Enregistement scientifique : n° 2549
Symposium : n° 38
Presentation : poster

Landuse and degradation of an altitudinal ecosystem : the páramo. Consequences on hydrodynamic properties of the recent volcanic ash soils

Utilisation des terres et dégradation d'un écosystème d'altitude : le páramo. Conséquences sur les propriétés hydrodynamiques de sols sur cendres volcaniques récents

POULENARD Jérome[1-2], PODWOJEVSKI Pascal[2], JANEAU Jean-louis[2], VIVEROS Pablo[3]

1 CNRS, Centre de Pédologie Biologique, 17 rue N-D des pauvres, 54501 Vandoeuvre les Nancy, France
2 ORSTOM quito ; Programme Gestions de zone d'altitude; AP 17 11 65 96 Quito Ecuador
3 Empresa Municipal de Agua potable de Quito, Quito, Ecuador

The páramo is constituted by altitudinal grasslands and is located on the northern part of the Andes chain (mainly in Venezuela, Colombia and Ecuador). The páramo occurs between the upper part of the andine forest and the lower limit of permanent snow. A tall graminacea (poacea), in dense tufts, forms the main part of the vegetation. The climate is very severe : low annual average temperature, high humidity with moderate rainfall, very weak evaporation.
With their high water retention, the soils of the páramo play an important rule in the watercycle in the Andes. They work like a hydric regulating mecanism : retention during humid periods and progressive liberation of water during dry periods.
Unfortunately, the function of the páramo is disturbed by a damaging landuse. They are caused by a progressive colonization of altitudinal grasslands by repeated fires, or by a cultivation (mainly potatoes). These grasslands are favourable to extensive pastures, exclusively for sheeps. But the surfaces of the pastures decrease while the size of the herds tend to increase forming locally an extreme overpasting.
Using rainfall simulation we have studied the consequences of land use on the soil hydrodynamic of Ecuadorians páramos. These simulations take in account the pedological diversity of the páramos : andisol still dominated by volcanic glass and melanic andisol with high water retention. They have been realized on undisturbed, burned, overgrazed and on cultivated páramo.
The results show a very high infiltration rate in the undisturbed páramo with both types of soil. Meanwhile in the case of anthropic degradation of páramo the results show a very drastic increase of runoff and erosion. For the well-developped Andisols this increase of runoff is linked to a development of hydrophobic aggregates. These soils content high amounts of allophane or Al-humus complexes and show an irreversible water-retention by drying.For the vitric andisol the high runoff rate is due to a crust formation process.
Some solutions have been suggested : (1) increase the yields of the cultivated surfaces to limit a colonization of the páramo, (2) increase the cultivable surface by the rehabilitation of eroded hardened volcanic ash soils (cangahua) located further down stream, and which present a high agronomic potential (3) modify the grazing uses by the introduction of the lama, specy much more adapted to these high grasslands.

Key words : degradation, rainfall simulation, volcanic ash soil, runoff, erosion, Ecuador
Mots clés : dégradation, simulation de pluie, sol de cendres volcaniques, ruissellement, érosion, Equateur

Enregistement scientifique : n° 2549
Symposium : n° 38
Presentation : poster

Landuse and degradation of an altitudinal ecosystem : the páramo. Consequences on hydrodynamic properties of the recent volcanic ash soils
Utilisation des terres et dégradation d'un écosystème d'altitude : le páramo. Conséquences sur les propriétés hydrodynamiques de sols sur cendres volcaniques récents

POULENARD Jérome[1-2], PODWOJEVSKI Pascal[2], JANEAU Jean-louis[2], VIVEROS Pablo[3]

1 CNRS, Centre de Pédologie Biologique, 17 rue N-D des pauvres, 54501 Vandoeuvre les Nancy, France
2 ORSTOM quito ; Programme Gestions de zone d'altitude; AP 17 11 65 96 Quito Ecuador
3 Empresa Municipal de Agua potable de Quito, Quito, Ecuador

Páramo : definition and properties :

The páramo is constituted by altitudinal grasslands and is located on the northern part of the Andes chain (mainly in Venezuela, Colombia and Ecuador)
The páramo occurs between the upper part of the andine forest and the lower limit of permanent snow.
A tall graminacea (poacea), in dense tufts, forms the main part of the vegetation. The climate is very severe : low annual average temperature, high humidity with moderate rainfall, very weak evaporation.
The soils are mainly recent volcanic ash soils which have progressively involve in function of the local climate and their age in vitricryands towards hydric melanocryands with a higher water retention (> 200% at 33 Kpa) (Poulenard et al. 1998).
With their high water retention, the soils of the páramo play an important rule in the watercycle in the Andes. They work like a hydric regulating mecanism : retention during humid periods and progressive liberation of water during dry periods (Guhl, 1968).

The degradation of the páramos

Unfortunately, the function of the páramo is disturbed by a damaging landuse. They are caused by a progressive colonization of altitudinal grasslands by repeated fires, or by a cultivation (mainly potatoes). These grasslands are favourable to extensive pastures,

exclusively for sheeps. But the surfaces of the pastures decrease while the size of the herds tend to increase forming locally an extreme overpasting (Acosta-solis, 1986).
These practices have important consequences on the ecology of the páramos plants : decreasing of the biomass, of the soil cover, but overall drastic decreasing of the water retention (humidity on field or at pF 2.5) and modification of the cation exchange capacity. The reduction of the high infiltration rate of these soils and the increasing of the runoff may induce uncontrolled water risings and limit the water availability during dry periods.
The main objectives of this present study is to analyse using rainfall simulation the consequences of land use on hydrological characteristics of the volcanic ash soil of neotropical alpine grassland (páramo).

Materials and methods

The rainfall simulator is the Orstom field infiltrometer (Asseline and Valentin, 1978). Two sites have been selected. One (site A) is located on the Pichincha Volcano near Quito at 4000 m a.s.l. The soil of this site is typically a vitric andisol. The results of soil characterization (Table 1) schown a relative high apparent density, a low amounts of amophous constituents (with a Alox+1/2 Feox < 2 %). .The soil is classified as an Thaptic vitricryands (Soil Survey Staff, 1994) or Vitric Andosols on the World Reference Base (Spaargen, 1994).
The second site (Site B) is located in the Carchi province, on north Ecuador at 3600 m a.s.l. . The soil is well developped andisol with large amounts of amorphous constituents (Alox + 1/2 Feox > 2 %) (Table 1). The bulk density is here very low with high associated porosity and the soil present a high water retention.
The soil is classified as an pachic and humic melanocryands (Soil Survey Staff, 1994) or Melano-alu Andosols on the modified WRB (Shoji et al., 1996).

Table 1 : Basic soil characteristics of the studied sites

	Depth (cm)	Bulk density ($g.cm^{-3}$)	Water content at 0,03 mPa ($kg.kg^{-1}$)	Alox+1/2 Feox (%)	Alp/Alox
Pichincha (A)					
1 A1	0-20	0,82	0,68	0,52	-
1 A2	20-40	0,9	0,550	1,05	0,72
2 A3	40-55	0,7	0,55	1,96	0,21
Carchi (B)					
1 A1	0-30	0,4	1,97	1,4	0,96
1 A2	30-85	0,6	1,24	3,06	0,41
2 A3	85-140	0,4	1,45	2,92	0,88

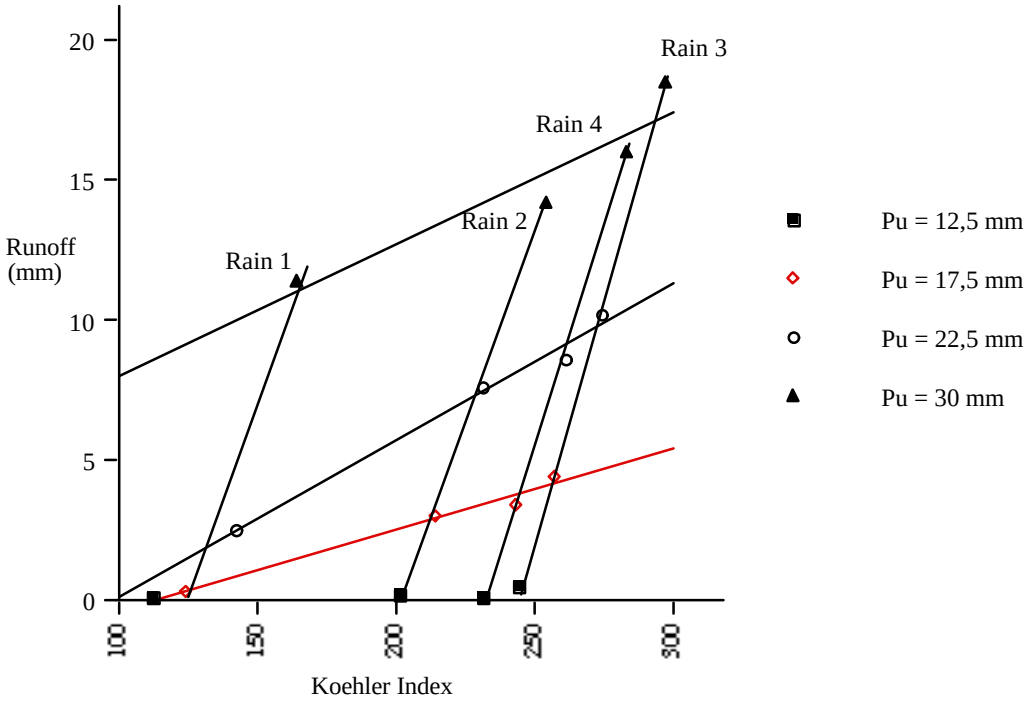
The rainfall simulation have been realized on both site on undisturbed, and on tilled páramo. Other simulations have been realized : burned in the Pichincha site and cultivated in the Carchi site. Three repetitions have been done for each land use. Four rain fall have been realised for each plot. The second rain occurs 3 hours after the end of the first rain, the third 12 hours after the end of the second and the fourth, 24 hours after the end of the third.
The koehler index is use to schow the effect of water content on the hydrodynamic. This index is calculated by : $Ik = Ik_{n-1} + Pu_{n-1}\, e^{(-a.ta)}$ where Ik is the koelher index; Pu, the

rain in mm; ta the time beween two succesive rainfall and a a coefficient. This index is adjusted on moisture content mesured on sample.
The hydrophobic process is mesured by a simple field test. A calibrated drop of water is put on agregates. The time of residence of this drop (TRD) in the aggregates superficie is mesured. This very simple procedure need many repetitions to be usefull. During each experiments, 40 repetitions have been done.

Results and discussions

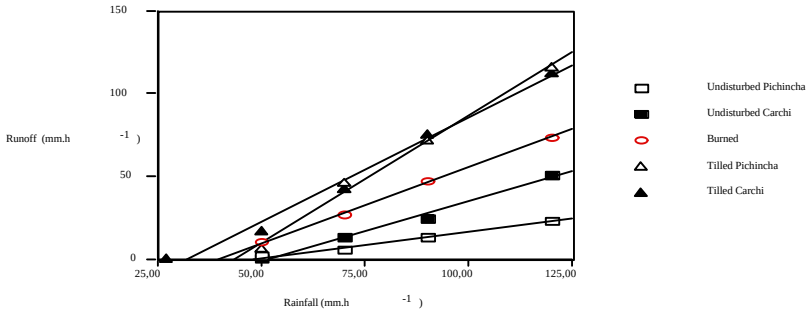
The results show a very high infiltration rate in the undisturbed páramo with both types of soil : the rate of runoff is less than 30%. The relation between runoff and Koehler index for undisturbed paramo of the pichincha site is shown in Fig n°1. There is a linear relation between soil moisture before the rain and runoff. With natural cover, in both site, the infiltration rate is controlled by moisture content of soil before the rain without crust fomation process.

Fig n° 1 : Runoff vs. Ik for Pichincha undsturbed site



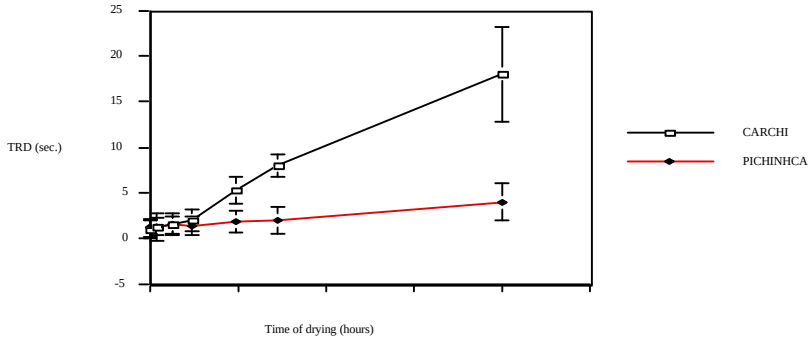
With Pu = Rainfall in mm

In the case of anthropic degradation of páramo the results show a very drastic increase of runoff intensity (Fig n°2). The effect of burning seems to be lower than for the tillage but in burned páramo the runoff is near 50 % higher than in undistrubed.
Fig n°2 : Relation between rainfall intensity and runoff intensity for different landuse



The effect of tillage seems to be the same for the both site. But the process is very different with formation with drying of hydrophobic agregates in the site with a well developped andisol (Fig n°3) and crust formation in the vitric site.
These results shown the effects of drying superficie in the gensis of runoff. The soil with large amounts of amorphous constituents which have major water retention change with drying are more suscpetible to runoff after tillage.

Fig. n°3 : Time residence of a drop vs. time of drying



Results of sediment loss during the simulated rainfall are in table n°2.The erosion is very low in undisturbed páramo and higher in used páramo.The erosion rate is particularly important in cultivated páramo. We have here an erosion by floating of agregates. The stable microagregates resulting of drying with low bulk density float on the runoff.

Table n°2 : Sediment loss in different landuse

	Sediment loss (g)			
	Rain 1	Rain 2	Rain 3	Rain 4
Undisturbed Pichincha	2,4	6,9	9,2	2
Undisturbed Carchi	6,5	9	10	3
Burned	33	83	101	47
Tilled Pichincha	92	166	231	93
Tilled Carchi	16	59	56	23
Cultivated	84	604	**446**	**350**

Conclusion

The effect of change in landuse are very important in hydrodynamic properties of volcanic ash soil of the páramo. The increase of runoff and erosion of the páramos is a major risk for the Andean population. Some solutions have been suggested to reduce this risk : (1) increase the yields of the cultivated surfaces to limit a colonization of the páramo, (2) increase the cultivable surface by the rehabilitation of eroded hardened volcanic ash soils (cangahua) located further down stream, and which present a high agronomic potential (3) modify the grazing uses by the introduction of the lama, specy much more adapted to these high grasslands.

References

Acosta-Solis M., 1986.- Los páramos del Ecuador.-Cultura, Vol VIII, n°24 a, 211-220

Asseline J., Valentin C., 1978.- Construction et mise au point d'un infiltromètre à aspersion.- Cah. ORSTOM, sér, Hydrol. Vol XV, n° 4, 321-349

Guhl E., 1968.- Los paramos circundantes de la Sabana de Bogota : Su ecologia y su importancia para el régimen hidrologico de la misma.- Coll. Geogr. n°9, 195-212

Poulenard J., Zebrowski C., Podwojevski P., Jeanroy E, Collinet J. Herbillon A.J., 1998 .- Les sols sur pyroclastes des páramos d'Equateur : Caractérisation générale.- Scéance thématique de l'AFES, Sols de montagne

Shoji S., Nanzyo M., Dahlgren R., Quantin P., 1996 .- Evaluation and proposed revisions of criteria for andosols in the world reference base for soil resources.- Soil Science. Vol. 161, N°9

Spaargaren O. (ed), 1994 .- World Reference Base for soil resources.- ISSS, ISRIC, FAO, Wageningen/Rome

Soil Survey Staff, 1994 .-Key to soil taxonomy, 5 th. Edition.- SMSS Tech. Monogr. N°19

Key words : degradation, rainfall simulation, volcanic ash soil, runoff, erosion, Ecuador

Mots clés : dégradation, simulation de pluie, sol de cendres volcaniques, ruissellement, érosion, Equateur