OVERGRAZING EFFECTS ON SOIL PROPERTIES IN THE PÁRAMO OF LLANGAHUA AND ESPERANZA (TUNGURAHUA, ECUADOR)

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High Andean grassland, or "Páramos", is a high-altitude ecosystem. It is usually located between the upper part of the mountain forest at 3500m above sea level and the lower part of the permanent snow at 4500 m a.s.l. The Páramo occurs irregularly in Venezuela, Colombia and Ecuador. The continuous grass layer forms the dominant ground cover. Soils developed on recent (Holocene) volcanic ashes in the entire northern half of Ecuador. The high water-retention properties of these soils associated with the specific vegetation confer to the Páramo an important role in water availability which is paramount for the majority of the Ecuadorian population (Luteyn, 1992).The study area is located in the province of Tungurahua on the occidental chain, 20 km north-western of the basis of the Chimborazo volcano with an elevation ranging from 3800 to 4200 m (Fig. 1).Due to a rapid increase of the rural population, especially after the agrarian reform of 1970, these areas were often degraded due to overgrazing. This study intended to show the effects of overgrazing by sheep on soil properties and vegetation in a transition zone from a sub-humid to a dry Páramo, managed by an indigenous community.

Soil properties. Due to the homogeneity of the recent deposits, most probably originated from the same source (Cotopaxi and/or Tungurahua; Winckell et al., 1991), the pedological differentiation results only from different climatic conditions (Colmet-Daage et al, 1967.). In the humid zone (north of the studied area), the soils have an udic regime and generally andic properties with a low bulk density (< 0.9), high accumulations of organic matter (>6%), and contain amorphous constituents (Quantin, 1995; Shoji et al, 1996). In the dry zone soils have an ustic regime with vitric properties, exposing a high amount (> 60%) of non-weathered primary minerals. Both types of soils have a bimodal granulometric composition (peaks at 10 μm and 100 μm) typical of volcanic deposits while in the southern part of the area soils are highly aeolian dependent with a monomodal granulometric peak at 100 μm which leads to a rapid transition to a xeric regime.

Overgrazing effects: Two main overgrazing effects impact on vegetation. Firstly, a strong decrease of the biodiversity (Jørgensen and Ulloa, 1994) and the accompanying biomass within the same area. This was similar to the effect of climatic change as evidenced in a more extended zone (Hofstede et al, 1995 ; Pels and Verweij, 1992). Secondly, the increase of the bare surface due to trampling which in turn increases the risk of erosion by favouring preferential paths for water flows and consecutive of steep slopes.

Destruction of the soil-cover results in the direct exposure of the topsoil at the surface and eventually to irreversible desiccation. This degradation appears as a retrogradation of evolved vitrisols-andisols to weakly evolved vitrisol by an increasing content of sand and slightly weathered minerals in the surface horizons, and, also to a decrease of the CEC. The Al+1/2Fe oxalate extract decreases from about 1.2% to less than 0.3%. The bimodal granulometric composition is less apparent in the upper horizon with a decrease of the 10 μm particles content. A possible segregation of fine particles is possible by lack of grass cover. This retrogradation is accompanied with a decrease of the Carbon content, most likely by mechanical erosion, from about 10g/kg to 4 g/kg. Moreover, the degradation of the soil cover induces a serious decrease of the soil-water content. In a humid area the soil moisture decreases from 70% to 15 % and in a dry area from 30% to less than 10%. However, it shows an important decrease of the water content at pF 2.5 after a complete saturation during 36 hours, at least. This means that the soil developed a strong water repellency which is more significant below the tussocks than on the bared surface.

Degradation of the Páramos by overgrazing does not affect solely the biodiversity, but also the soil properties. It results in a severe decrease of the Carbon content and an irreversible decrease of the soil-water content. The main recourse of sheep breeders is the selling of organic manure to the market gardeners of the Ambato valley so that the organic matter deficit is incremented. The organic layer of degraded soils exhibits also a strong water repellence which increases the erosion sensibility and limits water infiltration. In a long term perspective, the water reserves of the Páramo are expected to decline..

Fig. 1 : Location of the studied area

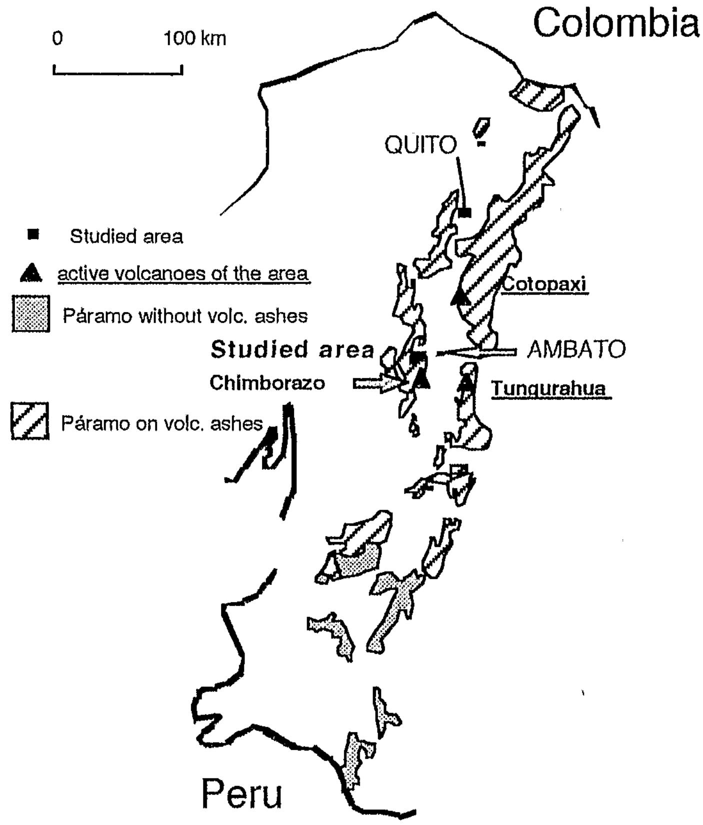

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Table 1 : some chemical properties of the upper horizons of caracteristic profiles of Llangahua and La Esperanza

profiles	horizons	pH H_2O	pH KCl	C	N	C/N	Exchangeable complex Ca^{++}	Mg^{++}	K^+	Na^+	Al^{3+}	S	CEC (T)	S/T
				g/100g	g/100g		cmol(+).kg^{-1}							%
HUMID PARAMO														
not degraded	LLA 20.1.	6.9	6.5	11.55	0.951	12.1	37.90	5.27	1.95	0.37	0.06	45.49	45.59	100
low flat area	LLA 20.2.	7.0	6.6	8.01	0.532	15.1	29.80	9.72	1.29	0.32	0.05	41.13	41.20	100
hill crest	ESP 41.1.	4.8	4.8	10.11	0.624	16.2	18.10	3.30	0.49	0.38	0.16	22.27	22.54	99
	ESP 41.2.	4.7	4.7	6.82	0.478	14.3	11.30	1.98	0.20	0.19	0.35	13.67	14.08	97
recolonization	LLA 21.1.	5.4	5.0	9.94	0.690	14.4	23.20	5.82	0.47	0.34	0.10	29.83	29.98	100
	LLA 21.2.	5.4	4.8	8.76	0.606	14.5	21.00	5.12	0.37	0.42	0.16	26.91	27.14	99
degraded	ESP 61.1.	5.2	5.1	7.94	0.495	16.0	22.90	6.41	0.41	0.34	0.10	30.06	30.18	100
weackly	ESP 61.2.	5.0	4.7	6.47	0.408	15.9	17.10	5.62	0.26	0.41	0.15	23.39	23.55	99
	LLA 22.1.	5.9	5.2	8.54	0.577	14.8	24.10	5.99	0.43	0.31	0.10	30.83	30.95	100
	LLA 22.2.	5.9	5.1	7.48	0.502	14.9	21.60	5.62	0.39	0.50	0.12	28.11	28.24	100
degraded	LLA 23.1.	5.4	4.9	4.74	0.322	14.7	18.30	5.98	0.37	0.61	0.13	25.26	25.42	99
strongly	LLA 23.2.	5.4	5.4	3.53	0.239	14.8	16.80	5.53	0.32	0.65	0.03	23.30	23.33	100
below tussock	LLA 24.1.			7.65	0.547	14.0	19.30	3.46	0.44	0.29	0.22	23.49	23.78	99
	LLA 24.2.			6.10	0.516	11.8	21.90	6.69	0.26	0.41	0.14	29.26	29.42	99
beside tussock	LLA 25.1.			5.56	0.444	12.5	20.00	5.42	0.33	0.31	0.10	26.06	26.18	100
	LLA 25.2.			4.66	0.347	13.4	18.80	5.25	0.36	0.40	0.10	24.81	24.92	100
DRY PARAMO														
not degraded	ESP 31.1.	5.3	5.3	6.95	0.425	16.4	20.50	4.96	0.61	0.21	0.06	26.28	26.37	100
	ESP 31.2.	5.0	5.0	5.44	0.380	14.3	16.10	4.39	0.27	0.38	0.11	21.14	21.27	99
degraded flat	ESP 21.1.	5.4	5.8	4.22	0.340	12.4	15.30	2.00	0.27	0.23	0.04	17.80	17.84	100
	ESP 21.2.	5.6	6.0	1.74	0.161	10.8	12.40	1.63	0.17	0.21	0.01	14.41	14.42	100
degraded slope	ESP 11.1.	4.8	5.1	4.02	0.280	14.3	11.90	2.27	0.33	0.16	0.06	14.66	14.73	100
below tussock	ESP 11.2.	5.7	6.0	1.70	0.133	12.8	13.50	3.17	0.52	0.23	0.02	17.42	17.44	100
EL ARENAL														
below tussock	ESP 1.2.	5.3	5.3	0.70	0.063	11.1	3.93	0.95	0.11	0.10	0.08	5.09	5.17	98
	ESP 1.3.	5.6	5.8	0.79	0.064	12.4	10.40	1.91	0.40	0.25	0.04	12.96	13.00	100
PANTANO														
organic matter	ESP 51.1	5.7	5.2											
	ESP 51.2.	5.2	5.1	12.42	0.966	12.9	23.40	8.36	0.57	0.52	0.08	32.85	33.00	100
	ESP 51.3.	5.3	5.1	7.52	0.559	13.5	20.10	6.42	0.42	0.57	0.07	27.51	27.62	100

Table 2. Some physical properties of the upper horizons of some caracteristic profiles of Llangahua and La Esperanza

profiles	horizons	texture CSa	FSa	CSl	FSl	Cl	H_2O	moisture	pF 300 KPa	B.D.
		g.100g^{-1}						g.100g^{-1}	g.100g^{-1}	
HUMID PARAMO										
not degraded	LLA 20.1.	3.1	15.0	2.1	34.0	35.5	5.9	53.08	68.37	
low flat area	LLA 20.2.	4.7	23.7	2.4	8.2	52.6	4.5	40.81	51.69	
hill crest	ESP 41.1.	3.7	22.3	10.5	33.9	6.9	4.3	89.80	77.61	0.68
	ESP 41.2.	5.7	26.4	7.6	30.4	12.7	4.6		70.48	
recolonization	LLA 21.1.	3.7	21.6	5.8	18.7	43.3	4.6	48.76	54.02	0.78
	LLA 21.2.	4.1	23.2	6.0	29.9	28.9	4.3	49.85	52.53	
degraded	ESP 61.1	3.4	16.5	9.8	30.6	3.3	5.1	31.30	42.59	0.80
weackly	ESP 61.2.	4.5	24.6	9.1	32.5	10.4	4.0	24.60	44.48	0.88
	LLA 22.1.	4.2	23.4	2.2	16.7	43.5	4.1	25.77	42.86	0.78
	LLA 22.2.	5.1	24.8	4.7	14.3	42.7	4.1	25.38	42.20	
degraded	LLA 23.1.	6.7	29.4	3.5	11.4	41.2	3.0	10.89	19.80	0.76
strongly	LLA 23.2.	8.1	30.1	9.0	27.7	17.9	2.7	15.47	25.26	
below tussock	LLA 24.1.	5.6	29.8	8.3	27.1	10.5	3.3	9.09	17.41	
	LLA 24.2.	5.8	27.8	6.7	18.5	24.7	3.2	11.19	25.54	
beside tussock	LLA 25.1.	6.7	29.4	8.8	27.8	10.9	3.1	11.31	28.88	
	LLA 25.2.	7.8	30.4	6.8	28.5	11.8	2.9	12.45	30.55	
DRY PARAMO										
not degraded	ESP 31.1.	4.3	26.0	14.0	28.8	8.1	3.8	31.31	31.54	0.74
	ESP 31.2	6.1	28.4	3.6	29.4	19.7	3.5	30.89	32.93	0.93
degraded flat	ESP 21.1.	8.0	36.2	13.9	26.2	6.3	1.8	10.43	15.54	0.99
	ESP 21.2	10.9	37.7	9.2	31.2	5.5	1.3		14.04	
degraded slope	ESP 11.1.	5.0	46.7	14.3	20.6	3.2	1.7	8.10	9.45	0.83
below tussock	ESP 11.2.	10.9	36.1	7.5	33.7	8.7	1.7	5.90	8.75	1.12
beside tussock	ESP 12.1							11.22		1.11
EL ARENAL										
below tussock	ESP 1.2.	18.5	59.8	3.8	10.4	4.7	0.8	7.99	16.29	1.21
	ESP 1.3.	15.0	49.0	6.8	19.1	6.5	1.9	18.96	25.72	1.30
beside Tussock	ESP 2.1							18.40		1.28
PANTANO										
organic matter	ESP 51.1.							472.71	399.26	0.11
	ESP 51.2	5.2	20.5	10.7	30.8	8.2	4.8	206.25	150.4	0.36
	ESP 51.3	5.3	27.6	7.1	31.6	13.6	4.4		65.07	

Csa : Coarse sands ; Fsa : fine sands ; Csl : coarse silts ; Fsl : fine silts ; Cl : clay ; B.D. : bulk density

Table 3. Extraction of amorphous components of the upper horizons of some caracteristic profiles of Llangahua and La Esperanza

profiles	horizons	oxalate Si	oxalate Fe	oxalate Al	oxalate Al+1/2 Fe	pyrophosphate Si	pyrophosphate Fe	pyrophosphate Al	Alp/Alo
			$g.kg^{-1}$		$g.100g^{-1}$		$g.kg^{-1}$		
HUMID PARAMO									
not degraded	ESP 41.2.	2.30	7.40	9.10	1.28	0.87	4.51	5.30	0.58
degraded	ESP 61.2.	1.39	5.34	5.80	0.85	0.70	3.38	3.61	0.62
DRY PARAMO									
not degraded	ESP 31.2.	0.93	3.94	4.00	0.60	0.57	2.36	2.57	0.64
degraded flat	ESP 21.2.	0.72	1.63	1.94	0.28	0.23	0.27	0.60	0.31
degraded slope	ESP 11.2.	0.54	1.87	1.62	0.26	0.31	0.35	0.40	0.25
EL ARENAL									
below tussock	*ESP 1.2.*	*1.11*	*1.83*	*2.36*	*0.33*	*0.21*	*0.28*	*0.56*	*0.24*