46 Soil Erosion and Conservation Research in Ecuador

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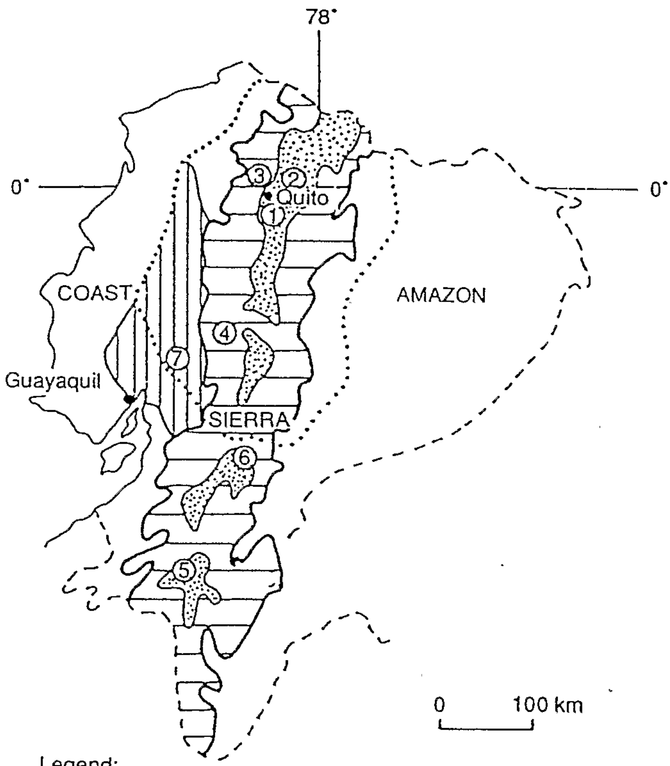
Among countries on the South American continent, Ecuador, with a total area of 270,670 km², is relatively small. It is characterised by the richness of its renewable natural resources, owing primarily to its equatorial location and the volcanic cordillera of the Andes. The mountains are responsible for a wide range of weather types, which vary over short distances, and soils with a rich agricultural potential. Since time immemorial man has profited from these favourable conditions and developed a flourishing agriculture with a great diversity of products ranging from tropical to temperate. At present, agriculture is a primary source of foreign exchange together with petroleum products (accounting for 40% and 50% of exports respectively).

Between 1974 and 1984 the French overseas development authority ORSTOM participated in the preparation of a cartographic inventory in scientific collaboration with the Ministry of Agriculture and Livestock of Ecuador (Figure 1). Several hundred maps resulted from this joint effort. Research activities in the programme were particularly detailed (at a scale of 1:50,000) in the Andean region of Ecuador known locally as *Sierra*. This region is geographically characterised by its equatorial location, its high mountain relief, and an extremely high density of agricultural activity. Earlier works by Colmet-Daage on soils (1978) and Gondard on land-use types in the *Sierra* (1981–83) made possible a better understanding of the area and stressed the importance of soil erosion as a limiting factor which is a considerable hindrance to the growth of agriculture. Water erosion in the form of rills is the dominant type of soil erosion (De Noni 1982).

THE ANDEAN CORDILLERA: THE IMPORTANCE OF NATURAL CONSTRAINTS

The Andes form an immense mountain barrier constituting an environment which is highly vulnerable to soil erosion because there is a direct relationship between slope, precipitation, agricultural use and the intensity of soil erosion. This enormous mountain system extends throughout the country, varying in width from 100 to 200 km, separating into two



Legend:

Inter-andean basin (1,500-2,800 m): Maize, pasture
Slopes of the Cordilleras (3,000-4,400 m): Potatoes, barley
Coastal region: Tropical agroforestry, pasture, maize

Borders of the Cordilleras
Limit of volcanic ash deposits

Erosion research stations (established: 1986-88):

1	Tumbaco	5	Loja
2	Cangahua	6	Cuenca
3	Mojanda	7	Ventanas
4	Riobamba		

FIGURE 1. Location of research stations of ORSTOM in Ecuador (De Noni et al 1989–90).

mountain ranges (cordilleras). The mountains have long and steep slopes (gradients over 50%) sected by gorges known locally as *quebradas*. In between the two cordilleras is an inter-Andean basin made up of a succession of basins with irregular topography and slopes (10–50%). The three different types of landscape that can be distinguished are described below.

The Zone Containing the Inter-Andean Basin

Although irregular, slopes are steep on the whole and this landscape is characterised by highly degraded volcanic soils. One example of such degradation is the particular land cover type known as *Cangahua*, a hard, infertile ash unsuitable for agriculture which covers 20% of the zone. The inter-Andean basin can be subdivided into two subzones:

- The first subzone is situated below the general level of the basin at an altitude below 2,400 m. It is a relatively flat area of low slopes (0–20%) and depressions covered with dry, bushy cactus and spinous vegetation. Traces of erosion exist everywhere, both in the parts which are only marginally protected by vegetation and in those which are irrigated but where water management is not sufficient.
- The second subzone of this inter-Andean basin is situated between 2,400 and 3,200 m. This is the actual basin, distinguished by a flat area with low slopes of less than 10% where a majority of the large farms (*haciendas*) are located. Erosion is not a major problem here. A dense network of deep valleys and canyons can also be observed, testifying to active regressive erosion on steep slopes of over 100%. Finally, in the higher parts near the mountains there are foothills with gradients over 25% where agriculture takes the form of small-scale farms (*minifundio*). This area is also characterised by a high degree of soil erosion.

The High Andean Zone

The high Andean zone extends upwards from 3,200 m . Slopes are between 40 and 70% while the river beds, which show the effects of heavy glacial erosion, have gradients between 20 and 40%. This is an area undergoing change where small-scale farms (*minifundio*) have been established for about 20 years.

The Zone Containing the Outer Slopes of the Mountain Systems

Here, the morphology resembles that found in the previous zone but there are even steeper slopes (over 70%). As altitude decreases, the vegetation cover becomes more dense and the prairies and temperate agricultural areas are progressively replaced by tropical vegetation.

The agricultural zones of the *Sierra* are highly sensitive to soil erosion as a result of the struggle with nature to establish agriculture. Erosion has become one of the principal features of the landscape. Because the soil has been totally degraded, one can often observe abandoned land. Furthermore, soil degradation means that agricultural plots have a low crop density.

Whatever the process of degradation, man has contributed to its acceleration. There are numerous examples of this trend. One can frequently observe the traditional agricultural practice of soil hacking with *l'asadon* (a type of hoe) up and down the slopes and on heavily cultivated slopes which have 100% vegetation cover in places and gradients between 40 and 70%. Tractors, whose role is becoming increasingly important, work the soil on slopes with gradients of up to 60%. Whenever the need for conservation becomes obvious, farmers usually put drainage ditches (known locally as *rayas*) across the slopes. These ditches do not provide sufficient protection against soil erosion because they are not dimensioned sufficiently for extreme events and because they do not have safe outflow and water collection systems.

SOIL EROSION IN ECUADOR

Mapping Principal Erosion Processes

On the basis of a general map of soil erosion produced for Ecuador, it was determined that 50% of the country's surface area is affected by processes of soil degradation. The Andes Mountains are the region with the greatest degradation: about 15% of the eroded land is found in the inter-Andean basin (1,500–3,000 m) and the remaining 35% is found in the highlands and on the outer slopes of the Andean cordillera. This also affects the coastal and Amazon regions to a minor degree. Soil erosion represents a potential local hazard in the latter two areas. In fact, along the coast as well as on the Galapagos Islands, soil erosion generally is barely visible. The provinces of Manabi and Esmeraldas are the most affected: here there are mass movements involving pasture land and associated with gravitational phenomena on the borders of the *mesas.* One hardly observes soil erosion in Amazonia. However, the intensity of chemical degradation is cause for concern and classical soil erosion could also develop there. The map also made it possible to assess the importance of the linear erosion of rivers.

Soil erosion damage is considered here in a larger sense, including rilling, transport and accumulation (Derruau 1988). During the cultivation period on agricultural land—9 months of the year from December to May—erosion by rain and anthropogenic erosion produce the results described below (De Noni 1982).

- Runoff is sheet-like as well as concentrated. This is the type of soil erosion which occurs particularly along the slopes of the inter-

Andean basin — with the exception of the Cuenca zone — regardless of the soil type and its geological origin. Landscapes suffering from this process have soils which are very shallow, mixed in their horizons and marked by forms of soil erosion extending from rills to gullies.
Soil loss studies carried out on test plots showed that the minimum intensity of rainfall needed to initiate such a process is between 10–15 mm/h. On slopes steeper than 10–20%, and wherever rainfall is sufficient, the effects of concentrated runoff become overwhelming and are apparent everywhere on the slopes. Depending on cohesive forces, texture and structure of the material, gorges and gullies show cross-sectional profiles from U-shapes to V-shapes. These linear forms rapidly develop into entire "badland" zones.

- Runoff associated with small mass movement is a process typical of soils which have a textural discontinuity with little depth. For example, in the northern part of the country (provinces of Carchi and Pichincha) as well as in the centre of Ecuador (province of Chimborazo) in the *Sierra*, a clayey, dark volcanic ash overlays another type of very hard ash called *cangahua*. Landslides of the clayey ash on the *cangahua* cause erosion in small steps. These small steps very rapidly produce areas 3–5 m long with the help of surface runoff. Joint processes of this type are initiated on slopes with gradients greater than 15–20%.
- Mass movements are localised in the basin of Cuenca, further north in the Cumbe zone. Erosion is manifested here by niches of solifluction which develop on hilly relief and on non-volcanic, reddish or red clayey soils. Here, the topographic profile of slopes is very irregular and the whole landscape looks bubbly.

Soil Erosion Measurements

Between December 1981 and June 1984 the authors established 5 test plots in order to measure soil loss and runoff on 50 m^2 (10 m$\times$5 m) areas. These test plots were enlarged after 1986 to form a station. They included plots with central conditions as well as experimental plots placed directly on farmers' fields. Every station was systematically equipped with two test plots, each with a surface area of 100 m^2, one graded as a control plot (continuous fallow) according to the prescriptions of Wischmeier and Smith (1978) and one cultivated by traditional methods. In addition, in some stations one or two experimental test plots with an area of 1,000 m^2 were installed to test simple conservation measures.

The following information was obtained between 1981 and 1984 on the 50 m^2 test plots:

- In Alangasi, two test plots were set up on a black loamy clay soil 30–40 cm deep developed on hard ash (*cangahua*). One plot on a slope, soil loss was 0.5 t/ha for 1986–87 and 7.6 t/ha for 1987–88 on the experimental plot; 1.6 t/ha for 1986–87 and 52.2 t/ha for 1987–88 for the 100 m^2 control plot; and 66.5 t/ha for 1986–87 and 189.7 t/ha for 1987–88 on the Wischmeier plot.

All in all, the above data indicate that soil loss from bare Wischmeier plots is considerable. The irregularity of erosive events from year to year is remarkable. What is certain, based on systematic observation, is that soil losses at all stations were smallest on the experimental plots.

TABLE 1
Conservation measures as tested on experimental plots

Station	Slope (%)	Type of cultivation	Conservation method on the experimental plots
Tumbaco	20	Maize (86–87); maize (87–88)	Grass strips with 3 grass species and pastures
Cangahua	20	Maize (86–87); maize (87–88)	Walls made of *cangahua*
Mojanda	40	Barley/potato/horse-bean (both years)	Walls made of sod and large areas planted with *quinoa*
Riobamba	20	Potato/barley/horse-bean (both years)	Grass strips in association with cultivated land (barley and horse-bean)

SOIL CONSERVATION IN ECUADOR: THE ORSTOM-MAG PROJECT

The overall lack of soil conservation methods and techniques made it difficult to select cultural and biological methods of soil conservation to be tested in the stations (De Noni, Viennot, Trujillo 1986). Moreover, any choice of measures should take the particular characteristics of the physical and human environment of the *Sierra* into consideration. On-farm and project experience gained in the USA or in West Africa is difficult to apply to mountainous farming systems in the Andes. Consequently, we decided to use conservation measures in the form of contour strips with walls made of stones or grass as barrier plants. Such systems seem to be a good method of controlling erosion since they retain soil while allowing surface runoff to pass through. Finally, little maintenance work is required from the farmer. Such conservation measures also promote increased infiltration of water behind the bunds, something of particular importance in the inter-Andean basin which is confronted with reduced rainfall and problems of water balance during the cultivation period. The spacing between contour structures was empirically set at 12 m.

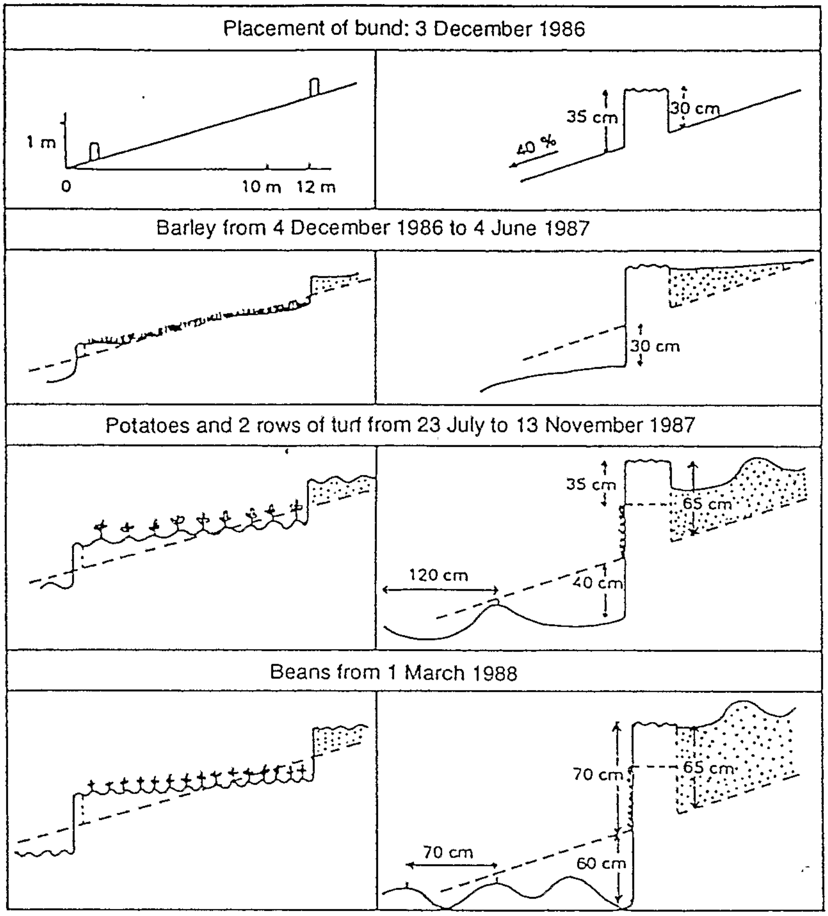


FIGURE 2. Terrace development from small earth walls due to cultivation practices, Mojanda Station, Ecuador (De Noni et al. 1989–90).

100 m bund. It is remarkable that the evolution of such a terrace is the result of cultivation alone and not of soil erosion.

The results of research on these experimental plots in the Andes Mountains of Ecuador are expected to have a considerable impact on the agricultural development of the region. They correspond fully with the expectations of our national partners in research (De Noni; Trujillo; Viennot 1987). In early 1989, based on these results, our national partners were able to initiate concrete conservation activities with farmers and expand their activity at the national level.

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Erosion, Conservation, and Small-Scale Farming

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* De Noni (G.) 1.549
* Roose (E) 1.349
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