Il Quaternario
5(2), 1992, 269-280

CLASSIFICATORY DISCRIMINANT ANALYSIS OF POLLEN DATA IN NORTH EASTERN ITALY - I. NUMERICAL METHOD

S.P. Evans
Laboratorio di Dendroecologia, Istituto di Chimica Agraria ed Ambientale, Facoltà di Agraria, Università Cattolica del Sacro Cuore, Piacenza, Italia

ABSTRACT - *Classificatory discriminant analysis of pollen data in North Eastern Italy - I. Numerical method* - Il Quaternario, **5**(2), 1992, p.269-280 - The paper describes the application of a numerical method (classificatory discriminant analysis) to a palynological data set. The method is based on classical multivariate analysis techniques and is intended to provide the objective dating, along the radiocarbon timescale, of undated pollen levels. Observations are classified into one of a number of pre-defined groups on the basis of one or more numerical variables; for each observation a discriminant criterion is developed using either a linear of a quadratic discriminant function; the discriminant criteria are then applied to a second data set and are used to classify data devoid of the classificatory numerical variable. Techniques estimating the probability of correct classification are described. In the present example radiocarbon dating is the classificatory variable; the discriminant criteria derived from radiocarbon-dated pollen levels are used to objectively place undated pollen levels along the radiocarbon timescale. The technique is applied to a pollen data set from north-eastern Italy, made up of published pollen diagrams developed in the period 1930÷1986; two subsets can be identified (labelled "pre-1958" and "post- 1958") on the basis of the ~3-fold increase in the number of pollen-identified species after 1958. In the post-1958 set a number of radiocarbon dated levels area available; discriminant criteria are derived from these and applied to all undated levels contained in both the pre-1958 and post-1958 subsets. This positions all pollen levels along the radiocarbon timescale. Implications of the application of this technique for palynology are diverse: pollen diagrams devoid of radiocarbon dating can be integrated with radiocarbon-dated pollen diagrams. Current gaps in the spatial coverage of palynological information can be (objectively) filled by pollen diagrams developed before, or devoid of, radiocarbon dating.

RIASSUNTO - *Analisi classificatoria discriminante di dati pollinici dell'Italia nord-orientale.- I. Metodo numerico* - Il Quaternario, 5(2), 1992, p. 269-280 - L'articolo descrive l'applicazione di un metodo numerico (l'analisi classificatoria discriminante) proposto come tecnica utile per fornire la datazione obiettiva, lungo l'asse temporale delle radiodatazioni, di livelli pollinici non datati. Il metodo si basa su tecniche classiche di analisi multivariata. Ciascuna osservazione viene assegnata ad uno di un numero pre-definito di gruppi sulla base di una o più variabili numeriche; per ciascuna osservazione viene sviluppato un criterio discriminante utilizzando una funzione discriminante lineare o quadratica; i risultanti criteri discriminanti vengono applicati ad un secondo insieme di dati e vengono utilizzati per classificare quei dati privi della variabile classificatoria. Vengono successivamente descritte tecniche per stimare la probabilità di una corretta classificazione dei dati. Nel presente caso la radiodatazione è la variabile classificatoria; i criteri discriminanti derivanti da livelli pollinici radiodatati vengono utilizzati per posizionare livelli pollinici non radiodatati lungo l'asse temporale delle radiodatazioni. La tecnica viene applicata ad un insieme di dati pollinici dell'Italia nord-orientale, composto da diagrammi pollinici già pubblicati e sviluppati nel periodo 1930÷1986; in esso sono riconoscibili due sotto-insiemi (definiti "pre-1958" e "post-1958") sulla base di un aumento fino a 3 volte del numero di specie identificate dopo il 1958. Nell'insieme post-1958 sono disponibili un numero di livelli pollinici radiodatati; criteri discriminanti ottenuti da questi vengono applicati a tutti i livelli pollinici non radiodatati e compresi sia nel sottoinsieme pre-1958 sia in quello post-1958; ciò posiziona tutti i livelli pollinici lungo l'asse temporale delle radiodatazioni. Le implicazioni derivanti dall'applicazione di questo metodo sono diverse: diagrammi pollinici privi di radiodatazioni possono essere integrati con diagrammi pollinici radiodatati. Vuoti nell'informazione palinologica sul territorio possono essere (obiettivamente) colmati utilizzando diagrammi pollinici sviluppati prima dell'introduzione, oppure privi, della radiodatazione.

Key-words: Palynology, paleovegetational reconstruction, classificatory discriminant analysis, multivariate analysis, radiocarbon dating, NE Italy, Holocene
Parole chiave: Palinologia, ricostruzione della paleovegetazione, analisi discriminante classificatoria, analisi multivariata, radiodatazioni, NE Italia, Olocene

1. INTRODUCTION

A regional approach to Holocene vegetation dynamics based on palynological information requires that pollen levels be positioned along an absolute timescale; this is usually achieved by the radiocarbon dating of organic material associated with analyzed pollen grains. However large quantities of data are available which are devoid of a radiocarbon date; these were developed either before the introduction of the radiocarbon technique, or absolute dating was not incorporated, for the more recent diagrams, into the research design.

The development of an appropriate methodology able to integrate older data with more recent and better-quality information is to be considered worthwhile, in that the older diagrams may still convey useful information on Holocene vegetation dynamics.

The methodology proposed in this paper tackles the problem of providing an objective temporal structure common to both radiocarbon-dated and undated pollen levels. This is initially achieved by associating a radiocarbon date to the structure of the pollen-identified vegetation identified in a given pollen level. This association, converted into a suitable numerical form, and for all available radiocarbon-dated levels, is then extended to all undated pollen levels in the same geographical area, under the assumption that specific time periods in a given geographical unit are characterized by a partic-

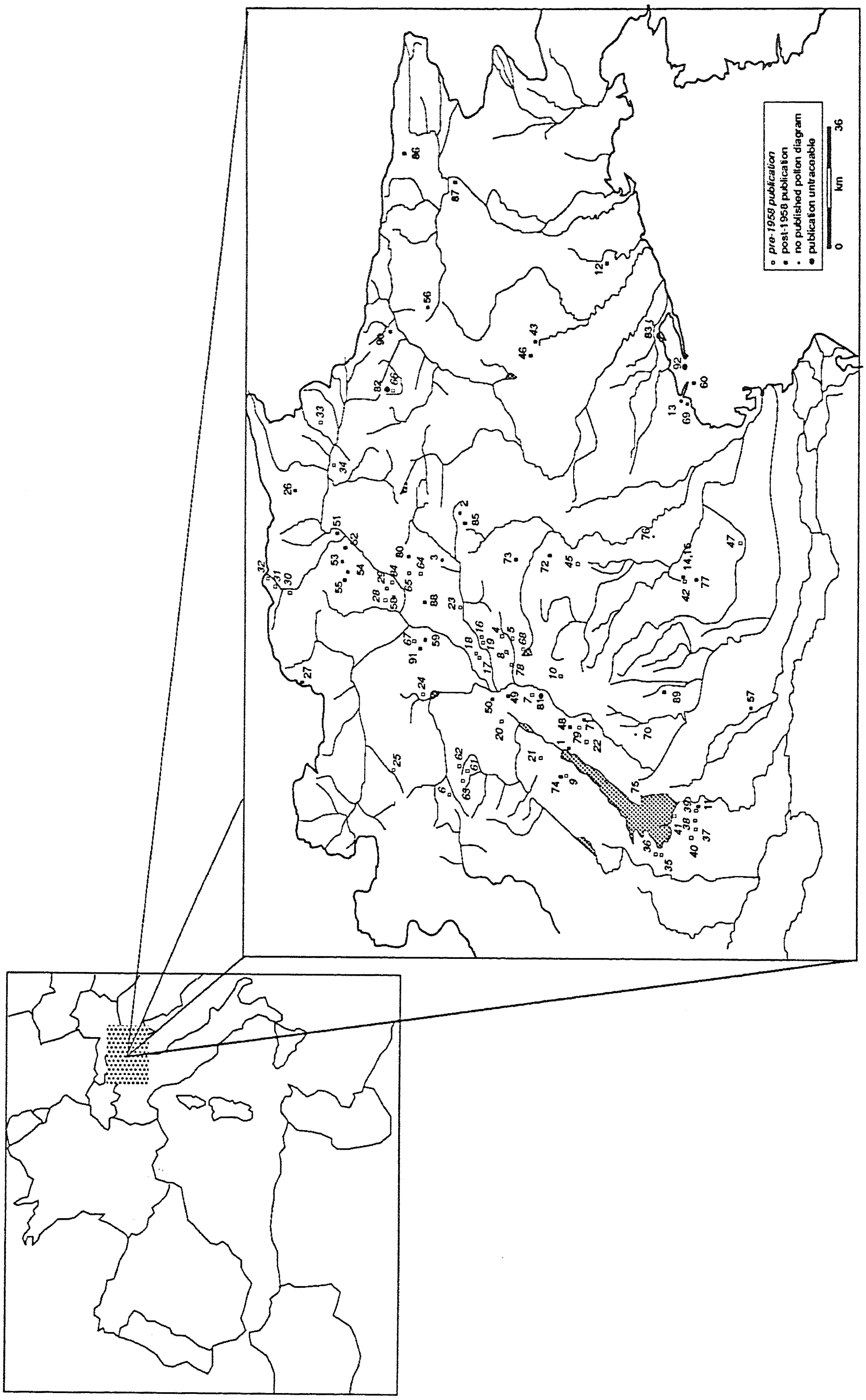

Fig. 1 - North-eastern Italy. Distribution map of sites sampled for palynological data; pre- and post-1958 sites are identified.
Italia nord-orientale. Distribuzione delle località campionate; vengono identificati i siti pre- e post-1958.

Table 1 - Pollen-identified species for each sampled location, ordered by year of publication.
Specie polliniche identificate per ciascuna località, ordinate per anno di pubblicazione.

n°.	location	year	*Abies*	*Alnus*	*Betula*	*Corylus*	*Fagus*	*Picea*	*Pinus*	*QM*	*Salix*	*Acer*	*Carpinus*	*Castanea*	*Fraxinus*	*Hippophae*	*Juglans*	*Juniperus*	*Larix*	*Ostrya*	*Pinus cembra*	*Pinus mugo*	*Populus*	*Quercus*	*Quercus ilex*	*Taxus*	*Tilia*	*Ulmus*
67	Montigli	1930	x		x	x	x	x	x	x																		
68	Pergine-Vigalzano	1930	x		x	x	x	x	x	x																		
61	Malga Ritorta	1930	x			x	x	x	x	x																		
62	Malga Patascos	1930	x		x	x	x	x	x	x																		
63	Malga Zeledria	1930	x		x	x	x	x	x	x																		
64	Kolbleggwiesen	1930	x	x	x			x	x	x																		
65	Karer-See	1930	x		x			x	x	x																		
79	Grunser Buhl	1930	x		x		x	x	x	x																		
37	Rande di Solferino	1931	x	x	x	x	x	x	x	x				x														
38	Barche di Solferino	1931	x	x	x	x	x	x	x	x				x														
39	Lago di Castellaro	1931	x	x	x	x	x	x	x	x	x			x														
40	Castel Venzago	1931		x	x	x	x		x	x	x			x														
41	Laghetto di Lugana	1931	x	x	x	x	x	x	x	x				x														
42	Lago di Fimon	1931	x	x	x	x	x	x	x	x				x														
43	Polcenigo	1931	x	x	x	x	x	x	x	x	x			x														
35	Saltarino Sotto	1931	x	x	x	x	x	x	x	x	x			x														
36	Saltarino Sopra	1931	x	x	x	x	x		x	x	x																	
8	Palù dei Fornasi	1932	x	x	x	x	x	x	x	x	x																	
9	Molina di Ledro	1932	x	x	x	x	x	x	x	x	x																	
21	Fiavè	1932	x	x	x	x	x	x	x	x	x																	
7	Bondone	1932	x	x	x	x	x	x	x	x	x																	
6	Tonale	1932	x	x	x	x	x	x	x	x	x																	
78	Civezzano	1933	x	x	x	x	x	x	x	x	x																	
84	Collalbo	1933	x	x	x	x	x	x	x	x	x										x							
28	Lago di Mezzo	1933	x	x	x	x	x	x	x	x	x																	
29	Maso Holt	1933	x	x	x	x	x	x	x	x	x																	
30	Stilves	1935	x	x	x	x	x	x	x	x	x																	
33	Val d'Anterselva	1935	x	x	x	x	x	x	x	x	x																	
34	Riscone	1935	x	x	x	x		x	x																			
31	Brennero Terme	1935	x	x	x	x		x	x	x																		
32	Passo del Brennero	1935	x	x	x	x	x	x	x	x	x																	
22	Creer	1940	x	x	x	x	x	x	x	x																		
23	Anterivo	1940	x	x	x	x	x	x	x	x																		
24	Palù Longa di Brez	1940	x	x	x	x	x	x	x	x																		
25	Alta Val Martello	1940	x	x	x	x	x	x	x	x	x																	
4	Miola di Pinè	1941	x	x	x	x	x	x	x	x	x																	
5	Laghestel	1941	x	x	x	x	x	x	x	x	x																	
16	Lago di Valda	1944	x	x	x	x	x	x	x	x																		
19	Brusago	1944	x	x	x		x	x	x	x																		
17	Lagabrun	1944	x	x	x	x	x	x	x	x																		
18	Vegiose	1944	x	x		x	x	x	x	x	x																	
10	Folgaria	1946	x	x	x	x	x	x	x	x	x																	
45	Laghetto di Lumera	1949	x	x	x	x	x	x	x	x	x																	
20	Lago di Molveno	1954	x	x		x	x	x	x																			
15	Lago di Fimon	1957	x	x	x	x	x	x	x	x	x			x														
47	Arquà Petrarca	1957	x	x	x	x	x	x	x	x				x				x										
1	Linfano di Torbole	1958	x	x	x	x	x	x	x		x										x	x		x			x	
57	Nogara	1959	x	x	x	x	x		x		x	x	x											x			x	x
2	Castrozza	1959	x	x	x	x	x	x	x		x	x	x											x			x	x
71	Monte Baldo	1960	x	x	x	x		x	x	x	x	x				x		x	x									
74	Lago di Ledro	1964	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x
13	Motte di Volpega	1965	x	x	x		x		x		x			x										x				x
48	Lago di Loppio	1965	x	x	x	x	x	x	x		x	x	x					x		x					x		x	x
60	Laguna di Venezia	1966	x	x	x	x	x	x	x		x	x	x	x	x		x		x	x				x			x	x
11	Lago di Castellaro	1968	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x
12	Portogruaro	1969	x	x	x	x	x	x	x		x		x		x		x	x		x				x			x	x
46	Bosco del Cansiglio	1969	x	x	x	x	x	x	x		x	x	x	x	x		x	x	x					x	x	x	x	x
14	Lago di Fimon	1972	x		x	x	x	x	x	x	x						x											
59	Montiggler See	1975	x		x	x	x	x	x	x	x	x		x	x		x	x					x					
91	Langmoos-Montiggl	1975		x	x	x		x	x	x						x	x	x										
58	Signater Kopl	1975	x		x	x	x	x	x	x	x	x			x			x	x	x	x		x					
77	Covoloni del Broion	1977		x	x	x		x	x		x	x	x		x			x		x				x			x	x
44	Lago di Massenza	1977	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x	x			x					
49	Pradestel	1977		x		x		x	x		x		x		x		x	x	x						x		x	x
50	Vatte di Zambana	1977		x	x	x			x						x									x			x	x
51	Sommersuss	1980	x	x	x	x		x	x		x				x	x		x	x		x			x			x	x
72	Forcellona	1980	x		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x		x		x	x		
73	Pieve Tesino	1980	x		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x		x		x	x		
52	Schwarzsee	1980	x	x	x	x	x	x	x				x		x			x	x		x			x			x	x
53	Malsch. Holler	1980	x	x	x	x	x	x	x				x		x		-	x	x	x	x			x			x	x
54	Dura Moor	1980	x	x	x	x	x	x	x			x	x		x			x	x	x	x			x			x	x
55	Rinderplatz	1980	x	x	x	x	x	x	x		x		x		x			x	x	x	x			x			x	
3	Vedes	1981	x	x	x	x	x	x	x	x	x	x	x				x	x	x		x	x						
89	Riparo Tagliente	1982		x	x	x			x		x							x		x				x			x	x
87	Cavazzo-Vuarbes	1982	x		x	x	x	x	x		x	x	x	x	x		x	x	x	x	x		x	x	x	x	x	x
56	Malga Varmost	1982	x		x	x	x	x	x		x	x	x	x	x		x	x	x	x	x		x	x		x	x	x
66	Passo di Pramollo	1982	x		x	x	x	x	x		x	x	x	x	x		x	x	x	x	x		x	x		x	x	x
26	Lappago	1982	x	x	x			x	x		x	x	x						x								x	
80	Grosses Moor	1983	x	x	x	x	x	x	x		x	x	x	x	x			x	x	x	x		x	x		x	x	x
27	Granati	1983	x	x	x	x		x	x			x	x					x	x		x						x	
85	Colbricon	1984		x	x	x	x	x	x			x	x					x	x	x	x			x			x	x
88	Nova Ponente	1986	x	x	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x			x		x	x	x
90	Comelico	1986	x		x	x	x	x	x		x	x	x	x	x		x	x	x	x	x			x			x	x

ular pattern in the pollen data. This assumption has always been used by palynologists (Birks & Gordon 1985), and is the basis for the relative chronosequencing and chronozonation of pollen data, even in the absence of independent temporal information.

Climate-modern vegetation pollen response functions using a technique similar to that presented in this paper have been used to reconstruct past climate from pollen stratigraphical assemblages; Birks and Gordon (1985) describe in detail methods, results and implications of this approach. Response functions have also been used in palynology, climatologyy (Guiot, 1985) and dendroclimatology for the quantitative reconstruction of environmental variables, such as temperature, rainfall and sea-level pressure (Cook & Kairiukstis, 1990).

Temporal calibration of palynological data has not so far been described in the literature.

2. THE DATA

The palynological data set used to test the methodology is made up of published pollen diagrams developed from a number of sites in north-eastern Italy. The set is characterized by a high concentration per unit area of sample sites (1 site for every ~1600 km^2, a 40x40 km quadrant); figure 1 gives the geographical location of sampled sites.

The set is made up of pollen spectra developed 1930÷1986; during this period, two fundamental changes take place which cause the set to be separated into two subsets:

a) the ~3-fold increase in the number of pollen-identified species after 1958. Table 1 lists the species identified for each sampled site, ordered by year of publication: the average number of pollen-identified species increases from 8 to 24 after 1958;
b) the introduction of radiocarbon dating in the 1960s. Table 2 lists the radiocarbon dates available, ordered by site.

The set is accordingly divided into two subsets labelled 'pre-1958' and 'post-1958'.

In a wider perspective this division reflects the shifts taking place in the way palynological data is gathered. Before 1958 the relative chronosequencing (the Blytt-Sernander zonal system) of Northern and Central Europe describing the overall pattern of vegetational change in the Holocene is well developed and generally accepted (Firbas, 1949; 1952). Terms and concepts adopted from this system are applied to the Alpine set, but evaluating the timing of apparently synchronous events proves difficult until the advent of radiocarbon dating and its application to palynology in the early 1960s.

Table 2 - Radiocarbon dates of sites in the data set. The sites are identified by a code, as specified in Table 1. The depth along the core of the radiocarbon date is given, together with the ^{14}C code, the radiocarbon date ± standard deviation, and the laboratory which carried out the analysis.

Radiodatazioni per le località comprese nel campione. I siti sono identificati mediante un codice, come specificato nella Tabella 1. Viengono riportati; la profondità lungo il carotaggio della datazione, il codice della data, la radiodatazione ± deviazione standard, ed il laboratorio di esecuzione.

Site	level in cm	14C code	Date BP	st. dev.	Laboratory
11	670		11250	120	Yale
20	200		2905	153	Pisa
26	48		4140	95	Teledyne Isotopes
27	1100	Hv-11000	5790	215	Hannover
27	450	Hv-11001	3830	70	Hannover
29	L7	R-1151	9320	50	Rome
49	L1	R-1150	8240	200	Rome
49	H2	R-1149	8200	50	Rome
50	8	R-489	7860	75	Rome
51	420	VRI-554	12700	200	Vienna
51	330	Hv-8471	10770	165	Hannover
51	250	Hv-8470	9135	90	Hannover
51	105	Hv-8469	6110	95	Hannover
51	55	Hv-8468	3585	60	Hannover
52	393	VRI-553	9370	150	Vienna
52	40	Hv-8472	1550	75	Hannover
53	240	VRI-537	8670	130	Vienna
53	210	Hv-8467	8385	65	Hannover
53	160	Hv-8466	6810	85	Hannover
53	120	Hv-8465	5050	75	Hannover
53	60	Hv-8464	2730	95	Hannover
54	470	VRI-539	10020	190	Vienna
54	405	VRI-548	8920	130	Vienna
54	340	VRI-549	7870	140	Vienna
54	190	VRI-550	5450	110	Vienna
54	95	VRI-551	2050	70	Vienna
54	55	VRI-552	1220	80	Vienna
55	550	VRI-538	11790	170	Vienna
55	510	VRI-540	10030	170	Vienna
55	415	VRI-541	8480	110	Vienna
55	120	Hv-8473	1495	150	Hannover
58	250	VRI-382	6200	100	Vienna
58	485	VRI-340	12310	170	Vienna
77	6	R-892	6930	60	Rome
90	180	Hv-6041	6920	95	Hannover
90	130	Hv-6040	6095	95	Hannover
90	40	Hv-6039	2045	50	Hannover
91	440	VRI-341	12850	180	Vienna

New impulses in the late 1970s and 1980s stem from new research objectives: describe climate-vegetation equilibrium and understand the influence of man-induced change on this relationship (Birks 1990, Overpeck *et al.*, 1991). The majority of ^{14}C dates in the Alpine data-set become available in this period, even if the radiocarbon dating of pollen data had been massively applied elsewhere for at least a decade. In fact only ~1.78‰ of sampled levels in the north-east Italy set are radiocarbon dated.

These shifts have the direct effect of making the 'pre-1958' set unbalanced and uninformative compared to the more recent one, and therefore obsolete. Recent European, continental and planetary scale reconstructions of Holocene vegetational dynamics and climate (Huntley & Birks, 1983, Delcourt & Delcourt, 1987, COHMAP, 1988, Prentice *et al.*, 1991) do not use the large amounts of data developed in the 1916 ÷ ~1960 period.

In order to achieve a spatial coverage of palynological data comparable to that obtained by grouping the pre- and post-1958 sets together, the older diagrams should be replicated. This is both costly and time-consuming; furthermore this may not always prove to be possible given that a number of bog sites have been destroyed in recent years.

3. THE METHOD

3.1 Outline of the method

Classificatory discriminant analysis (Hand, 1981, Anderson, 1984) is proposed; this technique falls within the category of multivariate analysis methods (Kendall, 1975). The starting point is a matrix (**X**) of m observations of p predictors which is to be related to an (**Y**) matrix of n obervations of q predictands; predictors are related to predictands using a *calibration function*.

Predictors are observations classified into one of a number of pre-defined groups on the basis of one or more numerical variables; for each observation a discriminant criterion is developed using either a linear of a quadratic discriminant function; the discriminant criteria (the *calibration functions*) are then applied to a second data set containing the *predictands*, and are used to classify data devoid of the classificatory numerical variable(s).

Table 3 - Univariate statistics of the predictor set. (N) is the number of observations; (Sum) is the sum of all the values of the given variable.

Statistiche univariate dei predittori. (N) è il numero delle osservazioni; (Sum) è la somma di tutti i valori della variabile.

Variable	No	Sum	Mean	Variance	Std. Dev.
Abies	38	2.56356	0.06746	0.01119	0.10576
Alnus	38	9.56340	0.25167	0.03002	0.17326
Betula	38	8.68935	0.22867	0.01630	0.12766
Corylus	38	3.79375	0.09984	0.00824	0.09078
Fagus	38	2.95393	0.07774	0.01957	0.13990
Picea	38	13.19523	0.34724	0.09208	0.30344
Pinus	38	26.84447	0.70643	0.10293	0.32083
Quercetum Mixtum	38	7.50263	0.19744	0.02786	0.16693
Salix	38	0.89759	0.02362	0.00363	0.06028

Sum - sum of the values for all observations

Classificatory discriminat analysis requires that the data be multinormally distributed; in the absence of multinormality non-parametric calibration functions can be developed. The calibration function is developed using either a linear or a quadratic discriminant function and predictands are classified into one of the pre-defined groups according to proximity (either Mahalanobis [D^2] or Euclidean distance) to the discriminant criterion.

The classificatory performance of the calibration can be evaluated by estimating the probability of correct classification: probability of membership for each predictor to its pre-defined group is assessed using a posterior probability function (Glick, 1978, Snapinn & Knoke, 1985). This estimates the probability of each observation being classified into its group: the estimated density of each group after classification and the prior probability of each case being assigned to one or other group is used; this may be both weighed and unweighed. In the present example prior probability is unweighed for all groups (see Table 5). Performance of the calibration function and the probability of misclassifying the predictands is evaluated in a similar way.

Verification of calibration functions using a second set of independent predictors has become a standard procedure with biological data (Birks & Gordon, 1985; Cook & Kairiukstis, 1990); unfortunately, given the small number of radiocarbon-dated pollen levels, the predictor set could not be divided into one, a first set used to develop the calibration functions, a second to verify their efficiency.

3.2 Application of the technique to a palynological set

In the case of a palynological set the *predictors* are a matrix of observations containing pollen levels for which both the frequency of pollen-identified species and the radiocarbon date associated with the layer are available. Each observation is placed into one of a number of arbitrary and pre-defined groups on the basis of the radiocarbon date; a discriminant criterion is derived using the ‰-frequency values of the pollen-identified

Table 4 - Univariate statistics of each temporal group.

Statistiche univariate di ciascun gruppo temporale.

Variable	No	Sum	Mean	Variance	Std. Dev.
Group = 14-12 kyr BP					
Abies	3	0	0	0	0
Alnus	3	0	0	0	0
Betula	3	1.06895	0.35632	0.00454	0.06738
Corylus	3	0	0	0	0
Fagus	3	0	0	0	0
Picea	3	0	0	0	0
Pinus	3	3.38926	1.12975	0.00628	0.07927
Quercetum Mixtum	3	0	0	0	0
Salix	3	0.13484	0.04495	0.00606	0.07785
Group = 12-10 kyr BP					
Abies	5	0	0	0	0
Alnus	5	0.18808	0.03762	0.00707	0.08411
Betula	5	1.63817	0.32763	0.01095	0.10463
Corylus	5	0	0	0	0
Fagus	5	0	0	0	0
Picea	5	0.16947	0.03389	0.00215	0.04641
Pinus	5	5.49706	1.09941	0.01629	0.1276
Quercetum Mixtum	5	0.42597	0.08519	0.00734	0.08570
Salix	5	0	0	0	0
Group = 10-8 kyr BP					
Abies	9	9	0	0	0
Alnus	9	1.69076	0.18786	0.01126	0.10614
Betula	9	1.21555	0.13506	0.01268	0.11261
Corylus	9	1.33271	0.14808	0.01566	0.12515
Fagus	9	0	0	0	0
Picea	9	1.52092	0.16899	0.05777	0.24036
Pinus	9	7.18272	0.79808	0.12757	0.35717
Quercetum Mixtum	9	2.68366	0.29818	0.04294	0.20722
Salix	9	0.27859	0.03095	0.00385	0.06207
Group = 8-6 kyr BP					
Abies	8	0.25227	0.03153	0.00341	0.05844
Alnus	8	2.55511	0.31939	0.00957	0.09781
Betula	8	2.11685	0.26461	0.02200	0.14831
Corylus	8	1.23405	0.15426	0.0009523	0.03086
Fagus	8	0.49530	0.06191	0.00972	0.09857
Picea	8	4.57913	0.57239	0.11779	0.34320
Pinus	8	3.57542	0.44693	0.02971	0.17238
Quercetum Mixtum	8	2.33480	0.29185	0.02755	0.16599
Salix	8	0.35533	0.04442	0.00938	0.09685
Group = 6-4 kyr BP					
Abies	4	0.59978	0.14994	0.01140	0.10675
Alnus	4	1.81548	0.45387	0.01391	0.11794
Betula	4	0.66740	0.16685	0.00160	0.03994
Corylus	4	0.38100	0.09525	0.00420	0.06484
Fagus	4	0.30411	0.07603	0.00779	0.08828
Picea	4	2.46890	0.61722	0.01542	0.12417
Pinus	4	2.14527	0.53632	0.00280	0.05295
Quercetum Mixtum	4	0.41805	0.10451	0.00916	0.09569
Salix	4	0.12883	0.03221	0.00415	0.06441
Group = 4-2 kyr BP					
Abies	6	1.24299	0.20716	0.02003	0.14153
Alnus	6	2.25642	0.37607	0.02002	0.14151
Betula	6	1.20334	0.20056	0.01211	0.11003
Corylus	6	0.52200	0.08700	0.00652	0.08073
Fagus	6	1.43178	0.23863	0.05853	0.24192
Picea	6	3.02169	0.50361	0.00528	0.07269
Pinus	6	3.07977	0.51329	0.04083	0.20207
Quercetum Mixtum	6	1.02150	0.17025	0.01100	0.10488
Salix	6	0	0	0	0
Group= 2-0 kyr BP					
Abies	3	0.46853	0.15618	2.41745E-6	0.00155
Alnus	3	1.05754	0.35251	0.00203	0.04507
Betula	3	0.77909	0.25970	0.00971	0.09853
Corylus	3	0.32399	0.10800	0.00104	0.03224
Fagus	3	0.72275	0.24092	0.0000873	0.00934
Picea	3	1.43512	0.47837	0.00239	0.04886
Pinus	3	1.97497	0.65832	0.00951	0.09752
Quercetum Mixtum	3	0.61864	0.20621	0.0004667	0.02160
Salix	3	0	0	0	0

Table 5 - Frequency and ‰ of radiocarbon dates for each temporal group: probability of classification per group is equal.

Frequenza e proporzione percentuale (‰) di radiodatazioni per ciascun gruppo temporale; la probabilità di classificazione per ciascun gruppo è uguale.

Group	Frequency	Proportion	Probability
14-12 kyr BP	3	0.078947	0.142857
12-10 kyr BP	5	0.131579	0.142857
10-8 kyr BP	9	0.236842	0.142857
8-6 kyr BP	8	0.210526	0.142857
6-4 kyr BP	4	0.105263	0.142857
4-2 kyr BP	6	0.157895	0.142857
2-0 kyr BP	3	0.078947	0.142857

species for each observation placed into each group.

The *predictands* are a matrix of observations containing pollen levels for which the ‰-frequency of pollen-identified species are available, but which are devoid of the radiocarbon date.

Calibration in this context estimates a time-dependent relationship between a set of *predictors*, pollen patterns for which absolute dating is available, and a set of *predictands*, or dependant pollen vectors devoid of ^{14}C dating. The discriminant criterion (*calibration function*) is then applied to the *predictands*, classifying each into one of the pre-defined temporal groups.

Raw pollen data has been normalized using the arcsin√ transformation of raw pollen scores. Calculations are carried out using SAS, versions 5 and 6.

4. RESULTS

4.1 Testing multinormality of the data set

Table 3 gives the univariate statistics of the predictor set, Table 4 those for each temporal group. Results indicate that the predictor set is not multinormally distributed, but that the data in each temporal group is multinormal. This provides support for the initial assumption that discrete vegetational groups in time are present in the set.

Non-parametric discriminant functions have also been developed to highlight any difference compared to parametric disciriminant functions. Results do not differ significantly from the more robust parametric discriminant function; the latter have consequently been used.

4.2 Creation of the predictor set

Seven arbitrary temporal groups each spanning 2 kyr BP have been defined, starting from 14 kyr BP; Table 5 gives the number of ^{14}C dates per temporal group.

4.3 Creation of the calibration function

Table 6 gives the pairwise generalized D^2 distance between groups as defined by the discriminant function.

A set of Multiple Analysis of Variance (MANOVA) statistics, as given in Table 7, indicates that groups are significantly separated between each other ($p>0.0001$).

4.4 Evaluating the classificatory performance of the calibration

A number of misclassified and reassigned predictors have been identified; results are summarized in Table 8.

Misclassified and reassigned predictors have not been removed from the predictor set, since these reflect shifts in vegetational patterns within a given time period.

Approximately 45‰ of the predictand set are reclassified into another group: summary results are given in Table 9.

It is not possible, and perhaps not useful, to give the posterior probability scores for each of the ~2100 pollen levels evaluated.

Six factors, either numerical or ecological, contributing to reclassification, both of predictors and predictands, can be identified:

- numerical:
  a) the small size of the predictor data set;
  b) a radiocarbon date ± standard deviation overlaps the dividing date between 2 groups (for example 5790±215, 10030±170 etc.);
  c) probability of reclassification into another group is

Table 6 - Pairwise generalized squared distances between groups.

Distanza generalizzata quadrata (D2) a coppie tra i gruppi.

From Group	Generalized Squared Distance to Group						
	14-12 kyr BP	**12-10 kyr BP**	**10-8 kyr BP**	**8-6 kyr BP**	**6-4 kyr BP**	**4-2 kyr BP**	**2-0 kyr BP**
14-12 kyr BP	0	2.38008	12.45128	39.62088	64.04309	57.82407	52.70551
12-10 kyr BP	2.38008	0	8.58331	31.18950	58.25738	51.36352	44.38374
10-8 kyr BP	12.45128	8.58331	0	22.64097	48.90074	48.59834	40.41740
8-6 kyr BP	39.62088	31.18950	22.64097	0	18.57793	18.23229	12.91899
6-4 kyr BP	64.04309	58.25738	48.90074	18.57793	0	4.60769	9.86117
4-2 kyr BP	57.82407	51.36352	48.59834	18.23229	4.60769	0	3.77486
2-0 kyr BP	52.70551	44.38374	40.41740	12.91899	9.86117	3.77486	0

Table 7 - Multivariate statistics and F approximations.
Statistiche multivariate ed approssimazioni del valore di F.

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.00752700	3.6307	54	121.8716	0.0001
Pillai's Trace	2.57797201	2.3437	54	168.0000	0.0001
Hotelling-Lawley Trace	15.10598213	5.9678	54	128.0000	0.0001
Roy's Greatest Root	11.37287294	35.3823	9	28.0000	0.0001

NOTE: F Statistic for Roy's Greatest Root is an upper bound.

Table 8 - Predictor set. Results of posterior probability of membership of each reassigned case to its temporal group: probability of belonging to the original or the reclassified group are given. A third group may also be identified: probability scores are not given. The table gives only misclassified observations: the majority are reclassified into temporally adjacent groups. Those assigned to distant time groups are marked with an asterisk.

Previsori. Risultati della probabilità posteriore di appartenenza di ciascun caso riassegnato al proprio raggruppamento temporale: viene data la probabilità di appartenenza al proprio gruppo od a quello di riclassificazione. Un terzo gruppo viene talvolta identificato: la probabilità non viene riportata. La tabella riporta solamente i casi misclassificati: la maggioranza vengono riclassificati in gruppi temporali adiacenti. Quelli assegnati a gruppi temporalmente più distanti sono individuati da un asterisco.

Site	14C date (± st. dev.)	height m a.s.l.	site coordinates	original group	re-classified group	posterior probability original group	posterior probability re-classified group
51	12700±200	870	46.46°N 11.39°E	14-12 kyr BP	12-10 kyr BP	0.21	0.79
91	12850±180	500	46.25°N 11.17°E	14-12 kyr BP	12-10 kyr BP	0.49	0.51
58	12310±170	1260	46.31°N 11.24°E	14-12 kyr BP	12-10 kyr BP	0.47	0.48
55	11790±170	2033	46.42°N 11.34°E	12-10 kyr BP	14-12 kyr BP	0.02	0.94
11	11250±120	100	45.22°N 10.38°E	12-10 kyr BP	14-12 kyr BP	0.43	0.55
54	10020±190	2080	46.42°N 11.34°E	12-10 kyr BP	10-8 kyr BP	0.43	0.51
52	9370±150	2033	46.42°N 11.34°E	10-8 kyr BP	12-10 kyr BP	0.44	0.45
51	9135±90	870	46.46°N 11.39°E	10-8 kyr BP	14-12 kyr BP *	0.03	0.60
53	8670±130	2050	46.42°N 11.34°E	10-8 kyr BP	12-10 kyr BP	0.13	0.78
53	8385±65	2050	46.42°N 11.34°E	10-8 kyr BP	8-6 kyr BP	0.01	0.99
90	6095±95	1400	46.35°N 12.30°E	8-6 kyr BP	2-0 kyr BP *	0.33	0.26
50	7860±75	650	46.09°N 11.04°E	8-6 kyr BP	10-8 kyr BP	0.01	0.95
27	5790±215	2076	46.54°N 11.06°E	6-4 kyr BP	4-2 kyr BP	0.03	0.80
54	5450±110	2080	46.42°N 11.34°E	6-4 kyr BP	4-2 kyr BP	0.67	0.16
53	5050±75	2050	46.42°N 11.34°E	6-4 kyr BP	4-2 kyr BP	0.03	0.47
27	3830±70	2076	46.54°N 11.06°E	4-2 kyr BP	6-4 kyr BP	0.00	1.00
51	3585±60	870	46.46°N 11.39°E	4-2 kyr BP	8-6 kyr BP *	0.00	0.98
20	2905±153	823	46.08°N 19.57°E	4-2 kyr BP	2-0 kyr BP	0.17	0.82
53	2730±95	2050	46.42°N 11.34°E	4-2 kyr BP	2-0 kyr BP	0.01	0.94
54	2050±70	2080	46.42°N 11.34°E	4-2 kyr BP	6-4 kyr BP	0.01	0.95
90	2045±50	1400	46.35°N 12.30°E	4-2 kyr BP	2-0 kyr BP	0.00	0.98

slightly greater than that of the original group. Generalized D^2 distance between temporally adjacent groups tends in fact to be low (Table 6);

- e c o l o g i c a l:
  d) local site conditions related to the geographical position of each site: for instance (51) and (90) are northerly sites with a continental Alpine climate. Pollen-identified vegetation is prevalently conifer-ous, despite being only at 850÷1400 m a.s.l.;
  e) local factors which lead to sudden shifts in vegetation;
  f) the boundaries of each temporal group are arbitrary and do not take into account pedoclimatic changes occurring within each group, conditions which become characteristic of the following/preceding group: for instance a single level may reflect vegetation characteristic of Sub-Boreal/Sub-Atlantic conditions, but the temporal group is dominated by sites reflecting Atlantic conditions. The single site will be reclassified into the Atlantic-dominated vegetation group.

5. DISCUSSION

The generalized D^2 distance (Table 6) indicates similarity between temporally adjacent groups and differences between groups further apart in time. Temporal groups roughly correspond to pollen chronozones proposed for the Eastern Alps (Bortenschlager, 1982):

The data indirectly reflects the migration pattern of single species: Table 4 gives the average proportion of each species in each temporal group, indicating which species was present/absent in each period.

Table 9 - Temporal variable assigned to the predictand set. Sites are identified by a code, as assigned in Table 1; a distinction is made between pre- and post-1958 sites. The palynologist/s, the year of publication, the height in m a.s.l., the coordinates and the number of cores taken are also given.

Variabile temporale assegnata all'insieme di predetti. Le località vengono identificate mediante un codice assegnato nella tabella 1; viene fatta una distinzione tra siti pre- e post-1958. Vengono inoltre riportati: il palinoologo/i, l'anno di pubblicazione, la quota altimetrica in m, le coordinate ed il numero di carotaggi effettuati.

site	Author/s	year of publication	height m a.s.l.	coordinates	n°. of cores	predicted group 14-12 Kyr	12-10 Kyr	10-8 Kyr	8-6 Kyr	6-4 Kyr	4-2 Kyr	2-0 Kyr
1	Paganelli et al.	1958	70	45.52°N 10.52°E	1	X						
2	Paganelli	1959	1475	46.16°N 11.48°E	1			X	X	X	X	
3	Paganelli et al.	1981	1496	46.15°N 11.18°E	1						X	
4	Lona	1941	970	46.07°N 11.14°E	1						X	X
5	Lona	1941	900	46.06°N 11.13°E	1						X	X
6	Dalla Fior	1932	1880	46.17°N 10.33°E	1					X		
7	Dalla Fior	1932	1550	45.59°N 10.38°E	1					X	X	
8	Dalla Fior	1932	900	46.07°N 11.10°E	1						X	X
9	Dalla Fior	1932	655	45.52°N 10.45°E	2						X	X
10	Lona	1946	1263	45.55°N 11.10°E	1			?			X	
11	Bertoldi	1968	100	45.22°N 10.38°E	2	X	X	X				
12	Buurman	1969	26	45.47°N 12.50°E	2							X
13	Bertolani Marchetti	1965	20	45.25°N 12.14°E	1	?						
14	Durante Pasa	1972	100	45.28°N 11.33°E	2			X				
15	Lona	1957	100	45.28°N 11.33°E	1			X			X	X
16	Lona et al.	1944	10	46.12°N 11.16°E	1		?		?		X	X
17	Lona et al.	1944	1370	46.09°N 11.07°E	1						X	
18	Lona et al.	1944	1250	46.09°N 11.07°E	1			?			X	
19	Lona et al.	1944	1100	46.11°N 11.19°E	1					X	X	
20	Marchesoni	1954	823	46.08°N 10.57°E	1						X	X
21	Dalla Fior	1932	654	46.59°N 10.50°E	2							X
22	Dalla Fior	1940	1550	45.47°N 10.70°E	1					X	X	
23	Dalla Fior	1940	1435	46.16°N 11.22°E	1					X	X	
24	Dalla Fior	1940	1574	46.26°N 11.06°E	1				X	X	X	
25	Dalla Fior	1940	2100	46.34°N 10.48°E	1			X				
26	Decarli et al.	1982	2323	46.55°N 11.48°E	1					X		
27	Decarli et al.	1983	2076	46.54°N 11.06°E	1					X	X	
28	Dalla Fior	1933	1260	46.32°N 11.24°E	1					X	X	
29	Dalla Fior	1933	1350	46.32°N 11.25°E	1					X	X	
30	Dalla Fior	1935	935	46.51°N 11.29°E	1					X	X	
31	Dalla Fior	1935	1300	46.59°N 11.31°E	1					X		
32	Dalla Fior	1935	1370	47.01°N 11.30°E	1					X		
33	Dalla Fior	1935	1100	46.53°N 12.08°E	1					X	X	
34	Dalla Fior	1935	900	46.47°N 11.58°E	1					X		
35	Keller	1931	230	45.30°N 10.30°E	1				X			X
36	Keller	1931	245	45.30°N 10.30°E	1							?
37	Keller	1931	130	45.23°N 10.34°E	1					X	X	X
38	Keller	1931	120	45.23°N 10.34°E	1					X	X	X
39	Keller	1931	100	45.22°N 10.38°E	1			X				X
40	Keller	1931	105	45.25°N 10.31°E	1			X				X
41	Keller	1931	74	45.26°N 10.40°E	1							X

Table 9 - *Cont'd*
Segue

site	Author/s	year of publication	height m a.s.l.	coordinates	n°. of cores	14-12 Kyr	12-10 Kyr	predicted group 10-8 Kyr	8-6 Kyr	6-4 Kyr	4-2 Kyr	2-0 Kyr
61	Fischer et al.	1930	1670	46.13°N 10.47°E	2			X	X	X		
62	Fischer et al.	1930	1830	46.13°N 10.47°E	1			X				
63	Fischer et al.	1930	1990	46.13°N 10.47°E	1			X				
64	Fischer et al.	1930	1700	46.32°N 11.38°E	1			X	X	X		
65	Fischer et al.	1930	1650	46.24°N 11.35°E	1			X				
66	Fischer et al.	1930	1770	46.35°N 12.15°E	1			X	X	X		
67	Fischer et al.	1930	495	46.25°N 11.16°E	1		X	X				
68	Fischer et al.	1930	503	46.04°N 11.13°E	1		X	X				
69	Paganelli	1966	0	45.26°N 12.16°E	1	no diagram						
70	Durante Pasa	1959	602	45.35°N 10.54°E	1	no diagram						
71	Beug et al.	1960	879	45.25°N 10.60°E	1	X	?	X				
72	Kral	1980	1330	45.57°N 11.37°E	1			X	X			
73	Kral	1980	1240	46.04°N 11.36°E	1						X	X
74	Beug	1964	655	45.52°N 10.45°E	3	X	X	X		X	X	X
75	Paganelli et al.	1983	25	45.34°N 10.42°E	1	no diagram						
76	Paganelli et al.	1984	30	45.35°N 11.45°E	1	no diagram						
77	Cattani	1977	120	45.25°N 11.33°E	1				X			
78	Dalla Fior	1933	450	46.05°N 11.11°E	1			X	?			?
79	Fischer et al.	1930	2000	45.49°N 10.58°E	1		X					
80	Kral	1983	1880	46.32°N 11.40°E	1			X	X	X	X	
81			654	45.59°N 10.38°E		unknown						
82	Bertoldi		1770	46.35°N 12.15°E		unknown						
83			5	45.59°N 10.38°E		unknown						
84	Dalla Fior	1933	1126	46.32°N 11.26°E	2				X			X
85	Cattani	1984	1930	46.16°N 11.45°E	1							X
86	Kral	1982	1520	46.34°N 13.17°E	1						X	X
87	Kral	1982	270	46.20°N 13.04°E	1			X				X
88	Kral	1986	1290	46.24°N 11.23°E	1				X		X	
89	Cattani	1987	250	45.33°N 10.59°E	2	X						
90	Kral	1986	1400	46.35°N 12.30°E	2				X	X	X	X
91	Schmidt	1975	500	46.25°N 11.17°E	2	X	X	X				
92	Horowitz	1966	-2	45.27°N 12.21°E		unknown						

no diagram - article published with no pollen diagram   unknown - article has not been traced
Lona - pre-1958 diagram Kral - post-1958 diagram

Table10 - Comparison between the arbitrary time groups and the chronozones proposed by Bortenschlager (1982) for the Eastern Alps.

Confronto tra i gruppi temporali arbitrari e le cronozone proposte da Bortenschlager (1982) per le Alpi orientali.

period	chronozone
14-10 kyr BP	glaciation and Younger Dryas III
10-8 kyr BP	Preboreal and Boreal
8-6 kyr BP	Boreal and Atlantic
6-4 kyr BP	Atlantic
4-0 kyr BP	Sub-Boreal and Sub-Atlantic

Validity of the results obtained can be checked using a simple rule-of-thumb: starting from the bottom level sampled within each core, each sampled level/batch of levels should progressively be assigned to a more recent temporal group. This is generally the case; it should be noted that individual levels within a batch of homogeneously-dated levels are occasionally reassigned to a different group. These are recorded with a question mark (?) in Table 9.

6. CONCLUSIONS

The technique provides a means of upgrading pre-radiocarbon pollen spectra by integrating them with more recent ^{14}C dated information. The procedure highlights the temporal pattern implicitly present in data; independent ^{14}C dating positions this pattern along a timescale.

There are a number of fundamental limitations to this procedure:

a) the dating of variations (climatic, vegetational, pedogenic, and/or man-induced), in single undated spectra is imprecise, since the procedure relies on the event also being recorded in a dated spectra: these may not necessarily be synchronous, or may even be absent;

b) geographical patterns in the data, for instance migration or man-determined change may also be flattened out for the same reason;

c) the absence of a second set of predictors to verify the efficiency of the calibration functions.

The results are intended as a summary of existing data, with pre-radiocarbon data acting as complementary information for the more detailed pollen sets developed in recent years. New acquisitions will improve the potentialities of the older palynological information, until such time as this can be completely replaced with a comparable set of precisely radiocarbon dated spectra. Pre-radiocarbon pollen data can still be used as complementary information for those areas where no recent diagrams are currently available, or can be integrated with more recent data in a regional approach towards Holocene vegetation.

ACKNOWLEDGEMENTS

I would like to thank Prof. Attilio A.M. Del Re for the preliminary discussions concerning the choice of the statistical method and for the subsequent revision of the manuscript. Thanks are also due to the three anonymous referees for their constructive criticisms of the draft.

CITED REFERENCES

Anderson T.W. (1984) - *An introduction to multivariate statistical analysis.* (2nd edition), John Wiley & Sons, Inc., New York, USA.

Bertolani Marchetti D. (1965) - *Climatic and floristic events of last Glacial and Postglacial in the lagoon of Venice.* Giorn. Bot. It., **73**(1-2), 100.

Bertolani Marchetti D. (1966-1967) - *Vicende climatiche e floristiche dell'ultimo glaciale e postglaciale in sedimenti della Laguna Veneta.* Mem. Biogeografia Adriatica, **7**, 193-225.

Bertoldi R. & Andreolli P.G. (1977) - *Analisi pollinologiche del deposito lacustre postglaciale di S. Massenza.* Natura Alpina, **28**(11), 75-82.

Bertoldi R. (1968) - *Ricerche pollinologiche sullo sviluppo della vegetazione tardiglaciale e postglaciale nella regione del Lago di Garda .* Studi Trentini di Sc. Nat., Sez. B (Acta Biologica), **45**(1), 87-162.

Beug von H.J. & Firbas F. (1960) - *Ein neues Pollendiagramm vom Monte Blado.* Flora, **150**(2-3), 179-184.

Beug von H.-J. (1964) - *Untersuchungen zur spat un postglazialen Vegetationsgeschichte im Gardaseegebiet unter besonder Berucksichtigung der mediterranen Arten.* Flora, **154**, 401-444.

Birks H.J.B. & Gordon A.D. (1985) - *Numerical methods in Quaternary pollen analysis.* Ac. Press, London, UK.

Birks H.J.B. (1990) - *Changes in vegetation and climate during the Holocene of Europe.* In: Boer M.M. & Dr Groot R.S. (eds.) *Landscape-Ecological Impact of Climate Change.* OIS Press, Amsterdam, Holland, 54-55, 133-158.

Bortenschlager S. (1982) - *Chronostratigraphic subdivision of the Holocene in the Alps.* In: Mangerud J., Birks H.J.B. & Jäger K.-D. (eds.) *Chronostratigraphic subdivision of the Holocene, Striae,* **16**, 75-79, Uppsala, Sweden.

Buurman P. (1969-1970) - *Pollen analysis of Holocene and Pleistocene sediments in the neighbourhood of Portogruaro (Venezia), Italy.* Mem. Biogeogr. Adriatica **8**, 41- 51.

Cattani L. (1977) - *Dati palinologici interenti ai depositi di Pradestel e di Vatte di Zambana nella Valle dell'Adige (TN) .* Preistoria Alpina **13**, 21-29.

Cattani L. (1977) - *La Grottina dei Covoloni del Broion (Colli Berici, Vicenza). Analisi pollinica.* Riv. Sc. Preistoriche **32** (1-2), 287-296.

Cattani L. (1984) - *Il paesaggio post-glaciale del Colbricon (Passo Rolle, Trento) in base alle analisi polliniche dell'insediamento mesolitico.* Preistoria Alpina **19**, 255-258.

Cattani L. (1987) - *Riparo Tagliente: la serie stratigrafica.* in Autori Vari, Prima della storia. Inediti di 10 anni di ricerche a Verona. Catalogo della mostra, 54-46, Verona, Italy.

COHMAP Members (1988) - *Climatic changes of the last 18,000 years: observations and model simulations.* Science **241**, 1043-1052.

Cook E.R. & Kairiukstis L.A. (1990) - *Methods of dendrochronology: applications in the environmental sciences.* Kluwer Ac. Publ., London, UK.

Dalla Fior G. (1932) - *Analisi polliniche di torbe e depositi lacustri della Venezia Tridentina.* Mus. Storia Nat. Venezia Tridentina, **1**(3-4), 139-166.

Dalla Fior G. (1933) - *Torbe del Renon.* Memorie del Mus. Storia Nat. Venezia Tridentina, **1**(5), 235-249.

Dalla Fior G. (1935) - *Analisi polliniche di torbe e depositi lacustri della Venezia Tridentina. IV. Depositi torbosi dell'Alto Isarco e del Bacino idrografico della Rienza.* Mem. Mus. Storia Nat. Venezia Tridentina, **3**(1), 65-85.

Dalla Fior G. (1940) - *Analisi polliniche di torbe e depositi lacustri della Venezia Tridentina.* Mem. Mus. Storia Nat. Venezia Tridentina, **10**, 121-176.

Decarli G. B. & Rigotti D. (1982) - *Analisi palinologiche e datazione assoluta con il metodo del Radiocarbonio relative al giacimento torboso situato a m 2323 s.l.m. nella Valle del Lago - Lappago (Bolzano).* Studi Trentini Sc. Nat., Sez. B (Acta Biologica) **59**, 3-18.

Decarli B. G. & Rigotti D. (1983) - *Analisi paolinologiche e datazioni del radiocarbonio relative alla torbiera dei Granati (m 2076 s.l.m.) nella Valle del Lago (Seewertal) presso il Passo del Rombo (Timmlsjoch), Bolzano.* Studi Trentini Sc. Nat., Sez. B (Acta Biologica), **60**, 9-24.

Delcourt P.A. & Delcourt H.R. (1987) - *Long-term forest dynamics of the Temperate zone: a case study of Late-Quaternary forests in Eastern North America.* Springer- Verlag, New York, USA.

Durante Pasa M.V. (1959) - *I depositi quaternari del Ponte di Veja. La Flora.* Mem. Mus. Civico Storia Nat. di Verona, **2**, 309-325.

Durante Pasa M.V. (1972) - *Analisi polliniche nell'insediamento preistorico di Molino Casarotto (Lago di Fimon).* Mem. Mus. Civico Storia Nat. di Verona, **20**, 9- 16.

Firbas F. (1949) - *Spät- und nacheisqeitliche Waldgeschichte Mitteleuropas I.* Gustav Fischer, Jena, Germany.

Firbas F. (1952) - *Spät- und nacheisqeitliche Waldgeschichte Mitteleuropas II.* Gustav Fischer, Jena, Germany.

Fischer O. & Lorenz A. (1930-1931) - *Pollenanalytische Untersuchungen an Mooren der Sudostalpen.* Zietschrift für Botanik, **24**, 186-197.

Glick N. (1978) - *Additive estimators for probabilities of correct classification.* Pattern Recognition, **10**, 211-222.

Guiot J. (1985) - *The extrapolation of recent climatological series with spectral canonical regression.* J. Climatol., **5**, 325-335.

Hand D.J. (1984) - *Discrimination and Classification.* John Wiley & Sons, Inc., New York.

Horowitz A. (1966-1967) - *Palynological studies in the Lagoon of Venice.* Mem. Biogeogr. Adriatica, **7**, 17-27.

Huntley B. & Birks H.J.B. (1983) - *An atlas of past and present pollen maps for Europe: 0- 13,000 years ago.* Cambridge University Press, Cambridge, UK.

Keller P. (1931) - *Die postglazialen Entwiklungsgeschichte der Walder von Norditalien.* Verlag Hans Huber, Berna, Switzerland.

Kendall M.G. (1975) - *Multivariate Analysis.* Charles Griffin & Co., London, UK.

Kral F. & Carmignola G. (1986) - *Ein Pollenprofil aus dem Wolfmoor bei Deutschnofen.* Der Schlern, **60**(12), 733-739.

Kral F. (1969) - *Zür Frage der naturlichen Fichtenverbreitung im Fagetum des Bosco del Cansiglio.* Mitt. Ostalp. Din. Pflanzensoz. Arbeitsgem, **9**, 261-273.

Kral F. (1980) - *Zür postglazialen Vegetationsgeschichte am Sudrand der Ostalpen. Pollenanalytische Untersuchungen im Val Sugana-Umkreis.* Bot. Jahrb. Syst., **101**(4), 575-593.

Kral F. (1982) - *Zür postglazialen Vegetationsgeschichte am Sudrand der Ostalpen. II Pollenanalytische Untersuchungen im nordlichen Friaul.* Bot. Jahrb. Syst., **103**(3), 343- 370.

Kral F. (1983) - *Ein pollenanalytischer Beitrag zur Vegetationsgeschichte der Seiser Alm.* Der Schlern, **57**(1), 31-36.

Kral F. (1986) - *Zür postglazialen Vegetationsgeschichte in den Sudlichen Ostalpen. Pollenanalytische Untersuchungen im Comelico.* Bot. Jahrb. Syst. ,**106**(3), 409-417.

Lona F. (1941) - *Analisi polliniche di due torbiere del Trentino.* Studi Trentini Sc. Nat., Sez. B (Acta Biologica), **33**, 149-171.

Lona F. (1946) - *La torbiera di Folgaria.* Nuovo Giorn. Bot. It., n.s. **53**(3-4), 576- 600.

Lona F. (1949) - *Il paesaggio floristico preistorico dell'Altipiano di Asiago.* Nuovo Giorn. Bot. It., n.s. **56**, 667-669.

Lona F. (1957) - *I depositi lacustri euganei: archivio paleontologico del tardo glaciale e del periodo postglaciale.* Mem. Biogeografia Adriatica, **5**, 3-11.

Marchesoni V. (1954) - *Il lago di Molveno e la foresta riaffiorata in seguito allo svaso.* Studi Trentini Sc. Nat., Sez. B (Acta Biologica), **31**, 9-24.

Marchesoni V. (1959) - *Ricerche pollinologiche in sedimenti torbosi della Pianura Padana.* Nuovo Giorn. Bot.It., n.s. **66**, 336-339.

Overpeck J.T., Bartlein P.J. & Webb III T. (1991) - *Potential magnitude of future vegetation changes in Eastern North America: comparison with the past.* Science, **254**, 692-695.

Paganelli A. & Bernardi M.A. (1981) - *Contributo alla storia della vegetazione e del clima del postglaciale del Trentino. Analisi pollinica del deposito torboso del Vedes (Val di Cembra).* Studi Trentini Sc. Nat., Sez. B (Acta Biologica), **58**, 375-391.

Paganelli A. (1959) - *Diffusione postglaciale della Picea, Abies e Fagus a S. Martino di Castrozza.* Studi Trentini Sc. Nat., Sez. B (Acta Biologica), **36**(1), 60-72.

Paganelli A. (1966-1967) - *Primi risultati di alcune analisi polliniche eseguite su di una terebrazione di Porto Marghera (Venezia).* Mem. Biogeogr. Adriatica, **7**, 151- 157.

Paganelli A. (1984) - *Storia climatico-forestale del Pliocene e del Quaternario.* In: Aspes A. (ed.) *Il Veneto nell'Antichità: preistoria e protostoria.* **I**, 69-94, Banca Pop. Verona, Verona, I.

Prentice I.C., Bartlein P.J. & Webb III T. (1991) - *Vegetation and climate change in Eastern North America since the last glacial maximum.* Ecology, **72**(6), 2038-2056.

Schmidt von R. (1975) - *Pollenanalytushce Untersuchingen zur spatglazialen bis mittelpostglazialen Vegetationsgeschichte im Raume Bozen.* Linzer Biol. Bietr. , **7**(2), 225-247.

Seiwald A. (1980) - *Beitrage zur Vegetationsgeschichte Tirols IV: Natzer Plateau. Villanderer Alm.* Ber. Nat. Med. Ver. Innsbruck, **67**, 31-72.

Snapinn S.M. & Knoke J.D. (1985) - *An evaluation of smoothed classification error-rate estimators.* Technometrics, **27**, 199-206.

Manoscritto ricevuto il 6.4.1992
Inviato all'Autore per la revisione il 3.8.1992
Accettato per la stampato il 22.9.1992