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Patagonian soils: a regional synthesis

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Abstract. *The objective of this article was to summarize and review critically the available information on soil heterogeneity at the regional scale. The result of this effort is a map at the suborder level and at an approximate scale of 1:10,000,000 were I pointed out the main inconsistencies between the local studies and the regional maps. I also provide a description of the main soil taxa and their distribution throughout the region and of the variability of the cartographic units. Considering the large map unit variability commonly found and the increasing use of soil properties for technical interpretations, soil survey development in Patagonia must be geared towards more quantification of map unit composition. Finally, an evaluation of both natural and human impact is provided.*

Introduction

Over the past 24 years, special attention was given to soil variability in Patagonia. The aim of these studies was to achieve a better understanding of the factors that control the patterns of soil distribution and landscape evolution. Existing soil studies are, however, partial or very local (Laya 1975 a-b, Imbellone and Ferrer 1980, Ferrer and Irisarri 1985, del Valle 1988, Rostagno and del Valle 1988, Rostagno et al. 1991, Stinico et al. 1996). In 1990, a systematic soil survey that considered also characteristics of soil degradation and land productivity was carried out in Argentina (INTA/CIRN 1990). This survey, however, shows discrepancies with other studies and problems of interpretation, particularly among provincial boundaries.

The objective of this article was to summarize and review the available information on soil heterogeneity at the regional scale. The result of this effort is a map at the suborder level and at an approximate scale of 1:10,000,000 were I pointed out the main differences between local studies and the regional map. I also provide a description of the main soil taxa and their distribution throughout the region and of the variability of the cartographic units. Finally, an evaluation of both natural and human impact is provided.

Generalization of soil patterns was largely based upon the examination of published soil surveys rather than upon explicitly documented procedures. International scientific literature on the subject is voluminous and excellent summaries can be found in Fridland (1976), Wilding and Drees (1983), Hole and Campbell (1985), Arnold and Wilding (1991), Brown and Huddleston (1991), Hall and Olson (1991), Wright (1996), Dunkerley and Brown (1997), and Berger (1997).

Materials and Methods

Study region
The vast territory of Patagonia in southern Argentina extends from about 37' to 55' S, south of the Colorado River (Figure 1). This region includes the Provinces of Neuquén, Rfo Negro, Chubut, Santa Cruz and Tierra del Fuego. It covers an area of about 786,595 km^2, which represents 28% of

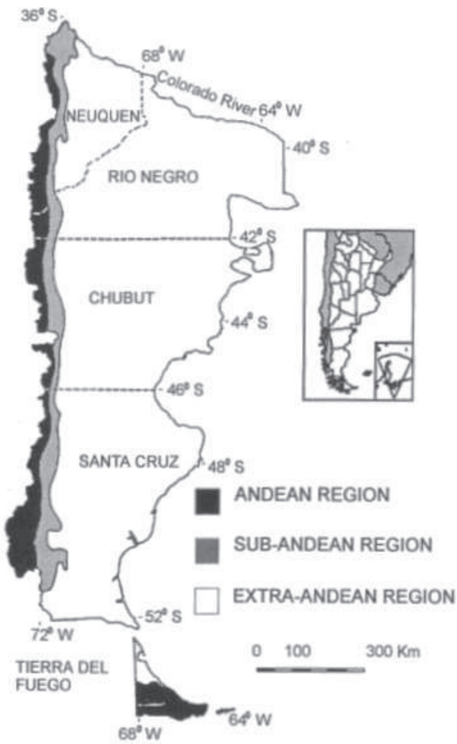

Figure 1. Study region.

continental Argentina. Climate is dry, cold and windy in most of the region. The Andean and sub-Andean areas have strong west to east precipitation gradient (> 3,000 mm to 300 mm). In the extra-Andean area, precipitation concentrates in winter and declines from 300 mm in the west to less than 150 mm in the east, increasing slightly towards the Atlantic coast.

Along the gradient of decreasing precipitation, starting from the subantarctic forest border, grass steppes give way to shrub-grass steppes and then to deserts. Thus, the region has a rich spectrum of vegetation types, including 45% shrub desert, 30% shrub-grass semi-desert, 20% grass steppe and 5 % water surface and minor types like meadows (Soriano 1983).

Soil classifications and soil maps

Soil data were derived from texts, maps and tables (Ferrer and Irisarri 1990, Godagnone and Irisarri 1990, Salazar et al. 1990, Salazar and Godagnone 1990 a-b), obtained from local specialists, or extracted from existing databases. Data utilized represent several hundreds of pedons over a wide range of soil conditions, parent materials, geography, sampling schemes and map units.

Soil cover diversity was explained in terms of: (a) taxonomic levels, updating the existing regional taxonomy (Soil Survey Staff 1997); (b) number, distribution and classes of soil map units; (c) magnitude of spatial variability among selected soil properties as a relative function of pedons and landscape units (map unit delineations); and (d) extent of natural and human disturbances (del Valle et al. 1998).

The procedures are discussed in the most recent version of the National Soils Handbook (Soil Survey Staff 1997). Additional revised chapters of this Handbook are accessible in the web page (www.statlab.iastate.edu/soils/soiltax/). Some equivalencies between the main Groups of soils of the FAO/UNESCO system (1989) and the Orders, Suborders and Great Groups of the Soil Taxonomy are presented (Table 1). These equivalencies are only approximate. A qualitative description of each of the major soil units of the FAO/UNESCO system has been added in parentheses (Buol et al. 1980).

A digital version of the soil map was obtained from National Soil Atlas of Argentina (CD-ROM version) (Aeroterra et al. 1995). The soil coverage per province was exported as vector coverage, and was rasterized with ERDAS Imagine (8.3.1) software (ERDAS 1998). Each one of map units were defined in terms of its dominant taxon (at the suborder level). The mosaic was built by using Lambert's Conformal Conic Projection. The pixel size assigned was 1,000 m x 1,000 m. Soil data were codified to facilitate comparisons. Frequency or one-way tables were used for analyzing categorical data. Percentages were computed in relation to the total number of cases (count data), but considering also the number of missing data. The coefficient of variation is a useful index to compare the variability among different soil properties, with the usual caution for interpreting its significance with transformed and non-transformed data, according to Wilding and Drees (1983). The ice sheets, continental glacial ice plateaus, located in the Santa Cruz Province was delimited on the digital map according to the location of the glaciers used by Warren and Rivera (1994).

At small scales, map units are commonly named as associations or consociations using taxa of high hierarchy (e.g. suborders). Four types of map units were used in the studies evaluated: consociations, complexes, associations and undifferentiated groups (Soil Survey Staff 1997). In a consociation, a single soil taxon or similar soils dominate the cartographic unit. As a rule, at least one-half of the pedons in a soil consociation are similar to that providing the name to the map unit. A complex may consist of two phases of a single soil type that are taxonomically distinct but non mappeable as separate units; it may consist of two or more soil types in the same cartographic unit, or of two or more types in different great groups or orders. Each association is defined in terms of the named taxonomic units, their relative proportion, and their pattern. The associations are named in terms of the more prominent taxonomic units. In either a complex or an association, each major component is normally present, though their proportions may vary from unit to unit. Undifferentiated groups consist of two or more taxa components that are not consistently associated geographically and, therefore, do not always occur together in the same map delineation. These taxa are included within the same map unit because use and management are similar.

Results and Discussion

Main soil taxa of Patagonia

The map presented in Figure 2 shows the geographic distribution of the major soils in the Patagonia based on INTA/CIRN (1990). Appendix 1 shows the approximate area in square kilometers and the percentages of soil orders, suborders and great groups (Soil Survey Staff 1997), based on a total area of 724,422 km^2 (92.1%).

The relative soil importance per province is as follows:

- Neuquén: Entisols (33.8%), Aridisols (19.0%), Andisols (16.4%), Mollisols (8.6%), Alfisols (2.1 %), Vertisols (0.7%), Inceptisols (0.4%), and Histosols (0.1 %).
- Río Negro: Aridisols (60.4%), Entisols (23.7%), Mollisols (2.1%), Andisols (2.0%), Alfisols (0.5 %), Inceptisols (0.2 %), and Vertisols (0.2 %).
- Chubut: Aridisols (55.0%), Entisols (18.6%), Mollisols (17.9%), Andisols (3.3%), Inceptisols (0.2%), and Alfisols (0.04%).
- Santa Cruz: Aridisols (51.3 %), Mollisols (20.0%), Entisols (19.0%), and Andisols (5.9%).

Table 1. FAO/UNESCO and the USA Soil Taxonomies comparison

FAO/UNESCO	SOIL TAXONOMY Order, Suborder and Great Group
Andosols (volcanic ash with dark surfaces)	Andisols, Xerands (xeric moisture regime)
- Vitric	- Vitrixerands
Arenosols (soils formed from sand)	Entisols, Psamments (sand)
	- Torripsamments (torric soil moisture regime)
Cambisols (light color, structure, or consistence change due to weathering)	Inceptisols, Aquepts (wet)
- Gleyic	- Humaquepts (histic, mollic or umbric epipedon)
Chernozems (black surface, high humus under steppe vegetation)	Mollisols, Ustolls (ustic soil moisture regime)
- Calcic	- Calciustolls (calcic horizon)
Fluvisols (water-deposited soils with little aleration)	Entisols, Fluvents (alluvium not sand)
- Calcaric	- Torrifluvents
Gleysols (mottled or reduced horizons due to wetness)	Mollisols, Aquolls
- Mollic	- Epiaquolls (episaturation)
Histosols (organic soils)	Histosols
Kastanozems (chestnut surface color, steppe vegetation)	Mollisols, Ustolls
- Luvic	- Argiiustolls (argillic horizon)
Lithosols (shallow soils over hard rock)	Lithic Subgroups
Luvisols (medium to high base status soils with argillic horizons)	Alfisols, Aqualfs
- Albic	- Albaqualfs (albic horizon)
Phaeozems (dark surface, more leached than Kastanozem or Chernozem)	Mollisols, Udolls (udic soil moisture regime)
- Luvic	- Argiudolls
Planosols (abrupt A-B horizon contact)	Alfisols, Xeralfs
- Mollic	- Haploxeralfs
Podzols (light-colored alluvial horizon and subsoil accumulation of iron, aluminum, and humus)	Spodosols, Humods
- Humic	- Haplohumods (Bh horizon predominant)
Regosols (thin soil over unconsolidated material)	Entisols, Orthents
- Calcaric	- Torriorthents
Solonchaks (soluble salt accumulation)	Aridisols, Salids (accumulation of salts more soluble than gypsum)
- Gleyic	- Aquisalids
Solonetz (high sodium content)	Alfisols, Aqualfs
- Gleyic	- Natraqualfs (natric horizon)
Vertisols (self-mulching, inverting soils, rich in montmorillonitic clay)	Vertisols, Torrerts
	- Salitorrerts (salic horizon)
	- Haplotorrerts (sodic horizon)
Xerosols (dry soils of semiarid regions)	Mollisols, Xerolls
- Luvic	- Argixerolls
Yermosols (desert soils)	Aridisols, Gypsids (accumulation of gypsum)
- Gypsic	- Petrogypsids (petrogypsic horizon)

- Tierra del Fuego: Inceptisols (37.4%), Mollisols (28.5%), Spodosols (8.4%), Andisols (7.6%), Histosols (4.3%), and Alfisols (2.3%).

The total area of the different soil orders in Patagonia is: Aridisols (49.5%), Entisols (21.9%), Mollisols (13.2%), Andisols (5.4%), Inceptisols (1.2%), Alfisols (0.5%), Spodosols (0.2%), Histosols (0.1 %) and Vertisols (0.1 %).

Cryogenic phenomena act as a soil cover differentiation factors in the Patagonian region. In fact, there are in Patagonia soils pertaining to the suborders Cryands, Cryorthents, Cryaquepts,

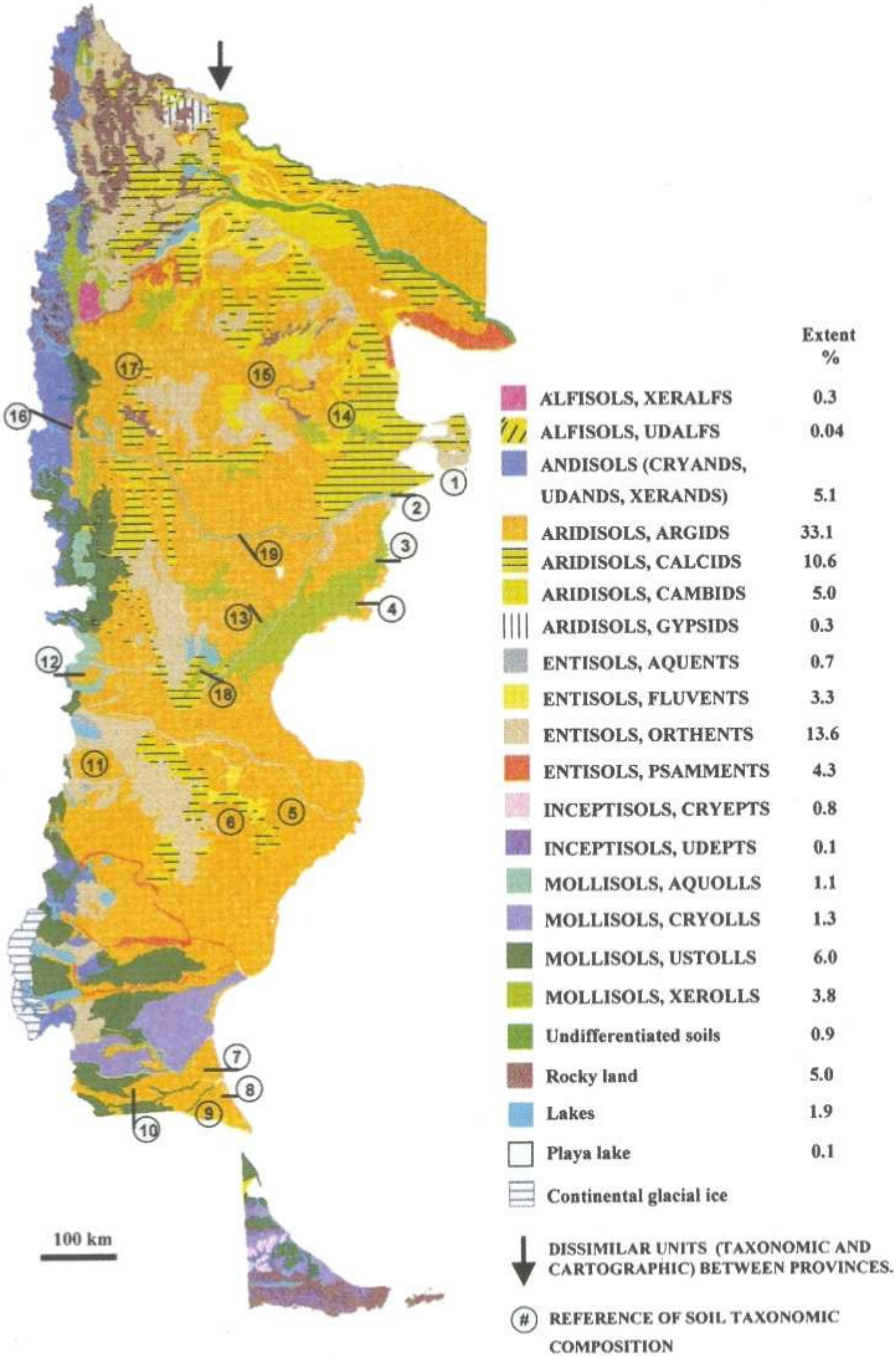

Figure 2. Area (in %) of the main soil classes at the suborder level (adapted from National Soil Atlas of Argentina in CD-ROM version, Aeroterra et al. 1995).

Cryolls, and probably Cryids (cold arid soils) . A case was made for the inclusion of Antarctica soils into the Aridisols order instead of being included as cryic versions of Entisols (Claridge and Campbell 1982). The new order of the Soil Taxonomy, the Gelisols, would be restricted to reduced areas of the Patagonian icefield (Santa Cruz province) and the Antarctica peninsula. The central concepts of Gelisols are soils with gelic materials underlain by permafrost. Diagnostic horizons may or may not be present. Permafrost influences pedogenesis by acting as a barrier to the downward movement of the soil solution.

Aridisols

Aridisols, as their name implies, are soils of dry places, mostly of deserts. Aridisols are the most widespread soils in Patagonia and dominate east of the parallel 71° W. They are found mainly on gentle slopes and occur on a variety of landforms, lithologic types, and on stable land surfaces of the late Pliocene-Pleistocene or greater age. The soil temperature regime ranges from frigid to isothermic. The soil moisture regime is aridic and torric but some Aridisols may have ustic or xeric regime. The six suborders classified are:

Argids - accumulation of clay.
Calcids - accumulation of carbonates.
Cambids - translocation and/or transformation of material.
Durids - accumulation of silica.
Gypsids - accumulation of gypsum.
Salids - accumulation of salts more soluble than gypsum.

Argids are dominant over Patagonia (33.1%). They occur either as associated soils or as inclusions in areas dominated by Calcids, Cambids, Salids, Durids, Orthents, Ustolls, and Xerolls. The Argids occupy terraces, plateaus, pediments, valley floors, hilly plains, and foothills. The important great groups are Natrargids (13.6%), Haplargids (10.9%) and Paleargids (8.6%). Chubut and Santa Cruz showed the largest area with the Natrargids.

Calcids (10.6%) occur on gentle to steep or gentle to moderate slopes of broad basins, structural terraces, rolling and irregular plains, hilly plains, plateaus, and pediments. The principal great groups are the Haplocalcids (8.0%) and Petrocalcids (2.6%). The associated soils include principally the Orthents, Fluvents and Xerolls suborders.

Cambids are the less developed Aridisols. Cambids have a cambic horizon within 100 cm of the soil surface. These soils may have other diagnostic horizons such as petrocalcic, gypsic, or calcic layers, but their upper boundary of the diagnostic horizons must be below 100 cm from the soil surface. Haplocambids are the most common of the Cambids in Patagonia (5.0%).

Durids (0.01 %) are the Aridisols which have a duripan which upper boundary is within 100 em of the soil surface. These soils occur on gentle slopes and developed from sediments that contain pyroclastics. The duripan is cemented partly with opal or chalcedony. Calcium carbonate is commonly present also. In Neuquen province, the Durids have an argillic horizon on top the duripan and this horizon is the basis for recognizing great group (Argidurids).

Gypsids (0.3%) are the Aridisols that have a gypsic or petrogypsic horizon within 100 cm of the soil surface. When they are close to the surface, crusting forms pseudo-hexagonal patterns on the soil surface. Petrogypsids occupy old surfaces in Neuquen province (2.1 %). However, the Haplogypsids are present on many segments of the Patagonian landscape. Some of them have calcic or related horizons, which overly the gypsic horizon.

Salids (0.5%) are common in depressions (playas) or in closed basins. Two great groups could be recognized: the Aquisalids, which are saturated with water for at least one month of the year and Haplosalids, which are drier.

Entisols

The central concept of Entisols is that of soils that has little or no evidence of development of pedogenic horizons. Their properties are determined largely by the parent material. Most Entisols have no diagnostic horizons, other than an ochric epipedon, and a very few an anthropic, albic or histic epipedon.

Entisols are the dominant soils in gentle to steep slope and represents 21.9% of the soils of the region. This order corresponds to cold soils, aridic soils, soils of river deposits, sandy materials, areas with shallow soil, and ustic soils on slide-slopes and local alluvium. The temperature regime of these soils is cryic, mesic and thermic, and the soil moisture regime aquic, ustic, xeric and torric. Four suborders are identified:

Aquents - wet soils.

Fluvents - soils formed in recent water-deposited sediments. Orthents - soils on recent erosional surfaces.

Psamments - sandy soils.

Aquents are the wettest Entisols and occupy an approximate area of 0.7%. These soils are often located on the margins of depressions where the soil is continuously saturated with water, in flood plains of streams where the soil is saturated part of year, or in wet, sandy deposits. They also occur either as associated soils or as inclusions in areas dominated by the Aquepts, Aquolls, or Fibrists. The great groups identified are:

Epiaquents / Endoaquents (0.2 %); aquents that have epi / endosaturation. Fluvaquents (0.3 %); aquents with irregular decrease in carbon contents with depth. Psammaquents (0.2 %); aquents with sand and loamy sand texture.

Fluvents are brownish to reddish soils formed in recent water-deposited sediments, mainly on flood plains, alluvial fans, and small streams. These soils occupy an approximate area of 3.3 %. The great groups identified are the Torrifluvents (2.6%) and Xerofluvents (0.7%).

Orthents are Entisols developed on recent eroded surfaces (13.6%). The erosion may be geologic or may have been induced by human impact. These soils occur also as associated soils or as inclusions in areas dominated by the Argids, Calcids, Cambids, Udalfs, Xeralfs, Udolls, Ustolls and Xerolls. The great groups identified are the Cryorthents (0.8%), Torriorthents (9.9%), Udorthents (0.6%), Ustorthents (0.1%), and Xerorthents (2.2%). Torriorthents are dominant on steep slopes of mountains, high plateaus, dissected high plains, and badlands bordering river valleys.

Psamments are coarse textured across the whole profile. Psamments are the dominant in areas of relatively minor extent (4.3%). The great groups identified are the Quartzipsamments (0.1%), Torripsamments (3.1 %) and Xeropsamments (1.1 %).

Mollisols

Mollisols are commonly the very dark colored, base-rich soils of the steppes. Nearly all of them have a mollic epipedon. Many also have an argillic or a natric horizon or a calcic horizon. A few have an albic horizon, a duripan or a petrocalcic horizon.

Mollisols generally occur in north-south belts, in the occidental portion of the Patagonian region. The total area occupy by this order is 13.2%. These soils formed mostly from unconsolidated Quaternary materials on gentle to moderate slopes. Mollisols also occur in mountains and plateaus. The soil temperature regime is cryic, frigid, mesic or thermic. The soil moisture regime is aquic, udic, ustic or xeric. Six suborders were identified in Patagonia: the Albolls (0.02%), Aquolls (1.1%), Cryolls (1.3%), Udolls 1.0%), Ustolls (6.0%), and Xerolls (3.8%).

Argialbolls are the Albolls that have an argillic horizon but do not have a natric horizon. Most of them have very dark gray to black coatings of humus and clay in the upper part of the argillic horizon. These soils are located in Neuquén province, and they are associated in the landscape with other Mollisols (Aquolls and Xerolls).

Aquolls are represented by four great groups: the Epi and Endoaquolls (0.7%), Calciaquolls (0.1 %), and Cryaquolls (0.3 %). Cryolls are frequent in the high mountains of Santa Cruz and Tierra del Fuego provinces. Most the Haplocryolls have a Iambic horizon. These soils formed mainly on Pleistocene or Holocene deposits or on surfaces of equivalent ages.

Argiudolls are found in Chubut (1.7%), Santa Cruz (0.6%) and Tierra del Fuego (6.6%) provinces. The Hapludolls developed in Holocene or late Pleistocene deposits and are located on gentle slopes. They are important soils in Chubut (0.4%) and Tierra del Fuego (3.8%) provinces.

Haplustolls are the dominant soils in large areas of Santa Cruz (11.4%) and Tierra del Fuego (12.0%) provinces. In the whole region, these soils account for 5.2% of the total area. Argiustolls

(0.1 %) and Calciustolls (0.7 %) are located on gentle to moderate slopes of tablelands and dissected plains.

Xerolls developed mostly on slopes ranging from gentle to moderate, in high plains, terraces, valleys, and on alluvial fans. Parent materials with some volcanic ash, glacial outwash or till, and alluvium from different sources is common. These soils developed in mid Pleistocene or earlier deposits or on surfaces of Tertiary age. The great groups are the Argixerolls (1.4%), Calcixerolls (0.7%) and Haploxerolls (1.7%). Calcixerolls are developed mainly in late-Pleistocene sediments or older materials on surfaces of comparable age. Haploxerolls are formed also in late-Pleistocene deposits.

Andisols

Andisols are soils developed in volcanic ejecta, and/or in volcaniclastic materials, whose colloidal fraction is dominated by short-range-order minerals or Al-humus complexes. Andisols covers a small area (5.4%). These soils can occupy any position in the landscape and can occur at any elevation. The soil temperature regime is cryic and the soil moisture regime is aquic, udic, ustic or xeric. The major great groups are the Aquands (0.3%), Cryands (0.4%), Udands (3.1%), and Xerands (1.6%). The great groups are the Epi/Endoaquands (0.3%), Vitricryands (0.4%), Fulvudands (1.4 %), Hapludands (1.6 %), Hydrudans (0.1 %) and Vitrixerands (1.6 %).

Inceptisols

Inceptisols are soils of cool to very warm humid and subhumid regions that has a cambic horizon and an ochric epipedon. Inceptisols, together with Entisols, are common in large areas of gentle to steep slopes in widely separated humid and sub-humid parts of Patagonia. Inceptisols occur in: (1) on geologically young sediments or landscapes; and (2) in areas where the environmental conditions inhibit soil development (Foss et al. 1983). The soil temperature regime is cryic, mesic or isomesic; the soil moisture regime is aquic, ustic or xeric. Vallerini and Marcolfn (1976) identified Inceptisols in the Santa Cruz province. Total area of Inceptisols is 1.2%. The major suborders are the Aquepts (0.3 %), Cryepts (0.8 %) and Udepts (0.14 %).

Alfisols

Alfisols have an ochric epipedon, an argillic horizon, moderate to high base saturation, and water is held in the soil at less than 1500 kPa tension during at least 3 months each year when the soil is warm enough for plants to grow. An Alfisol may also have a fragipan, a duripan, a kandic horizon, a natric horizon, a petrocalcic horizon or plinthite. Alfisols that are very wet during part of the year have an umbric epipedon.

Alfisols occur in widely separated areas of Patagonia covering 0.5% of the region. Alfisolic landscapes are characterized by: (1) a moderate abundance of layer lattice clay, and (2) a subsuperficial argillic horizon. The soil temperature regime ranges from cryic to mesic, and the soil moisture regime includes aquic, ustic or xeric. Most of the Alfisols in Patagonia, developed from unconsolidated materials of Pleistocene age or similar level and on moderate to steep slopes. Vallerini and Marcolfn (1976) identified Alfisols in the Santa Cruz province. The major great groups are the Haploxeralfs (0.3%) and Epi/Endoaqualfs (0.2%).

Spodosols

The feature that is common to most Spodosols is the presence of a spodic horizon, in which amorphous mixtures of organic matter and aluminum, with or without iron, have accumulated. Spodosols are located in Tierra del Fuego (8.4%). They occur in high mountains and along the lakes. The soil temperature regime is cryic and the soil moisture regime is aquic or udic. The suborder Humods has 6% or more organic carbon in the spodic horizon. Burgos (1985) reported the presence of the Spodosols in the southwest of the Santa Cruz province.

Table 2. Some controversial areas in soil taxonomic composition

Ref. Fig.2	Soil Atlas		Other reports		
	Landscape	Dominant taxa	Dominant taxa	Associated or Subordinate taxa	Reference
1	Plains plateaus of gravel, wind erosion forms, coastal plains and enclosed depressions	Orthents	Psamments	Argids, Calcids, Orthents, Salids	Rostagno (1981)
2	Lower flood plains	Aquolls	Fluvents	Torrerts, Cambids, Salids, Aquents, Psamments, Orthents	Laya (1981)
3	Structural terraces and coastal plains	Xerolls	Orthents	Fluvents, Argids, Calcids, Psamments, Cambids, Salids, Rocky land	Beeskow et al. (1987)
4	Coastal peneplain and littoral marine environments	Argids	Orthents	Calcids, Argids, Rocky land	
5 - 6	Exhumed and covered peneplain, tablelands of basalt and of gravel	Argids	Orthents Calcids	Argids, Rocky land	del Valle (unpublished)
7	Old glacial landscape, intermontane basin, mountain upland	Argids	Luvic Kastanozems		Burgos (1985)
8			Rankers		
9		Ustolls	Eutric Fluvisols		
10		Argids Ustolls	Eutric Cambisols Luvic Phaeozems Dystric Cambisols	Histosols , Humic , Podzols · Rocky land	
11	Tablelands of basalt, border plateaus	Argids	Cryorthents	Cryolls, Rocky land, Crypsamments	del Valle (unpublished)
12	Tablelands of gravel, border plateaus	Argids	Cryorthents	Cryolls, Xerorthents, Haploxerolls	Beeskow et al. (1987)
13	Plain plateaus, pediplains, intermontane basin	Xerolls	Argids	Orthents, Calcids, Salids, Cambids, Rocky land	
14	Pediplains, intermontane basin	Xerolls	Calcids	Durids, Argids, Orthents, Salids, Rocky land	del Valle (unpublished)
15	Tablelands of basalt, border plateaus, high and low mountains, enclosed depressions	Argids	Orthents	Argids, Xerolls, Calcids, Cryolls, Psamments, Rocky land	Beeskow et al. (1982) and del Valle (unpublished)
16	Old glacial landscape associated with fluvial environments, foothills	Argids	Udolls	Psamments, Fluvents, Aquents, Aqualfs	del Valle (1978)
17	High and low mountains, hilly plains, hill country, and foothills, intermontane basin, tablelands of basalt, border plateaus, river valley landforms	Argids	Orthents	Calcids, Argids, Psamments, Salids, Aquents, Aquolls, Rocky land	Speck et al. (1982)
18	River valley landforms	Xerolls	Argids	Fluvents, Cambids, Orthents, Psamments	Laya and Plunkett (1983)
19	River valley landforms	Aquolls	Fluvents	Cambids, Aquents, Aquolls, Salids, Xerolls, Argids, Orthents, Calcids, Psamments, Aquepts	Irisarri and Mendía (1988)

Histosols

Histosols are soils formed in organic soil materials. The general rule is that a soil is classified, as a Histosol if half or more of the upper 80 cm is organic. Histosols are dominant in small areas of west Patagonia (0.1 %). They also occur associated with or included in areas of Andisols, Entisols, Mollisols and Inceptisols. The soil moisture regime is peraquic. Vallerini and Marcolfn (1976) reported the existence of the Histosols in Rio Negro, Chubut and Santa Cruz provinces. Fibrists are the wet Histosols in which the organic matter has been only slightly decomposed.

Vertisols

Vertisols are clayey soils which have deep, wide cracks part of the year and slickensides within 100 cm of the mineral soil surface. They shrink when dry and swell when moistened. Vertisols are dominant in small areas (0.1 %). Torrerts were localized in the Chubut province, in valleys and alluvial plains formed from marine and lacustrine clay deposits. These soils are sodic (sodic Haplotorrerts) or saline (Salitorrerts) and occupy large areas of bare ground (Arcs et al. 1990).

Controversial areas

Major discrepancies in the Soil Atlas (INTA/CIRN 1990) are evident across provincial boundaries where contrast among taxonomic units at the sub-order level appears (Neuquén and Río Negro). Numbers in Figure 2 refer to local surveys or observations that are not in agreement with the proposed taxonomic composition in the Soil Atlas. Because of the constraints imposed by technology, cost and the complexities of some soil patterns, errors in estimating the taxonomic composition of a map unit are unavoidable (Miller et al. 1979). However, the results from the Soil Atlas revealed under or overestimations in some soil categories selected as central or dominant in the map unit. Unfortunately this soil survey do not prepared tables indicating the qualities, use limitations, and the hazards or risks of each of the taxonomic units used. The main discrepancies that I found are highlighted on Table 2.

Spatial variation of soil

Table 3 summarizes the principal landscapes and parent materials of Patagonian soils. The arrangement of soils is not always the same from landscape to landscape. Productivity of landscapes varies with the character and areal distribution of component polypedons (Buol et al. 1980). Thus, variation in soil conditions within the total landscape can be divided into three main components: (a) variation within individual landforms or geomorphic elements (summit, shoulder, backslope and toeslope); (b) variation between landforms of the same soil category; and (c) variation between landforms of different soil categories.

Soil heterogeneity depends upon the combined effect of all the landscape components (climate, relief, biotic community, parent material). Soils in Patagonia present characteristics mostly related to the arid conditions under which they have evolved. The spatial variability of these features increases with the degree of aridity. Under extreme aridity, local soil and topographic conditions change the vegetation cover. Where aridity is less severe, the vegetation shows greater uniformity (Arcs et al. 1990).

A remarkable characteristic of the arid soils in Patagonia, as well as of many other desert soils, is that the properties of surface or near-surface horizons vary over short distances. Soils have quite different leaching characteristics, salinity levels and moisture contents over short distances, although they developed under the some atmospheric climate (Súnico et al. 1996). Consequently, soils could be taxonomically similar but functionally different (Dunkerley and Brown 1997).

If Entisols are considered as being very young compared to other classes of mineral soils, then the relative areas occupied by Entisols and older soils could be considered as indexes of chronological uniformity or diversity (Hole and Campbell 1985). Mollisols without argillic horizons may be considered to be chronologically intermediate between Entisols and Alfisols.

The analysis of the published soil maps, their legends and accompanying documents (INTA/CIRN 1990) reveals that maps have been spatially summarized. The results were maps with fewer, larger and more broadly defined map units (mostly in Chubut and Santa Cruz provinces). Precision was lost because units were relabeled into more general taxonomic categories. General map units are useful representations of geomorphic regions and soil-landscapes, but cannot be used as a pedologic information source because they include too much soil diversity. Some map units include members of as many as three different classes at order level (Table 4). Both the complexity

Table 3. Landscapes and parent materials of Patagonian soils

Soil category	Landscape	Slopes *	Parent rock
ALFISOLS			
- Aqualfs	Lacustrine plains.	NL	Lacustrine sediments, glacial till
- Udalfs	High and low mountains and foothills.	M to S	Colluvium, glacial till.
- Xeralfs	Dissected high plains.	G	Glacial till.
ANDISOLS			
- Aquands	Lake plains, wet uplands, and depressions.	NL	Ash, pumice or other
- Cryands	Rock outcrops. Mountain upland.	M or S	pyroclastic materials fresh or
- Udands	Mountain upland, hilly plains, hill country, foothills, and old glacial landscape. Rock outcrops.	M to S	reworked.
- Xerands	High and low mountains, hilly plains and foothills.	M to S	
ARIDISOLS			
- Argids	Intermontane basin[1], upland plains[2], tablelands of basalt and of gravel.	G to M	Clayey Plio-Pleistocene plain sediments with alluvial or eolian mantle.
- Calcids	Peneplains, pediments, rolling and irregular plains, tablelands of basalt and of gravel, coastal plains, outcrops of friable materials, border plateaus, and high plains.	G to S, or G to M	Alluvium, soft tertiary sediments, fine grained volcanic rocks
- Cambids	Intermontane basin[1].	G to M	Alluvium, soft tertiary
- Durids	High plains dissected and foothills.	G	sediments.
- Gypsids	Pediplains.		Continental or marine sedimentary rocks.
- Salids	Alluvial flats and plains, playa lake plain, relict lake plain, stream channels, and flood plains.	NL to G	Alluvium, soft tertiary sediments.
ENTISOLS			
- Aquents	Lake plains, wet uplands, and depressions	NL	Non uniformity of parent rocks.
- Fluvents	River valley landforms [3].	G	Alluvium.
- Orthents	Rock outcrops. Mountains, high plateaus, high plains, and badlands.	M or S	Non uniformity of parent rocks.
- Psamments	Wind erosion forms.	G	Eolian.
HISTOSOLS			
- Fibrists	Lake plains, wet uplands, and depressions.	NL	Lacustrine or alluvium sediments, glacial deposits.
INCEPTISOLS			
- Aquepts	Lake plains and wet uplands.	NL	Lacustrine or alluvium sediments.
- Cryepts	Rock outcrops.	M or S	Non uniformity of parent rocks.
- Udepts	Rock outcrops.	M to S	
MOLLISOLS			
- Albolls	Depressions of rolling plains.	NL to G	Alluvium.
- Aquolls	Lake plains, wet uplands, and depressions.	NL	Lacustrine or alluvium sediments, glacial deposits.
- Cryolls	Rock outcrops and smooth uplands.	M or S	Non uniformity of parent rocks.
- Udolls	Old glacial landscape associated with fluvial environments,	G or M,	
- Ustolls	smooth uplands, tablelands of basalt and of gravel, broad or narrow plains, and rolling to broad and undulating	and M to S	
- Xerolls	ridge-tops of dissected plains. Rock outcrops.	G to M	
SPODOSOLS			
- Humods	High and low mountains and foothills.	G	Sandy quartzitic sediments.
VERTISOLS			
- Torrerts	Alluvial flat and plains, and depressions.	NL	Alluvium, soft sandstones,
- Xererts	Alluvial flat and plains.		siltstones and claystones of Tertiary sediments.

1 Intermontane basin landforms include: terraces, basin floor and piedmont slope (erosional and depositional). 2 Upland plains (plateaus and structural terraces) dissected by valleys, depressions and deep canyons. 3 River-valley landforms include large and small valleys, terraces and complexes of footslopes and backslopes. * Slope classes: NL= nearly level; M: moderate; G: gentle; S: steep; Gentle: mainly less than 10 %, not including nearly level; Moderate: mainly between 10 and 25 % ; Steep: mainly steeper than 25%.

and contrast of soil combinations describe the degree of their heterogeneity. The main areal combinations in soil complexes were Andisols, Aridisols, and Entisols with Aridisols (Río Negro); Inceptisols with Mollisols (Tierra del Fuego); and Mollisols with Entisols (Chubut). Soil

Table 4. Heterogeneity of soil combinations. Map unit composition. Number and (percent of area) of soil combinations at the orders level and type of map unit

Soil combinations at order level	Neuquén	Río Negro	Chubut	Santa Cruz	T. del Fuego
Alfisols					1 (1.1) Cn
Alfisols with Entisols	3 (2.2) A				
Alfisols with Entisols and Aridisols	1 (0.4) A				
Andisols	1 (7.4) A	4 (2.0) Cm	1 (0.5) Cm		
			1 (1.2) A		
Andisols with Inceptisols	1 (4.0) A	1 (0.4) Cm			
Andisols with Mollisols	3 (9.8) A		1 (1.9) A	1 (2.5) A	1 (2.0) A
Andisols with Mollisols and Histosols	1 (1.2) A				
Andisols with Mollisols and Inceptisols					1 (12.7) A
Aridisols	1 (0.4) A	2 (0.4) Cn	1 (0.6) Cn	5 (4.0) Cn	
		21 (18.3) Cm	6 (13.5) Cm	4 (14.4) Cm	
		20 (14.6) A	10 (22.6) A	6 (12.3) A	
Aridisols with Alfisols		1 (0.2) Cm	1 (0.1) Cm		
		1 (1.1) A	1 (0.1) A		
Aridisols with Andisols				1 (2.9) Cm	
Aridisols with Entisols	9 (18.3) A	14 (9.4) Cm	6 (11.4) Cm	1 (6.7) Cm	
		21 (25.2) A	10 (11.4) A	3 (5.4) A	
Aridisols with Entisols and Mollisols			1 (0.5) A	1 (3.6) A	
Aridisols with Entisols and Vertisols		1 (0.8) A			
Aridisols with Mollisols		2 (0.8) Cm	1 (0.1) Cm	1 (7.5) Cm	
			4 (3.6) A	2 (2.0) A	
Entisols	9 (16.3) A	1 (0.3) Cn	1 (0.6) Cn	3 (1.9) Cn	
		1 (0.1) Cm	2 (0.8) Cm	1 (0.1) Cm	
		5 (1.3) A	1 (0.6) A	2 (4.2) A	
Entisols with Aridisols	8 (15.4) A	9 (5.6) Cm	1 (2.2) Cm	2 (2.9) Cm	
		12 (10.5) A	4 (2.9) A	1 (1.2) A	
Entisols with Aridisols and Alfisols	1 (4.0) A				
Entisols with Mollisols	7 (7.7) A	1 (1.5) A	2 (4.8) A		
Inceptisols		1 (0.1) A	1 (0.2) Cn		1 (9.4) A
Inceptisols with Histosols					1 (6.9) A
Inceptisols with Mollisols					1 (2.6) Cm
					3 (5.6) A
Inceptisols with Spodosols					1 (8.8) A
Inceptisols with Spodosols and Histosols					1 (22.2) A
Mollisols	1 (0.5) A	1 (0.7) Cm	1 (0.1) Cn	2 (1.1) Cn	3 (5.4) Cm
			1 (0.6) Cm		2 (2.8) A
			2 (4.5) A		
Mollisols with Andisols	1 (1.1) A	1 (0.6) Cm	1 (0.01) Cm	1 (5.9) A	
			2 (0.3) A		
Mollisols with Andisols and Entisols			1 (2.1) A		
Mollisols with Aridisols			4 (4.1) A	1 (0.1) A	
Mollisols with Entisols	3 (1.6) A		1 (1.4) Cm	1 (5.2) Cm	
			4 (6.3) A	3 (13.6) A	
Mollisols with Entisols and Aridisols		1 (1.0) Cm			
Mollisols with Inceptisols					2 (13.2) A
Mollisols with Vertisols	2 (3.4) A				
Undifferentiated complex	*	2 (3.5) U			
Subtotal of kinds of map unit:					
Consociations: Cn		3 (0.7)	4 (1.5)	10 (7.0)	1 (1.1)
Complexes: Cm		56 (39.1)	21 (30.6)	11 (39.7)	4 (8.0)
Associations: A	52 (93.7)	62 (55.1)	48 (66.4)	21 (50.8)	14 (87.1)
Undifferentiated groups: U	*	2 (3.5)			
TOTAL	52 (93.7)	123 (98.4)	73 (98.5)	42 (97.5)	19 (96.2)

*Not calculated, but delineated. Consociations: Cn; Complexes: Cm; Associations: A; Undifferentiated groups: U.

associations correspond to: Alfisols with Entisols, Andisols with Mollisols, Entisols, and Entisols with Aridisols (Neuquén); Aridisols with Entisols (Río Negro); Mollisols with Entisols (Santa Cruz); Inceptisols with Spodosols and Histosols, and Mollisols with Inceptisols (Tierra del Fuego).

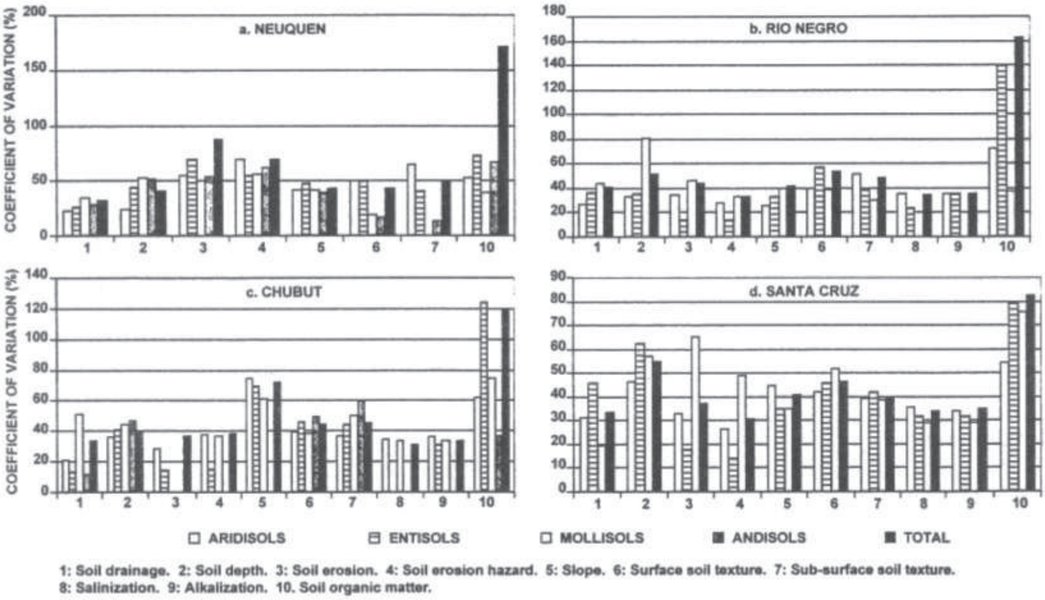

Figure 3. Observed variability among selected soil properties as a function of pedons (by taxonomic classes at the order level).

The use of associations and complexes reflects order or disorder in the arrangement of soil bodies over the landscapes. The assemblage of soil bodies within the province forms a mosaic of interlocking areal units. Size and diversity of the components of the soil bodies reflect the origin and characteristics of specific soil-landscapes. According to Wilding and Drees (1983) the factors shaping the soil combinations may be presented as follows: (a) landforms, (b) geomorphic elements, (c) soil-forming factors, and (d) interactions of above factors.

Figures 3a to 3d show the variability among selected soil properties (drainage, depth, erosion, erosion hazard, slope, surface and sub-surface soil texture, salinization, alkalization, and organic matter) as a function of pedons (by taxonomic classes at order level). The variability among components is expressed in terms of taxonomy for Andisols, Aridisols, Entisols, Mollisols and all taxas together, and in terms of diagnostic soil properties. Associated with changes in soil properties, others causes of nonuniformity could be related to parent material, dissimilar hydrology, differential erosion and accretion, biological factors (including human influence), and sampling and analytical errors (Wilding and Drees 1983).

The generalized order of spatial variability observed was relatively consistent among soil classes, soil properties and provinces. For example, the variability of the percentage of organic matter is as follows:

- Neuquén: Mollisols < Aridisols < Andisols < Entisols
- Rio Negro: Mollisols < Aridisols < Entisols
- Chubut: Andisols < Aridisols < Mollisols < Entisols
- Santa Cruz: Aridisols < Mollisols ≅ Entisols

Table 5. Percentage occurrence of soil property compositional data for drainage, depth, erosion status, erosion hazard and slope

Soil property	Neuquén	Río Negro	Chubut	Santa Cruz
Drainage				
Count data	72	64	70	44
Missing data	1	0	0	0
- Very poorly	1	8	6	
- Poorly	6	5	1	7
- Somewhat poorly	6			2
- Moderately well	4	9	9	18
- Well	38	31	29	11
- Somewhat excessively	26	31	34	32
- Excessivelly	18	16	21	30
Depth				
Count data	72	64	70	44
Missing data	1	0	0	0
- Shallow (< 0.3 m)	3	7	6	11
- Moderately shallow (0.5-0.3 m)	15	22	13	14
- Moderately deep (1.0-0.5 m)	48	52	56	27
- Deep (>1.0 m)	33	19	26	48
Erosion status				
Count data	32	54	37	39
Missing data	41	10	33	5
Water erosion				
- Slight	22			
- Moderate	3	17	6	9
- Severe	1			2
Wind erosion or soil blowing				
- Slight	16			
- Moderate		20	19	27
- Moderate to severe			4	
- Severe		2		7
Combined erosion				
- Moderate		39	19	30
- Severe	1	6	6	14
Erosion hazard				
Count data	60	57	56	42
Missing data	13	7	14	2
- Slight	11			
- Moderate	53	48	67	36
- Severe	6	17	11	34
- Very severe	18	23	1	25
Slope				
Count data	72	64	59	44
Missing data	1	0	11	0
- <1%	3			2
- 0-2%	36	59	49	43
- 2-8%	14	22	10	14
- 8-16%	18	9	16	21
- 16-30%	16	4	6	18
- >30%	12	6	4	2

1 Percentages were computed relative to the total number of cases (count data).

To account for the presence of similar and dissimilar soils, physical, chemical and landscape compositional properties for each province were summarized in Tables 5 and 6. Patagonian soils are well drained and somewhat excessively drained all over the region, except for Santa Cruz where a

Table 6. Percentage occurrence of soil property compositional data for surface and subsurface textures, salinization, alkalinization and organic matter.

Soil property	Neuquén	Río Negro	Chubut	Santa Cruz
Surface texture				
Count data	71	64	70	44
Missing data	2	0	0	0
- Sand		11	10	11
- Loamy-sand	33	30	24	23
- Sandy-loam	41	37	40	36
- Loam	11	9	9	9
- Silt-loam		2	2	2
- Sandy-clay-loam	7	5	6	7
- Clay-loam	1		1	5
- Silty-clay	1	2		
- Sandy-clay		4	1	2
- Clay	3		7	5
Subsurface texture				
Count data	66	63	69	44
Missing data	7	1	1	0
- Sand	4	6	4	9
- Loamy-sand	14	14	16	14
- Sandy-loam	38	38	24	40
- Loam	7	3	11	7
- Silt-loam	1			2
- Sandy-clay-loam	7	3	19	9
- Clay-loam	6	22	4	5
- Silty-clay-loam		2	1	
- Sandy-clay	3	3	3	
- Clay	11	8	16	14
Salinization				
Count data		64	70	44
Missing data		0	0	0
- Non saline		80	86	77
- Saline		20	14	23
Alkalization				
Count data		64	70	44
Missing data		0	0	0
- Non sodic		75	79	75
- Sodic		25	21	25
Organic matter				
Count data	58	62	69	42
Missing data	15	2	1	2
- <0.5%	18	22	14	2
- 0.51-1.0%	11	34	26	21
- 1.1-2.0%	25	23	22	30
- 2.1-3.0%	10		15	20
- 3.1-6.0%	3	11	4	14
- 6.1-9.0%	3	2	9	9
- >9.1%	10	5	9	

1 Percentages were computed relative to the total number of cases (count data).

variety of drainage classes occurs. Most provincial soils are moderately deep, but deep soils are more frequent in the Santa Cruz province. The lack of data hampers the assessment of the soil erosion status and hazard. More than 30% of the surface area of Rio Negro and Santa Cruz is exposed to some kind of erosion. In Santa Cruz, about 60% of the area has severe and very severe soil erosion hazard. The prevailing terrain slopes are between 0 and 2%, followed by 16-30%. In the Neuquén province, large areas have slopes above 30%. Sandy loam is the prevailing surface and subsurface texture. Clayey subsurface textures are more frequent in Chubut and Santa Cruz. Salinization and alkalization are similar in all provinces, but organic matter contents are dissimilar. While values in Neuquén, Río Negro and Chubut provinces are in the medium range, those of Santa Cruz province seem to be somewhat overestimated.

Human impact and natural disturbances

The complexity of both natural and human impacts on the soil cover was documented in the Patagonian region (arid, semiarid and dry sub-humid) by del Valle et al. (1998). In this study, the aridity of climate or its aridization is perceived as the major factor (precondition) of desertification, according to Kust (1992).

Land degradation is both a form of ecosystem self-regulation and a cause of ecosystem fragmentation. The ecological equilibrium of Patagonia is highly susceptible to man's impact and the present methods of natural rangeland management, based on an extreme overuse in space and time. Overgrazing and woodcutting result in a gradual degradation of vegetation, which causes a reduction of the total cover and of the number of plants, the disappearance of valuable fodder species, the invasion of undesirable species, and finally the decrease of available forage. The effects of overuse of this resource are also evident in soil erosion. The consequences of the anthropic impact are also aggravated by drought phases.

Results reported evidence that 93.6% (73.5 million ha) of the region (78.5 million ha) showed some degree of desertification, from slight (9.3%), moderate (17.1%), moderate-severe (35.4%), severe (23.3%) to very severe (8.5%).

Slight desertification affects 32.4% of Tierra del Fuego, 16.6% of Río Negro, 6.6% of Chubut, 5.9% of Neuquén and 5 % of Santa Cruz. The largest areas of slight degraded rangelands were situated in the Austral Zone (Tierra del Fuego), followed by the North (Neuquén-Río Negro), Central (Chubut) and South (Santa Cruz) zones.

Moderate desertification occurs with similar percentages of 17.0, 18.4 and 17.6 in Neuquén, Río Negro and Chubut, respectively. Santa Cruz has 14.4 % and Tierra del Fuego has 33.3 % of the surface areas affected.

Moderate to severe desertification, affecting the loss of rangelands and their conversion into wasteland, badlands or desert, occurred in similar properties from the North zone to the South zone, with 39.4% in Chubut, 36.1% in Río Negro, 34.9% in Santa Cruz, 32.0% in Neuquén and 6.8% in Tierra del Fuego.

Severe desertification affects 30.5% of Neuquén, 26.2% of Santa Cruz, 22.9% of Río Negro and 19.4% Chubut. The largest areas of very severe desertification occurred in the South, followed by the Central zone, corresponding to playas and other barren areas of the landscape exposed to natural land degradation. Considering the severe and very severe status together, the lands in extreme degradation were situated in the drylands of the South (38.4%), North (31.5%) and Central (30.7%) zones.

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Appendix 1. Approximate area of the different soil taxa in the Patagonian region (in hundreds of km^2).

Soil order, suborder and great group	Code*	Neuquén	Río negro	Chubut	Santa cruz	Tierra del Fuego	Region
ALFISOLS					?		
- Aqualfs							
. Albaqualfs	AA	0.28 (0.03)					0.3 (0.004)
. Epi / Endoaqualfs	AF/AI+		8.8 (0.4)	0.32 (0.01)		2.2 (1.1)	11.3 (0.2)
. Natraqualfs	AE		1.4 (0.1)	0.61 (0.03)			2 (0.03)
- Udalfs							
. Natrudalfs	AJ+					2.6 (1.2)	2.6 (0.04)
- Xeralfs							
. Haploxeralfs	AV	18.6 (2.0)					**18.6 (0.3)**
. Palexeralfs	AW	1.12 (0.1)					1.12 (0.02)
Subtotal		20 (2.1)	10.2 (0.5)	0.93 (0.04)		4.8 (2.3)	**35.9 (0.5)**
ANDISOLS							
- Aquands							
. Epi/ Endoaquands	IA+	7.1 (0.8)				15.8 (7.6)	22.9 (0.3)
- Cryands							
. Vitricryands	II+		3.4 (0.2)	2.77 (0.1)	29.1 (1.2)		35.3 (0.4)
- Udands							
. Fulvudands	IJ+	46.1 (4.9)	22.3 (1.1)	35.6 (1.6)			104 (1.4)
. Hapludands	IN+	101 (10.7)	14.8 (0.7)	10.4 (0.5)			**126 (1.6)**
. Hydrudands	IL+		0.7 (0.03)	9.9 (0.4)			10.6 (0.1)
- Xerands							
. Vitrixerands	IK+			14.6 (0.7)	115 (4.7)		**130 (1.6)**
Subtotal		154 (16.4)	41.1 (2.0)	73.4 (3.3)	144 (5.9)	15.8 (7.6)	**428 (5.4)**
ARIDISOLS							
- Argids							
. Haplargids	DB	11.8 (1.3)	333 (16.4)	243 (10.8)	270 (11.1)		858 (10.9)
. Natrargids	DD	2.2 (0.2)	244 (12.0)	433 (19.3)	389 (15.9)		**1069(13.6)**
. Paleargids	DE	26.9 (2.9)	185 (9.1)	123 (5.5)	342 (14.0)		678 (8.6)
- Calcids							
. Haplocalcids	DF+	45.4 (4.8)	203 (10.0)	319 (14.2)	59.3 (2.4)		626 (8.0)
. Petrocalcids	DJ+	68.7 (7.3)	89.1 (4.4)	37.5 (1.7)	7.29 (0.3)		203 (2.6)
- Cambids							
. Haplocambids	DG+		143 (7.1)	79.3 (3.5)	172 (7.1)		395 (5.0)
- Durids							
. Argidurids	DA+	0.82 (0.1)					0.8 (0.01)
- Gypsids							
. Petrogypsids	DI+	19.4 (2.1)					19.4 (0.3)
- Salids							
. Aqui / Haplosalids	DK+	2.6 (0.3)	28.1 (1.4)		12.4 (0.5)		43 (0.5)
Subtotal		177 (19.0)	1226 (60.4)	1236 (55.0)	1252 (51.3)		**3892 (49.5)**
ENTISOLS							
- Aquents							
. Epi / Endoaquents	EC+	4.9 (0.5)			7.81 (0.3)		12.7 (0.2)
. Fluvaquents	EB		0.28 (0.01)		21.5 (0.9)		21.8 (0.3)
. Psammaquents	EE			16.8 (0.7)			16.8 (0.2)
- Fluvents							
. Torrifluvents	EI	15.3 (1.6)	97.9 (4.8)	59.5 (2.6)	29.3 (1.2)		202 (2.6)
. Xerofluvents	EL		4.39 (0.2)		51.6 (2.1)		56 (0.7)
- Orthents							
. Cryorthents	EM	1.8 (0.2)		26.9 (1.2)	37.1 (1.5)		65.8 (0.8)
. Torriorthents	EN	177 (18.8)	188 (9.3)	188 (8.4)	221 (7.5)		**775 (9.9)**
. Udorthents	EO				25.4 (1.1)		25.4 (0.6)
. Ustorthents	EP			11.2 (0.5)			11.2 (0.1)
. Xerorthents	EQ	47 (5.0)	16 (0.8)	90 (4.0)	41.9 (1.7)		195 (2.2)
- Psamments							
. Quartzipsamments	ES				7.14 (0.3)		7.1 (0.1)
. Torripsamments	ET	55.3 (5.9)	146 (7.2)	12.3 (0.5)	33.1 (1.4)		247.2 (3.1)
. Xeropsamments	EW	16.5 (1.8)	27.8 (1.4)	15.7 (0.7)	24.6 (1.0)		84.7 (1.1)
Subtotal		318 (33.8)	481 (23.7)	421 (18.6)	500 (19.0)		**1720 (21.9)**

Soil order, suborder and great group	Code*	Neuquén	Río negro	Chubut	Santa cruz	Tierra del Fuego	Region
HISTOSOLS			?	?	?		
- Fibrists							
. Haplofibrists	HD+	1.13 (0.1)					1.13 (0.01)
. Sphagnofibrists	HE					8.98 (4.3)	**8.98 (0.09)**
Subtotal		1.13 (0.1)				8.98 (4.3)	**10.1 (0.1)**
INCEPTISOLS							
- Aquepts							
. Cryaquepts	IH					16.6 (7.9)	16.6 (0.2)
. Humaquepts	IE	3.78 (0.4)					3.78 (0.1)
- Cryepts							
. Dystrocryepts	IU+					7.21 (3.4)	7.21 (0.1)
. Eutrocryepts	IV+					54.6 (26.1)	**54.6 (0.7)**
- Udepts							
. Dystrudepts	IO+		2.92 (0.1)				2.92 (0.04)
. Eutrudepts	IW+		1.07 (0.1)	4.53 (0.2)			5.60 (0.1)
Subtotal		3.78 (0.4)	3.99 (0.2)	4.53 (0.2)		78.5 (37.4)	**90.8 (1.2)**
MOLLISOLS							
- Albolls							
. Argialbolls	MA	1.15 (0.1)					1.15 (0.02)
- Aquolls							
. Epi or Endoaquolls	MF+	9.82 (1.0)		25.4 (1.1)	23.9 (1.0)		59.1 (0.7)
. Calciaquolls	MD		6.27 (0.3)	3.66 (0.2)			9.93 (0.1)
. Cryaquolls	MCH			21 (0.9)			21 (0.3)
- Cryolls							
. Haplocryolls	MX+				85.9 (3.5)	12.8 (6.1)	98.7 (1.3)
- Udolls							
. Argiudolls	MW+			37.3 (1.7)	14.1 (0.6)	13.9 (6.6)	65.3 (0.8)
. Hapludolls	MJ			8.24 (0.4)		7.96 (3.8)	16.2 (0.2)
- Ustolls							
. Argiustolls	MK		9.49 (0.5)				9.49 (0.1)
. Calciustolls	ML				54.6 (2.2)		54.6 (0.7)
. Haplustolls	MN/Y+ +		17.4 (0.9)	126 (5.6)	240 (11.4)	25 (12.0)	**408 (5.2)**
- Xerolls							
. Argixerolls	MQ	35.1 (3.7)		34.9 (1.6)	36.3 (1.5)		106 (1.4)
. Calcixerolls	MR			55 (2.4)			54.9 (0.7)
. Haploxerolls	MT	35.5 (3.8)	9.07 (0.4)	90.2 (4.0)	0.56 (0.02)		135 (1.7)
Subtotal		81.5 (8.6)	42.3 (2.1)	401 (17.9)	455 (20.0)	59.6 (28.5)	**1040 (13.2)**
SPODOSOLS					?		
- Humods							
. Haplohumods	SA+					17.6 (8.4)	17.6 (0.2)
Subtotal						17.6 (8.4)	**17.6 (0.2)**
VERTISOLS				?	?		
- Torrerts							
. Sali/ Haplotorrerts	VG+		3.17 (0.2)				3.17 (0.03)
- Xererts							
. Haploxererts	VF+	6.68 (0.7)					**6.68 (0.07)**
Subtotal		6.68 (0.7)	3.17 (0.2)				**9.85 (0.1)**
Total Soil		762 (81.1)	1808 (89.1)	2136 (95.0)	2352 (96.4)	185 (88.5)	**7244 (92.1)**
Undifferentiated soils (1)							
	CoRC/RN **	71.2 (3.5)				71.2 (0.9)	
MISCELLANEOUS AREAS (2)							
Areas with little soil:							

Soil order, suborder and great group	Code*	Neuquén	Río negro	Chubut	Santa cruz	Tierra del Fuego	Region
- Rocky land	R	156[1] (16.6)	120 (5.9)	77.4[2] (3.4)	26.5[3] (1.1)	16.19 (7.7)	397 (5.0)
- Playa lake	S		3.36 (0.2)	1.87 (0.1)			5.23 (0.1)
Continental glacial ice plateaus	G	0.65 (0.1)			***		0.65 (0.01)
Lakes	L	21.9 (2.3)	28 (1.4)	30.2 (1.3)	60.9 (2.5)	7.87 (3.8)	149 (1.9)
Total (1) and (2)		179 (19.0)	222 (11.0)	109 (4.8)	87.4 (3.6)	24.1 (11.5)	622 (7.9)
TOTAL		941	2030	2246	2439	209	7866 (100)

* Code letters in data column can be found in Soil Atlas of Argentina (INTA/CIRN 1990). + Great group eliminated or modified (Soil Survey Staff 1997). ++ Map unit MYli - 1 (Santa Cruz province) was considered like Torriorthents. ** Not calculated, but delineated. *** Not delineated, included within Mollisols (?).? Doubtful absence of taxa in existing reports. 1 includes R1, R2 and R3, and rock outcrops within soil map units. 2 rock outcrops within soil map units, and scarcely delineated. 3 rock outcrops within soil map units, and not delineated.