THE SOIL

IPROMO COURSE 2015

Food security in mountain areas EXtraordinary Potential

Michele Freppaz PhD – University of Torino (DISAFA – NatRISK)

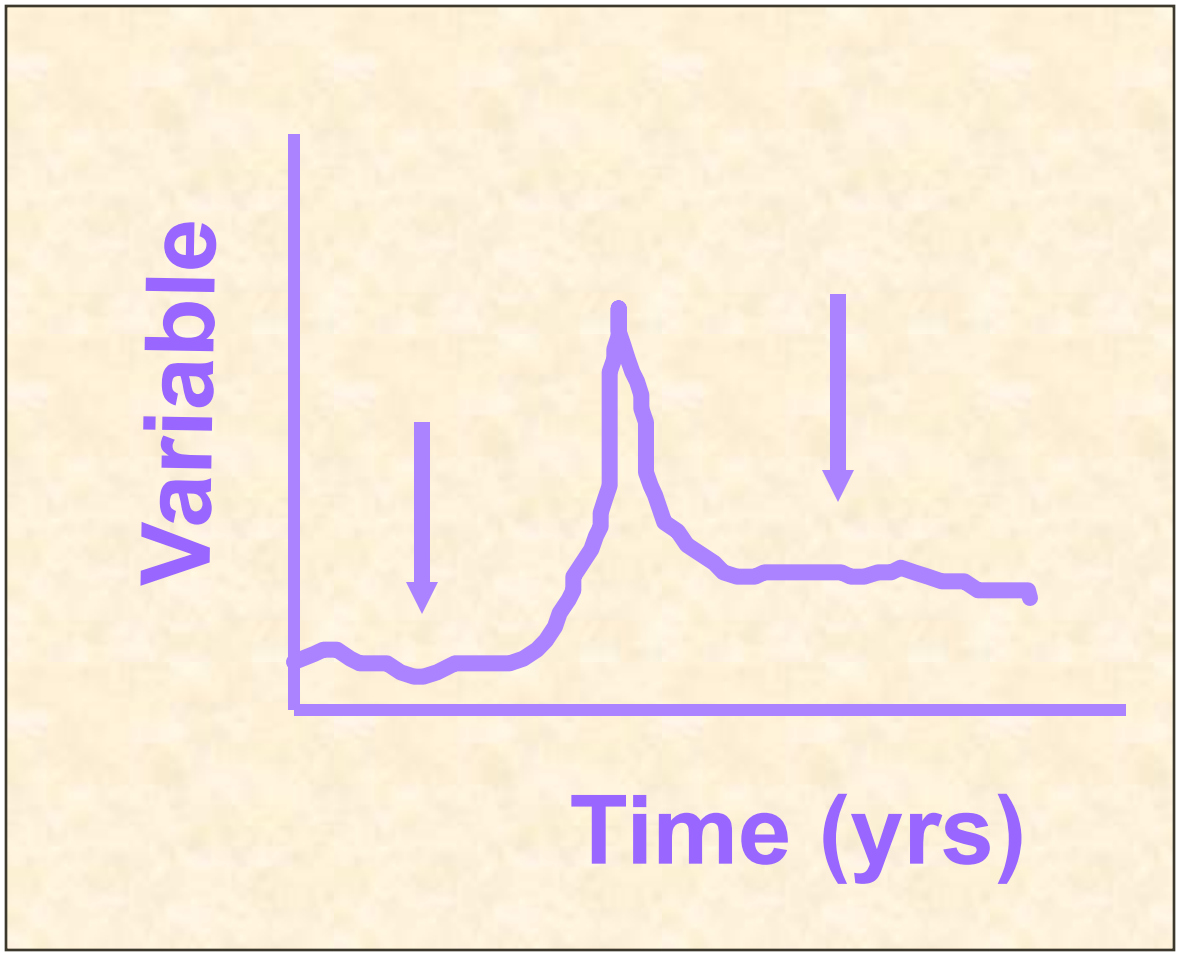
michele.freppaz@unito.it

Mountain Partnership
working together for mountain peoples and environments

NatRisk

UNIVERSITÀ
DEGLI STUDI
DI TORINO

Only 10 percent of studies capture unusual events



Unusual events reset systems. Short-term studies initiated before and after a rare event are viewing different system states.

LTER Italia
Italian Long-Term Ecological Research Network

unlock the SECRETS IN THE SOIL

Life, actually.

What is the soil

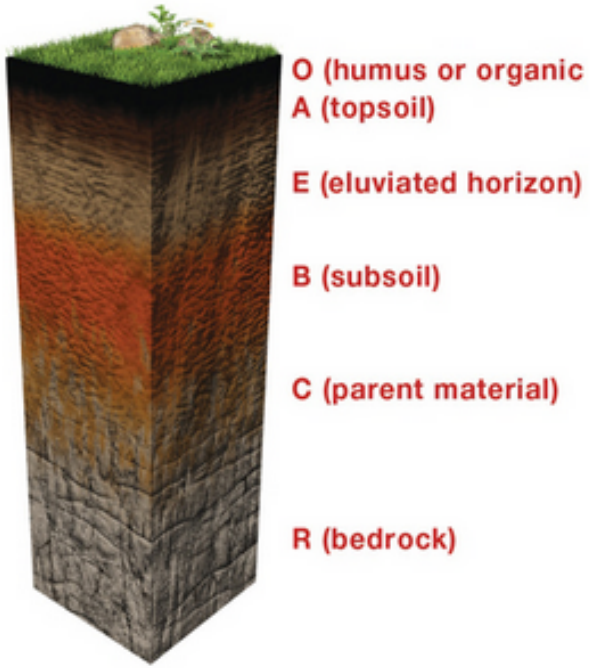
2015
International
Year of Soils

Soil is 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 (Soil Taxonomy, 2nd Edition).

Soil Profile

There are different types of soil, each with its own set of characteristics. Dig down deep into any soil, and you'll see that it is made of layers, or horizons (O, A, E, B, C, R). Put the horizons together, and they form a soil profile. Like a biography, each profile tells a story about the life of a soil. Most soils have three major horizons (A, B, C) and some have an organic horizon (O).

The horizons are:



O - (humus or organic) Mostly organic matter such as decomposing leaves. The O horizon is thin in some soils, thick in others, and not present at all in others.

A - (topsoil) Mostly minerals from parent material with organic matter incorporated. A good material for plants and other organisms to live.

E - (eluviated) Leached of clay, minerals, and organic matter, leaving a concentration of sand and silt particles of quartz or other resistant materials - missing in some soils but often found in older soils and forest soils.

B - (subsoil) Rich in minerals that leached (moved down) from the A or E horizons and accumulated here.

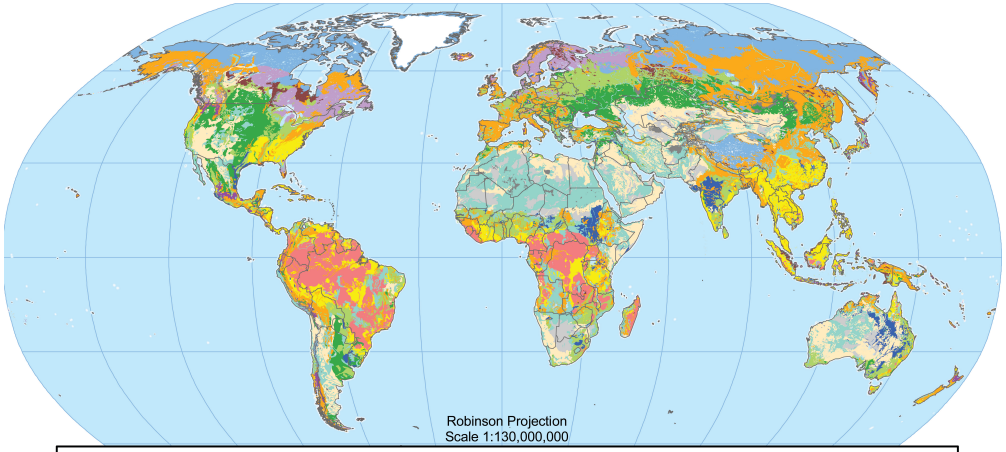
C - (parent material) The deposit at Earth's surface from which the soil developed.

R - (bedrock) A mass of rock such as granite, basalt, quartzite, limestone or sandstone that forms the parent material for some soils - if the bedrock is close enough to the surface to weather. This is not soil and is located under the C horizon.

http://www.soils4kids.org/about

FACTORS OF SOIL FORMATION

Global Soil Regions

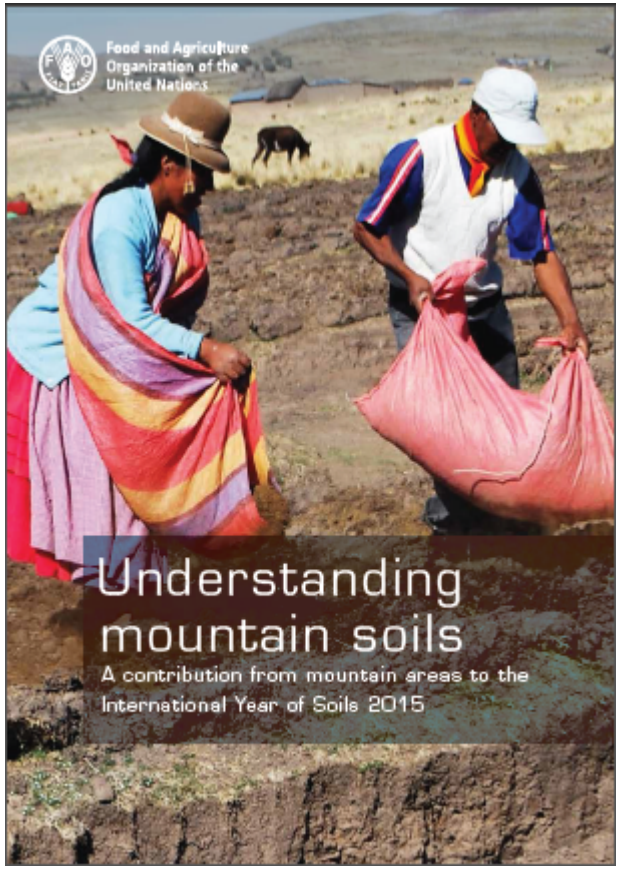


USDA NRCS US Department of Agriculture
Natural Resources
Conservation Service

Soil Survey Division
World Soil Resources
soils.usda.gov/use/worldsoils

November 2005

TOPOGRAPHY



Box 1: Mountain definition according to elevation class

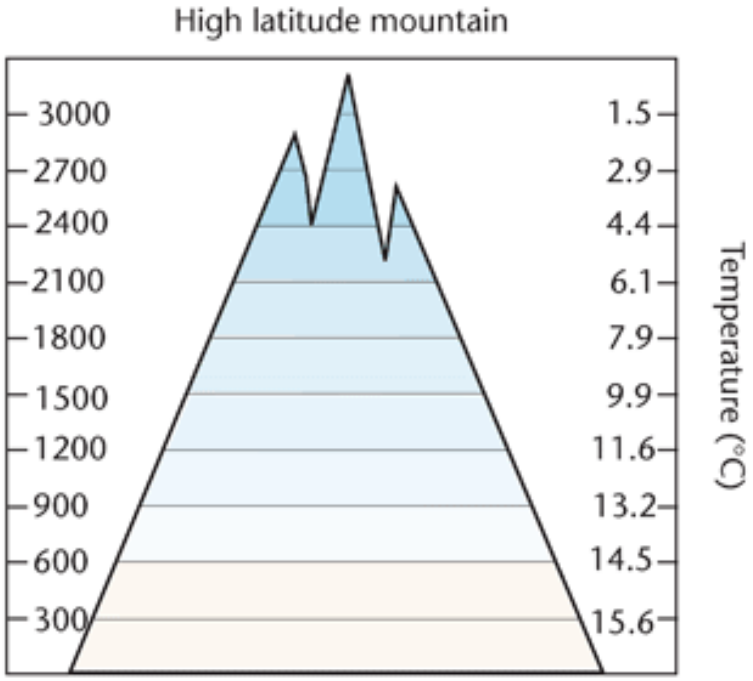
In this publication, mountains are defined according to a topographic criterion that combines metres above sea level (masl), steepness of slope and local elevation range. This classification was developed in 2000 by the United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC) in order to represent the environmental gradients that are key components of mountain environments.

- Class 1: elevation ≥ 4 500 m.
- Class 2: elevation 3 500–4 500 m.
- Class 3: elevation 2 500–3 500 m.
- Class 4: elevation 1 500–2 500 m and slope ≥ 2°.
- Class 5: elevation 1 000–1 500 m and slope ≥ 5 or local elevation range (LER) > 300 m.
- Class 6: elevation 300–1 000 m and LER > 300 m.

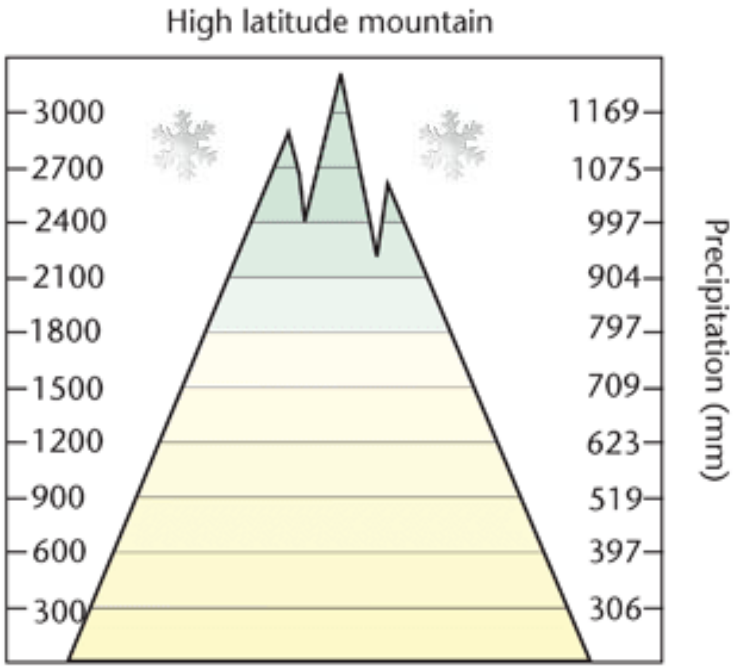
www.mountainpartnership.org

FAO. 2015. *Understanding Mountain Soils: A contribution from mountain areas to the International Year of Soils 2015*, by Romeo, R., Vita, A., Manuelli, S., Zanini, E., Freppaz, M. & Stanchi, S. Rome, Italy.

CLIMATE



Air temperature



Precipitation

Korner, Alpine Plant Life

GELISOLS

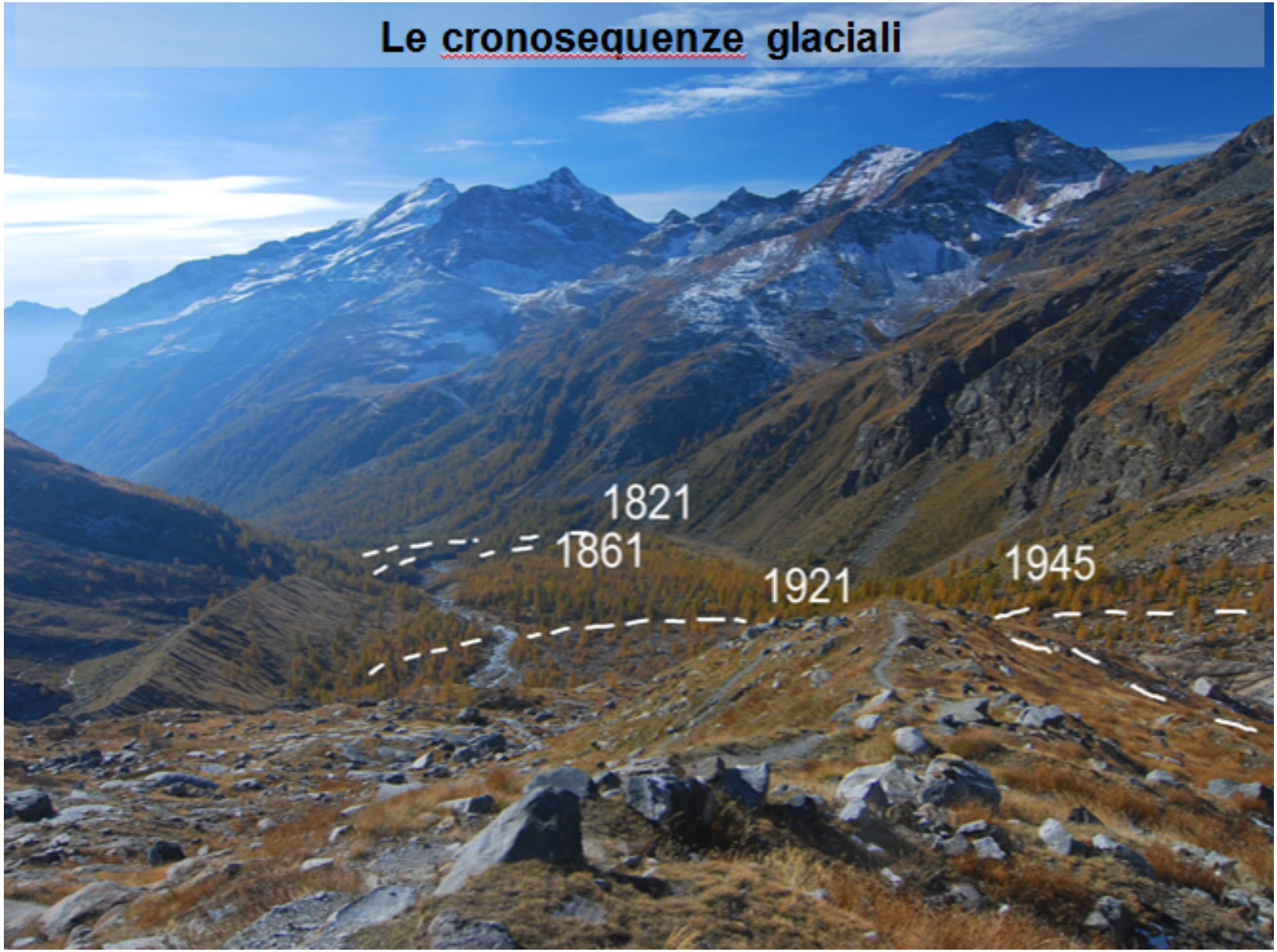
SPODOSOLS

CAMBISOLS

TIME: Glacial Chronosequence

1922

Le cronosequenze glaciali



Le cronosequenze glaciali

Little vegetation cover (<5%)

Few pioneer species: Epilobietum fleischeri

2003

Le cronosequenze glaciali

Larch – Rododendron forest

Tick litter layer (OL-OF-OH) constituted by larch and rododendron residues

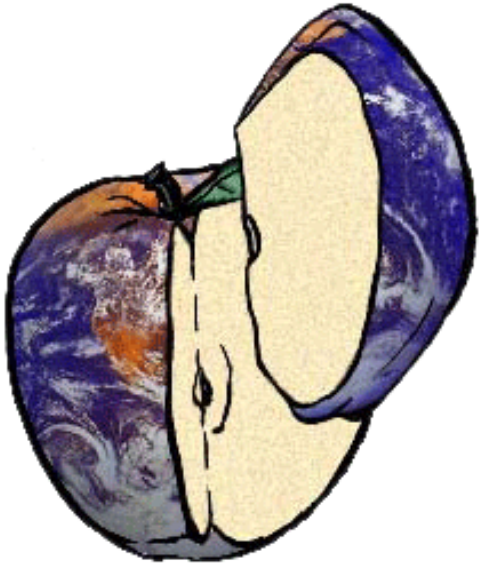
E horizon with weak platy structure

BC horizon with weak illuviation of Fe-Al

Haplic Regosol (Dystric)

1880

How much soil is there?



The three quarters (75%) you just removed represents how much of the earth is covered with water - oceans, lakes, rivers, streams. What is left (25%) represents the dry land.

50% of that dry land is desert, polar, or mountainous regions where it is too hot, too cold or too high to be productive.

So cut that dry land quarter in half and toss one piece away.

http://folknouveau.com/soil/app2.htm

Mountaineous Regions

The Food and Agriculture Organization of the United Nations (FAO) has estimated that around 45 percent of the world's mountain areas is not, or only marginally, suitable for growing crops, raising livestock or carrying out forestry activities.

FAO. 2015. *Understanding Mountain Soils: A contribution from mountain areas to the International Year of Soils 2015*, by Romeo, R., Vita, A., Manuelli, S., Zanini, E., Freppaz, M. & Stanchi, S. Rome, Italy.

How much soil is there?

When 50% is removed, this is what is left. (12.5% of the original)

Of that 12.5%, 40% is severely limited by terrain, fertility or excessive rainfall. It is too rocky, steep, shallow, poor or too wet to support food production.

Cut that 40% portion away.

http://folknouveau.com/soil/app2.htm

How much soil is there?

You are left with approximately 10% of the apple.

The remaining 10% (approximately*)- this small fragment of the land area - represents the soil we depend on for the world's food supply. This fragment competes with all other needs - housing, cities, schools, hospitals, shopping centers, land fills, etc., etc. And, sometimes, it doesn't win.

*There is difficulty within the scientific community in coming up with an exact figure

http://folknouveau.com/soil/app2.htm

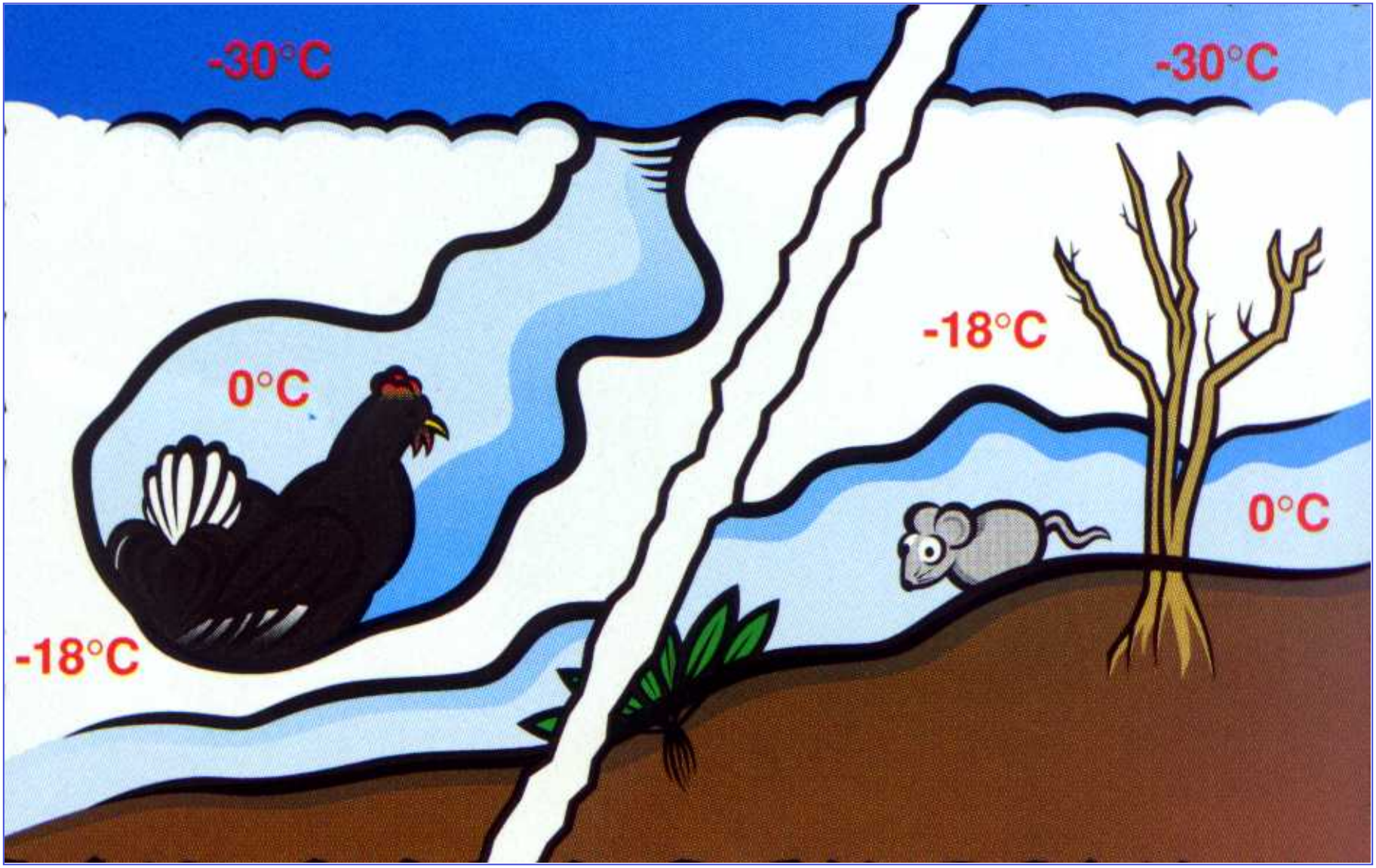
Soil functions

1. Soils serve as media for growth of all kinds of plants.
2. Soils modify the atmosphere by emitting and absorbing gases (carbon dioxide, methane, water vapor, and the like) and dust.
3. Soils provide habitat for animals that live in the soil (such as groundhogs and mice) to organisms (such as bacteria and fungi), that account for most of the living things on Earth.
4. Soils absorb, hold, release, alter, and purify most of the water in terrestrial systems.
5. Soils process recycled nutrients, including carbon, so that living things can use them over and over again.
6. Soils serve as engineering media for construction of foundations, roadbeds, dams and buildings, and preserve or destroy artifacts of human endeavors.
7. Soils act as a living filter to clean water before it moves into an aquifer.

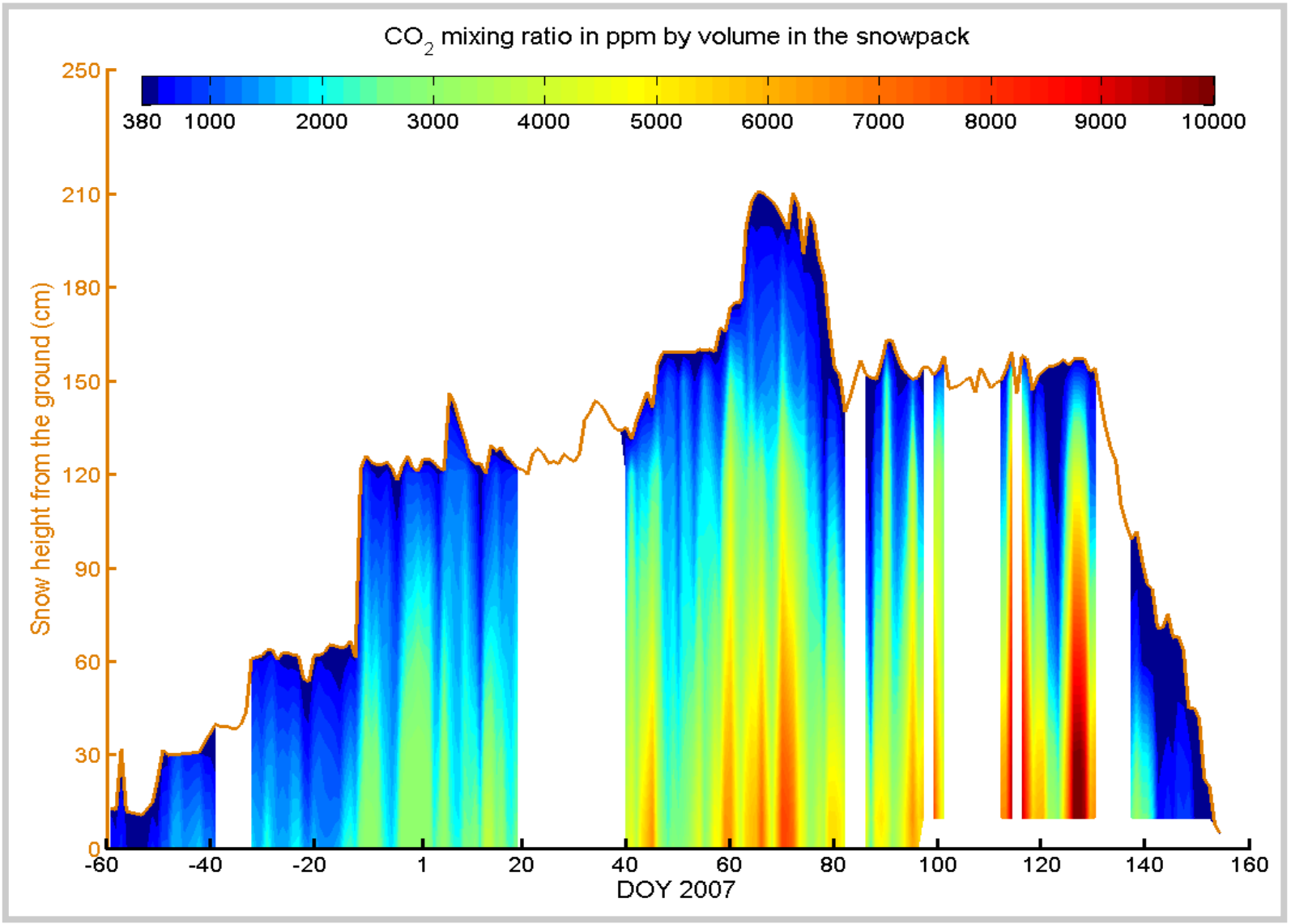
http://www.soils4kids.org/about

1. Soils as a media for plant growth

2. Soils modify the atmosphere

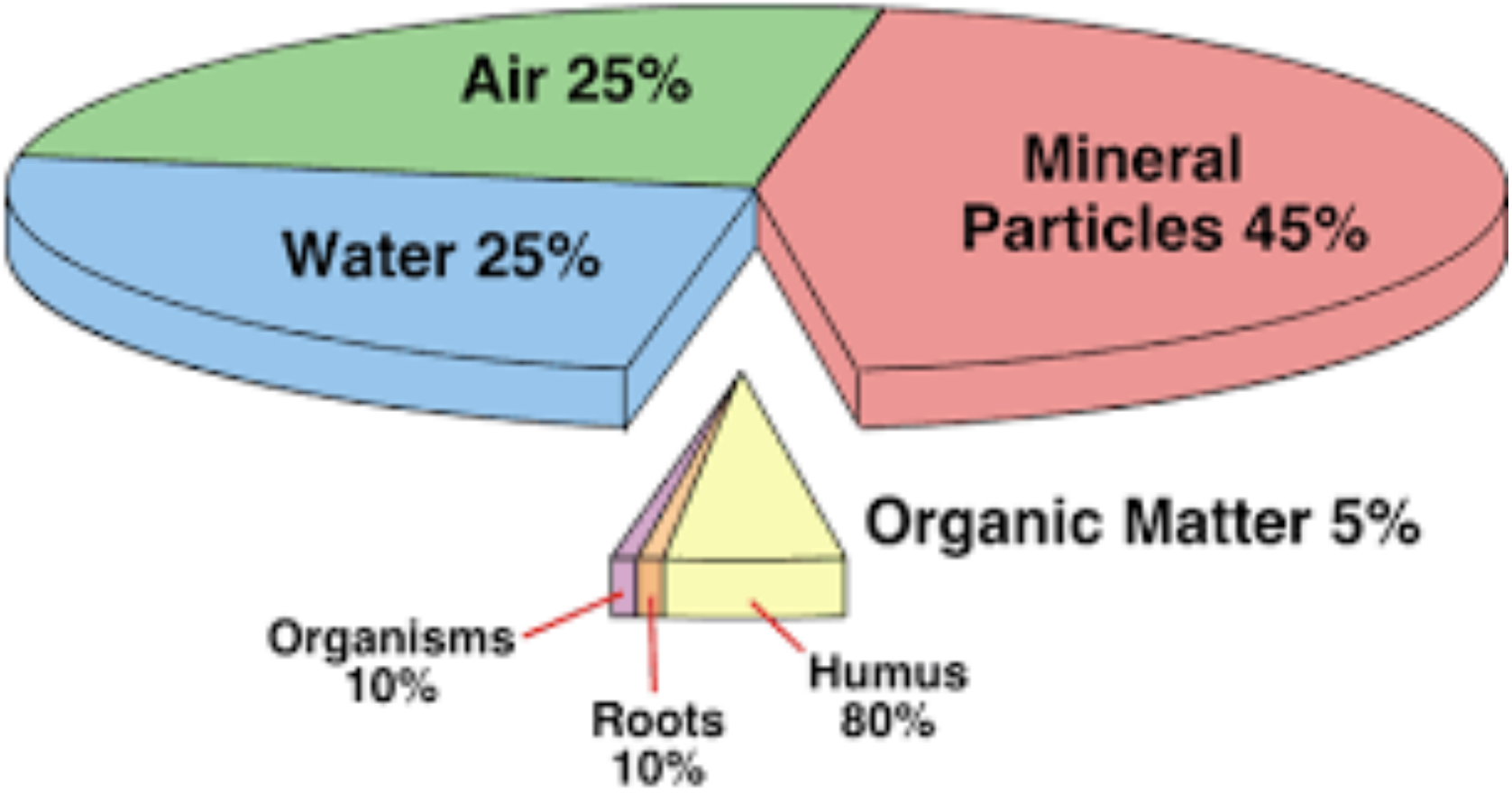


2. Soils modify the atmosphere




3. Soils provide habitat for animals
Arvicola delle nevi (Chionomys nivalis)

4. Soils absorb and hold water



Composition of soil by volume (%)

5. Soil processes recycle nutrients

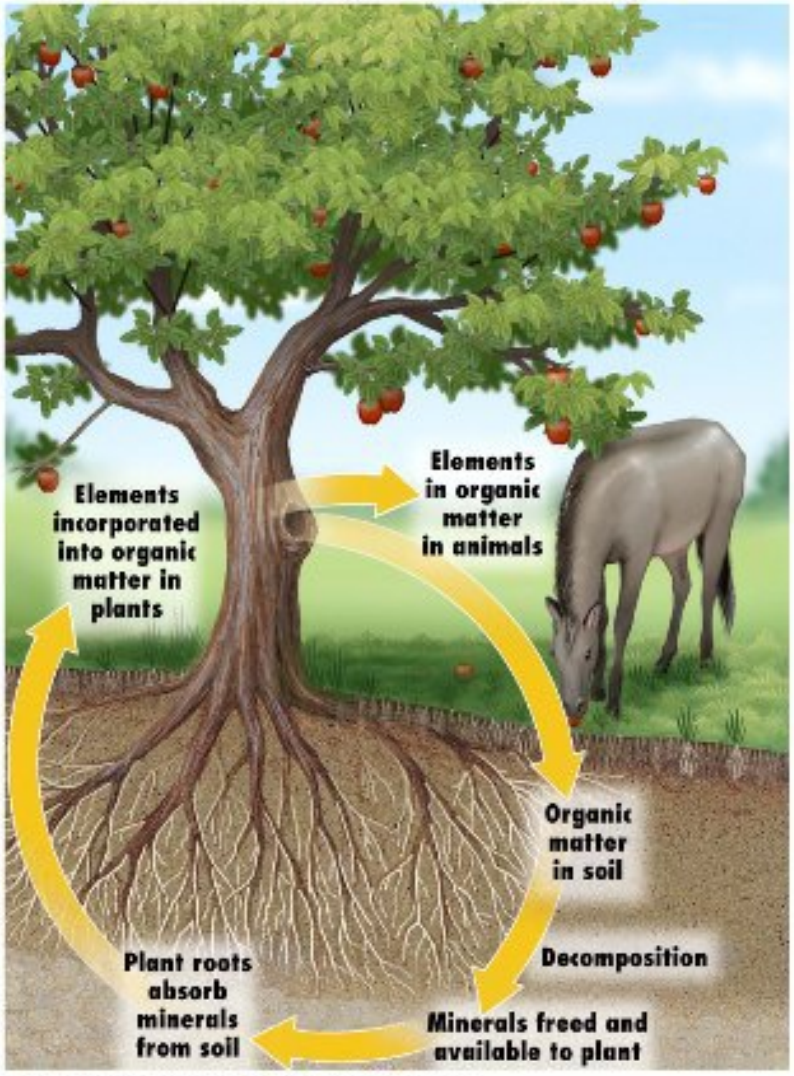


Figure 12-14 Visualizing Environmental Science, 1/e

Table 3: Guidelines for rating soil fertility indicators (ILACO, 1985 and Landon, 1991)

	Ca cmol/kg^{-1}	**Mg cmol//kg^{-1}**	**K cmol/kg^{-1}**	**Total N. (%)**	**Avail. P ppm**	**Org. M (%)**	**C/N**
Very High	>20	>8	>1.2	>0.300	-	>60	
High	10-20	3-8	0.6-1.2	0.226-3.00	>50	4.3-6.0	
Medium	5-10	1.5-3	0.3-0.6	0.126-0.225	15-50	2.1-4.2	
Low	2-5	0.5-1.5	0.2-0.3	0.050-0.125	<15	1.0-2.0	
Very low	<2	<0.5	<0.2	<0.050	-	<1.0	

Note: **Available P does not have very low or very high levels**.

Table 4: Qualitative rating of soil fertility in the Obudu Mountains

Slope positions	Org. C	OM	TN	AV.P	Ca	Mg	K	Na
Summit	-	Low	Low	Low	Low	Medium	Medium	-
Lower toe	-	Low	Low	Low	High	Medium	Very high	-
Middle toe	-	Low	Low	Low	Low	Medium	High	-
Toe	-	Low	Low	Low	Low	Medium	Medium	-
Base	-	Low	Low	Low	Low	Medium	Medium	-
Shoulder	-	Low	Low	Low	Low	Medium	High	-

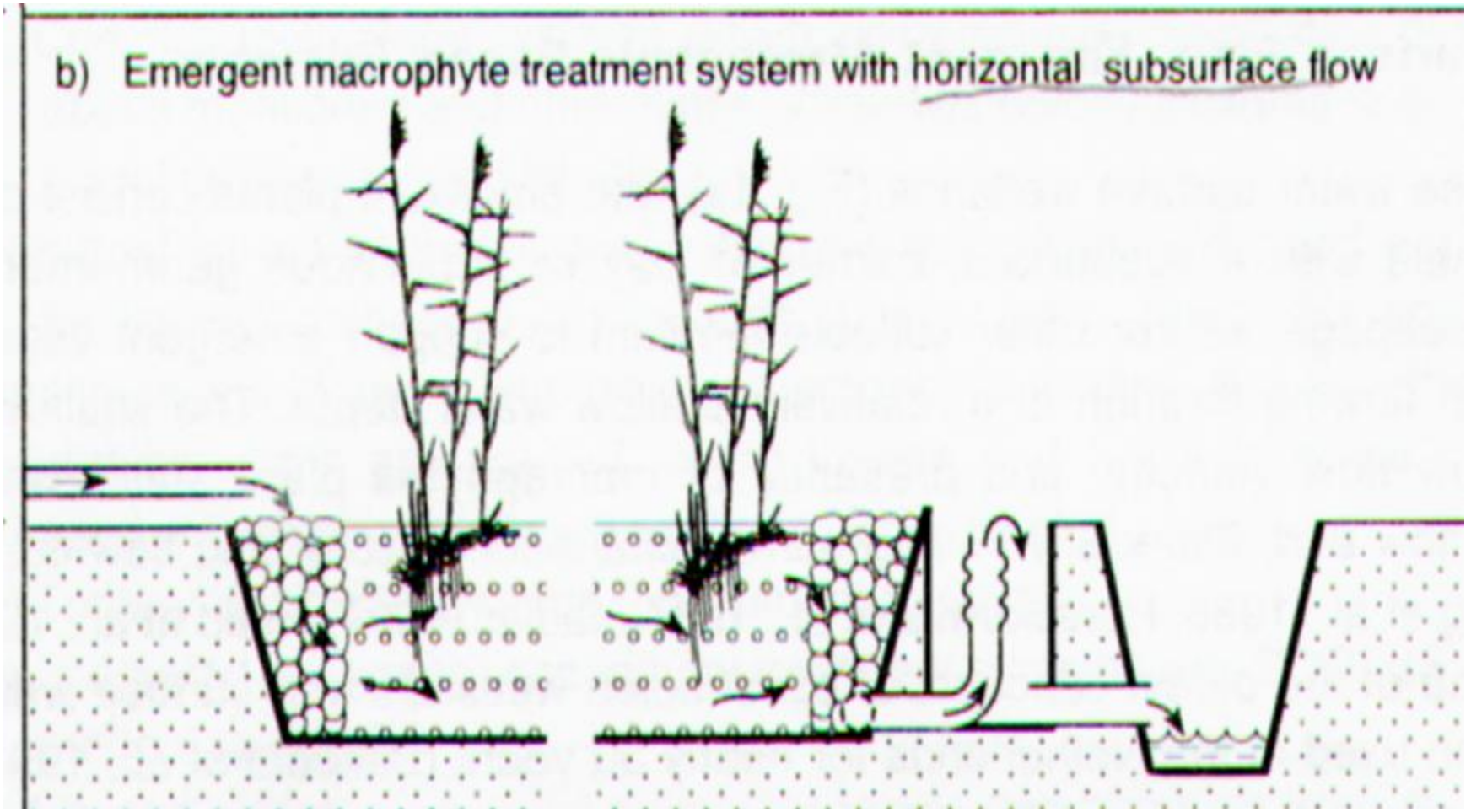
Source: Analysis by authors (2014).

Amuyou and Koting (2015) Evaluation of mountain soils for sustainable agriculture and food security in Nigeria: the case of Obudu. European Journal of Physical and Agricultural Sciences 3, n.2: 1-8.

6. Soils serve as engineering media for construction

7. Soils act as a living filter

Constructed wetlands



Gorra, Freppaz, Zanini, Scalenghe (2014) Mountain dairy wastewater treatment with the use of a irregularly shaped constructed wetland (Aosta Valley, Italy), Ecological Engineering 73: 176-183

Soil functions

Soils deliver ecosystem services that enable life on Earth

2015 International Year of Soils

fao.org/soils-2015

Food and Agriculture Organization of the United Nations

with the support of

Mountaineous Regions

The Food and Agriculture Organization of the United Nations (FAO) has estimated that around 45 percent of the world's mountain areas is not, or only marginally, suitable for growing crops, raising livestock or carrying out forestry activities.
Thus mountain peoples, who are largely family farmers and livestock keepers, have had to develop different ways of averting or spreading risks to survive.

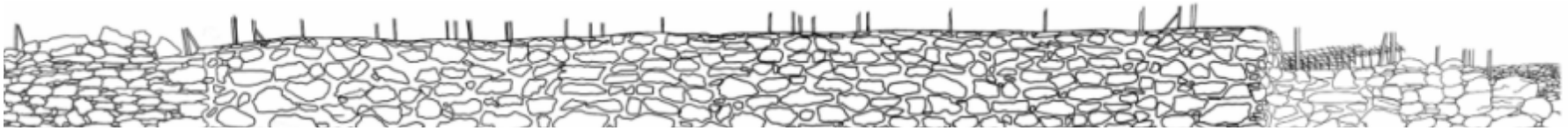
Mountain peoples have adopted, adapted or developed a host of agricultural systems that help them manage their land, especially their soil, sustainably.

FAO. 2015. *Understanding Mountain Soils: A contribution from mountain areas to the International Year of Soils 2015*, by Romeo, R., Vita, A., Manuelli, S., Zanini, E., Freppaz, M. & Stanchi, S. Rome, Italy.

Contouring. Growing crops on sloping land is a major cause of accelerated erosion, unless soil and water conservation measures are widely practiced. On gentle slopes, this requires contour farming (*i.e.* ploughing, planting and weeding across rather than down the slope). In higher rainfall areas, it requires construction of permanently vegetated contour bunds or ridges with retention or diversion ditches to break up the slope, increase rainwater capture and infiltration, reduce runoff volume and velocity and hence minimize erosion.

FAO. 2015. *Understanding Mountain Soils: A contribution from mountain areas to the International Year of Soils 2015*, by Romeo, R., Vita, A., Manuelli, S., Zanini, E., Freppaz, M. & Stanchi, S. Rome, Italy.

Terracing. For sustainable cropping on steep slopes, progressive or bench terraces are required which are costly and require substantial labour for their construction and maintenance. The resulting change in landscape, however, can be extremely productive as shown by breathtaking terracing systems worldwide, many of which are recognized and designated as Globally Important Agricultural Heritage Systems (GIAHS). For example, in the Andes, the terracing systems provide soil conservation which induces the formation of deeper soils and enlarges cultivated areas, ensures sunlight for longer periods during the day, increases water storage, and allows for a more efficient use of water for irrigation. It also contributes to protecting agricultural fields from possible landslides, because the use of rocks in the building of the faces of the terraces strengthens the mountain slopes.



FAO. 2015. *Understanding Mountain Soils: A contribution from mountain areas to the International Year of Soils 2015*, by Romeo, R., Vita, A., Manuelli, S., Zanini, E., Freppaz, M. & Stanchi, S. Rome, Italy.
Stanchi, Freppaz, Agnelli, Reinsch, Zanini (2012) Properties, best management practices and conservation of terraced soils in Southern Europe (from Mediterranean areas to the Alps): A review. Quaternary International 265: 90-100

ALPTER

PER INFORMAZIONI

sito web: **www.alpter.net**

e-mail: **info@alpter.net**

CONTATTI NAZIONALI

Italia

Regione Veneto franco.alberti@regione.veneto.it

Regione Liguria orietta.gattulli@regione.liguria.it

Regione Valle d'Aosta c.galliani@regione.vda.it

IREALP - Milano info@irealp.it

Austria

Università BOKU -Vienna arne.arneberger@boku.ac.at

Francia

A.D.I. - Nizza jean-marie.castex@wanadoo.fr

Slovenia

Università di Lubiana lucija.azman@arh.unj-f.si

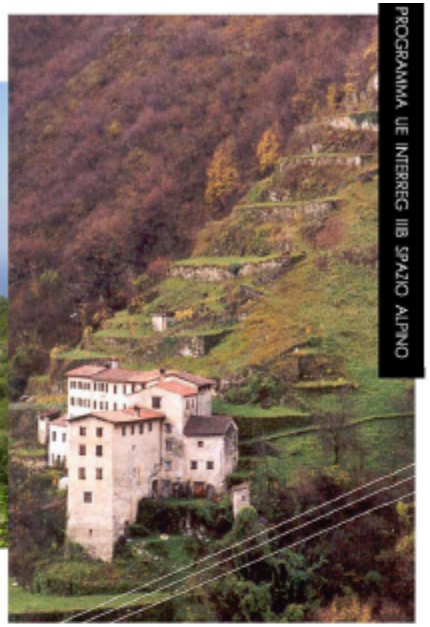
Svizzera

Regione Bregaglia michael@movingalps.ch

Progettazione grafica: Luca Lodarti, Andrea Bonato, Andrea Mancuso, Giampolo Puppin

ALPTER

Co-finanziato dalla Unione Europea



PROGRAMMA UE INTERREG IIB SPAZIO ALPINO

PROGETTO ALPTER

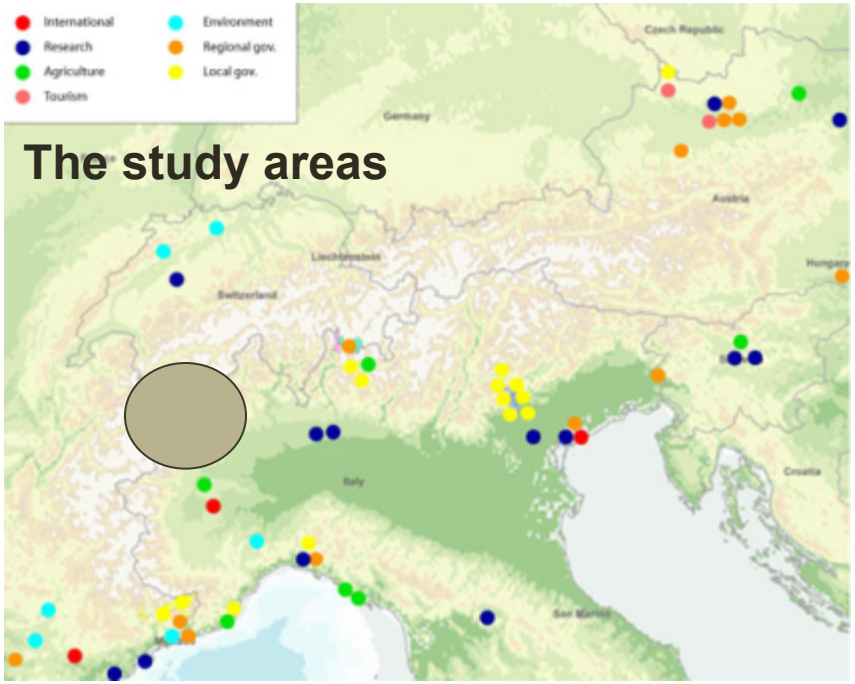
PAESAGGI TERRAZZATI DELL'ARCO ALPINO

Un progetto per la promozione e il recupero dei terrazzamenti agricoli nelle Alpi

PARTNER DEL PROGETTO

Regione Veneto
Regione Liguria
IREALP - Milano
Università BOKU - Vienna
Università di Lubiana
A.D.I. - Nizza
Regione Valle d'Aosta
Regione Bregaglia
U.N.E.S.C.O.

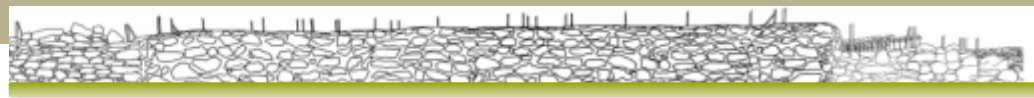
THE ALPTER NETWORK ACROSS THE ALPINE SPACE



www.alpter.net

- Terraced areas distributed in the world since ancient times.
- Terraces were primarily symbolic markers of power, but they also functioned as agricultural fields, defensive sites, habitation locations and religious centers.

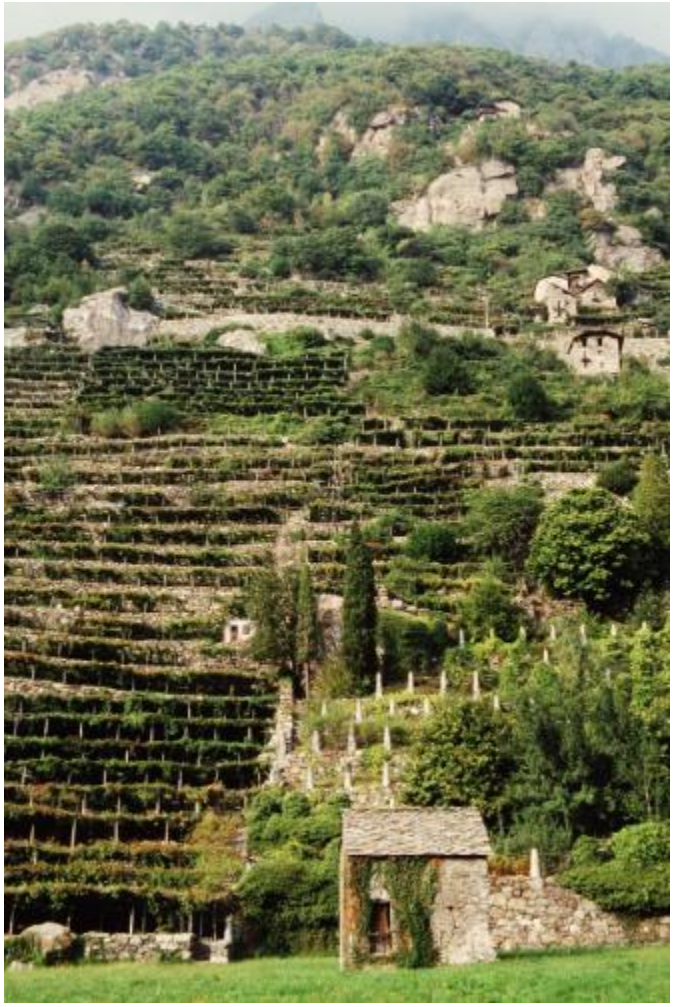
Island of Babeldaob, Republic of Palau



Location		Early Ages (yr B.P.)		
Continent/Region	**Subregion**	**Agriculture**	**Terracing**	**Comments on Terracing Ages**
Eastern Asia	China	8500-11,500	3000	Uncertainty about older age
	Japan/Korea	3000-5000	?	
Southern to SE Asia and Oceania	India/Indochina	5000-7000	2300-3100	3100 yr B.P. Pakistan
	Philippines	3400-5000	2000	
	Papua New Guinea	9000	?	Ancient but uncertain age
	Polynesia	1000-3600	1100	
Southwestern Asia	Near East	10,000	3000-5000	Possible 5000 yr B.P. age for gabarbands in Baluchistan. 5000-9000 yr B.P. speculated for origin of terrace agriculture.
Europe	Mediterranean	8000	2500-4000	4000 yr B.P. Italy, 3700 yr B.P. Crete
	Eastern Europe	5000-7000	?	
	Western Europe	5000-7000	2000-3500	Early ages for lynchets
Africa	North Africa	6500	3000	Runoff terraces; 2450 yr B.P. Ethiopia.
	SubSaharan Africa	3000-5000	500	Uncertainty about older age.
MesoAmerica		5000-10000	2500	
South America		4000-5000	2500	
North America		3000-5000	1000	Uncertainty about older age

Sandor, 1998

- In mountainous areas with favourable climate, agriculture has been intensively practised in the valleys bottom.
- The need of cultivable and well exposed areas determined the extensive anthropogenic terracing of a large part of the valley flanks.



Valleé d'Aoste, Italy

- One of the most distinctive components of the landscape of Mediterranean mountain environments is agricultural terraces.
- Mostly cropped in almond, hazel-nut, olive trees and vineyards.

Spain, Canary Islands

- Most of the historical terraces are of bench type with dry stone walls.
- They need a large amount of labour since they were built and maintaned by hand.

Dry Stone wall in Valle d'Aosta – NW Italian Alps

- **Functions:**

a) Water control

b) Microclimatic modifications

c) Soil retention and erosion control

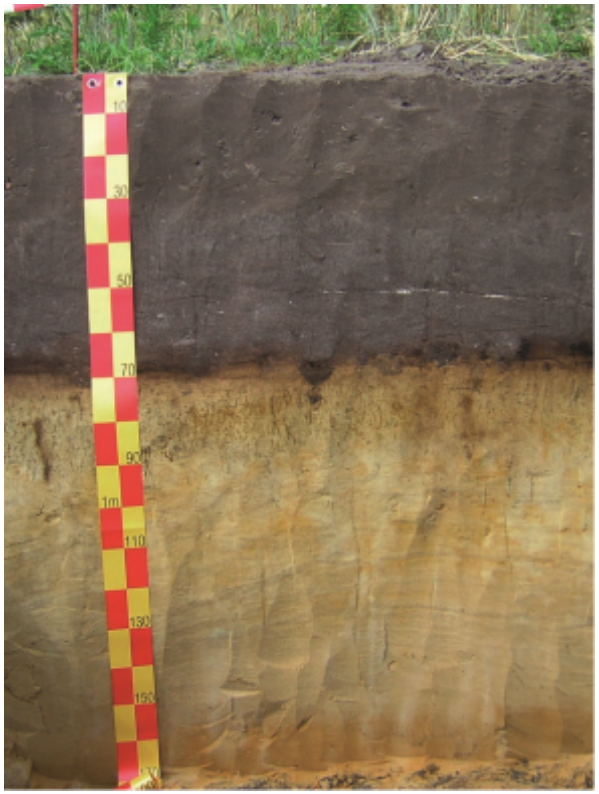
d) Soil accumulation

Anthropogenic soils

TABLE 1

Rationalized Key to the WRB Reference Soil Groups

1.	Soils with thick organic layers:	Histosols
2.	Soils with strong human influence	
	Soils with long and intensive agricultural use:	Anthrosols
	Soils containing many artefacts:	Technosols
3.	Soils with limited rooting due to shallow permafrost or stoniness	
	Ice-affected soils:	Cryosols
	Shallow or extremely gravelly soils:	Leptosols



2013 Soil of the Year: plaggic anthrosol

The 2013 Soil of the Year, plaggic anthrosol, is testimony to an historical process involving removal of the upper layer of low-fertility soils, which were then mixed with manure and spread on fields – thus allowing for the creation of fertile topsoil on depleted soil. However, this process left behind large heathland or dune areas off Germany's coasts.

http://www.umweltbundesamt.de

Different types of anthropogenic soils (Dudal et al., 2004):

- Human induced change of soil class (e.g. by land use practices such as waterlogging).
- Human-made diagnostic horizons (e.g. by application of organic matter).

Northern Italy

- Human induced new parent materials (e.g. by unconsolidated material from landfills).
- Human induced deep soil disturbance (e.g. pipelines, excavations).

- Human induced topsoil changes (e.g. liming, tillage).
- Human induced change of landform (e.g. **Terracing**).

NW Italy

- Terracing necessarily results in topographic change because its primary purpose is to create stable, gently sloping surfaces.
- Landscapes are transformed into stepped agroecosystems.

Cinque Terre, Italy

- The several traditional processes for constructing the terrace soil body fall into 2 main categories:

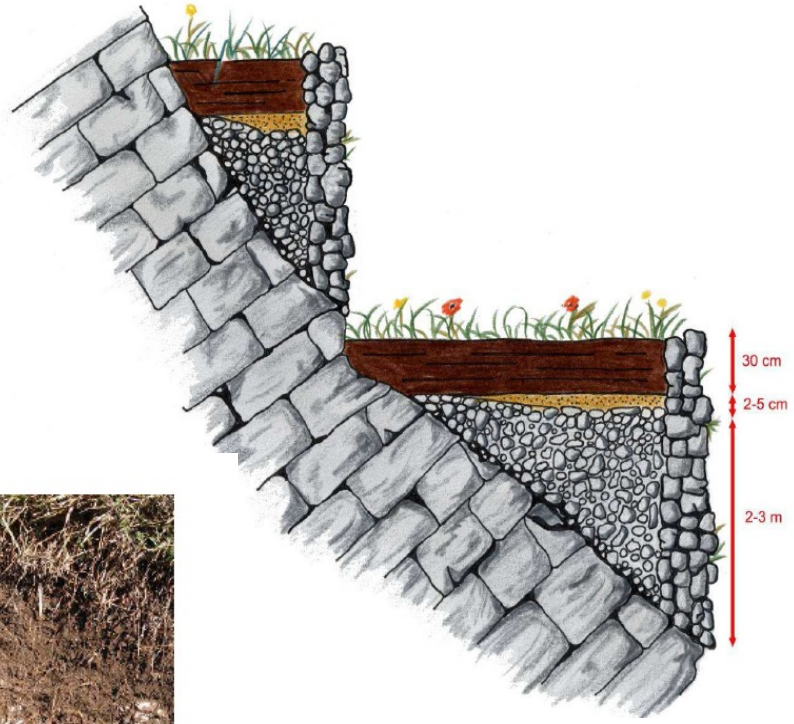
1. Alluvial/colluvial sedimentation
2. Direct emplacement by hand

Loess Plateau, China

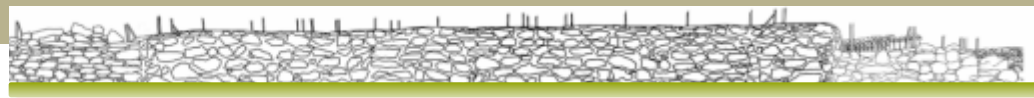
- The direct emplacement (versus natural sedimenation processes) greatly influence subsequent soil properties.
- Material originating on the local slopes of from greater distances such as valley floors.

Mali, Plateau Dogan

- The soils used for terrace agriculture have distinctive natural properties in comparison to uncultivated soils.



Valstagna (NE Alps, Italy)

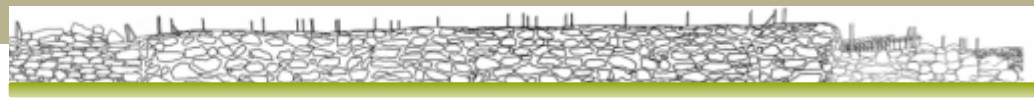


Characteristics of mountain terrace agriculture (modified from Sandor, 1998):

- **Geomorphic processes:** slope decrease, some colluvial sedimentation
- **Construction practices:** large walls, direct emplacement of soil from local slopes or valley floors
- **Management practices:** fertilization, some irrigated

Characteristics of mountain terrace soils (modified from Sandor, 1998):

- **Soil morphology:** thickened A horizons, buried horizons, plaggen horizons, texture changes, clay illuviation, structure and pore changes
- **Soil chemistry:** cases of organic C, N, P increase, CEC change, pH change
- **Soil biology:** soil fauna, enzime activity changes



Buried horizons: characteristics of terraced soils where filling has occurred without destruction of the original soil.

Texture changes:
common, especially in upper horizons directly changed by filling and mixing of soil materials. Artificial gravel layers at the front of some terraces to aid drainage.

Soil chemistry:

- Processes inducing increases in elements are additions in irrigation or runoff as well as fertilization.

- Decreases in elements results from crop removal as well as leaching and erosive processes.

WORLD SOIL RESOURCES REPORTS

103

World reference base for soil resources 2006

A framework for International classification, correlation and communication

ARNAD I

12 years old vineyards

PERGOLA-SHAPED

Technic Cambisol (Escalic)

CAMBISOLS

Soils having

1. a **cambic horizon** starting within 50 cm of the soil surface and having its base 25 cm or more below the soil surface or 15 cm or more below any plough layer; or
2. An anthraquic, hortic, hydragric, irragric, plaggic or terric horizon; or
3. A fragic, petroplinthic, pisoplinthic, plinthic, salic or vertic horizon starting within 100 cm of the soil surface; or
4. One or more layers with andic or vitric properties with a combined tickness of 15 cm or more within 100 cm of the soil surface

Cambic horizon (1)

1. **texture in the fine earth fraction of very fine sand**, loamy very fine sand, or finer; and
2. **soil structure** or absence of rock structure in half or more of the volume of the fine earth; and
3. evidence of alteration in one or more of the following:

a. higher chroma, higher value, redder hue, or **higher clay content than the underlying or an overlying layer**; or

b. evidence of removal of carbonates or gypsum; or

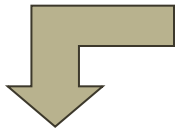
c. presence of soil structure and absence of rock structure in the entire fine earth, if carbonates and gypsum are absent in the parent material and in the dust that falls on the soil; and

Cambic horizon (2)

4. **does not form** part of a plough layer, does not consist of organic material and does not form part of an anthraquic, argic, calcic, duric, ferralic, fragic, gypsic, hortic, hydragric, irragric, mollic, natric, nitic, petrocalcic, petroduric, petrogypsic, petroplinthic, pisoplinthic, plaggic, plinthic, salic, sombric, spodic, umbric, terric, vertic or voronic horizon; and
5. **thickness of ≥15 cm**.

Prefix qualifiers

Folic
Anthraquic
Hortic
Irragric
Plaggic
Terric
Technic
Leptic
Vertic
Fluvic
Endosalic
Vitric
Andic
Endogleyic
Fractiplinthic
Petroplinthic
Pisoplinthic
Plinthic
Ferralic
Gelistagnic
Stagnic
Haplic



Having 10 % or more (by volume, by weighted average) **artefacts** in the upper 100 cm from the soil surface

Artefacts:

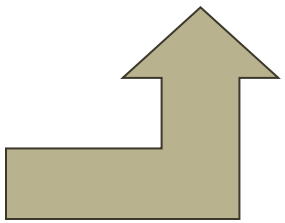
Examples of artefacts are **bricks,** pottery, **glass**, crushed or **dressed stone**, industrial waste, garbage, processed oil products, mine spoil or crude oil.

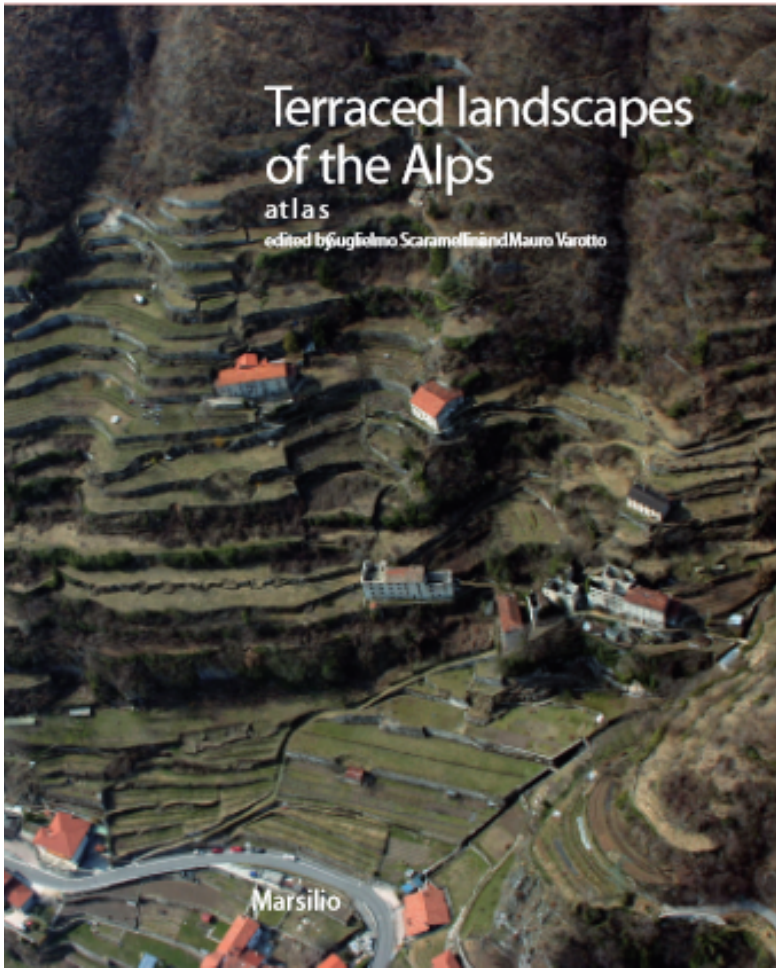
Suffix qualifiers

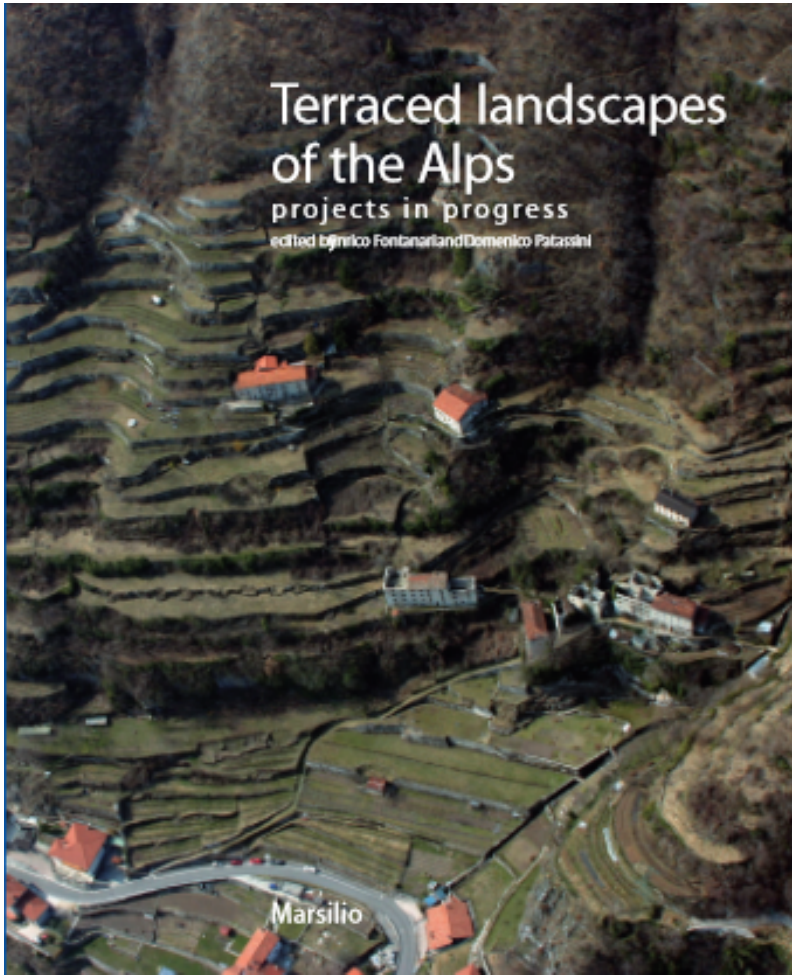
Fragic
Manganiferric
Ferric
Ornithic
Ruptic
Colluvic
Gypsiric
Calcaric
Tephric
Alumic
Sodic
Alcalic
Humic
Dystric
Eutric

Laxic
Turbic
Gelic
Oxyaquic
Greyic
Hyperochric
Takyric
Yermic
Aridic
Skeletic
Siltic
Clayic
Rhodic
Chromic
Escalic
Novic

Occurring in human-made terraces







http://www.alpter.net/ALPTER-Project-final-publications.html?lang=en

Food and Agriculture Organization of the United Nations

Healthy soils are the basis for healthy food production

michele.freppaz@unito.it

LTER Italia
Italian Long-Term Ecological Research Network