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Soil erosion and its control in Chile - An overview

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ABSTRACT

Accelerate erosion in Chile is a consequence from land use that degrade soil such as compaction, loss of organic matter and soil structure. The erosion is favored by the very hilly landscape of the country that increases erosivity index and the high erodibility given by an elevated annual rate of rainfall with irregular distribution.

Several experiences have demonstrated that adequate crop management and crop rotations can minimize erosion. The most effective control is achieved conserving and improving soil structure with management systems that include regular use of soil- improving crops, return of crop residues and tillage practices, thus avoiding unnecessary breakdown soil or compacted soil structure. Conservation tillage increased organic matter levels improving stabile soil structure, aeration and infiltration.

Key Words: Water erosion. Soil degradation. Crop management. Soil quality.

RESUMEN

La erosión puede deberse a causas naturales, erosión geológica o acelerada. Esta última se induce con la actividad antrópica y los agentes primarios agua y viento, es la forma de degradación más severa del suelo. La degradación del suelo precede a la erosión acelerada, como la compactación, disminución del contenido de materia orgánica, perdida de la estructura de suelo, pobre drenaje interno y problemas asociados a la acidificación del suelo.

La erosión puede ser controlada conservando la cobertura protectora vegetal, con la creación de barreras contra los agentes erosivos y modificaciones en el paisaje que permiten controlar el monto y la tasa de escorrentía superficial. Las rotaciones culturales bien planificadas aumentan la calidad del suelo y reducen la erosión.

Para lograr un control efectivo sobre la erosión, es necesario mejorar la calidad de la estructura mediante manejos culturales que incluyen cultivos mejorados y con retornos de materia orgánica en forma de residuos de cosecha y guanos, y prácticas de laboreo que no dañan a la estructura. Una labranza conservadora del suelo mejora su calidad al incrementar los niveles en materia orgánica, mejorando la estructura, aireación e infiltración. Las siembras y labores del suelo que se realizan en curva de nivel también reducen la perdida del suelo.

Palabras Clave: Erosión hídrica. Degradación. Suelos. Calidad. Cultivos.

Table 1. Area and degree of erosion in Chile.

		Farm- and Forestland	Country
	ha (10^3)	%	%
Slight erosion	5.360	17.4	7.2
Dominate erosion	94.75	30.5	12.7
Moderate erosion	875	2.7	1.1
Severe erosion	3.260	10.5	4.4
Total	18.870	61.1	25.4

INTRODUCTION

Erosion is a deterioration of soil by the physical movement of soil particles. The most important erosion agents are wind and water; but in most instances these are important only after men, animals, insects, diseases or fire have removed or depleted the soil cover.

The natural rate of soil formation assumed for Andisols and Ultisols from southern Chile is approximately 0.3 -0,7 mm or 2 - 8 t ha^{-1} each year. Although these academic estimates may not accurately represent the processes occurring across the country, they do indicate that in many areas the rate of soil erosion currently outweighs soil formation (INIA, 1985)

In Chile the susceptibility to accelerated erosion and the high rate of its occurrence depend principally on land use favored by the accidented geomorphology, climate, soil properties and nature of vegetation cover. The growth of intensive agricultural activities in the last 70 years resulted in the removal by burning of native vegetation across large areas.

Soil loss is preceded by soil degradation, especially soil compaction that induces loss of organic matter and soil structure. The use of heavy tillage and forest harvesting equipment disturb structure. The agricultural exploitation area is located between arid to humid and temperate climate. The country is endowed with a complex landscape. Therefore, long cultivation or continued grazing with inadequate management promotes accelerated erosion.

The highly variable geomorphology and climate lend to a great array of soil, water and vegetative conditions. Only 5% of the country are arable land for agriculture, 25% for pasture and forestry. More than 80% of the usable surface is held in private ownership. The responsibility for stewardship of this land lies in the hands of about 320.000 individuals less than 5% of our population (INE, 1998)

Erosion rates in some areas in Chile are greater than100 tones per hectare per year. The erosion affects 25% of the total country and more than 60% of the total usable land. Erosion rates have been multiplied in the last 50 years twice as much with increase of population, Table1, (MINAGRI; 1978).

In Chile the amount of rain erosivity depends principally on its intensity and annual irregular distribution. In Central and South Chile 5-8% of the annual precipitation (from 500 to 2500 mm y^{-1}) has a high kinetic energy. The range of erosivity oscillates between 27 and 35 Megajoule ha^{-1} mm^{-1}.

The erodibility range as index to measure the potential for soil loss without alteration, considering management factors or conservation practices for the main soils of agricultural use in Chile is just as follows: Alfisols 0.2-0.5, Ultisols 0.3-0.45 and Andisols <0.06.

It is frequently that traditional tillage and cropping practices with heavy machines cause poor soil structure and result in compaction contributing to increase erodibility; even eroded sites tend to be more erodible than the original soils. Erodibility factor of a not altered and degraded Ultisol from Southern Chile oscillate between 0.3 and 0.67 and Alfisols from 0.2 to 0.54 respectively. Soils covered the greatest proportion of eroded surface.

Water erosion is the most significant agricultural problem for soil conservation throughout Chile. Almost any area where crops are grown, food is produced and forest is harvested, has to deal with this problem. 15000 hectares per year are estimated to be lost by erosion in Chile (SAG, 1975). However, erosion is not always readily visible on cropland because farming operations may

Table 2. Soil Loss reduction compared to bare Ultisol from Southern Chile.

Crops	% reduction
Continuous winter wheat	18
Rotation of 1year wheat, 2 years pasture	33
Rotation of 2 years wheat, 5 years pasture	62
Permanent pasture	78
Forestry	87

Table 3. Effect of forage crops in rotation on aggregate stability of a Ultisol from southern Chile.

Cropping System	Water-stable Aggregates >0.25mm(%)	Yield of wheat (t ha^{-1})
Rotation 2 years grains, 2 years pasture	23	35
Rotation 2 years crops, 5 years grass	62	56

cover up its signs. Other important types of erosion in Chile by water flow include landslides in the Coastal and Andean Mountains.

EFFECTS OF SOIL EROSION

On-Site effect implications of soil erosion extend beyond the removal of valuable topsoil. Growth and yield are directly affected through the loss of natural nutrients, applied fertilizers and pesticides. The yield in wheat on moderate eroded Chilean farmland is less than 30% than on the same not altered soil. The areas with extreme erosion still used for agriculture fall up to 80%.

Off-site impacts of soil erosion are not always as apparent as the on-site effects. Sediments damage road structure, every year an important sector of the country is paralyzed due to river increases that destroy highways or bridges. With the silts more than 400 km of diverse navigable rivers have been lost, useful life of most of the reservoirs has decreased when filled with silts. Eutrophication has increased in all the water sources with contribution of nutrients coming from silts.

SOIL DEGRADATION

The primary cause of soil degradation is its use in activities for, which are not apt. The first sign of soil degradation is the loss of structure that is evidenced by compaction. Compaction takes place mainly with tillage operations when humidity conditions of a soil are excessive. In areas where intensive, "mechanized" agriculture is practiced, soil compaction ranks highly with other forms of land degradation as a major threat to sustaining current agricultural production levels. In the Coastal mountains in Southern Chile where Ultisols (clay soils) are predominant over 80% of these soils are compacted. With forest harvesting by heavy machines the compacted area increases to 30.000 hectares per year. The effects of compaction are frequently simultaneous with water erosion (Ellies and Smith, 1998)

The causes of soil compaction are divided into two types: tillage-induced and traffic-induced compaction. The first is caused by primary tillage under less than optimum soil moisture conditions. Excessive secondary tillage destroys soil structure, allowing the surface soil to puddle, crusts, and reach densities greater than would otherwise occur in an untilled state. Furthermore, many of today's larger tillage implements exert tremendous stresses and pressures on the soil at the base of the plow layer. This frequently leads to the formation of a plowpan at depth. The major compaction problem, however, is associated with the rear wheel of the tractor running in the open furrow, forming a compacted layer at even greater depths.

Traffic-induced compaction is caused primarily by wheel traffic associated with farm operations and animal footprints and is of greatest concern in the subsoil zones. It has been estimated that conventional tillage practices and other planting-harvesting farm operations, as much as 80% of the field area will be wheel tracked on an annual basis or much of the field area receives 5 or 8 wheel passes. The concern about using heavy vehicles on wet soils shows

Table 4. Effect of corn stover residues on aggregate stability and erosion of a Ultisol.

Residue Management	Water-stabile Aggregates > 0.25 mm (%)	Soil loss (t ha^{-1})
Stover burned	17	47
Stover not removed, plowed	47	27
Stover not removed, not plowed	78	5

Table 5. Comparison of organic matter content for plow and no-tillage systems in Ultisols from Chile.

Tillage System	Depth (cm)	Organic Matter (%)
Plow	0-10	8
	10-20	4
No-tillage	0-10	11
	10-20	6

that, at a given tire contact pressure, soil porosity and density gets deeper into the subsoil with increasing vehicle axle loads, passes and soil moisture content.

SOIL MANAGEMENT TO PREVENT EROSION

Farm management decisions should consider the potential for erosion under different practices, especially on marginal land for crop production. Areas at high risk for erosion due to steep slopes or erodible soils may be better suited for pastures or forest.

The best ways to reduce erosion is protect the soil surface with growing plants or crop residues. Row crops such as wheat reduce erosion potential by third of fallow land, which is still considered excessive. Sod crops such as permanent pasture keep soil erosion to a minimum and should, therefore, be used in rotation with other crops where erosion is a problem. Compared to continuous wheat, forage or pasture crops reduce soil loss by about 70%, Table 2 (Sandoval et al., 1994).

Increase grass covering or high residue crops combined with other conservation practices such as conservative tillage reduce erosion. With an increment in the participation of grassland in crop rotations, water stability of aggregates and yields are increased (Table 3). Perennial crop or plow down forages add organic matter and improve soil quality and better structure. Improved soil structure allows more water to filtrate reducing runoff and erosion.

Returning crop residues to the soil helps to replace organic matter and plant nutrients. Rotations, which include forages, return more residues to the soil and increase fertility. Therefore good soil structure is a result of management systems that include both the frequent return of organic matter in residues or manure and tillage practices avoiding unnecessary breakdown of soil structure. Crops and grass in a rotation improve soil structure as reflected by an increased degree of aggregate stability (Ellies and Hartge, 1992).

Corn stove residues, when not removed, also improve soil structure and reduce erosion. Best results are obtained when the crop residuals remain on surface (Table 4). However, soil losses from plowed soil -even where the stove is not removed and incorporated to subsoil- can easily exceed the limit of erosion tolerance for Chilean Ultisols (8 tons per ha) considered tolerable for most situations. By leaving corn stove residue at the soil surface as with no till or mulch tillage, soil losses may be reduced below tolerable limits (Ellies and Contreras, 1997).

Soils high in organic matter have large, stable aggregates that resist erosion. A soil with stable aggregates also has larger pore spaces to hold water. With this increased moisture-holding ability, there is less pounding in fields, and less runoff and erosion.

Tillage practices also affect soil structure. Excessive tillage, however, can break down soil aggregates. Excessive tillage wastes time and energy. Timeliness of tillage operations is also important.

High residue crops in rotation with cover crops and conservation tillage increase amounts of organic matter compared to conventional tillage. It is difficult to increase organic matter where moldboard plowing is taking place (Kahnt, 1981).

It is estimated that many soils from Chile have lost from 20 to 50 percent of the soil carbon content of surface layer since cultivation began at the end of the 19th century. The combination of adding organic residues to the soil surface, with not disturbance of existing organic matter stocks below the surface, can result in increases of organic matter in the soil. The amount of time to increase or-

Table 6. Effects of tillage treatments on bulk density and coarse pores at 10 cm depth on a Ultisol.

Tillage System	Bulk density (g cm^{-3})	Coarse pores (%)
Traditional Tillage	1,37	12,2
Reduced Tillage	1,12	17,5

ganic matter is determined mainly by climate and the amount of crop biomass produced and left on the soil surface.

Table 5 shows an increase in organic matter with no-till continuous corn and after seven years in comparison with permanent ploughing in an Ultisol from Coastal Mountains under humid climate conditions. The increase in organic matter was largest near the surface but decreased slightly below 10 cm. (Crovetto, 1998).

Conventional tillage buries the protective crop residue cover and disturbs the soil. Raindrops and running water easily detach the loose soil particles. Still when bulk density of the upper soil under zero tillage is greater than under a traditional system, the quality of a continuous porous system or aggregation increase coarse pores and their continuity.

Zero tillage systems protect soils on steeper, longer slopes or with high clay content, such Ultisol, from erosion. Reduced and minimum tillage systems leave a good crop residue cover to prevent erosion and conserve soil moisture.

With reducing tillage the traffic with heavy machines decreases, this conserves the looseness and the pore system of the soil (Ellies et al, 1993). Compared to traditional plowing, water-related soil losses are reduced with any tillage practice that leaves the soil surface undisturbed. The effect on soil erosion by tillage methods is listed in Table 7. (Riquelme, 1998). The zero tillage still continues advantageous when carried out under adverse conditions, as winter, in comparison with other systems of traditional tillage in better climatic seasons.

Tillage and crop planting across, rather than with the slope, can reduce soil loss, even strip cropping across the slope compared to up-down slope cropping. Proper timing and planting are necessary to protect disturbed areas. All these simple practices of soil management have slowly been incorporated in the traditional agriculture.

Table 7. Reduction in soil losses compared to conventional autumn plowing.

Tillage Practice	Soil loss reduction (%)
Spring plowing	12
Spring chisel	28
Autumn chisel	67
Winter zero tillage	75

The soil management's that control erosion in Chile has been proven to be successful. However, a massive application of these for farmers is low. The acceptance of new management is hindered in a mean with social problems linked to poverty and subsistence farmland.

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