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GEOCHEMICALBEHAVIOUR OF CATCHMENTS WITH DIFFERENT LAND COVER: EFFECT OF LAND ABANDONMENT

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ABSTRACT: The characteristics of water geochemistry of several catchments in the San Llorenç National Park have been studied. These catchments are occupied by different plant covers and subject to different land-uses. The statistical analysis shows that the most natural catchments behave in a very different way than those affected by human activities.

RESUMEN: Se ha estudiado la composición geoquímica del agua en varias cuencas del Parque natural de San Llorenç. Estas cuencas están ocupadas por distinta cubierta vegetal y afectadas por diferentes usos del suelo. El análisis estadístico demuestra que las cuencas más naturales funcionan de manera muy distinta a las cuencas con intervención humana.

Key-words: Geochemistry, Water resources, Plant cover, Land-Use changes, Catalonia, Spain.

Palabras clave: Geoquímica, Recursos hídricos, Cubierta vegetal, Cambios de uso del suelo, Cataluña, España.

1. Introduction

In developed countries cultivated land has steadily decreased in recent decades, partly because poor farmland is normally abandoned. In the Mediterranean area, this process has increased drastically since the middle of the 20th century due to a series of social, economic and environmental factors. Several authors have studied the effects of farmland abandonment from different points of view (Arnáez-Vadillo, *et al.* 1993; Gallart & Llorens, 1996; García-Ruiz, *et al.*, 1995; Llorens, *et. al.*, 1995). Most analyses consider detailed aspects of hydromorphology and water geochemistry on experimental plots and catchments.

In this paper we analyse the solute outputs of seven catchments in a protected area along the Coastal Catalan Range, NE Spain. The main goal was to assess the effect of different land-uses on solute outputs.

2. The study area

Seven catchments were selected in the Sant Llorenç National Park along the Catalan Inner Range (from 300 to 1100 m a.s.l.) (Figure 1). The lithology is Eocene conglomerates composed of a calcareous matrix including heterometric Palaeozoic rocks, limestone, lutite and sandstone (Nadal, 1997).

The plant cover is characterised by sclerophyllous forests with communities of evergreen oaks (*Viburno-Quercetum*) and pines, and some deciduous forests of hazels (*Corylus avellana*) and oaks (*Quercus pubescens*). The potential vegetation is oak forest (Pinto, 1988). The park also includes holm oak forests, oak forests, pine forests, scrubs, abandoned farmland and some small active fields. These communities are the result of intense human activities in the past including agriculture, livestock management and forest clearing.

The climate is Mediterranean, somewhat modified by the altitude. The maximum precipitation (Figure 2) is in autumn (September, October and November) and spring (May) and the minimum is in winter and summer with an important water deficit in summer. Temperatures are highest in the driest periods (summer).

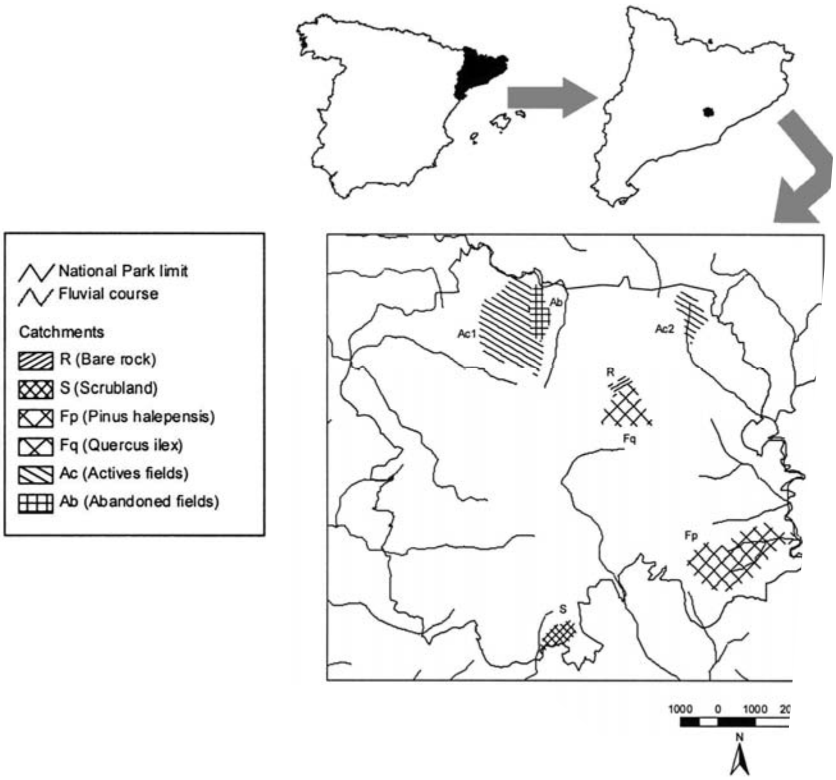

Figure 1. Location of the study area and the selected catchments

Table 1. The process of farmland abandonment

	agricultural fields (ha)	*index*
Active in 1956	415	100
Active in 1972	173	41,69
Active in 1994	102	19,37

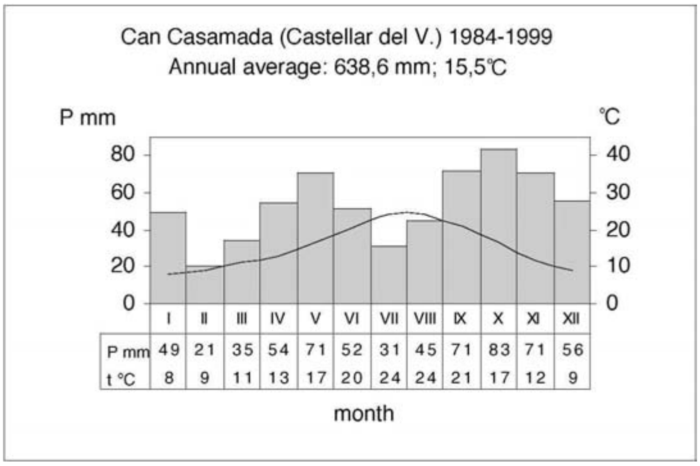

Figure 2. Precipitation and temperature in «Can Casamada», St. Llorenç Natural Park.

There was a strong demographic pressure in this area between the 9th and 14th centuries (Ballbe, 1987). During the 14th and 15th centuries the best lands were intensively cultivated, which considerably reduced forest to the less accessible areas.

This traditional system (based on wheat and barley cultivation) continued until the middle of the 20th century. Now agriculture is a residual activity. Table 1 summarises the evolution of the cultivated area since the middle of the 20th century.

3. The catchments

Seven catchments were selected with the following characteristics (Figure 3):

<u>Rock (R)</u>: a small headwater catchment in the upper part of the study area, scarcely forested with a predominance of bare rock. Altitude ranges from 1052 (Montcau Peak) to 770 m a.s.l.

<u>Holm oak (Al)</u>: located in the upper part of the Riera de les Arenes stream, predominantly covered by holm oak forest. Altitude ranges from 1052 (SE hillslope of the Montcau Peak) to 800 m a.s.l.

<u>Pine (Pi)</u>: intensively managed in the past but no fields were included in the sampling points. Homogeneously covered by pine forest. Altitude ranges from 630 to 340 m a.s.l.

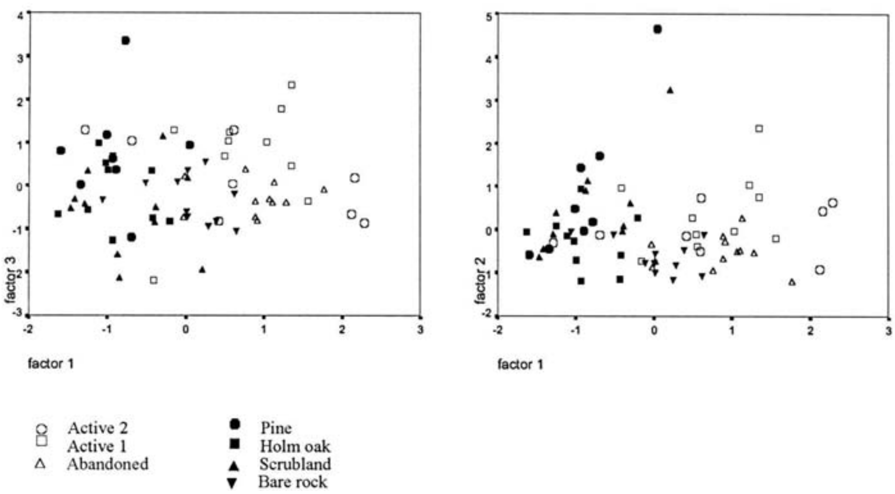

Figure 3. Factorial analysis. Factor 1 versus Factor 3, and Factor 1 versus Factor 2.

Scrub (M): burned by a forest fire 20 years ago, now covered by dense scrub with a clear trend to oak forest in the most favourable places. Altitude ranges from 740 to 480 m a.s.l.

We also considered three active catchments (Ac1, Ac2 and Ab) that have been strongly affected by human activities. Their land-use is less homogenous, as in most marginal agricultural land in Mediterranean mountain areas (Lasanta, 1996).

Active1 (Ac1): only 2% is used for agricultural purposes (although it was well represented in the analytical results) and the rest is colonised by pines. Altitude ranges from 750 to 420 m a.s.l.

Active2 (Ac2). only 0.65% is farmland and the rest is covered by oaks. Altitude ranges from 700 to 560 m a.s.l.

Abandoned (Ab): abandoned vineyards and orchards (belonging to Mura, the main settlement in the area) have been covered by pines and scrubs. Altitude ranges from 700 to 450 m a.s.l.

4. Sampling and analysis

The average number of rainy days in the study area is relatively low (75.3 per year). Precipitation levels surpass 10 mm about 18 days per year. As a result, runoff only occurs during a few rainy episodes and may last several hours.

Water samples were taken by hand at the lowest points of the catchments during or immediately after a rainstorm. Water temperature, pH and electrical conductivity were measured in the field. The remaining parameters were measured at the Physical Geography Laboratory (LGF) and the Instituto Pirenaico de Ecologia (IPE) (Table 2).

Table 2. Parameters analysed and the corresponding methods

Parameter	*Method of analysis*
PH	Portable pH-meter Crison 502
Electrical conductivity	Portable conductivimeter Crison 502
Dry residue	Evaporation in stove at 105ºC
NO3	Spectrophotometry at 220 and 274 nm.
HCO3	Volumetric method
Cl	Mohr Method
Ca	Complexometry
Mg	Complexometry
N	Photometry flame
K	Photometry flame

5. Results

Table 3 summarises the sequence of statistical analyses applied to the data from each catchment. Data were processed using SPSS 10.0 software.

Table 3. Sequence of statistical analyses

<table>
<tr><td rowspan="2">normal distribution and homogeneity of variance</td><td>➚ parametric test ➔ Anova ➔ Scheffé</td><td rowspan="2">factorial analysis</td></tr>
<tr><td>➘ non-parametric test ➔ Kruskal-Wallis ➔ Dunn</td></tr>
</table>

After applying the statistical analyses to each parameter several groups of catchments were obtained (table 4). Two groups were clearly defined based on CE, RS, HCO_3, CL, Ca and Mg. The first one included Ab, Ac1 and Ac2 catchments and the second one Scrub, Pine and Oak (table 5). No clearly defined groups were identified in terms of pH, $NO_{3,}$ N or K.

Table 4. Geochemical analysis of seven catchments

pH	*Elec. Cond.*	*Dry residue*	*NO_3*	*HCO_3*	*Cl*	*Ca*	*Mg*	*N*	*K*
R	8,3	318,5	351,8	1,1	189,8	8,8	43,3	15,1	2,60,4
Al	8,2	175,4	210,4	0,7	105,7	6,7	27,6	6,9	1,61,2
Pi	8,2	163,1	179,1	2,5	91,5	7,3	28,5	4,3	2,33,6
M	7,8	169,2	193,9	1,5	92,8	8,5	27,1	5,9	2,81,3
Ab	8,2	435,0	441,1	0,5	272,2	11,1	52,8	26,0	3,61,1
Ac1	8,3	367,1	419,6	0,7	213,2	14,9	47,2	21,4	5,02,9
Ac2	8,2	403,9	385,0	0,8	258,1	13,0	61,3	18,0	3,81,9

Table 5. Groups of catchments for each parameter

pH	*CE*	*RS*	*NO_3*	*HCO_3*
R Oak Pine Scru b Ab Ac1 Ac2	R **b** **Ab** **Oak** **Ac1** **Pine** **Ac2**	**Pine** Ac1 **Ac1** **Oak** Ac2 **Ac2** **Scru** **b** **Ab**	R Oak Pine Scru b Ab Ac1 Ac2	**Scru** R **b** **Oak** **Ab** **Pine** **Ac1** R **Ac2**
Cl	*Ca*	*Mg*	*N*	*K*
Oak R **Ab** **Pine** Ab **Ac1** **Scru** Ac2 **Ac2** **b** R	R **Scru** **Ab** **b** **Oak** **Ac1** **Pi** **Ac2**	**Scru** **b** R **Oak** **Ab** **Pi** **Ac1** R **Ac2**	Oak A Pine Ac2 R Scru b Ac2 Ab Acl	R Scru Pine b Oak Ac1 Ab Ac2 Ac1 Ac2

Finally, a factorial analysis was performed to corroborate the results. Ten variables were ordered according to three principal components that explained 80% of the initial variance. The first component was related to all the variables except NO_3, K and pH. The second component explained NO_3 and K and the third one referred to pH. Making a graph of component 1 versus component 3, it is the first component which dominates the distribution of the types of catchments. Making a graph of factors 1 and 2, it is the factor 1 which discriminates the catchments (Figure 2). Component 3 (pH) does not discriminates in a clear form, as indicated by the initial analyses.

6. Conclusions

Based on the results in Table 6, the catchments could be clearly classified into groups that were more "natural" and another more "humanised". The former underwent less radical pressures (forest activities) that did not involve high levels of deforestation. The latter include cultivated land and have supported a relatively strong human pressure for centuries including complete deforestation. The majority of the parameters analysed were quite different between the two groups of catchments, with the exception of pH and nitrates. Sodium and potassium levels were also quite similar between natural and humanised catchments

In conclusion :

i) "Natural" catchments are covered by shrub that protects the soil (and, consequently, water quality) in a similar way to forest (pine and oak woods). Thus, no strong disturbances are required to improve the hydromorphological functioning of hillslopes and catchments. Oak and pine forests have comparable values of solute outputs due to their dense underbrush.

ii) Among the "humanised" catchments, Ac1 and Ac2 always appeared together in the statistical analyses which suggests that even a small amount of cultivation can increase the export of nutrients. Another very interesting result was that abandoned catchments always appeared next to "active" catchments, suggesting that farmland abandonment may change the aspect of the territory but its function remains tied to the effects of agricultural activity for decades.

Acknowledgements

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Appendix 1: Land uses in catchments. (units in km^2)

Cover		*Area by land use*	*Total area*	*% studied land use*
Bare Rock			0,15	52,32
	Bare Rock	0,077		
	Evergreen-Oak grove	0,068		
	Shrubland	0,002		
Pine grove			2,74	78,82
	Pine grove	2,161		
	Abandoned	0,024		
	Active	0,001		
	Unproductive	0,001		
	Evergreen-Oak grove	0,182		
	Bare Rock	0,208		
	Shrubland	0,165		
Evergreen-Oak grove			1,01	83,87
	Evergreen-Oak grove	0,011		
	Evergreen-Oak+pine grove	0,835		
	Shrubland	0,005		
	Bare Rock	0,158		
Shrubland			0,45	69,56
	Shrubland	0,315		
	Evergreen-Oak grove	0,091		
	Evergreen-Oak+pine grove	0,026		
	Bare Rock	0,021		
Active1			2,95	1,86
	Active	0,055		
	Abandoned	0,189		
	Pine grove	0,047		
	Evergreen-Oak grove	0,021		
	Evergreen-Oak+pine grove	2,275		
	Shrubland	0,081		
	Bare Rock	0,280		
Active2			0,65	4,00
	Active	0,026		
	Abandoned	0,006		
	Pine grove	0,057		
	Evergreen-Oak grove	0,218		
	Shrubland	0,272		
	Bare Rock	0,066		
	Unproductive	0,002		
Abandoned			0,63	10,39
	Abandoned	0,065		
	Active	0,009		
	Pine grove	0,025		
	Evergreen-Oak+pines	0,441		
	Shrubland	0,059		