Vegetatio **93**: 131–141, 1991.

Regressive dynamic and denudation processes of vegetation on volcanoes in the 'Chaîne des Puys' (French Massif Central): assay of interpretation

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Accepted 3.2.1991

Keywords: French Massif Central, Heathlands, Multiple Correspondence Analysis, Regressive dynamic, Volcanic vegetation

Abstract

Some large bald areas, taking up the southern volcanoes hill-sides of the Chaîne des Puys (French Massif Central) are studied on an ecological point of view, by means of Multiple Correspondence Analysis applied to a contingency array environmental variables X plots, the plots being preliminarily studied in a syntaxonomic way. Four denudation processes are determined: natural screes (related to high declivity), rubbles resulting of intense passage, excess of grazing and a spontaneous regression of senescent heaths (degenerate phase) would happen, especially when particular local conditions are realized (impoverishment of soils, inhibiting action of *Calluna vulgaris* (L.) Hull, remoteness of trees, exposure, lavas characteristics...).

Introduction

The Chaîne des Puys (French Massif Central, see the map) is a chain constituted by about sixty volcanoes (strombolian and pelean types) north-south lined up at 1000 m up, 35 km long and 3 or 4 wide. The earliest eruption probably traces back about 8000 years B.P. Formerly cultivated for wood and sheep-farming, the chain shows in its greatest part large areas covered with heathlands and bilberry-heathlands.

These heaths covering the bases and hill-sides of volcanoes are as many former and current sheep-walks. However, on the hill-sides, the heaths present some large bare surfaces exposing the volcanic materials.

This set of different structures characterized by a very low percentage of covering (pioneer and rupicolous lawns) has been already studied (Coquillard *et al.* 1988a & b) in a syntaxonomic way. We try in this study to display the main ecological factors and processes in the beginning of the intense damages and resulting groups.

Method

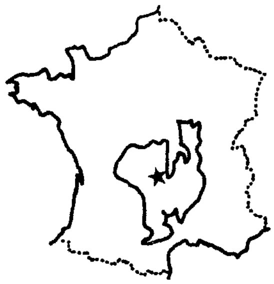
The data are constituted by 27 plots-corresponding to 27 relevés-choosen among the four plant groups recently studied:

- provisional group of *Sedo-Scleranthetea* (pioneer and degradation issued lawns).
- the *Biscutello lamotti-Galeopsietum segeti subass. jasionetosum laevi and subass. typicum* – 2 variants – (screes).

Five plots have been added, issuing from ripe

Table 1. Variables and categories codification. All variables have been transformed in qualitative type. I: Topographic situation. II: Local topography. III: Slope (in degree). IV: Exposure. V: Bare soil (in %). VI: Scorias in soils profiles (in %). VII: Blocks in soils profiles (in %). VIII: Thin soils components. IX: Substrate type: texture (ash-falls or cones lavas), chemistry (basalt, trachyandesit and trachyt). X: Herbaceous covering (in %). XI: Ligneous covering (in %). XII: Anthropozoogenic pressure.

Variables	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Categories	brow (1)	right slope (5)	<20 (8)	South (12)	<25 (18)	<15 (23)	<10 (27)	Present (30)	basaltic ash-fall deposits (32)	<15 (38)	<10 (40)	no pressure (43)
	top of versant (2)	convex slope (6)	21–27 (9)	South-east (13)	26–50 (19)	16–50 (24)	11–35 (28)	Absent (31)	trachyandesitic ash-fall deposits (33)	>15 (39)	10–50 (41)	low touristic pressure (44)
	mid. of versant (3)	concave slope (7)	28–30 (10)	East (14)	51–75 (20)	51–75 (25)	>35 (29)		trachytic ash-fall deposits (34)		>50 (42)	high touristic pressure (45)
	bott. of versant (4)		>30 (11)	South-west (15)	76–85 (21)	>75 (26)			basaltic cones (35)			grazing pressure (46)
				West (16)	>85 (22)				trachyandesitic cones (36)			
				North-West (17)					trachytic domes (37)			



Map 1. Situation of the Chaîne des Puys in the Massif Central.

heaths, called protoclimax (mature phase) by G. Baudière (1973), and from 6 heaths showing the typical signs of senescence (great number of dead heads of *Calluna vulgaris* (L) Hull.) in order to search eventual connections between the heath senescence and damaged habitats elective communities.

For each of these plots, 12 variables (environmental factors and feature of vegetation) have been sampled (see Table 1). The complete disjonctive array of 38 plots × 46 categories is analysed by the correspondence analysis method. Because of the presence of qualitative variables, the factorial plane examination is directed: first by the variable-axis correlation ratio, according to the multiple correspondence analysis method (Pialot *et al.* 1984) (Fig. 1), which must be maximum; secondly by the usual category-axis inertia index in relation to each successively studied axis.

In addition to the classical graphics of the correspondence analysis, we adopt the representation recommended by these authors, in which 'for each category we calculate the mean m and the variance s^2 of the plots coordinates on the axis. Each category is represented by a normal

Table 2. First four variables-axis correlation ratioes. Underlined values are corresponding to distributions represented on Figure 2.

Axis	Variables											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
F_1	0.41	0.003	0.17	0.2	0.86	0.49	0.18	0.51	0.56	0.002	0.81	0.23
F_2	0.41	0.06	0.03	0.17	0.71	0.52	0.05	0.02	0.47	0.41	0.56	0.54
F_3	0.26	0.11	0.46	0.47	0.64	0.26	0.21	0.13	0.34	0.72	0.008	0.36
F_4	0.16	0.14	0.22	0.54	0.45	0.46	0.25	0.23	0.59	0.03	0.15	0.008

$$\eta^2_{F_1 q} = \frac{1/n \sum_{j \in J(q)} x_{.j}(\bar{F}_1(j))^2}{\lambda_1}$$

where $\lambda_1 = \frac{1}{n} \sum_{j \in J(q)} x_{.j} s^2_{F_1}(j) + \frac{1}{n} \sum_{j \in J(q)} x_{.j}(\bar{F}_1(j))^2$

and : n = number of relevés (plots),

F_1 = relevés coordinates on the first axis ,

J(q) = index set of categories belonging to the variable q,

$x_{.j}$ =number of relevés corresponding to the category j .

Fig. 1. Correlation ratio index (from D. Pialot *et al.* 1984).

curve with parameters m and s'. The local topography and percentage of blocks of too weak correlation ratios to the first four axes are not represented.

Interpretation of $F_1 \times F_2$ plane

Along the F_1 axis (Fig. 2A) we note the separation between the plots of the 18 category (low % of bare soil) and the other ones. The high means of categories 2 (top of versant), 23 (low % of scorias), 42 (high % of ligneous covering), and high variances of 30 (presence of thin soil components) and 32 (basaltic ash-fall deposits) have the same cause. On the left end, the categories 22 (very high % of bare soil), 26 (very high % of scorias), 31 (absence of thin soil components), 35 and 36 (basaltic and trachyandesitic cones) are superposed. The Figure 3 corroborates these observations; the categories which have highly contributed to F_1 axis are, from positive to nega-

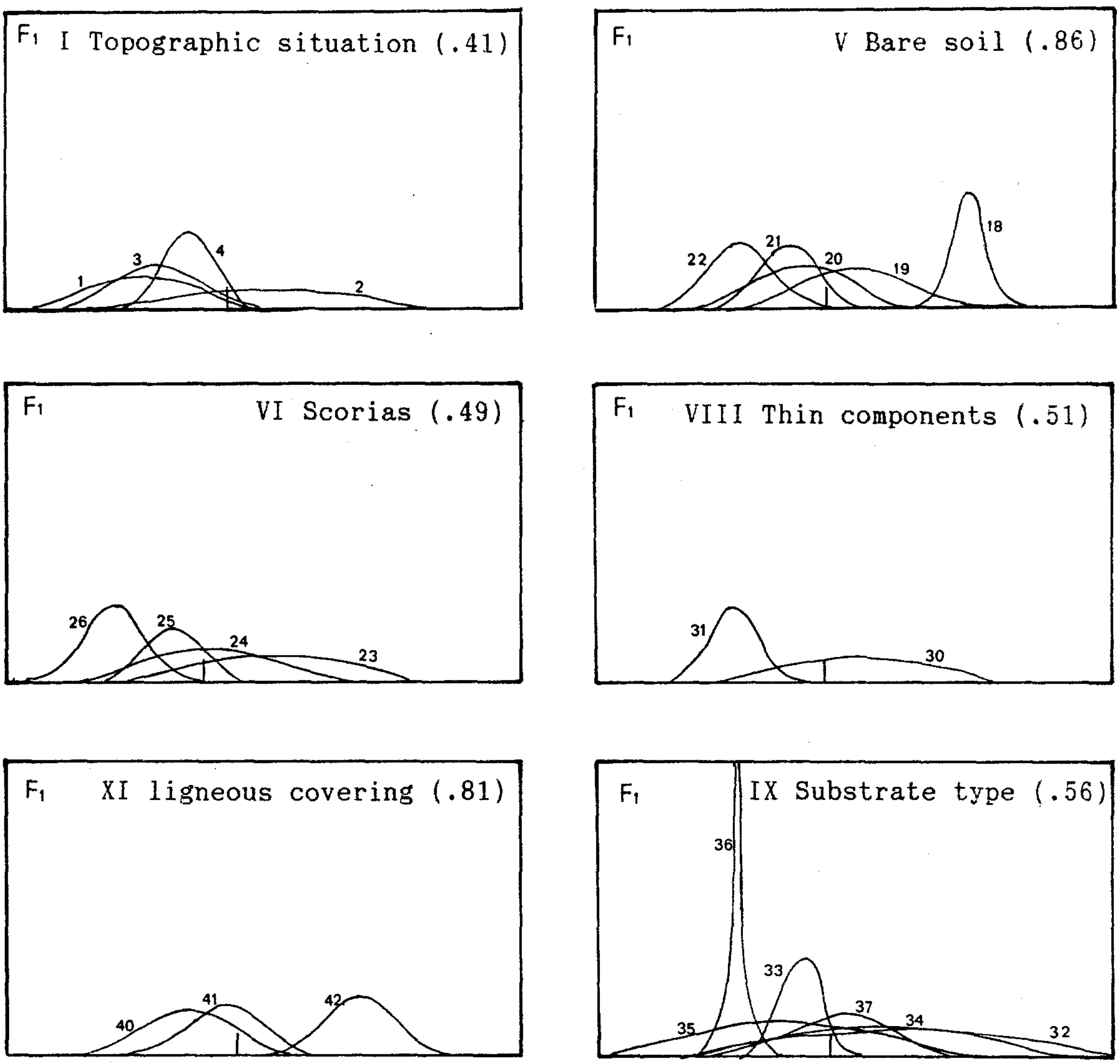


Fig. 2. Normal curves plots coordinates on correspondence analysis axis. A: axis 1 (F_1); B: axis 2 (F_2); C: axis 3 (F_3); D: axis 4 (F_4). The categories distributions represented are corresponding to correlation ratioes values >0.30.

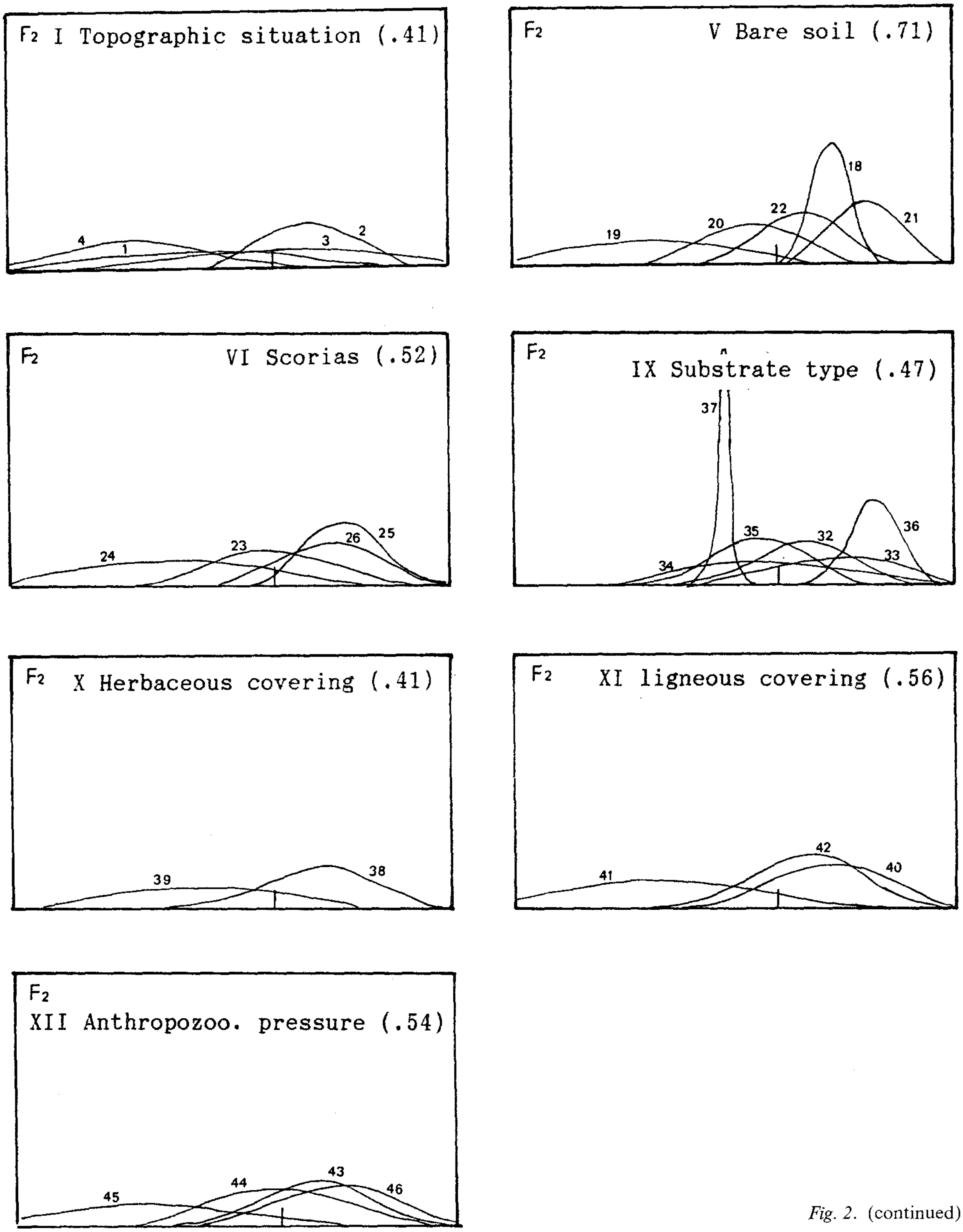


Fig. 2. (continued)

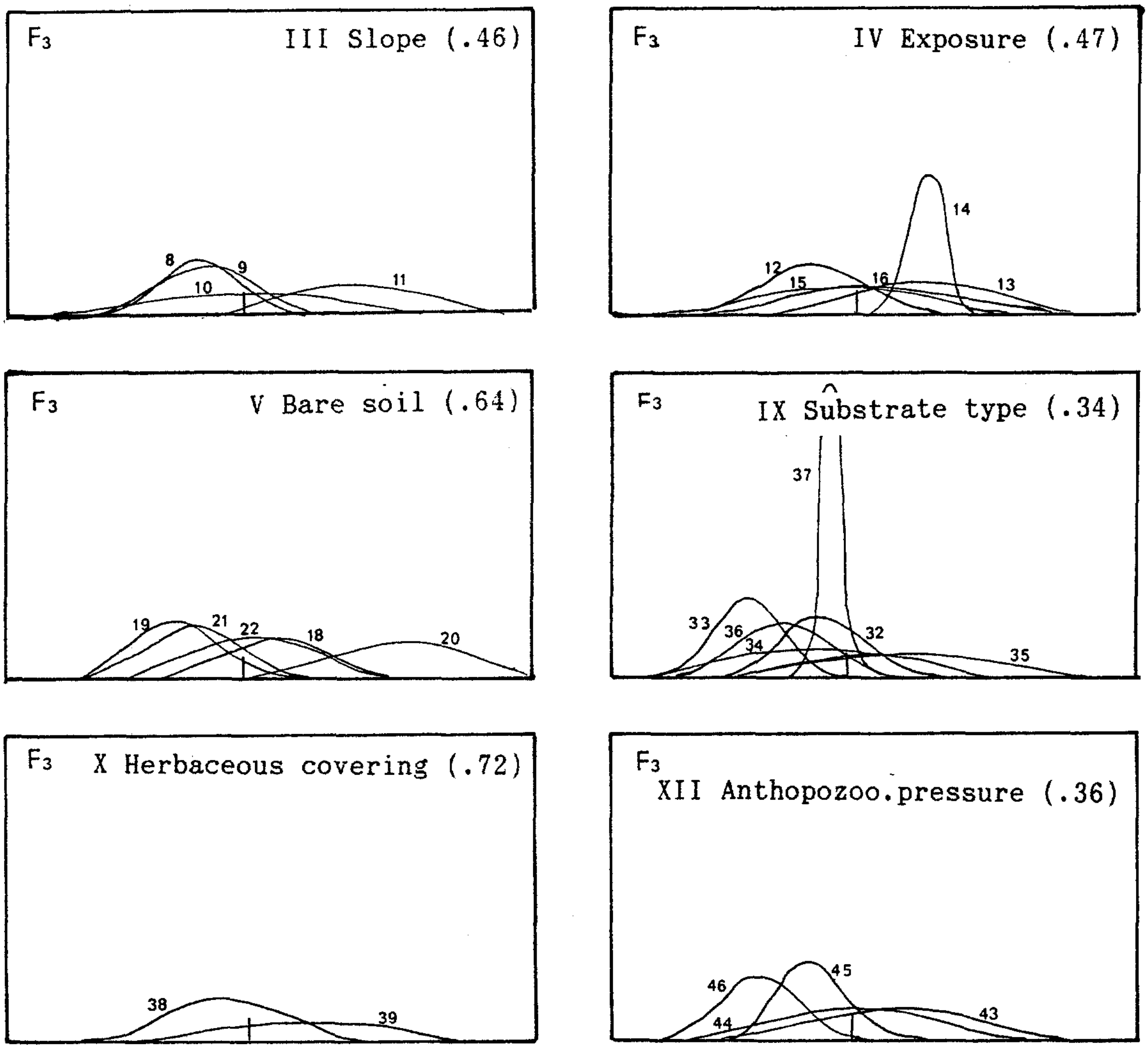
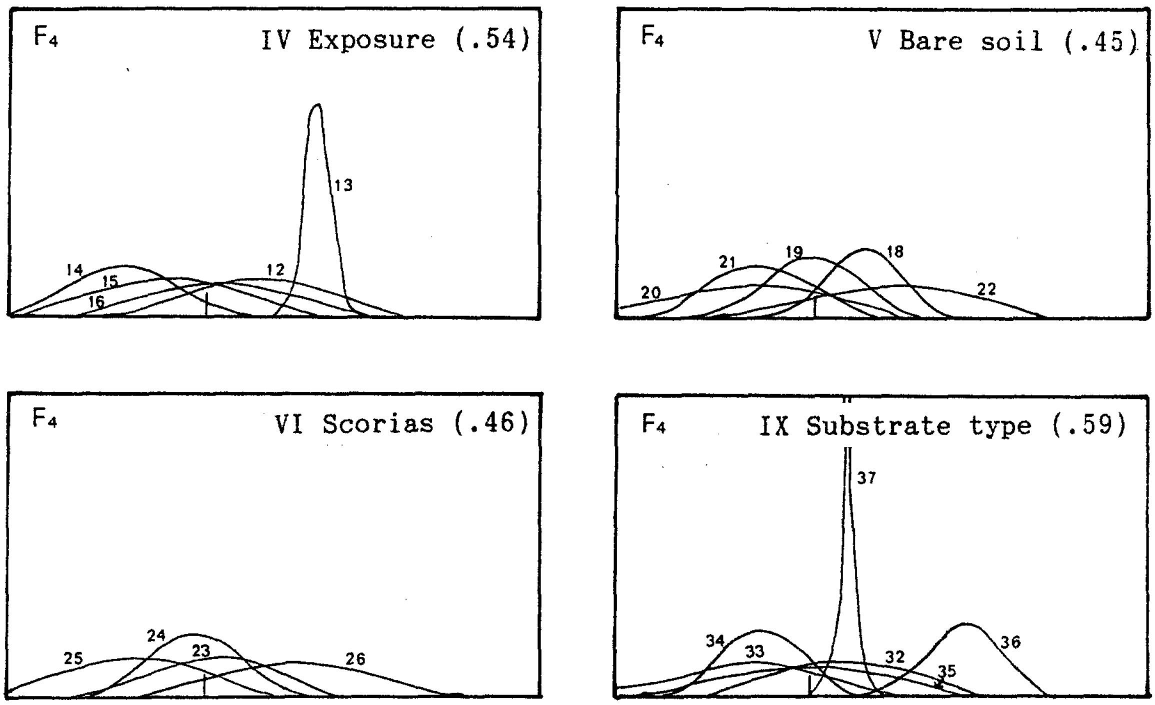


Fig. 2. (continued)

tive end: 18, 42, 32, 23, 2, and then 35, 22, 31, 26. The plots associated with these extrema belong to the *Biscutello-Galeopsietum subass. typicum and subass. jasionetosum* (negative end), the positive ones being some protoclimax and senescent heaths. Therefore, this first factor must be considered as a gradient opposing rupicolous groups of mobile screes bound to the high granulometry of basaltic cones, to the biotops of very important biologic and pedogenetic potentialities entirely colonized (protoclimacic and senescent heaths), established on basaltic ash-fall deposits of low granulometry, at the top of versant and in stable situation.

The variables distribution along the second axis (Fig. 2B) conducts us to associate to the *Biscutello-Galeopsietum jasionetosum* the following categories: 45 (high touristic pressure), 1 (brow situation), 4 (bottom of versant), 41 (average ligneous covering), 19 (average % of bare soil), 24 (average % of scorias), 39 (herbaceous covering $>15\%$). The F_2 axis certainly represents a decreasing touristic pressure gradient and the *Biscutello-Galeopsietum jasionetosum* a result of this pressure. The rôle played by the plots of the *Sedo-Scleranthetea* community on the negative end of the axis 2 can be explained by the resumption of the colonizing dynamics in the edging areas



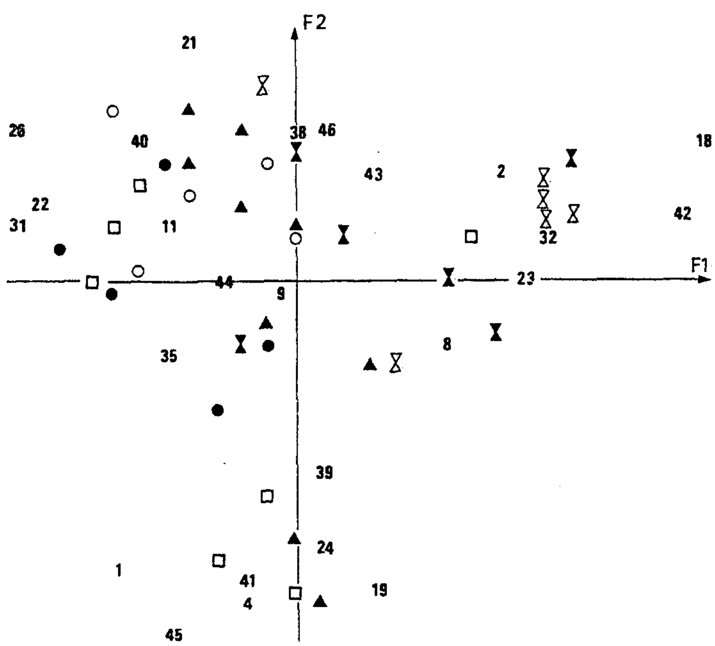


Fig. 3. F_1 X F_2 plane. The high and medium contribution (inertias) categories are only represented. All plots are represented. $I_{F1} = 11.98\%$; $I_{F2} = 10.36\%$. ▲ *Sedo-Scleranthetea* provisional group. ● *Biscutello-Galeopsietum subass. typicum* var. *Herniaria glabra*. ○ *Biscutello-Galeopsietum subass. typicum* var. *Athyrium filix–femina*. □ *Biscutello-Galeopsietum subass. jasionetosum laevi*. ⧗ Senescent heathes. ⧖ Ripe heaths (protoclimax).

of very frequented places. On the positive end, all the differently determined other plots are clustered (Fig. 3).

Interpretation of the $F_1 \times F_3$ plane

The categories distribution along the F_3 axis (Fig. 2C) suggests a link between the high declivity (11), high % of bare soil (20), south-east exposure (13), however with high variances. On the opposite, the means of the following categories are coinciding: south exposure (12), low and average declivities (8 and 9), trachyandesitic ash-fall deposits and trachyandesitic cones (33 and 36), average % of bare soil (19), grazing pressure (46).

The factorial graph $F_1 \times F_3$ (Fig. 5) corroborates that high contributions to this third factor are among these categories. This factor could be considered as a decreasing pressure gradient, which would be determinative of the *Sedo-Scleranthetea* lawns. In other respects, this axis separates the mobile biotops (screes and rubbles of tourism) from stable ones, issuing from the grazing pressure.

Interpretation of the $F_1 \times F_4$ plane

We can establish that F_4 axis organizes a gradient inside the most constraining biotops. This one shows, indeed, a link, on one hand, between high % of bare soil (20 and 21), scorias (25), east exposure (14), trachytic ash-fall deposits (34), and on the other hand, between very high % of bare soil (22), scorias (26), south-east exposure (13), trachyandesitic cones (36) (Fig. 2D). The graph (Fig. 5) and contribution examination, demonstrate that senescent heaths have got an important weight in the gradient (negative end); an obvious link exists between the heath senescence and the

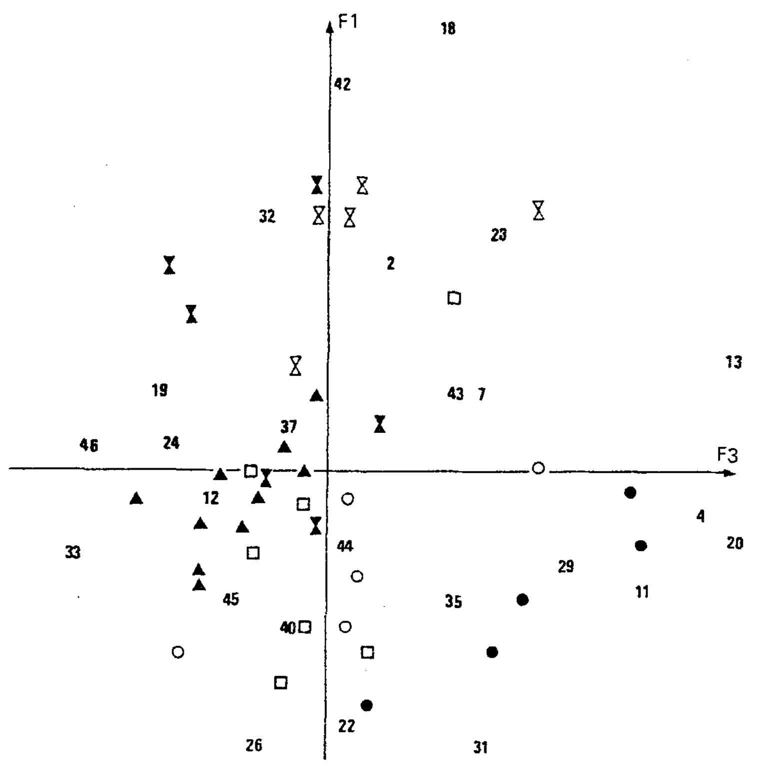


Fig. 4. $F_1 \times F_3$ plane. $F_{F1} = 11.98\%$; $I_{F3} = 9.02\%$. See legend Figure 3.

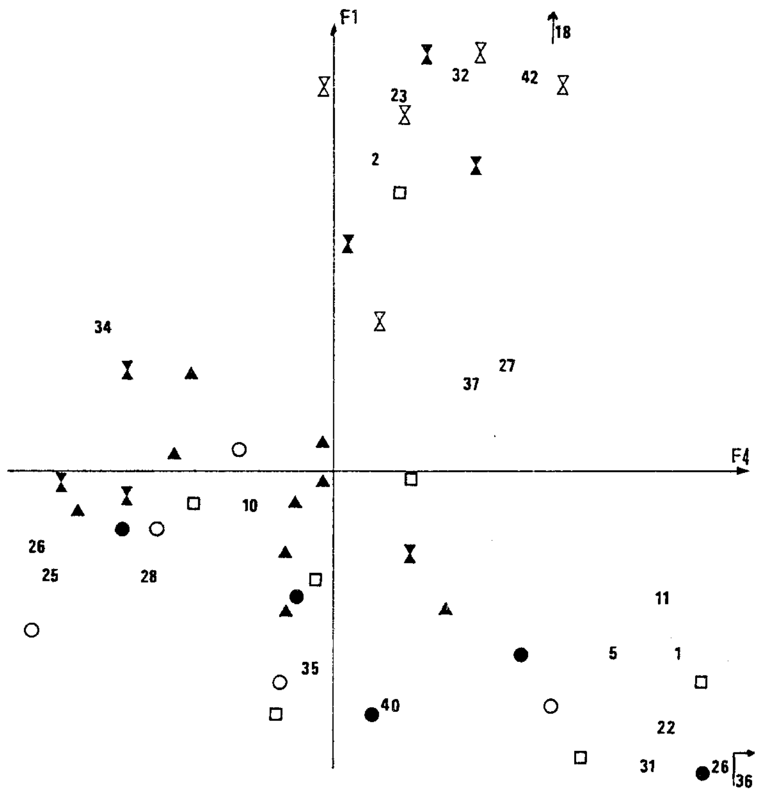


Fig. 5. $F_1 \times F_4$ plane. $I_{F1} = 11.98\%$; $I_{F4} = 7.92\%$. See legend Figure 3.

moving off of the substrates, without any estimable anthropozoogenic pressure. Thermophilic exposures and the lavas nature may have a preponderent rôle in this link.

Discussion

The analysis, therefore allows to discern four denuding processes of the hill-sides volcanoes:

1. Natural screes. Never colonized by an important vegetation cover. They are, above all, some mobile surroundings because of the high declivity (>25°), and rather basaltic cones elective, the relief of which is still very young. The group which succeeds to remain is the *Biscutello lamotti-Galeopsietum segeti subass. typicum*.
2. The rubbles resulting of the intense passage. Two factors are essential in this great extension process:
   - the very light and unargillaceous soils (muddy andosols especially, (Hétier 1975)) easily eroded after the destruction of superficial vegetation.
   - the inherent instability of the scoriaceous lavas; this degradation is an irreversible one, for the reason of soil thickness diminution and next suppression. The ultimate group belongs to the *Biscutello-Galeopsietum segeti subass. jasionetosum*.
3. Excess of grazing. The regressive dynamic leads to set up lawns belonging to the *Sedo-Scleranthetea* community; the substrate is stable, dynamic potentialities are almost intact.
4. A self-catalytic process of erosion in the heaths can be considered. Indeed, the senescent heath, 30–35 years old, shows some little gaps with bare soil, following the death of *Calluna vulgaris* heads (Gimingham 1978) and takes a 'flayed' look. The noncolonization of these gaps would result of synerging factors: impoverishment of soils nutriments by the traditional management (Loiseau & Merle

1981), inhibiting action of *Calluna* roots on germination (Salas & Vietez 1975) and/or mycorhization of certain species (Robinson 1972) – particularly the woody ones –, remoteness of reproductive trees (Doche 1986), thermophilic exposure, acidity of lavas... Slope and structural instability of eruptive rocks induce the growth of bare spots falling in large and joining bald areas, ending to a complete baldness of the versant, uncovering the volcano main part. The local ecology plays an eminent rôle in the phenomenon induction, the most favourable conditions to its development being high declivity (>25°), thermophilic pedoclimate and soils spreaded out on trachytic or trachyandesitic substrates (podzolic to andopodzolic soils).

Such a diminution of soil thickness – however a less important one – has been already related by Baudière, then by Doche, respectively in south and center of the Massif Central, about heaths colonizing some basaltic lavas.

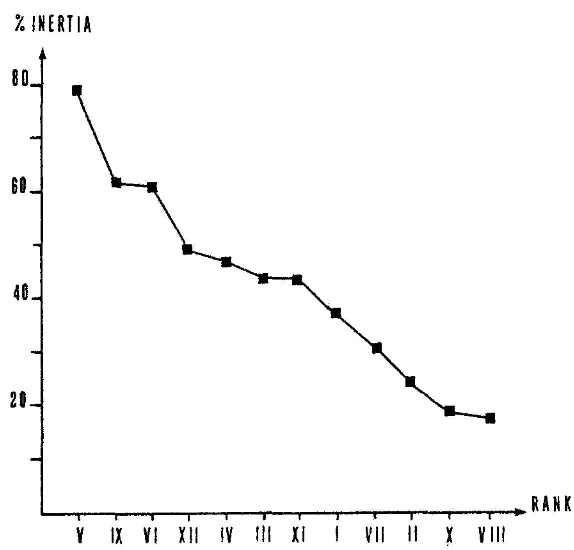


Fig. 6. Environmental variables hierarchy. The hierarchy is obtained according with a method already used by one of us (P. Coquillard 1986). We sum up the categories inertia index of each variable and then weight this value with the inertia of the considered factor axis. The final table is obtained by summing up, for each variable, the results calculated about the six first factorial axis (this corresponding to 52.34% of the total matrix inertia).

A variables hierarchy has been realized from the categories inertia index (Fig. 6). This shows the predominant rôle of geormorphologic (V, VI, III), geologic (IX) and anthropozoogenic (XII) variables types in the analysis. The feature vegetation variables seem having played only a secondary one.

Conclusion

The degradation of the vegetation covering the Chaîne des Puys, therefore is a complex phenomenon which origin lies, at one and the same time, in the actual and passed human practices. The traditional and ancestral (XIIIth cent. at least) cultivation of hill-sides volcanoes by grazing in a mining way-night folding in flat and arable zones –, the great instability of soils and volcanic substrates making the ripe heaths fragile, are probably the principal factors of the particular process of spontaneous regression.

The economy, since the middle of the sixties, imposes a general suspension of grazing in the greatest part of the chain, while tourism shows a constant growing. So, we can expect an important increasing of these phenomenons which endanger the high value and well known landscape of the 'Chaîne des Puys'.

Meanwhile, some important questions still remain, about the importance and the exact mechanism of inhibitory action from *Calluna*, typology of fragile zones and measures to avoid such a degradation.

Acknowledgements

We are especially gratefull to J.C. Vennat (Physic and Biophysic department, UFR of Pharmacy, Clermont-Ferrand) and M. Roux (Faculté des Sciences et Techniques St Jérôme, Marseille) for valuable discussions on mathematic aspects of this paper.

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