EROSION PROCESS CAUSES AND RISKS BASED ON INFORMATION FROM AN INVENTORY OF RENEWABLE NATURAL RESOURCES: AN EXAMPLE FROM THE HIGHLANDS OF ECUADOR

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The soil erosion problems are the origin of the existing unplowed and the surface decrease of agricultural frontier on the Highland Region of Ecuador or "Sierra". These problems are of large magnitude with serious consequences.

According to conclusions of the different studies and specially from the general soil erosion map of Ecuador (scale 1:1'000.000) the most affected region by this phenomena is the Interandine Region or Sierra. The main reasons are the natural conditions of this region (irregular topography, volcanic ash soils, large climatic variation, etc.) and also the antropic activities which increase the soil erosion problem.

This phenomena is very serious in the Sierra and it is possible to affirm that the "Soil erosion problem is the main characteristic of this Region".

For this reason it is very important and urgent that erosion studies be initiated in order to fully capture the extent of actual erosion and to predict potential erosion problems in order to make practical works for the use, management and conservation of soil and water.

On these problems the studies started only two years ago and in few zones because all the soil scientist are dedicated to conclude the soil inventory to scale 1:200.000 in all the country. For this reason we do not have enough base to really identify this problem and it will not be possible until the results of the iniciated experimental studies are ready (5, 10 or more years).

The results of the cartographic information from the inventory of renewable natural resources (soil, water, geology, geomorphology, ecology, land use, actual use of the soil, socio-economical data, etc.) made from 1973 to 1985 by PRONAREG-ORSTOM is a good information to solve this problem.

OBJECTIVES

The purposes of the following study is to present in a fast and illustrative form a diagnosis of the principal erosion process, its causes and risks in the Ecuatorian Highland Region of Ecuador or "sierra" in order to fully capture the extent of actual erosion and to predict potential erosion problems.

METHODOLOGY

The procedure used in this study consisted first on analysis of the cartographic information from the inventory of renewable natural resources made during 1973-1985 by PRONAREG-ORSTOM in relation to the: soils, slope, actual use of soils and vegetation and climatic aggresivity. These data belong to the zone located between the cities Latacunga and Ambato, to the scale 1:200.000, second an adaptation of all the existing information was made according to the purpose of this work, finally a correlation between the different cartographic information used was made to arrive to the practical conclusions.

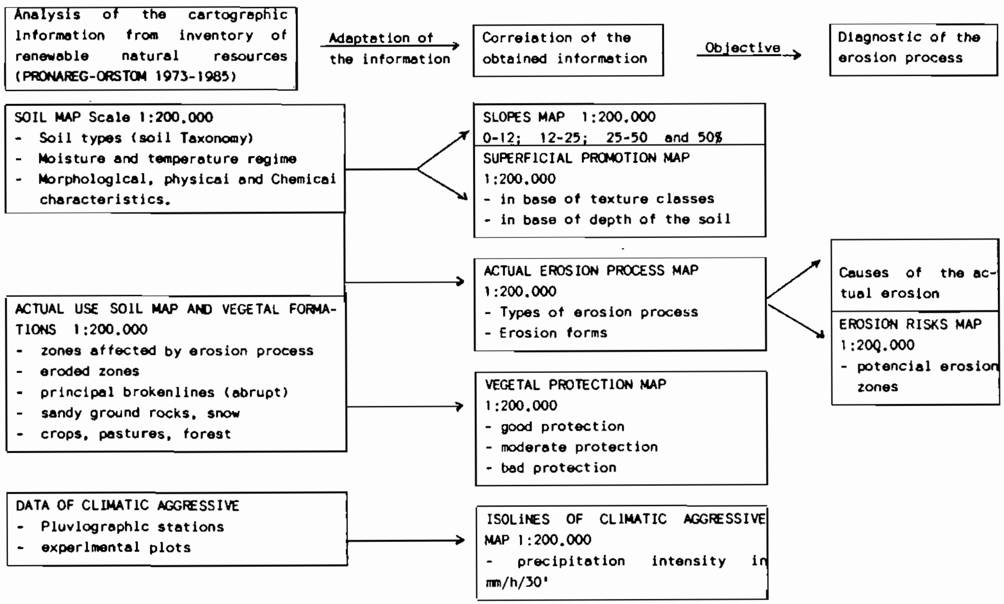
In this sense in the following schema is possible to appreciate the used methodology (**Figure 1**).

ELLABORATION OF THEMATIC MAPS

By adapting existing cartographic information of the inventory of renewable natural resources from the different maps belonging to the zone between Latacunga and Ambato, scale 1:200.000 (**Figure 2**).

Figure 1

METHODOLOGY



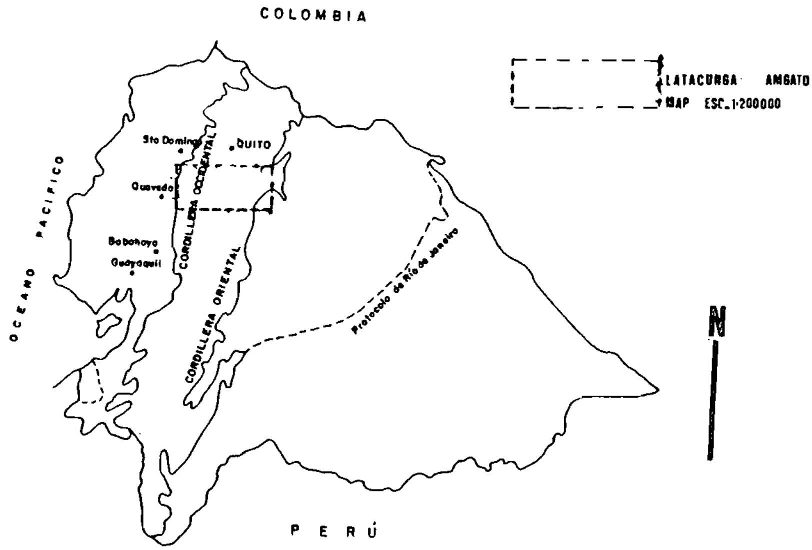


Figure 2

<u>Map of Actual Erosion Process</u>

According to the schema of this methodology, the map of the actual erosion process is the result of the interpretation and adaptation of the information from the soil and actual use of the soil maps that belong to the studied zone. From the actual use of soil map it was possible to distinguish four zones well differenciated: zones in process of erosion, eroded zones, zones with principal broken lines (abrupts) and zones with sandy ground, rocks and snow. However only the first three zones were considered in this study because the last one belong to the Cotopaxi volcano and consequently it is a zone without agricultural and forest use.

Based of these three zones it was overlaped, the soil map information (soil types and slopes). From this overlapping was possible to define different types of actual erosion processes.

<u>Eolian actual erosion process</u>: Inside of the eroded or in process of erosion zones it was detected when it was good correlation between gentle slopes (0-12 %) and fine soil texture, with the following erosive forms:

- Rebdous: small sandy accumulations around the herbaceous vegetation
- Nebkas: the same as Rebdous, but they are located around shrubby vegetation
- Yardangs: are eolian abrasions after wind sandy particle transportation, due to the vertical and horizontal smashing with the soil.

2) <u>Mixed concentrated and diffuse runoff associated with eolian process</u>: Here there are more than 12% of slope and fine soil texture, with the following erosion forms:

- Similar erosion forms as described for eolian processes, and also rills, gullies, and small broken line erosion forms.

3) <u>Concentrated and diffuse runoff</u>: Here there is only this actual erosion process without eolian erosion with the following erosion forms:

- Rill, gully, small broken lines and locally medium and big broken lines.

4) <u>Mixed concentrated and diffuse runoff associated with small mass movements</u>: Here the degree of slope is similar to the former but in the soil profile it is evident the presence of argilic horizont, with the following erosion forms:

- Water shed with stepped talus, with rill and gully erosion forms.

5) <u>Very concentrated runoff</u>: In this case the principal aspects are outcropping parent material mostly endurated and cemented volcanic material called **cangahua** (Duripan according to the Soil Taxonomy

USDA). The slopes here are more than 70% with the following erosion forms:

- big broken lines mostly

It is very important to realize that the analysis and interpretation of this information was complemented by field observation. This map of actual erosion process is the basic document on which there were executed each one of the comparative analytical operations in this study.

Ellaboration of Other Thematics Maps

After determining the different map areas of this actual erosion process and according to proposed methodology, it was made a comparative study by overlapping the maps at scale 1:200.000, of the following four variables: slopes, superficial formations, vegetal protection and climatic aggressivity.

The first three variables were determined and mapped adapting the existing information related to the soil and actual use of the soil to the map scale 1:200.000. Regarding the last variable, its information was not on the map. For this reason was necessary to prepare these data.

The data in reference consisted in determining the precipitation intensities in milimeters by hour with a duration of 30 minutes and mean frequency. Based on the pluviographic stations net-work it was possible to draw the lines of equal intensity (isolines).

The final purpose of this study is to obtain for each type of process a formula that is a combination of the four variables.

The analysis and interpretation was made variable by variable, with each one of the different actual erosion processes. However, it is necessary to know for each variable its related characteristics:

1) MAP OF SLOPES

Symbols	Ranges	Degrees of erosion
P1	0-12 %	Weak
P2	12-25 %	Light - Moderate
P3	25-50 %	Strong
P4	50-70 %	to
P5	more than 70%	Very strong

These ranges were obtained from soil map (7 classes) but reduced to 5 classes according to the erosion degrees

2) MAP OF PLANT/COVER PROTECTION

Symbol	Soil protection	Crops and/or vegetation
C1	Good plant protection	pasture, highland-pastures forest and shrubbery
C2	Moderate plant protection	weedhook crops, vegetables and fruits
C3	Bad plant protection	maize mainly

These types were determined based on the different types of specified crops and vegetation that there are in the maps of actual use of the soil

3) MAP OF SURFACE FORMATIONS

Symbol	Dominant soil texture	Soil depth
S1	Sandy clay - clay	Superficial to moderate depth: 12-75 cm.
S2	Coarse, medium and fine sand	from 0 to 75 cm
S3	Loamy to sand	moderate depth 25 to more than 75 cm
S4	Rock - outcroping and slopes, more than 70%	without

These types of surface formations were defined in base to the information analysed and adapted from soil map scale 1:200.000.

4) MAP OF CLIMATIC AGGRESSIVITY

Symbol	Degrees of climatic aggressivity	Precipitation intensity
I1	Weak	Less than 20 mm/ hour/30'
I2	Moderate	20-50 mm/hour/30'
I3	Strong	more than 50 mm/ hour/30'

The degree of climatic aggressivity was defined in three classes according to the study that is being made in seven runoff experimental plots (by PRONAREG-ORSTOM-PRONACOS).

RESULTS

Based on the analysis and adaptation of the overlaped different thematic maps, the results are the following:

Causes of Actual Erosion

With former knowledge also was overlaped each variable on the map of actual erosion process with the purpose to define the dominant formula according to the frequency of the affected surfaces: ICPS.

With this procedure it was possible to know the percentage of each one and its area in square kilometers. The way to obtain these results is indicated in the following table:

Formula	PARTIAL SURFACES OF EACH FORMULA (SP)		TOTAL SURFACE FOR EACH FORMULA (ST)	% OF EACH FORMULA RELATION TO THE TOTAL
I2 C1 P5 S4*	1 + 1.5 + 2 + 5 + 2	=	11.5	15.6
I2 C1 P4 S4	1.5 + 0.5	=	2.7	2.7
I2 C1 P2 S2	1.5	=	1.5	2.0
I2 C1 P5 S4	4.5	=	4.5	6.1
I2 C2 P4 S4	7.0 + 2	=	9.0	12.1
I2 C3 P5 S3	2.5 + 1	=	3.5	4.7
I2 C3 P5 S4	2.5	=	2.5	3.4
I2 C3 P5 S2	2.0	=	2.0	2.7
I2 C3 P1 S2	1.5	=	1.5	2.0
I2 C3 P5 S4	22.0 + 12.0	=	34.0	46
I2 C3 P4 S4	2.0	=	2.0	2.7
	TOTAL	=	74.0 cm^2 = 296 km^2	

* According to the results obtained until this date from seven runoff experimental plots was considerated that the climatic aggressivity (I) is the first variable that is cause of actual erosion process and next one is vegetal protection (C) followed by the slopes (P) and finally the superficial formations (S). In the present example I2 represents the degree of dominant climatic aggressivity in all hydric erosion processes.

From the interpretation of these results the conclusion is that the dominant formula according to its frequency and affected area is: I2C3P5S4 in a surface equivalent to the 46% of the total area affected by very concentrated runoff (296 square kilometers)

I2	C3	P5	S4
Moderate climatic aggressivity: precipitation intensity between 20-50 mm/hour/30'	Bad vegetal protection	Slopes: more than 70%	Soils with actual cangahua outcropping

However before following the analysis of the variables in all the zones, it is necessary to make some considerations about the zones represented by the very concentrated draining.

In this sense it is necessary to indicate that with the field work and the soils and actual use of the soils surveys of those zones it was possible to prove that they have a dominion of areas with to the abrupt or broken lines which represent subvertical faces with natural vegetation and with intermittent water course, meaning inherited erosion, with low intensity at present. Also these brokwn lines are basically formed by outcrop of hard material that is normally cemented by silica and calcium carbonate.

In order to find the variables that explain the actual erosion process, its forms of erosion and risk, and based on former considerations, it was necessary to eliminate from this analysis three zones, because their origin belong to other morpho-climatic period. In the same way and according to the following procedure for the very concentrated runoff zones, it was carried on the analysis of each one of the eroded zones.

First, according to each variable, and after, based on the affected surface. Hereafter it is presented the calculation for each process.

Zones with eolic and runoff process

Formula	SP	ST	% in relation to the total
P5 C(1.2)S2	2.5	2.5	15.6
P3 C(4.2)S2	1.5	1.5	9.3
P3 C2 S1	1.0	1.0	6.2
P3 C(1.2)S3	3.0	3.0	18.9
P3 C(1.2)S2	1.5	1.5	9.4
P3 C3 S3	0.5	0.5	3.1
P3 C3 S2	0.5 + 4	4.5%	28.1
P4 C3 S2	1.5	1.5	9.4

TOTAL: 16.0 cm^2 = 64 km^2

Zones with small mass movements and runoff process

P2C351 0.5

Total: 0.5 square centimeters = 2 square K

Zones with eolic process

P1 C2 S1	2.0	2.0	26.6
P1 C3 S2	0.5	0.5	6.7
P1 C3 S2	0.5	0.5	6.7
P1 C3 S2	2.0 + 2 =	4.0	53.3
P1 C3 S2	0.5	0.5	6.7
	TOTAL	7.5 cm^2 = 30 km^2	

Zones with concentrate and diffuse runoff

P4 C2 S3	4.0	4.0	10.3
P4 C2 S2	3 4	= 7.0	17.9
P4 C3 S2	4 1	= 5.0	12.8
P3 C3 S2	1.5+1+3+5+2 =	12.5	32.0
P3 C2 S3	3.5	3.5	9.0
P3 C2 S1	2.0	2.0	5.1
P2 C3 S2	1	1.0	2.6
P2 C2 S2	1	1.0	2.6
P3 C3 S2	3	3.0	7.7
	TOTAL	39 cm^2 = 133 km^2	

The total eroded area as a result of past and actual processes including the very concentrated runoff, is in total 548 square kilometers that represents a 6% approximately of Latacunga-Ambato map. The affected area for all actual erosion process is approximately 252 square kilometers that represents 3% of the total surface of Latacunga-Ambato map. The affected area by the dominant actual erosion process (concentrated and diffuse runoff) is 133 square kilometers that is equal to the 1.5% of the total surface of Latacunga-Ambato map.

Potential Erosion

After the definition of the dominant formula from variable group for each zone with actual erosion it was possible to elaborate the risks map or potential erosion map. For example, for processes of concentrate

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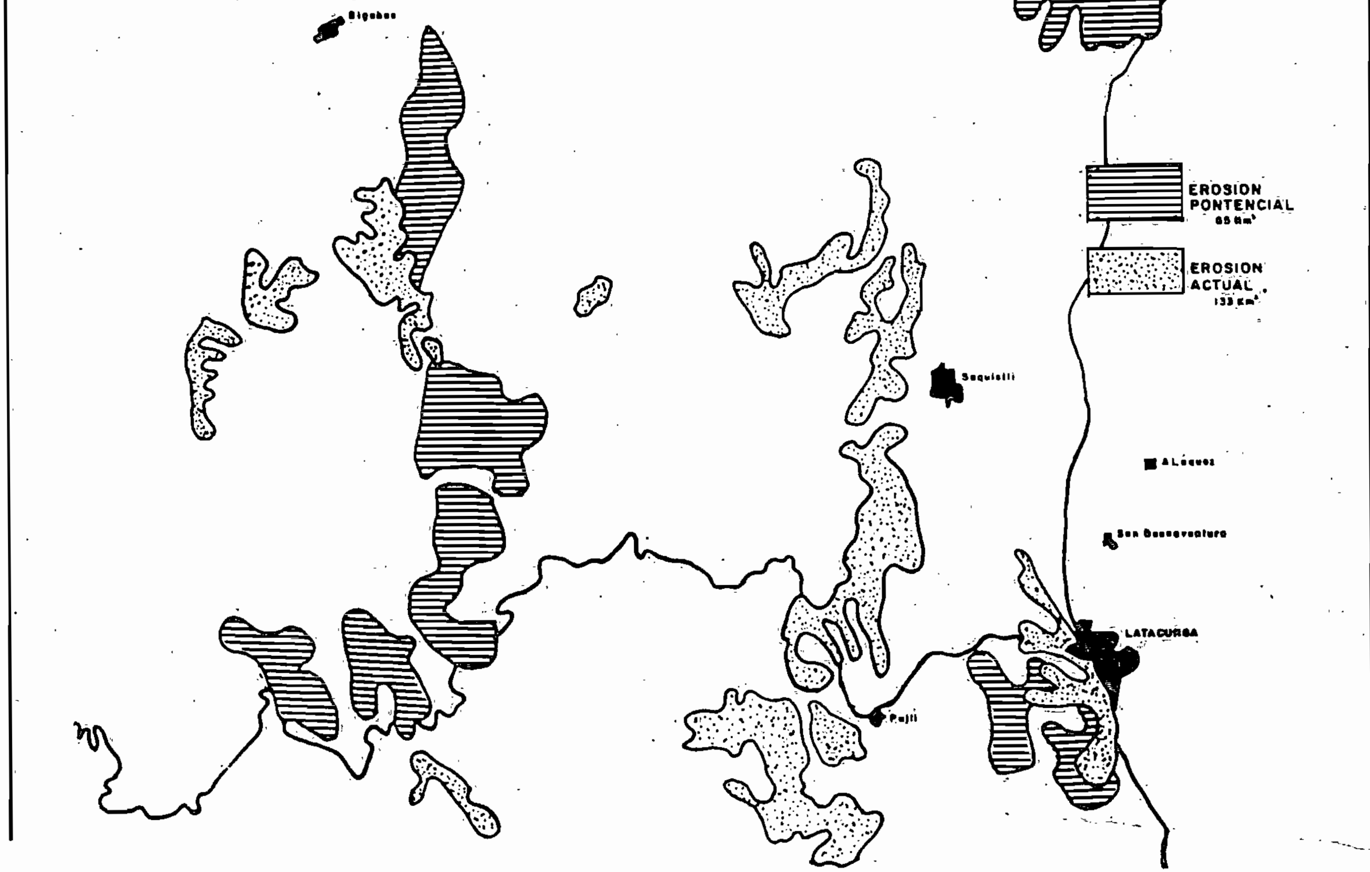
EXAMPLE CONCENTRATE AND DIFFUSE DRAINING



and diffuse type runoff, which is the most important for the affected surface, it was possible to define the zone with potential erosion in base of the dominant formula that represents this process: I2C(3.2)P(4.3)S2. Based on this formula it was determined in the map of plant cover protection the class 2 (moderate) and 3 (bad), afterwards in the map of slopes the class 3 (25-50%) and 4 (50-70 %). The same operation was carried on the surface formation map in the sandy soils (S2). When this task was concluded, by overlaping the maps it was possible to determine the zones with erosion risks or zones of potential erosion that in this case are approximately 65 km^2. In the same way it was determined the potential erosion for other zones affected by other types of erosion process.

CONCLUSIONS

From this proposed methodology it is possible to obtain a new knowledge regarding the erosive phenomena according to the following information:

- To determine fron the cartographic and geomorphological point of view the different types of erosion processes.

- To define the actual causes of the erosive process based on a compound formula that includes explicative variables of this phenomena (factors that are the origin and conditioning factors of erosion), classified according to their importance.

- To determine for each type of actual erosion process the potential zones in which they develop.

Finally, it is very important to have a diagnosis about the erosion process with its causes and risks for each agricultural zone with problems of this kind before defining policies related to the use and conservation of soil and water. Really, the comparison of this new information summarized in the three former points, plus information related to the actual use of the soil and land capability is a good data source base, to improve any type of agricultural planification.

UNIVERSIDAD CENTRAL
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SOCIEDAD VENEZOLANA DE LA CIENCIA DEL SUELO

SOIL CONSERVATION AND PRODUCTIVITY

PROCEEDINGS
IV INTERNATIONAL CONFERENCE ON
SOIL CONSERVATION
MARACAY-VENEZUELA, NOVEMBER 3-9, 1985

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"SOIL AND WATER
CONSERVATION TO
PREVENT FOOD
SHORTAGE"

"CONSERVACION
DE SUELOS Y AGUA PARA
PREVENIR DEFICIT
DE ALIMENTOS"

This volume is based on the

IV INTERNATIONAL CONFERENCE ON SOIL CONSERVATION

held in Maracay, Venezuela - November 3-9, 1985

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SOIL CONSERVATION AND PRODUCTIVITY

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Apartado 1208 - Las Acacias
Maracay, Venezuela

MANUFACTURED IN VENEZUELA

ISBN 980-265-924-X