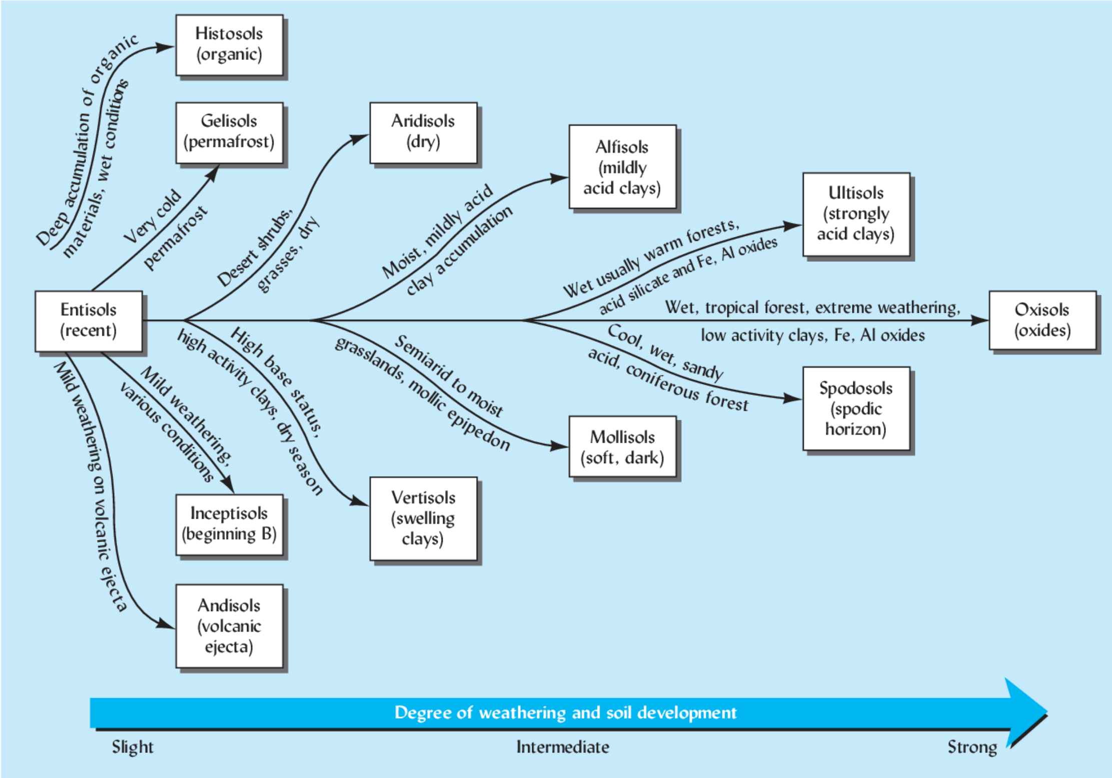


Figure 6 - general degree of weathering and soil development in the different soil orders classified in Soil Taxonomy. Also, the general climatic and vegetative conditions under which soils in each order are formed.

(https://www.semanticscholar.org/paper/Soil-Classification-77-3.1-Concept-of-Individual-1/056f8dd791cef9e37d1d12e6790554817d041aa2)

Soil order	Major criterion	Soil forming factors
Andisols	Volcanic ash materials	pm > t > r > cl > v
Vertisols	Dominance of swelling clays	pm > cl > r > v > t
Entisols	No genetic horizons	t > pm > cl > r > v
Inceptisols	Few diagnostic horizons	t > cl > r > pm = v
Spodosols	Spodic horizon, forest, low BS%	cl = pm = v > r = t
Aridisols	Soils of arid areas	cl > r > r = t = pm
Mollisols	Dark, grassy, high OM and BS%	cl > v > r = t = pm
Alfisols	Diagn. horiz. medium BS%, forest	cl > v > r > t = pm
Ultisols	Argillic horiz. low BS%, forest	cl > t > v > r = pm
Oxisols	Oxic horiz. highly weathered	cl > t > v > r = pm
Gelisols	Cold, permafrost	cl > r = v = pm > t

(pm = parent material, cl = climate, r = relief, v = vegetation, t = time, BS = Base Saturation, OM = Organic Matter, Diagn = Diagnostic, Horiz = Horizon).

Figure 7 - Ranking and major criteria of soil-forming factors in the mineral soil orders of Soil Taxonomy (after S.Kumar Singh, 2025)

2.2. Soils of Huanta & Ayacucho

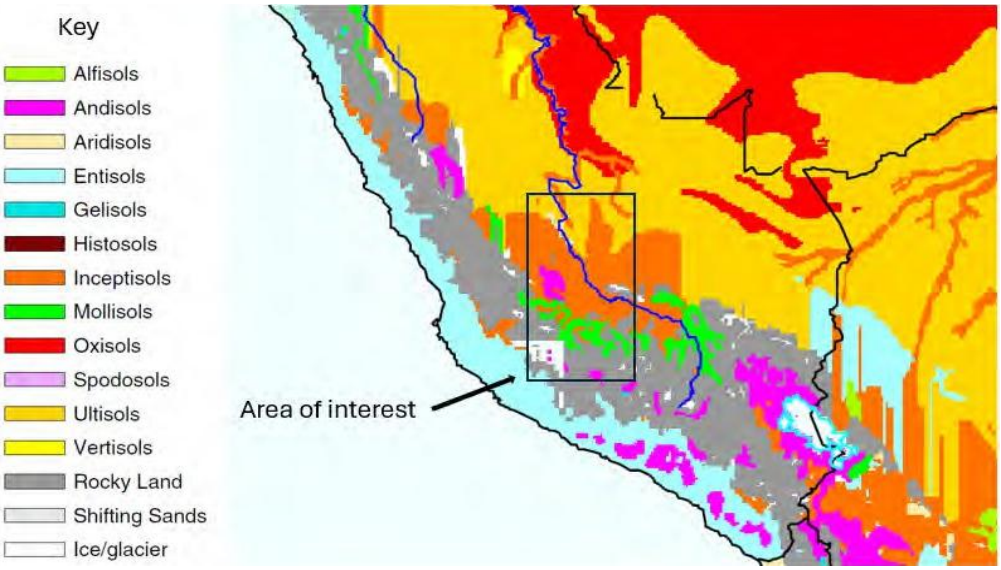


Figure 8 - Generalised map of soil orders in southern Peru.

2.2.1 Orders

In the Ayacucho region, soil distribution reflects the combined effects of Andean topography, volcanic and sedimentary parent materials, strong elevation gradients, and marked spatial variation in moisture availability. Around Huanta, mapped soil **orders** are dominated by Entisols, Inceptisols, Aridisols, Andisols,and Histosols.

Andisols: this is the dominant soil type in the lower Cachi valley below Huanta towards Ayacucho.

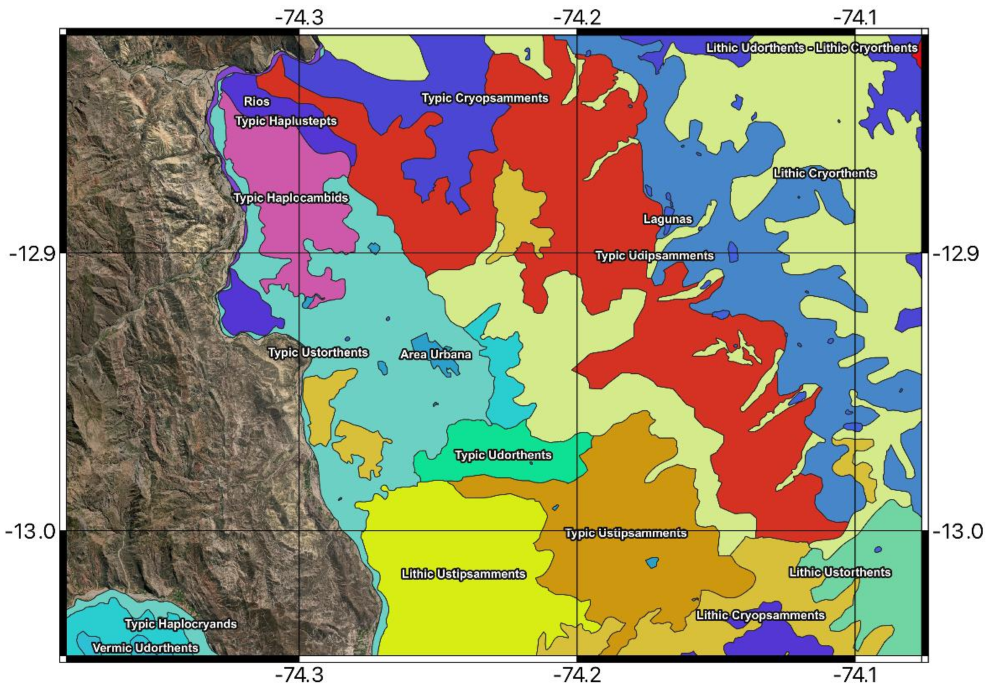
Histosols: these are soils strongly associated with high Andean wetland systems such as bofedales in the Sierra Razuhuillca.

Inceptisols: soils dominant in the mid-Ayacucho catchment.

Mollisols: soils in the headwater sub-catchments of the rivers Cachi, Mantaro, Pampas and Apurímac that have formed principally in dry forests and valley grasslands.

Ultisols: the soils in the lower Apurímac, east of the Sierra Razuhuillca, reflect the more humid conditions of the subtropical and tropical environments of the east flank of the Andes.

Figure 9 - Soils subgroups in the Huanta area (Adapted from Figure 11 - see below)



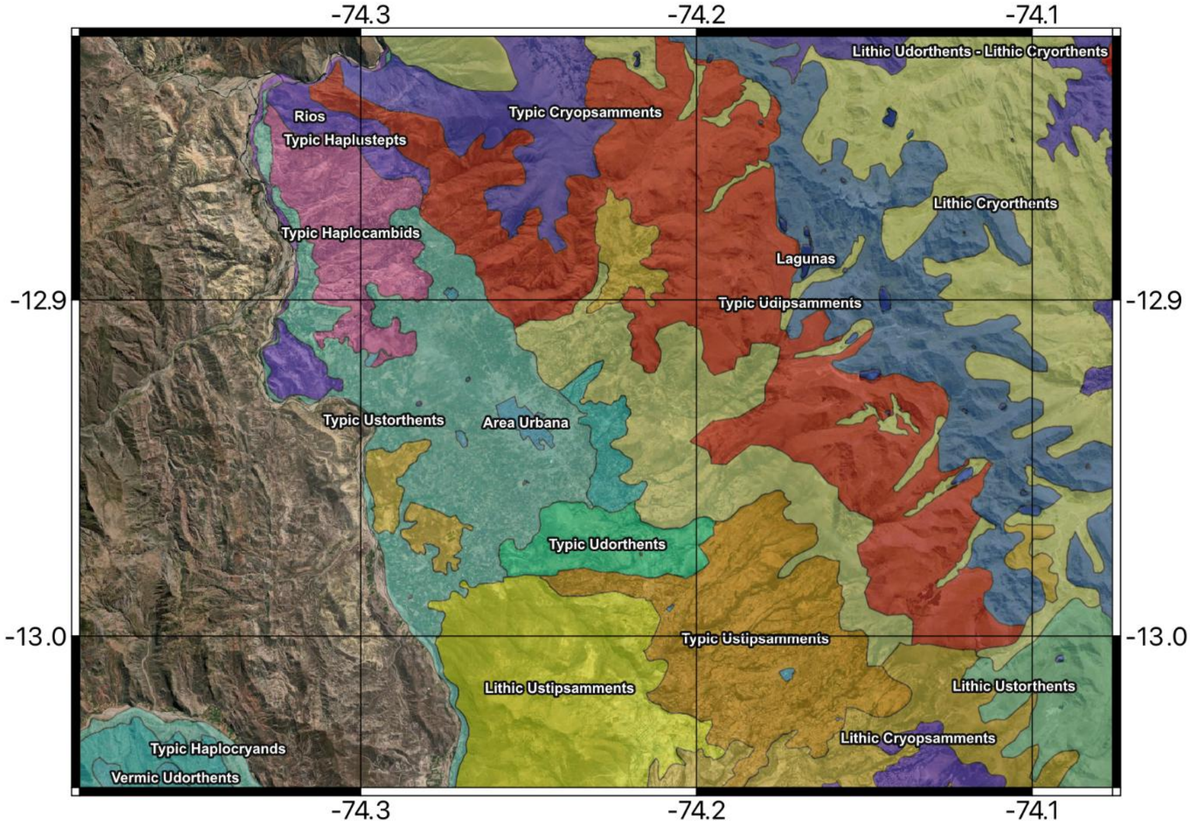


Figure 10 - Soils subgroups of the Huanta area overlaid on a map of the physical landscape (Adapted from Figure 11 - see below)

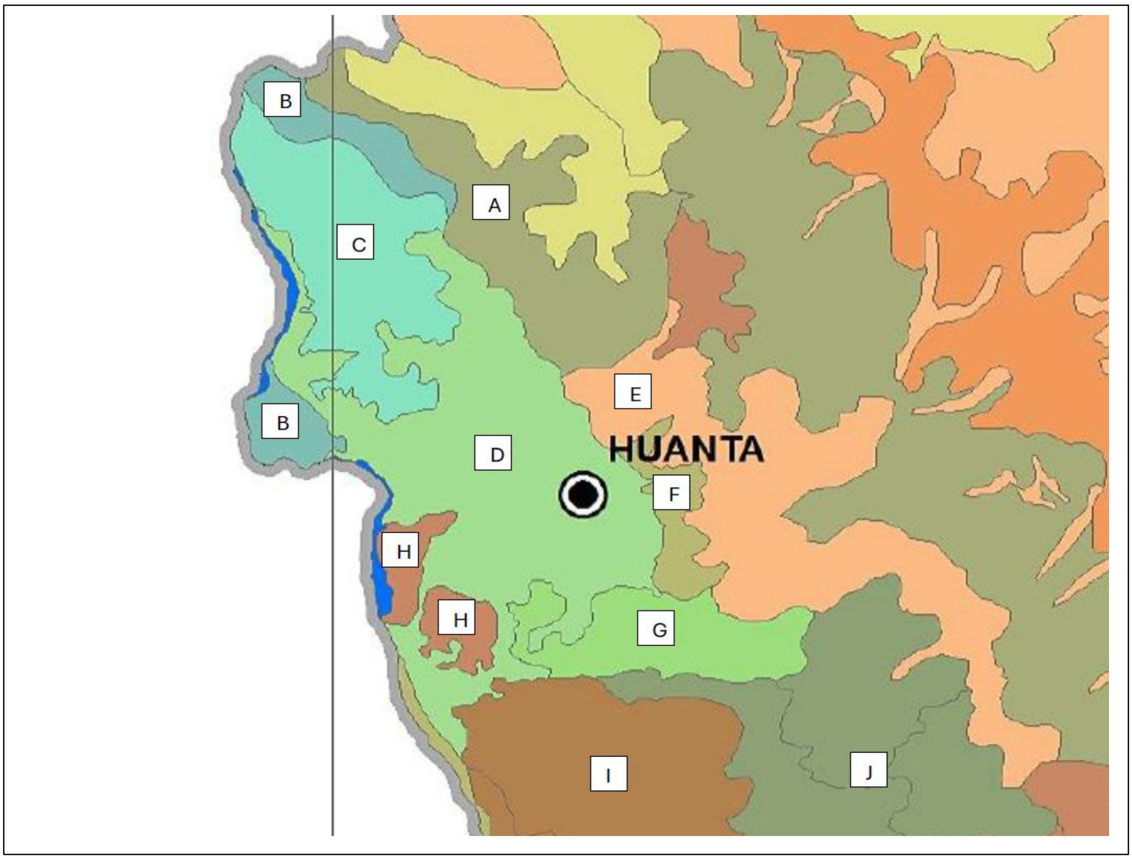


Figure 11 - Soils subgroups in the Huanta area
(https://siar.minam.gob.pe/ayacucho/publicaciones/?nid=295804)

Map code	Soil subgroups
A	Typic Udipsamments
B	Typic Haplustepts
C	Typic Haplocambids
D	Typic Ustorthents
E	Lithic Cryorthents
F	Typic Haplocryands
G	Typic Udorthents
H	Lithic Cryopsamments
I	Lithic Ustipsamments
J	Typic Ustipsamments
	Typic **soils from the Huanta area / Suelos** ***Típic*** **de la zona de Huanta**
	Lithic **soils from the Huanta area / Suelos** ***Lithic*** **de la zona de Huanta**

Table 1 - Key to map of soil subgroups in the Huanta area and estimates of respective areas (https://siar.minam.gob.pe/ayacucho/publicaciones/?nid=295804)

Soil subgroup	Description	Order	Climate
A. Typic Udipsamments	excessively drained, sandy, and nutrient-poor soils. They feature sandy textures throughout, lack significant soil horizons.	**Entisols**	Humid climates with evenly distributed rainfall.
B. Typic Haplustepts	have a moderate profile development, and generally lack extremes like heavy clay, high sodium, or wetness.	**Inceptisols**	Semi-arid to sub-humid moisture regimes.
C. Typic Haplocambids	characterized by minimal horizon development, a cambic (altered) subsurface horizon, and typically feature a redistribution of carbonates below the main soil zone.	**Aridisol**	Semi-arid to arid environments.
D. Typic Ustorthents	young, undeveloped mineral soils.	**Entisols**	Semi-arid to sub-humid, very clear dry seasons.
E. Lithic Cryorthents	shallow, permanently cold (cryic) soils found in extreme environments like alpine summits or Arctic / Antarctic. They sit directly on solid bedrock (lithic contact) at very shallow depths, usually less than 50 cm	**Entisols**	Cold-climates.
F. Typic Haplocryands	cold, high-altitude volcanic ash soils found in mountainous or alpine regions that lack unusual characteristics like deep saturation (aquic), extreme dryness (xeric), or cementation.	**Andisols**	Usually cold-climates.
G. Typic Udorthents	young, weakly developed, and heavily disturbed soils, lacking distinct, mature horizons due to human earth-moving, or severe erosion, they do not have the prolonged wetness of "aquic" soils.	**Entisols**	Found in humid or temperate climates.
H. Lithic Cryopsamments	shallow, sandy soils composed primarily of coarse, poorly developed sandy material underlain by solid bedrock at shallow depths.	**Entisols**	Found in cold environments.
I. Lithic Ustipsamments	coarse, sandy texture with no significant soil horizon development (Psamments), shallow depth to solid, unweathered bedrock, typically found within 50 cm of the surface.	**Entisols**	Semi-arid climates with distinct wet and dry seasons (Ustic).
J. Typic Ustipsamments	a sub-group of sandy, undeveloped soils (Psamments), composed almost entirely of unconsolidated sand so have a very low capacity to retain water and nutrients.	**Entisols**	Found in arid to semi-arid climates.

Table 2 - Soil and climatic details of soil subgroups found in the Huanta area

Source: USDA Soil Taxonomy: https://www.nrcs.usda.gov/resources/guides-and-instructions/soil-taxonomy

2.2.2. Geology & Soils in the Huanta area

The Sierra Razuhuillca consists of Paleozoic rocks, geological formations deposited approximately 540 to 250 million years ago across seven distinct geological periods from the Cambrian to the Permian.

The farmed Huanta area, below the sierra Razuhuillca, is covered by three formations which underlie the soils there:

-the volcanic Molinoyocc Formation in the south, around La Vega;

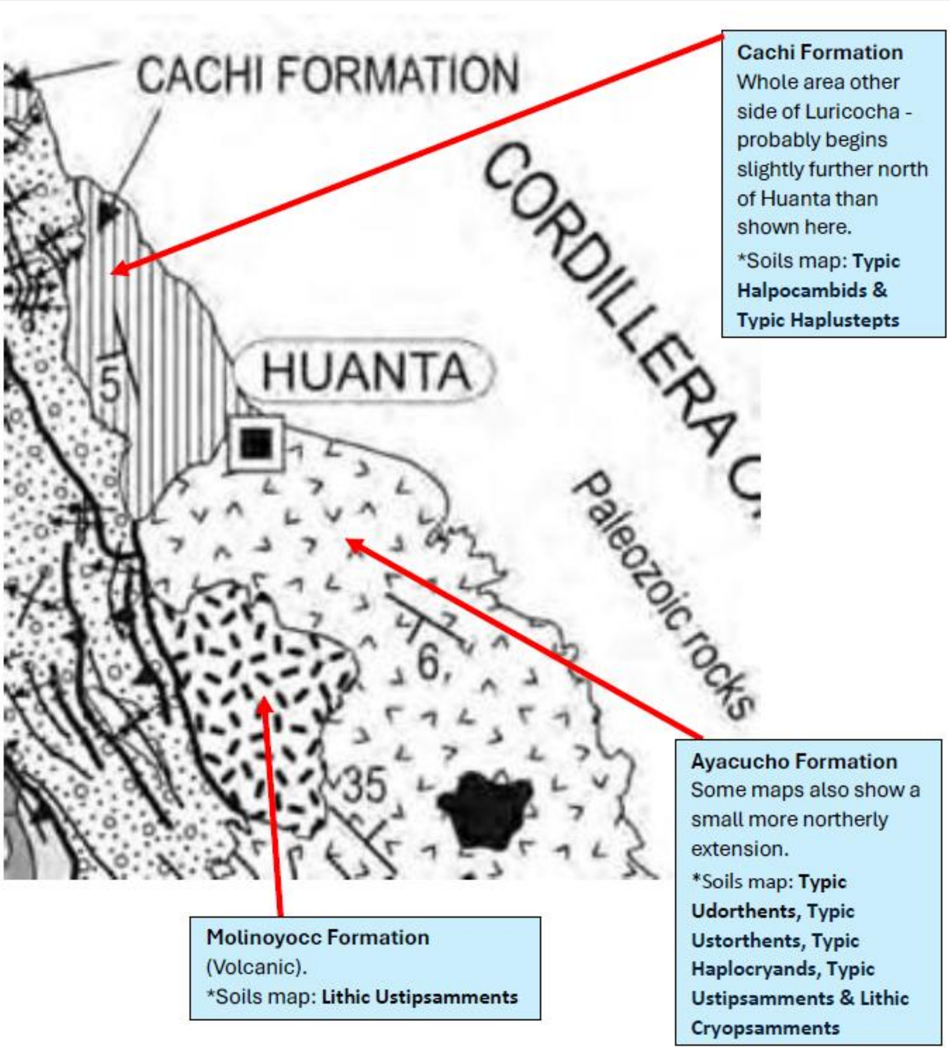
-the Ayacucho Formation south of Huanta; and

-the Cachi Formation, north of Huanta.

However, the latter two are overlain by substantial layers of sediments deposited in periods of glacial melt and by rivers flowing down from the Sierra Razuhuillca as well as some deposits of volcanic ash. Consequently, it is only the rocks of the Molinoyocc formation that are likely to have a direct impact on the composition of soils in the Huanta area.

Figure 12 - Geology of the Huanta region and its links to soil subgroups

(https://www.researchgate.net/publication/296484499_EARLY_MIOCENE_BIMODAL_VOLCANISM_AND_SYN-EXTENSIONAL_DEPOSITION_THE_LARAMPUQUIO_FORMATION_AYACUCHO_INTERMONTANE_BASIN_CENTRAL_PERU_VOLCANISMO_BIMODAL_DEL_MIOCENO_INFERIOR_Y_SEDIMENTACION_BAJO_CONDICION)



Other references

https://soillookup.com/soil-taxonomy

www.nrcs.usda.gov/sites/default/files/2022-06/Illustrated_Guide_to_Soil_Taxonomy.pdf

https://sinia.minam.gob.pe/sites/default/files/siar-puno/archivos/public/docs/1386.pdf

3. DATA COLLECTION

Soil sample and data collection should be carried out in a consistent and repeatable way so that results from different sites can be compared reliably. At each selected sampling point, the field team should record the physical condition of the soil, collect a representative soil sample, and document relevant site characteristics such as vegetation cover, stone content, soil depth, soil colour, texture, pH, electrical conductivity, and soil temperature. All measurements should be recorded on the field data sheet at the time of sampling, together with the site code, date, time, GPS location and any observations that may influence interpretation of the results.

3.1. Sampling protocols

Care needs to be given to selecting the soil sample points so that a representative sample of soil is collected. For soils, sample sites are often divided into four subareas with a sample collected from each subarea. These four samples will then be mixed to create a single sample for the whole site.
Composite samples are suitable where the aim is to obtain an average soil condition for a relatively uniform area, such as a field. Composite sampling should not be used where localised contamination, salinity patches, erosion features, manure piles or other small-scale anomalies are being investigated. In such cases, individual point samples should be retained and analysed separately.

The options for choosing the points from which the samples will be taken are as follows:

3.1.1. Simple Random sampling

From the access point to the sample area (i.e.. edge of a field), face away from the area and throw an object forcibly over your shoulder. Where the object lands is the centre of the sample point.

3.1.2. Complex sampling

A. Random sampling

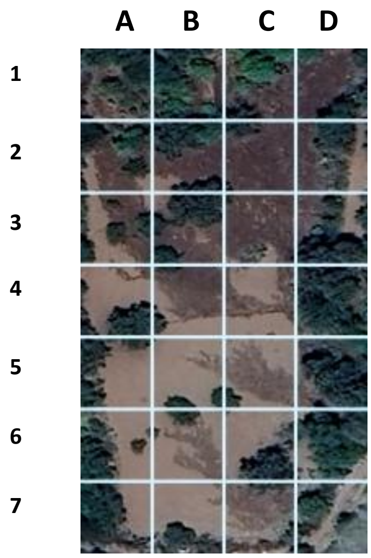
On an image (ie. satellite image) of the sample area (i.e.. a field) place a numbered grid such as the examples below, which could represent the sample area.
Generate random numbers using a random number generator such as: www.random.org
to obtain numbers to identify the number of sites required.

B. Stratified random sampling

Divide the area into four equal sectors. The diagrams below could represent one sector. Then follow the instructions above for Random sampling to generate a point or points in each sector.

C. Systematic sampling

On an image (ie. satellite image) of the sample area (i.e.. a field) place a numbered grid.
Depending on the number of sampling points required, select every 'nth' site to visit.



1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	20
21	22	23	24
25	26	27	28

Figure 13 - strategies to divide up a site or part of a site to obtain samples

3.2. Field sample and data collection

3.2.1. Equipment: augur, tape measure, ruler, trowel, soil pH meter, soil conductivity meter, Munsell chart, quadrat (0.5m x 0.5m), gloves, ziplock plastic bags (A4), permanent pen, camera, clipboard, data collection sheet (field), etc.

Once at the selected location, place the quadrat centered on the location. If an object was used to select the location, remove the object.

3.2.2. Soil depth (cms): in one corner of the quadrat use the augur to record soil depth.

Place the augur towards one corner of the quadrat, apply downward pressure and twist until the augur cannot enter any more. This means the augur has either reached the bedrock or an obstacle such as a large stone, compacted layer or other obstacle within the soil profile.

If the former (bedrock), extract the augur by counter-turning and measure the depth - you may need to use a tape measure to do this. Mark the point on the augur shaft at which it disappears into the earth so that the depth it entered can be measured on removal.

If the latter (an obstacle), repeat the measurement at other corners of the quadrat - as stated above - calculate the mean depth of all measurements and note the possible nature of the obstacle.

If it is possible to fully sub merge the augur into the ground, then record the length of the augur shaft and indicate that the depth is greater than this by adding a '+' on the data recording sheet.

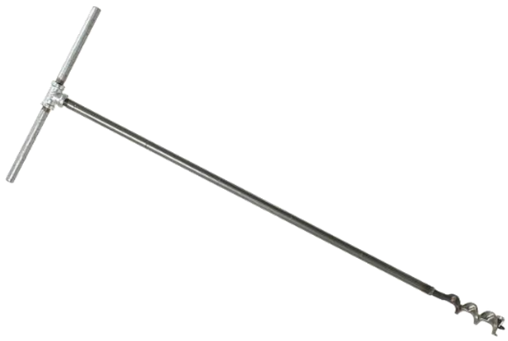


Figure 14 - Soil augur

3.2.3. Soil sample: use a clean trowel at each sampling point to clear and remove the top 2-5cms of 'material' such as loose surface litter, plant debris, and obvious foreign material from about a third of the area within the quadrat, before sampling.

Collect at least 0.5kg of the exposed soil in a plastic bag to a depth of no more than 20cms from each sampling point at the site. Discard any stores larger than small gravel and as much vegetative matter as possible.

If more than one sample is being collected at the site, these should then be mixed together to form a single sample for the site.

Each sample bag should be labelled externally and, where possible, with a second label placed inside the bag. The label should include the site code, sample point code, date, time, collectors, sampling depth, and whether the sample is individual or composite. The same information should be entered on the field data sheet.

3.2.4. Soil pH (L): Hanna Groline HI981030

Field pH readings should be treated as indicative because they are affected by soil moisture, temperature, probe contact and the amount and type of water added. Where water must be added, use **deionised** water where available. If deionised water is not available in the field, use the cleanest available water and record the water source.

Preparation: the probe should be cleaned and stored using an appropriate cleaning and / or storage solution **NOT** distilled water.

Calibration -

-press the **ON/OFF** button until **'CAL'** and then **'pH 7.01'** is displayed.

-place the probe in **pH 7.01 buffer solution** and **wait** until the reading is stable.

-immediately press the **ON/OFF** button to **save** the calibration and **'Sto'** will be displayed once it is stored.

-if this procedure is not followed immediately, the **option** to calibrate at **pH 4.01** will appear. If this is required, **place** the probe in **pH 4.01 buffer solution** and **wait** until the reading is stable., **press** the **ON/OFF** button to **save** the calibration and '**Sto**' will be displayed once it is stored.

Use: if the exposed soil is sufficiently soft, the pH can be measured directly in the ground.
NB. If the probe tip of the pH meter is made of glass and very fragile, carry out the test in the plastic bag containing the soil sample. This should be done on the ground, so the sample temperature is not impacted through the handling of the sample.

Figure 15 - Soil pH meter

Readings should be taken in a **dry sample** - if the soil is very dry and/or hard, break it up - and a **wet sample** - dampen the sample with a measured amount of **deionized** or **bottled** water **NOT** distilled water before placing the probe in it.

Place the pH probe tip at least 5cms into the soil sample and wait until the reading stabilises.

Also, record the soil temperature.

3.2.5. Soil conductivity (µS/cm) (L): Hanna Groline HI98331

Electrical conductivity values depend strongly on the measurement method. Direct field readings in dry or wet samples (see above), saturated-paste readings, and soil-water liquid extract readings may give different values. The same method and/or methods should be used and recorded with every EC measured sample.

Calibration:

-press the **ON/OFF** button until **'CAL'** and '**1.41 USE'** is displayed.

-place the probe in the **centre** of a beaker containing **calibration solution** (HI7031) well away from the sides of the beaker and **wait** until the reading is stable.

-wait until '**REC**' and then '**Sto**' is displayed.

Use:

If the exposed soil is sufficiently soft and moist, conductivity can be measured directly in the ground.

However, if the pH is being measured in a plastic bag, then carry out the conductivity test there as well. This should be done on the ground, so the sample temperature is not impacted through the handling of the sample.

Readings should be taken in a **dry sample** - if the soil is very dry and/or hard, break it up - and a **wet sample** - dampen the sample with **deionized NOT** <u>distilled water</u> before placing the probe.

Place the conductivity probe tip at least 5cms into the soil sample and wait until the reading stabilises.

Also, **record** the **soil temperature.**

Figure 16 - Soil conductivity meter

3.2.6. Stone content (%):

Assess the soil within the quadrat for the percentage of material present that is larger than gravel (> 1cm in diameter) and make an assessment according to the available categories on the data collection sheet.

3.2.7. Soil colour (L):

Use the **Munsell chart** to identify the soil colour (and codes) for both a dry (if possible) and a damp (wet) sample.

It is most likely that soils from the Huanta area will fall in to categories 5YR, 7.5YR or 10YR.

Soil colour should be assessed in natural daylight where possible, avoiding strong direct sunlight, deep shade, or artificial light. Record whether the colour was measured using a dry or wet sample, because moisture can darken the apparent colour.

Take a small amount of soil and choose one of the colour chart pages that appears to be most representative of the colour of the soil sample.

Place the soil on the white page following the colour chart page so that the sample is visible through the circle associated with the colour that appears most similar in colour to the sample.

Move the sample around between the circles until it can be confirmed which circle is most closely matched with the colour of the sample.

Record the code (i.e.. 7.5YR 3/3) for that circle from the opposite page in the Guide.

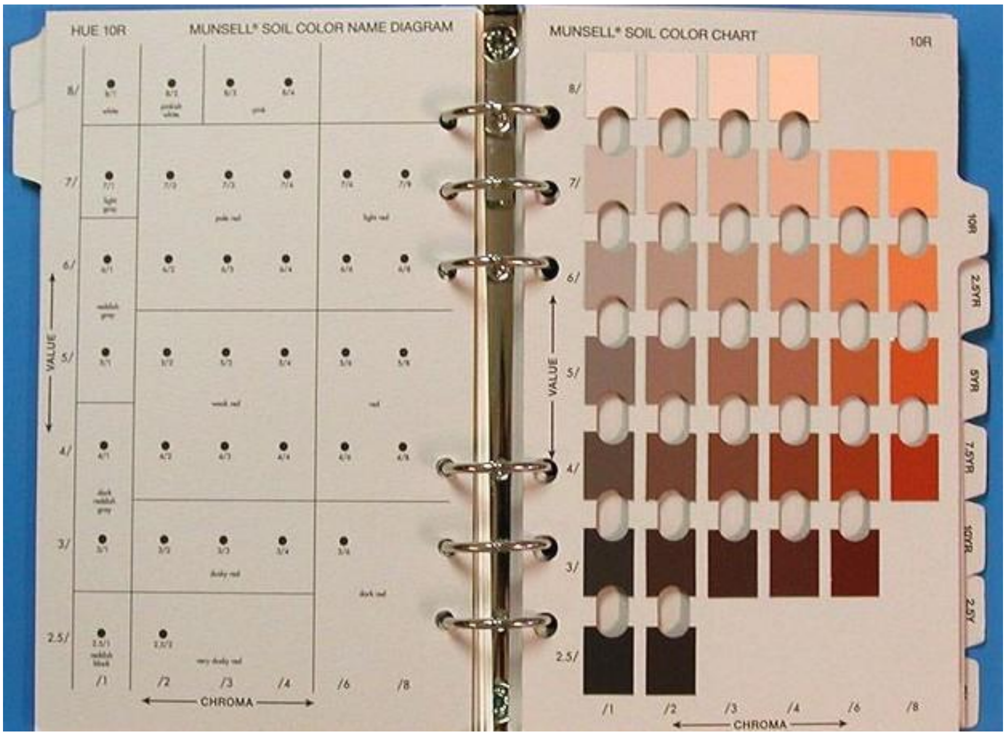


Figure 17 - Munsell chart

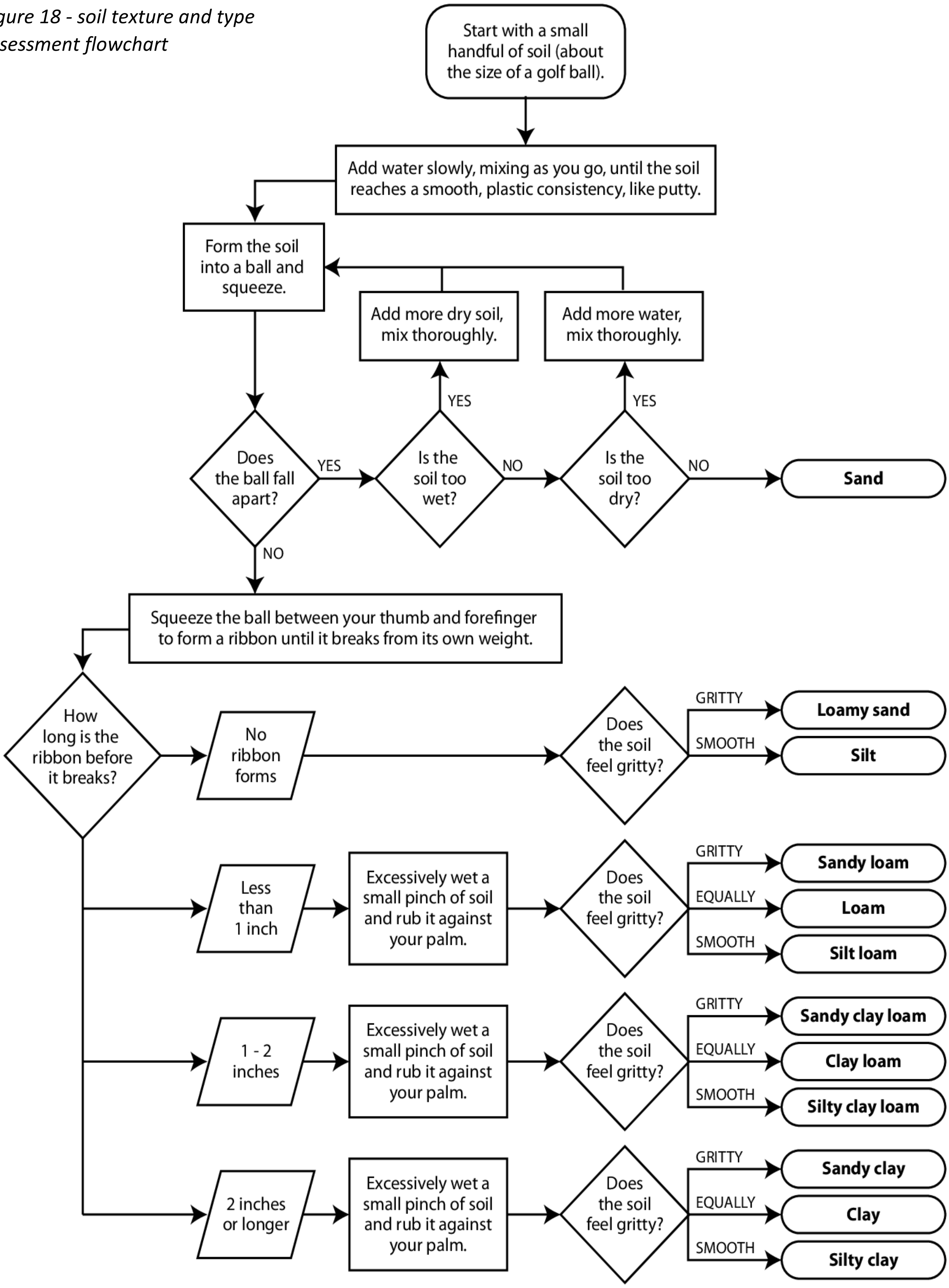
3.2.8. Soil texture / type (L): a

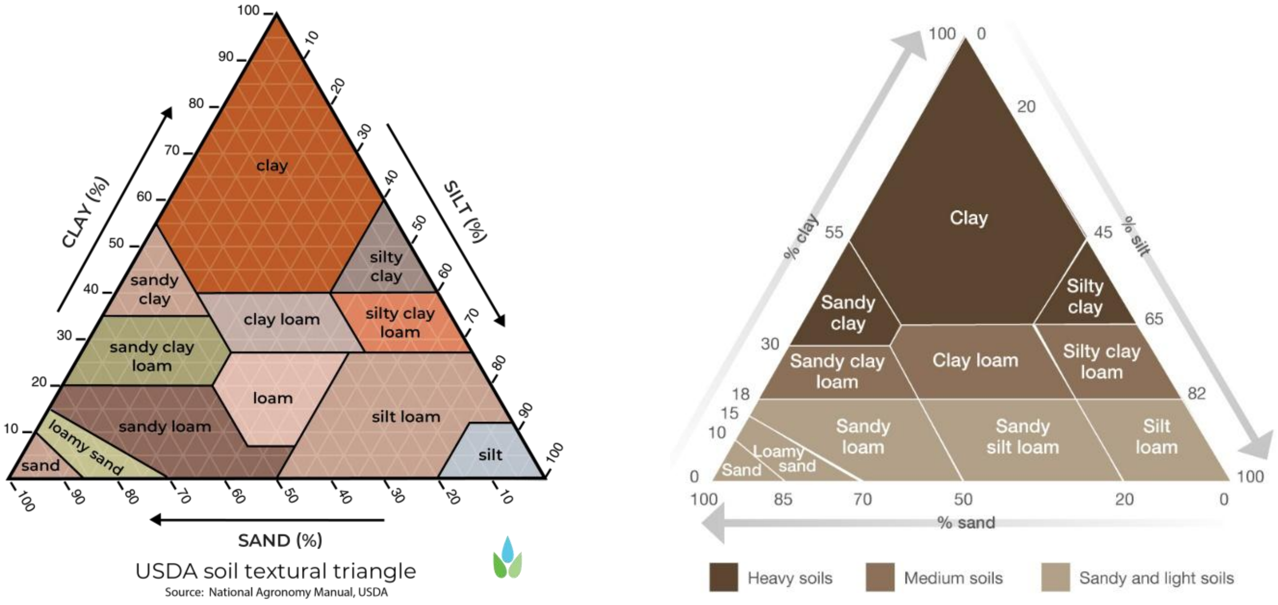
Assessment by hand is approximate and should be used as a rapid classification method. Where precise particle-size data is required, laboratory particle-size analysis should be conducted.

Take a small amount of damp soil and roll it into a small ball about the size of a cherry or plum (stages 1-3 in the diagram below). Then roll the ball into a long, thin strip (ribbon) or sausage and follow through the flowchart (see below) to identify the soil texture and type.

A soil identification triangle can be used to identify the approximate percentage of clay, sand and silt in the sample.

Figure 18 - soil texture and type assessment flowchart





NB. *The colours in the chart do not relate to the actual soil colours.*

Figure 19 - Soil identification triangle (two examples)

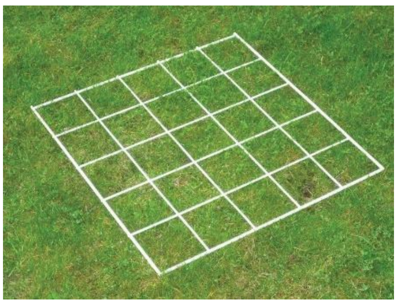
3.2.9. Vegetation cover (%): assess the surface area within the quadrat for the percentage of vegetation cover, i.e. bare soil/exposed soil v full coverage (i.e. grass?) and make an assessment according to the available categories on the data collection sheet.

NB. this is best done in an area of 'natural' vegetation, otherwise, it is difficult to determine the impact of human activities or inputs to the area impacting on vegetation growth. In cultivated fields, vegetation cover reflects recent land management, crop stage, grazing and disturbance, and should not be interpreted as a direct indicator of the natural soil condition. In natural or semi-natural areas, vegetation cover may provide more useful information on soil moisture levels, fertility, erosion risk and disturbance.

Place the quadrat so that the selected sample point is in the centre of the quadrat. All data recordings need to be recorded from within this quadrat. Each small square within he quadrat represents 4% of the area of the quadrat.

Estimate vegetation cover before removing any vegetation, litter or foreign material. After the estimate has been recorded, remove only the material necessary to expose the soil sampling area.

Figure 20 - Quadrat suited to assessing vegetation cover



3.2.10. Photos: a series of photos should be taken to reflect -

-the landscape context of the site: a general locational photo.

-access to the site: a photo showing the road or path access.

-the whole area of the site (i.e. a field).

-the sampling points (i.e. the wider quadrat areas).

-any notable site features such as erosion, salinity, irrigation channels, manure, burning, stones, contamination, or vegetation changes.

L. (Laboratory) - *these and other tests should be redone in the laboratory in controlled conditions.*

3.3. Laboratory sample processing and analysis

Field measurements provide rapid indicative values and should be recorded at the time of sampling. However, pH, electrical conductivity, colour, texture, and chemical/nutrient tests should, where possible, be repeated under laboratory conditions using standardised preparation procedures. Laboratory results should be treated as the primary analytical results, while field results should be used for site interpretation, cross-checking and identifying unusual conditions requiring further study.

3.3.1. Quality assurance and quality control
Quality-control samples should be included where results will be used for scientific reporting or management decisions. At a minimum, one duplicate field sample should be collected for every 10–20 samples, or at least one duplicate per field day. Field duplicates must be collected using the same method as the original sample and labelled with a different ‘blind code’.

Equipment must be cleaned between all samples to reduce cross-contamination.

It is best practice to recalibrate pH and conductivity meters on a daily basis, if practical.

3.3.2. Equipment & materials: ruler, soil pH meter, soil conductivity meter, Munsell chart, gloves, scales, pestle & Mortar (agate), petri dishes (glass - heat resistant), soil test kits, spoons, sieves, drying oven, plastic containers (ie. plastic cups), ziplock plastic bags (C5), data collection sheet (lab.), etc.

3.3.3. Sample preparation: Laboratory preparation should match the intended analysis.

For routine pH, EC, soil colour, soil texture and nutrient-kit testing, samples should normally be air-dried, gently disaggregated, and sieved to obtain the fine-earth fraction.

For geochemical or total-element procedures requiring homogenised fine powder, full sample pulverisation may be required.

To pulverize samples use an agate pestle & mortar, a spoon and a sieve so that the whole subsample consists of very fine material. It is best to use an agate mortar and pestle which have an impermeable surface so there cannot be any cross-contamination between samples. However, the mortar and pestle should always be fully cleaned and dried between samples.

Use the scales to prepare subsamples as required.

Figure 21 - Agate pestle & mortar

3.3.4. Sample drying: the drying temperature should be selected according to the intended analysis. Air-drying is suitable for many routine soil tests. Oven-drying may be used where rapid drying is required, but the temperature and duration must be recorded. Samples intended for organic matter, nitrogen or biological analyses should not be overheated unless the method specifically requires it. It is best to undertake several ‘test runs’ with a selection of samples at different timings and temperatures to confirm the most appropriate parameters to dry the samples.

Place 50grs of pulverised sample on a glass, heat resistant petri dish. Remove any remaining material larger than sand and any obvious vegetation.

Example: place in the oven at 80℃ for an hour.

3.3.5. Sample analysis:

Also see the instructions in the ‘Field sample & data collection’ section.

3.3.5.1. Soil pH - place some of the **original** soil sample in a container (i.e. plastic cup) to carry out the test. If the soil is very dry and/or hard, break it up and dampen it slightly with distilled water.

Readings should be taken in a **dry sample** - if the soil is very dry and/or hard, break it up - and a **wet sample** - dampen the sample with distilled water before placing the probe in it.

Place the pH probe tip at least 5cms into the soil sample and wait until the reading stabilises.

3.3.5.2. Soil conductivity (μS/cm) - place some of the original soil sample in a container (i.e. plastic cup) to carry out the test. If the soil is very dry and/or hard, break it up and dampen it slightly with **deionized NOT** distilled water.

Readings should be taken in a **dry sample** - if the soil is very dry and/or hard, break it up - and a **wet sample** - dampen the sample with **deionized NOT** distilled water before placing the probe.

Place the probe at least 5cms into the soil sample and wait until the reading stabilises.

Also, record the **soil temperature.**

3.3.5.3. Soil texture / type - take a small amount of damp soil and roll it into a small ball about the size of a cherry or plum. Then roll the ball into a long, thin strip or sausage and follow through the flowchart (See above) to identify the soil texture and type.

3.3.5.4. Soil colour - use the **Munsell chart** (see above) to identify the soil colour (and codes) for both a dry (if possible) and a damp (wet) sample.

3.3.5.5.Chemical content - use a soil test kit to measure levels of Nitrates, Potassium & Phosphorous. Commercial soil test kits provide approximate values and are useful for rapid screening. Results should be interpreted as only indicative unless validated against laboratory methods. For formal reporting, nutrient concentrations should be measured by an accredited or standardised laboratory method, with units, extraction method and detection limits clearly stated.

3.4. Soil analysis & agricultura

The following diagrams may assist in determining the most appropriate crops to grow in the soils of the Huanta area and some of the challenges that may arise.

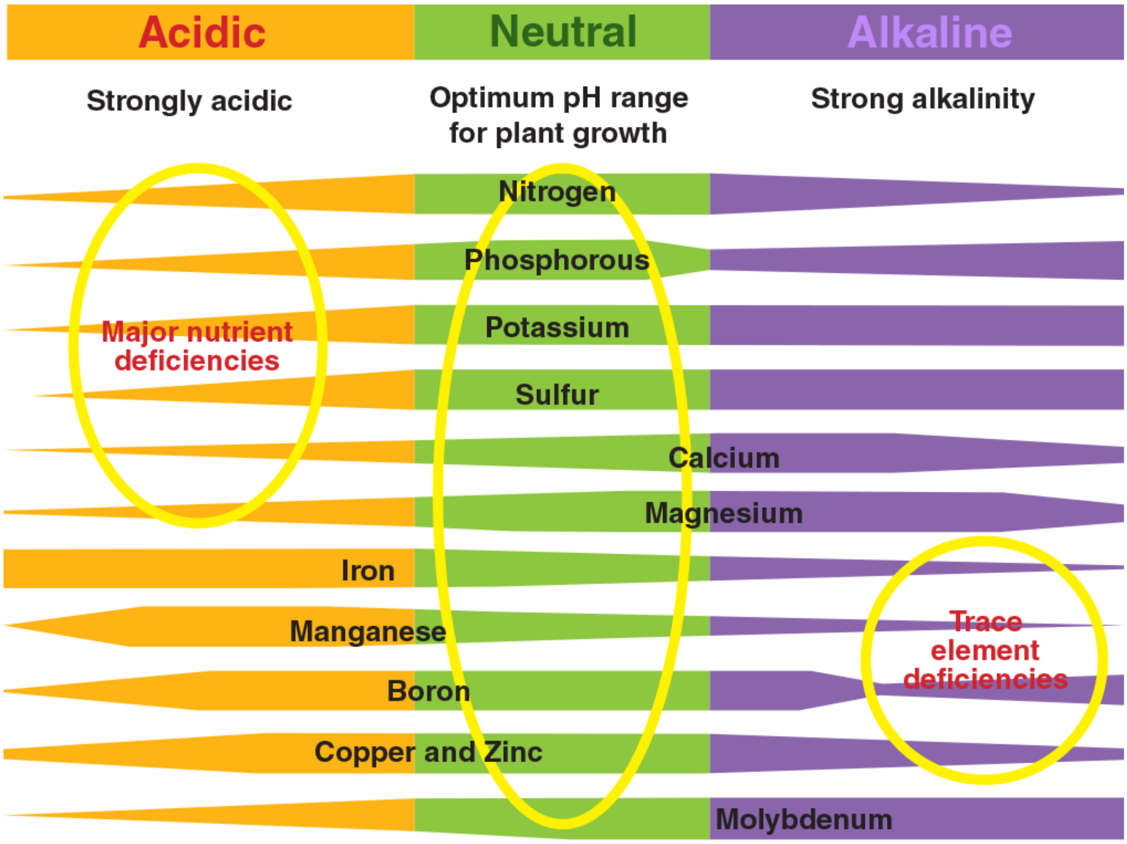


Figure 22 -- Soil pH and Nutrient availability

(Source: Bluedale - http://www.bluedale.com.au)

Most soils and water sources in the Huanta area tend towards alkaline and in some cases with the water from springs, significantly alkaline. This means that any crops requiring iron, manganese, boron, copper or zinc may struggle.

Figure 23 - Interpreting soil pH and conductivity values (below)

Soil pH	
3.5 - 10.0	**Most soils (Acidic - Alkaline)**
5.0 - 7.0	**Higher rainfall**
6.5 - 9.0	**Drier areas**
5.5 - 7.0	**Good plant growth**

Soil conductivity

Loose sands: have a typical electrical conductivity of 0.01-1 mS/m (10-1000 µS/cms)

Some clays: have a typical electrical conductivity of 1 mS/m (1000 µS/cms)

Below 400 µS/cm: are considered marginally or non-saline

Above 800 µS/cm: are considered severely saline

Plant growth: is usually best between 0.8-1.8 m/Sm (800-1800 µS/cms) , and should not exceed 2.5 (2500 µS/cms)

Figure 24 - Interpreting soil conductivity values for specific crops commonly grown in the Huanta area (above)

Figure 25 - Soil solution EC range

Crop	Ideal EC range
Tomato	1.5 - 3.0 mS/cm
Strawberry	0.8 - 1.2 mS/cm
Lettuce	0.9 - 1.5 mS/cm
Bell Pepper	0.8 - 1.4 mS/cm
Watermelon	2.0 - 2.5 mS/cm

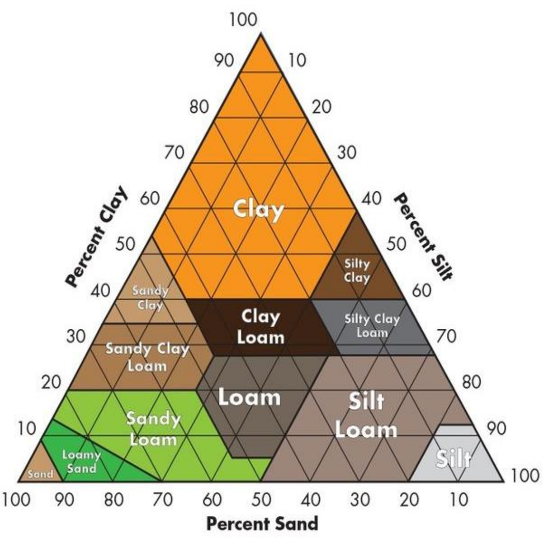
Crop pH ranges should be treated as general guidance only. Actual crop performance will also depend on soil texture, salinity, drainage, irrigation water quality, nutrient status, organic matter, climate, and management. Where possible, crop recommendations should be based on both soil-test results and local agronomic experience.

Figure 26 - most appropriate soil pH values for growing selected crops

Crop	pH		Crop	pH
Fruits			**Vegetables**	
Lemon	6.0 - 7.0		Artichoke	6.5 - 7.5
Melon	5.5 - 6.5		Barley	6.0 - 7.0
Orange	5.0 - 7.0		Lettuce	6.0 - 7.0
Pomegrante	5.5 - 6.5		Maize	6.0 - 7.5
Strawberry	5-0 - 7.5		Onion	6.0 - 7.0
Tomato	5.5 - 6.5		Pepper	6.0 - 7.0
Walnut	6.0 - 8.0		Wheat	6.0 - 7.0
Watermelon	5.5 - 6.5			

Top soil (<20cms) sample data collection sheet / Datos de muestras de suelo superficial (<20cms)

A.SITE details / Sitio	
Site name/Nombre:	**Site code/Codigo:**
Location/Ubicación:	**GPS*: South/Sur** **West / Oeste**
Date/Fecha:	**Altitude/Altitúd*:**
Weather/Tiempo:	**Air temp (℃):**
***GPS location details and the altitude will be recorded using Google earth on the data results spreadsheet.**	

B.SOIL characteristics / Características del suelo			
pH		**Depth (cms):**	
Conductivity (μcms) **Temperature (℃)**		**Depth (cms):**	
Depth / Profundidad (cms)			
Munsell chart colour & code (Refer to Munsell):			
Soil texture (see graph):			
Soil structure / estructura: *Crumb (1-6mm)* *Platy (1-10mm)* *Blocky (5-75mm)* *Prismatic (10-100+mm)* *Columnar (10-100+mm)*			

Stone (Piedra) content:	*None* *Very Few* *Few* *Some* *Many* *Very many*
Organic content:	*Undecomposed litter (L)* *Humus rich layer (A)* *No litter (N)* *Partially decomposed litter (F)* *Well decomposed humus litter (H)*

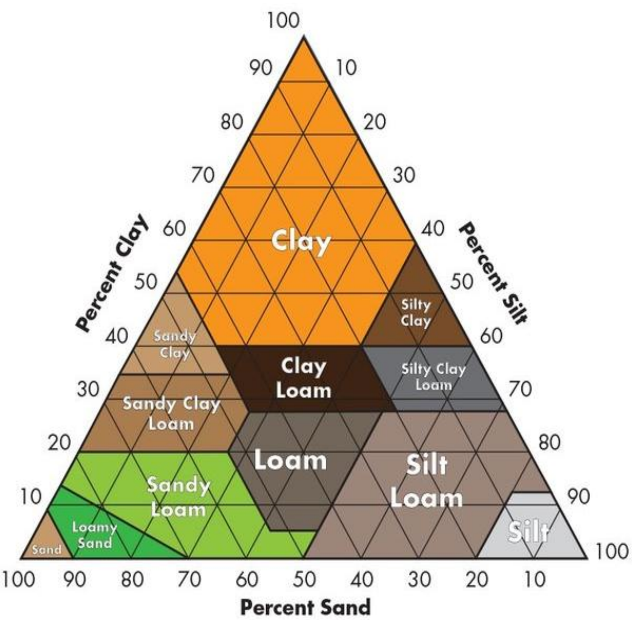
C.LOCATION characteristics / Características de la ubicación	
***Slope / Pendiente:**	*Flat* *Gentle* *Moderate* *Steep* *Foot-slope* *Toe-slope*
Description -	
***Drainage / Drenaje:**	*Very poor* *Poor* *Average* *Good* *Very good*
Description -	
***Vegetation cover (%)**	*0%* *25%* *50%* *75%* *100%*
Description -	
***Land use/Uso del terreno**	*Crops* *Pasture* *Scrub* *Orchard* *Woodland* *Bare soil* *Cosechas* *Pasto* *Matorral* *Huerta* *Bosque* *Suelo*
Description -	

D.OTHER comments / Otros comentarios
(Carbonate content (grs) – to be calculated later / Contenido de carbonato (grs) – para calcular más tarde)

Soils Lab.data collection sheet / Hoja de recogida de datos del Laboratorio de Suelos

A.SITE details / Sitio	
Site name/Nombre:	
Site code/Codigo:	**Date/Fecha:**

B.SOIL characteristics / Características del suelo

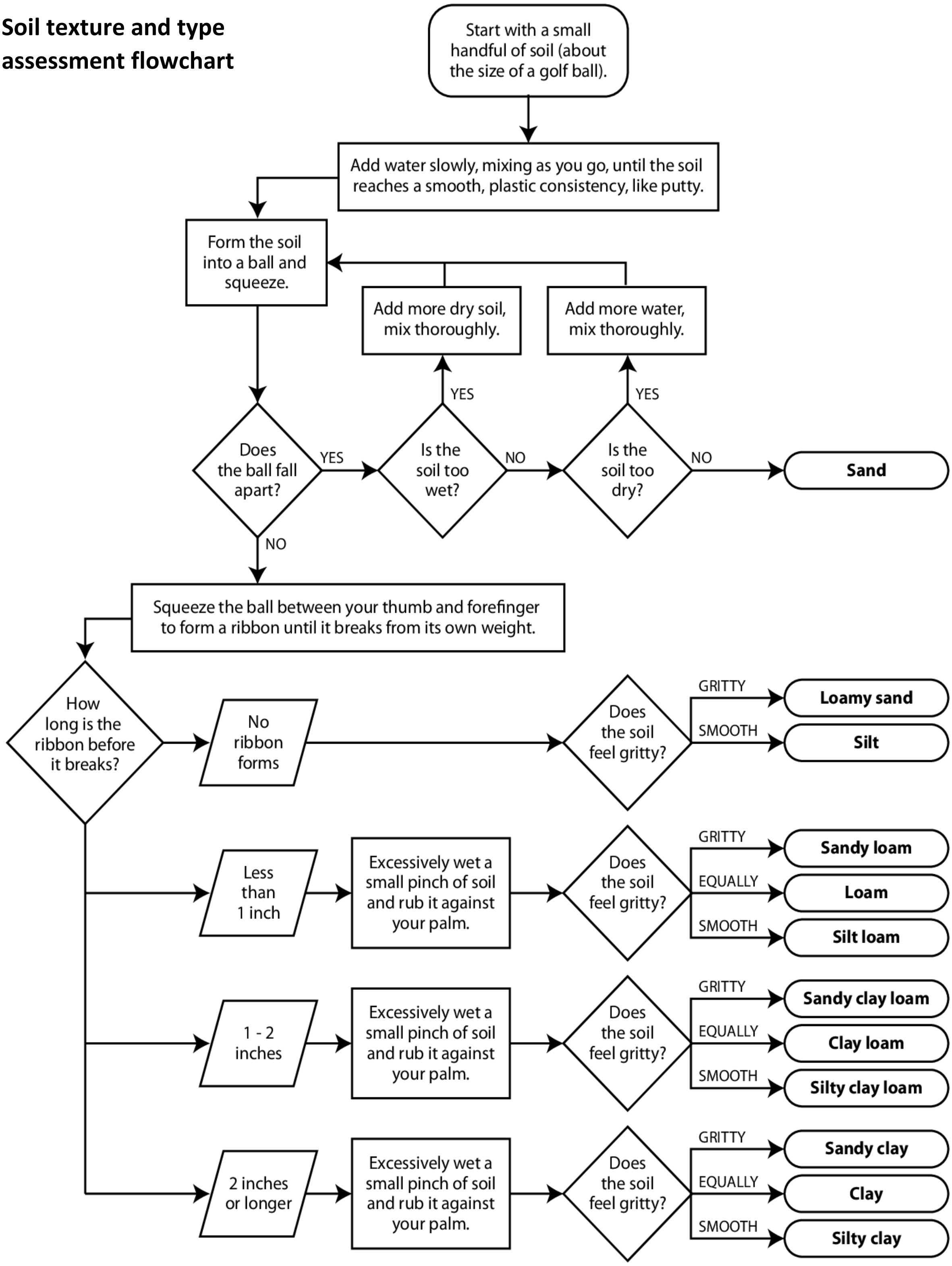
pH **Temperature (℃)**		
Conductivity (µcms) **Temperature (℃)**		
Munsell chart colour & code (Refer to Munsell):		
Soil texture (see graph)**:**		
Soil structure / estructura: *Crumb (1-6mm)* *Platy (1-10mm)* *Blocky (5-75mm)* *Prismatic (10-100+mm)* *Columnar (10-100+mm)*		
Stone (Piedra) content:	*None* *Very Few* *Few* *Some* *Many* *Very many*	
Organic content:	*Humus rich layer (A)* *No litter (N)* *Undecomposed litter (L)* *Partially decomposed litter (F)* *Well decomposed humus litter (H)*	
Carbon content (gr):		

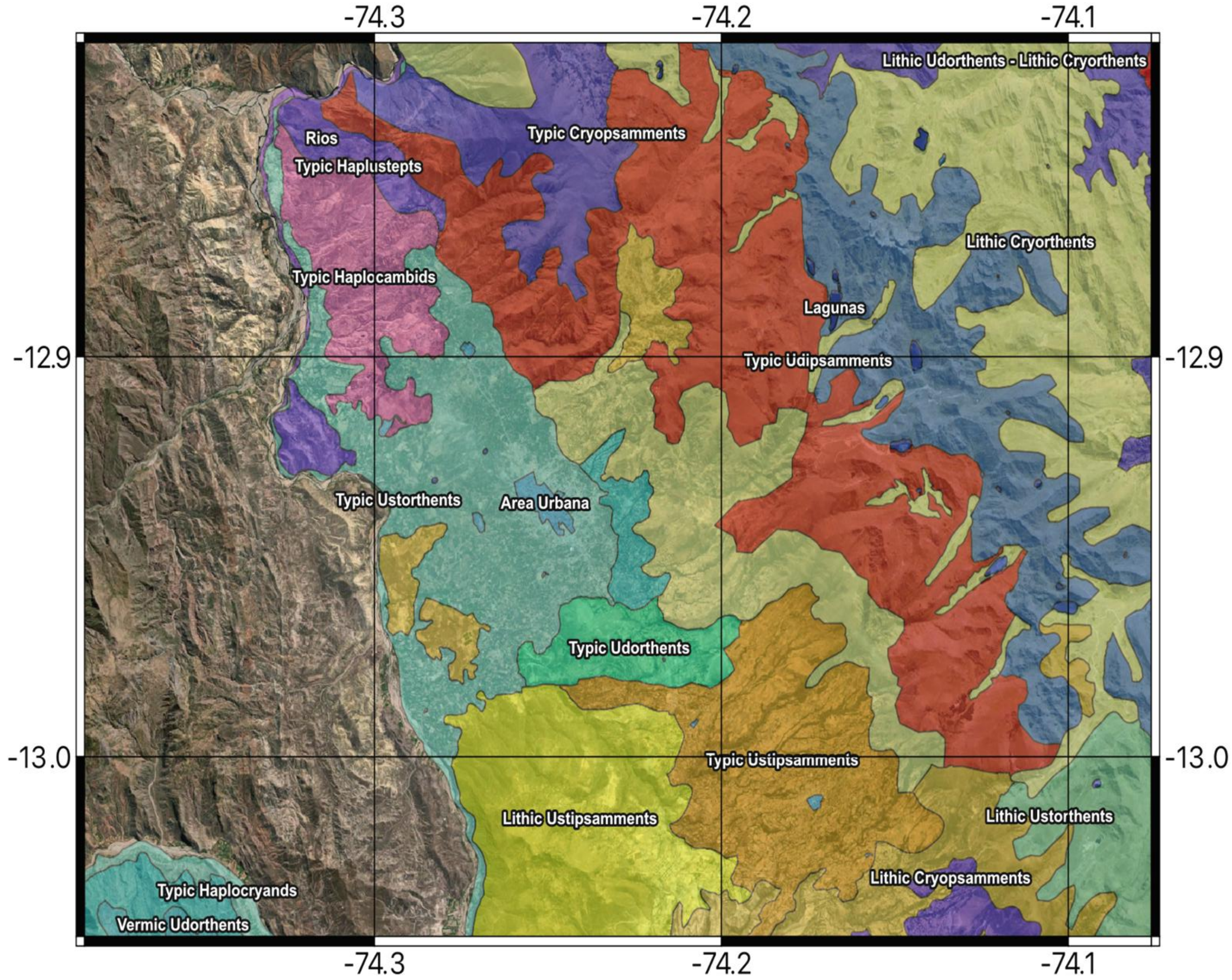
C.Chemical tests / Pruebas quimicas

Nitrogen / Nitrógeno:	*Traces*	*Low*	*Medium*	*High*
Potassium / Potassio:	*Traces*	*Low*	*Medium*	*High*
Phosphorous / Fosforo:	*Traces*	*Low*	*Medium*	*High*
pH:				

D.OTHER comments / Otros comentarios

Soil texture and type assessment flowchart

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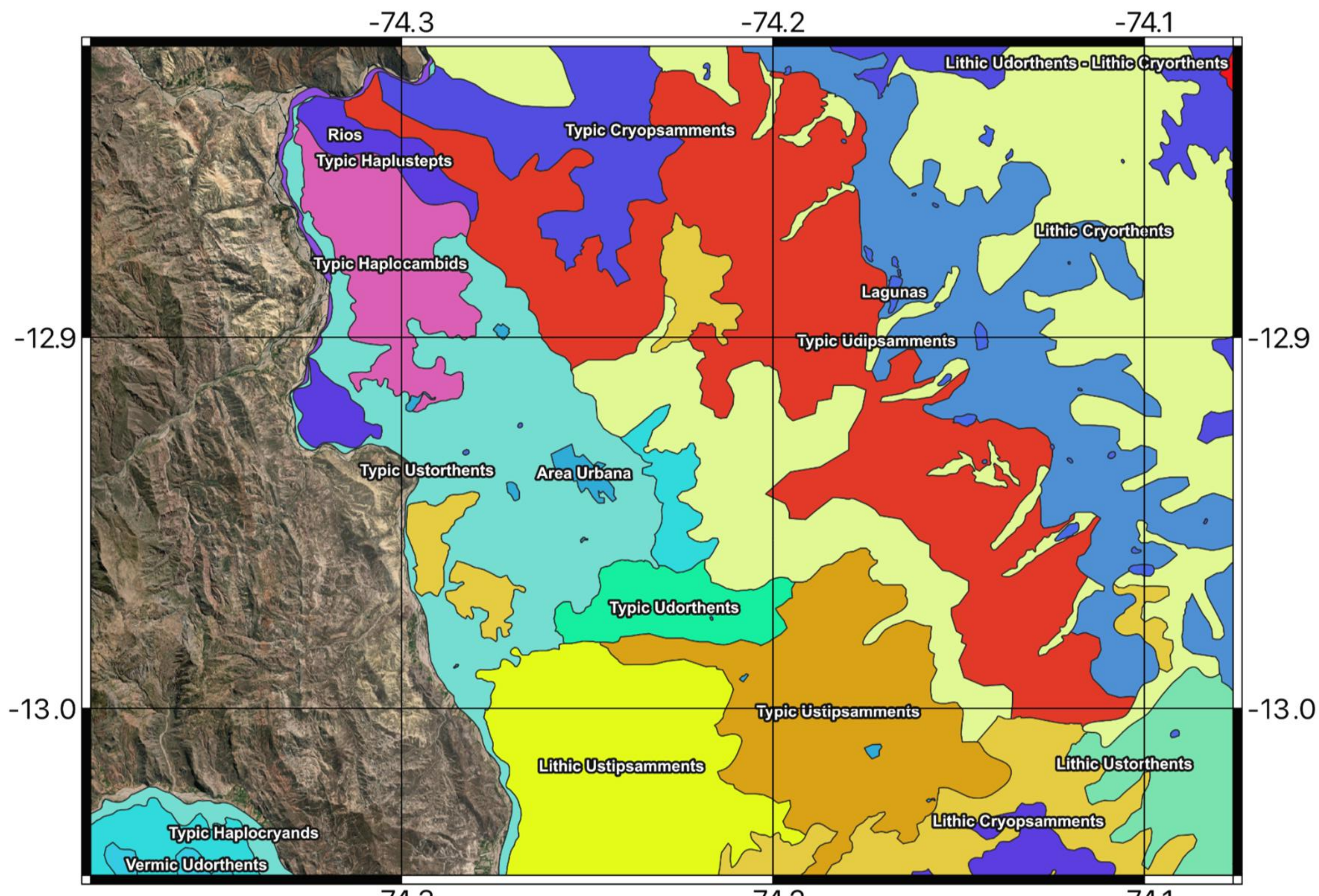
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Lagunas
Typic Udipsamments
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Area Urbana
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Vermic Udorthents