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CLUSTER ANALYSIS IN POLLEN DATA OF HOLOCENE VEGETATION IN NORTHERN IRELAND: 12,000 TO 1,000 YEARS BP. II. PHYTOGEOGRAPHICAL RECONSTRUCTION

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ABSTRACT - *Cluster analysis in pollen data of Holocene vegetation in Northern Ireland:12,000 to 1,000 years BP. II. Phtogeograpical reconstruction* - Il Quaternario, 5(1), 1992, p. 85-98 - In a previous paper (Evans, 1992) non-hierarchical unconstrained cluster analysis has been applied to a selection of Northern Ireland pollen data. In the present paper the identified vegetation types are mapped at intervals of 1,000 years starting from 12,000 BP. The effects of migrating taxa and man-induced forest clearance on the Holocene distribution of vegetation types in the area are described. Local vegetational chronosequences (Jessen, 1949; Mitchell ,1951), the European vegetation types described by Huntley & Birks (1982) and the post-glacial distribution of arboreal species in the British Isles as described by Birks (1990) are compared with the groups identified by the cluster analysis.

RIASSUNTO - *Cluster analysis di dati palinologici della vegetazione olocenica dell'Irlanda del Nord: 12,000 a 1,000 anni BP. II. Ricostruzione fitogeografica* - Il Quaternario, 5(1), 1992, p. 85-98 - In un precedente lavoro (Evans, 1992) la *cluster analysis* è stata applicata ad una selezione di dati palinologici dell'Irlanda del Nord. Nel presente lavoro le diverse unità vegetazionali identificate vengono mappate ad intervalli di 1,000 anni a partire dal 12,000 BP. Vengono descritti gli effetti di specie migranti e della deforestazione antropica sulla distribuzione olocenica dei tipi vegetazionali identificati. Viene effettuato il confronto delle unità vegetazionali con le locali cronosequenze della vegetazione (Jessen, 1949; Mitchell, 1951), con i tipi vegetazionali europei descritti da Huntley & Birks (1982) e la distribuzione delle specie arboree nel post-glaciale delle Isole Britanniche decritta da Birks (1990).

Key-words: Palynology, Northern Ireland, vegetation types, pollen-vegetation maps, vegetation chronosequences
Parole chiave: Palinologia, Irlanda del Nord, tipi vegetazionali, cartografia vegetazione-pollinica, cronosequence vegetazionali

1. INTRODUCTION

A number of vegetational units have been identified in a selection of Northern Ireland pollen data using unconstrained cluster analysis (Evans, 1992). Clusters are positioned along a radiocarbon timescale, and vegetation types are mapped at intervals of 1,000 years starting from 12,000 BP.

This paper discusses the results in phytogeographical terms, and compares them with the chronosequences developed in the early 1950s, still used as reference zonations by local archæologists and paleœcologists. Data is also compared with the European vegetation types identified by Huntley & Birks (1982) and with the Holocene distrubution pattern of arboreal species proposed by Birks (1990).

2. DISCUSSION

2.1 Existing chronosequences

Two different chronozonations have been developed for Northern Ireland: Jessen's (1949) and Mitchell's (1951) schemes, which have remained substantially unaltered since publication. Table 1 schematically reproduces both chronozonation schemes; no absolute or relative dating is provided.

Both are parallel up to zones VI and VII; substantial differences are then apparent. Mitchell emphasizes man-induced changes in vegetation, with zonation largely based on the behaviour of the *Pinus* curve. As originally intended neither bears any indications as to climatic change, despite the use of the terms 'Boreal' and 'Atlantic', borrowed from Blytt-Sernander chronozones adopted by Firbas for Central Europe (1949). The term 'rational limit', here abbreviated to R.L., is defined as "the point at which the pollen curve begins to rise to sustained high values" (Jessen, 1949).

A third chronosequence is available, Huntley & Birks' (1982) European vegetation types. These are derived from a principal components analysis of approximately 850 pollen diagrams throughout Europe. Values of each species present in each vegetation type are summarized in Table 2: these are expressed as a percentage value.

Alnus sp is absent from their classification and has been added since it is currently present in the vegetation of Northern Ireland: soil pollen samples contain 1÷2% of its pollen grains (Huntley & Birks, 1982). Its introduction into their scheme is intended to allow a closer adherence with the different vegetational units identified for Northern Ireland by the clustering method.

Composition of the vegetational types resulting from the cluster analysis is given in Table 3: in order to ease comparison, data is presented as in Table 2.

Figure 1 gives the spatial distribution of vegetation types mapped at 1,000 year intervals starting from 12,000 yrs BP.

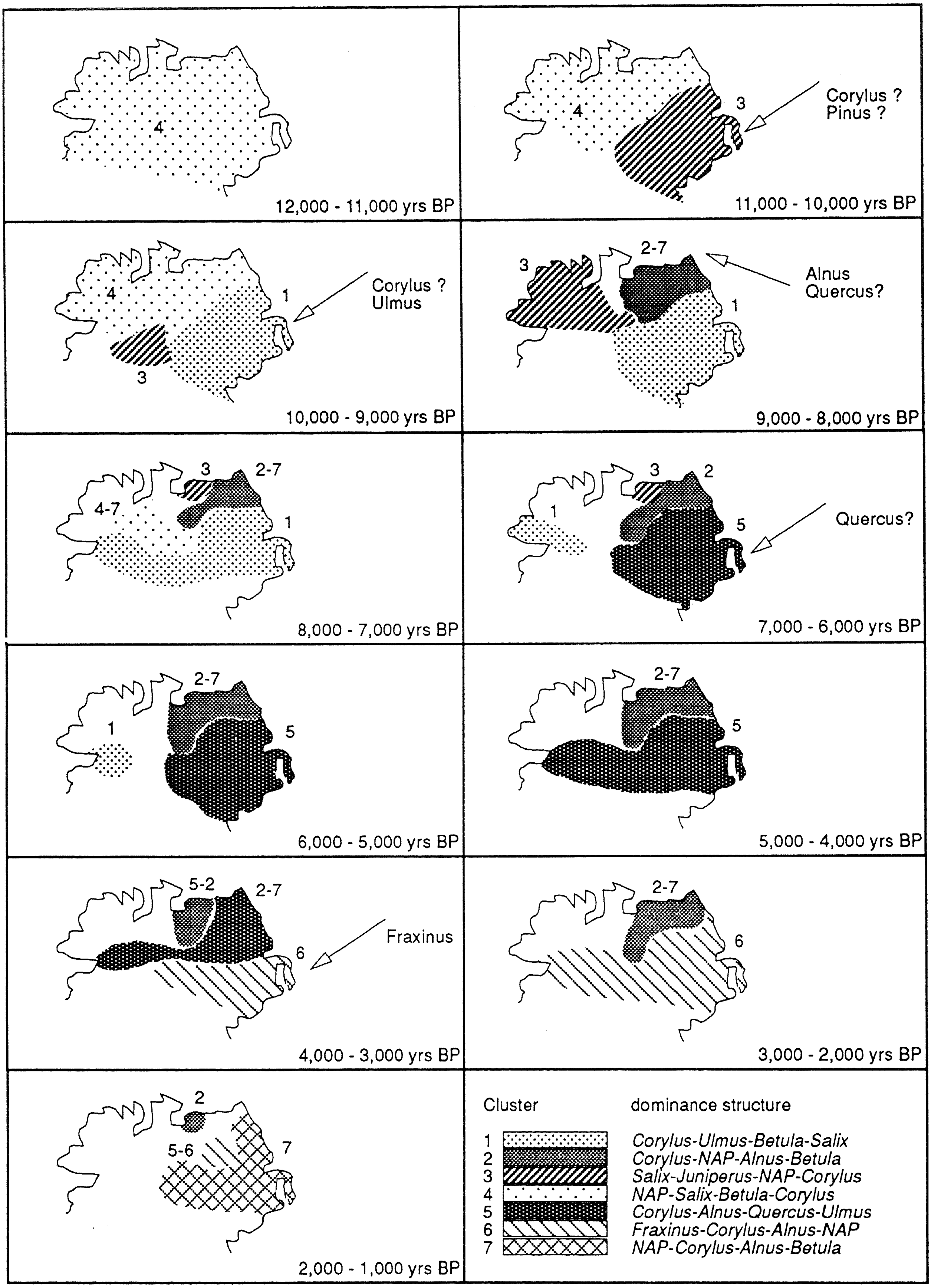
4
12,000 - 11,000 yrs BP
4
3
Corylus ?
Pinus ?
11,000 - 10,000 yrs BP
4
1
3
Corylus ?
Ulmus
10,000 - 9,000 yrs BP
3
2-7
1
Alnus
Quercus?
9,000 - 8,000 yrs BP
3
2-7
4-7
1
8,000 - 7,000 yrs BP
3
2
1
5
Quercus?
7,000 - 6,000 yrs BP
2-7
1
5
6,000 - 5,000 yrs BP
2-7
5
5,000 - 4,000 yrs BP
5-2
2-7
6
Fraxinus
4,000 - 3,000 yrs BP
2-7
6
3,000 - 2,000 yrs BP
2
5-6
7
2,000 - 1,000 yrs BP
Cluster
dominance structure
1 Corylus-Ulmus-Betula-Salix
2 Corylus-NAP-Alnus-Betula
3 Salix-Juniperus-NAP-Corylus
4 NAP-Salix-Betula-Corylus
5 Corylus-Alnus-Quercus-Ulmus
6 Fraxinus-Corylus-Alnus-NAP
7 NAP-Corylus-Alnus-Betula

Table 1 - Jessen and Mitchell's palynological chronosequences
Cronosequenze palinologiche di Jessen e Mitchell.

<table>
<tr><th></th><th>JESSEN (1949)</th><th>MITCHELL (1951)</th></tr>
<tr><td>late glacial</td><td colspan="2">Zone I -- older Salix herbacea period
Zone II -- late-glacial Betula period (Allerød)
Zone III -- younger Salix herbacea period
drop in Betula and rise in Pinus curves</td></tr>
<tr><td>post-glacial</td><td colspan="2">Zone IV -- post-glacial Betula period
Betula dominant, much Salix, decrease in NAP</td></tr>
<tr><td>Boreal</td><td colspan="2">Zone V -- Corylus-Betula period
much Betula, little Pinus, R.L. of Corylus
Zone VI -- Corylus-Pinus period
R.L. of Ulmus and Quercus
VIa: maximum of Corylus
VIb: highest values of Ulmus
VIc: highest values of Pinus, minimum of Corylus</td></tr>
<tr><td>Atlantic</td><td>Zone VII
R.L. of Alnus
disappearance of Pinus (end of VIIb)
· decline in Ulmus and rise of Alnus
rise in Corylus

VIIa: Alnus-Quercus-Pinus period
VIIb: Alnus-Quercus period</td><td>Zone VII
increase of Alnus
fall of Pinus
high Ulmus
rise in Corylus</td></tr>
<tr><td>Sub-boreal</td><td></td><td>Zone VIII (Pagan period)
early rise of Quercus
later drop of Quercus
decline of Ulmus
rise of Corylus
rise of Betula
rise of NAP (ribwort plantain)</td></tr>
<tr><td>Sub-Atlantic and Historic</td><td>Zone VIII
disappearance of Pinus
maximum of Quercus</td><td>Zone IX (Christian period)
maximum of Quercus
rise of Corylus
low ribwort plantain
in middle, low Corylus
appearance of planted trees:
Fagus and Ulmus

Zone X
planted trees, especially
Fagus, Ulmus and Pinus</td></tr>
</table>

Modified and reduced from Smith (1970).

Fig. 1 - Northern Ireland. Distribution of the vegetation types identified by the cluster analysis at 1,000 year intervals starting from 12,000 years BP. Migrating species are identified; (?) indicates uncertainty as to whether a species is migrating during more than one time period.

Irlanda del Nord. Distribuzione dei tipi vegetazionali identificati dalla cluster analysis ad intervalli di 1,000 anni a partire dal 12,000 BP. Vengono identificate le specie migranti; (?) indica un'incertezza cronologica, in quanto la specie viene identificata in più intervalli temporali.

2.2 Migrating species

During the early Holocene, new species migrated into Northern Ireland. The clustering method has identified the migrating species, and has timed their arrival. Huntley & Birks (1982) and Birks (1990) have identified 2 potential source areas for migrating species, namely (i) southern Ireland, (ii) Galloway, the southern Highlands and the islands of Kintyre, Jura, Arran and Islay (SW Scotland).

Table 2 - European pollen-identified vegetation types (modified from Huntley & Birks, 1982): values of each species are expressed as a percentage.

Tipi vegetazionali europei identificati dai pollini (modificato da Huntley e Birks, 1982): i valori di ciascuna species sono espressi come percentuali.

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
1. Tundra	<5		<10b		< 50	>10	< 50		
2. Birch	<5		<10b		> 50	<10	> 50	<5	
2b. Xeric variant	<5		<10b	>10	> 50	<10	> 50	>5	
3. Birch-conifer	<5		<10b		< 50		> 50	<5	
3b. Xeric variant	<5		<10b	>10	< 50		> 50	<5	
4. Northern mixed conifer-deciduous	>5		>10b				> 50		<10
5. Mixed deciduous	>5		<10a				> 50		>10
6. Montane mixed conifer-deciduous	>5	<5	>10a				> 50		<10

Key:
Mixed deciduous: *Corylus*-type, *Fraxinus excelsior*-type, *Ulmus* sp, *Quercus* sp (deciduous);
Mediterranean: *Fraxinus ornus*, *Ostrya*-type, *Quercus* sp (evergreen);
Montane-Boreal: (a) *Picea excelsa*;
(b) *Picea excelsa*, *Pinus sylvestris*;
APC1 - Arboreal pollen count 1: total tree pollen;
APC2 - Arboreal pollen count 2: total tree pollen excluding *Pinus sylvestris* and *Betula* sp.

Deciduo misto: tipo-Corylus, tipo Fraxinus excelsior, Ulmus sp, Quercus sp (deciduo);
Mediterraneo: Fraxinus ornus, tipo Ostrya, Quercus sp (sempreverde);
Montano-Boreale: (a) Picea excelsa;
(b) Picea excelsa, Pinus sylvestris;
APC 1 - polline arboreo 1: polline arboreo totale;
APC 2 - polline arboreo 2: polline arboreo totale escluso Pinus sylvestris e Betula sp.

Table 3 - Cluster characteristics expressed as component variables for comparison with Huntley and Birks' European vegetation types.

Caratteristiche dei raggruppamenti espresse come variabili componenti per il confronto con i tipi vegetazionali europei proposti da Huntley e Birks.

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
1	>5		<10b	<10	< 50	<10	> 50	>5	<10
2	>5		<10b	>10	< 50	<10	> 50	>5	>10
3	>5		<10b	>10	< 50	>10	> 50	>5	<10
4	>5		<10b	>10	< 50	<10	< 50	>5	<10
5	>5		<10b	<10	< 50	<10	> 50	>5	>10
6	>5		<10b	<10	< 50	<10	> 50	>5	>10
7	>5		<10b	>10	< 50	<10	> 50	>5	<10

3. RESULTS

Results are discussed in blocks of 3,000 years starting from 12,000 yrs BP. Clusters are compared with the European vegetation type which most closely resemble each cluster; variants are also proposed. The cluster is compared to the Jessen-Mitchell chronozonation scheme.

A section on the phytogeography of each 3,000 yr period follows; potential source areas of migrating species are tentatively identified.

3.1 Period: 12,000 ÷ 9,000 yrs BP

The following clusters have been identified in this period:

Table 4

Period yrs BP	Identified clusters
12,000 - 11,000	4
11,000 - 10,000	4, 3
10,000 - 9,000	4, 3, 1

3.1.1 Comparison 1

Dominance structure of cluster 4 :

Table 5

cluster 4	NAP	SAL	BET	COR
mean	72.83	8.52	5.66	4.77

Cluster 4 is recorded at Weir's Lough, Altnahinch, Slieve Gallion and Meenadoan.

The comparison with Huntley and Birks' vegetation types is given in Table 6.

Overall similarity between cluster 4 and the xeric birch formation is close:

- the coniferous component (*Picea* and *Pinus*) is absent since species have not reached Ireland;

Table 6

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
2. Birch	<5		<10b		> 50	<10	> 50	<5	
2b. Xeric variant	<5		<10b	>10	> 50	<10	> 50	>5	
3. Birch-conifer	<5		<10b		< 50		> 50	<5	
3b. Xeric variant	<5		<10b	>10	< 50		> 50	<5	
cluster 4	>5		<10b	>10	< 50	<10	< 50	>5	<10

- the mixed deciduous component (and the APC 2) in cluster 4 reaches values just above 5%.

Given the insular nature of Ireland, variants of the patterns developed at a continental scale are to be expected, given that passage of migrating species is restricted to a few crossing points only.

— Jessen and Mitchell chronosequence*:* **Zone II** - late-glacial birch period.

— Vegetational characteristics of cluster 4: a xeric variant of an open willow-birch formation, made up of sparse *Salix*, *Betula*, *Corylus* and *Juniperus* shrubs. All arboreal species are poorly represented, with high NAP values indicating an open, tundra-like vegetation.

3.1.2 Comparison 2

Dominance structure of cluster 3:

Table 7

cluster 3	SAL	JUN	NAP	COR
mean	37.62	18.98	13.65	13.45

Cluster 3 is recorded at Killymaddy, Weir's Lough and Sluggen Moss.

— Comparison with Huntley and Birks' vegetation types (see Table 8):

Table 8

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
2. Birch	<5		<10b		> 50	<10	> 50	<5	
2b. Xeric variant	<5		<10b	>10	> 50	<10	> 50	>5	
cluster 3	>5		<10b	>10	< 50	>10	> 50	>5	<10

Overall similarity between cluster 3 and the xeric birch formation is close. However:

- *Salix* is more pronounced than *Betula*;
- *Corylus* values begin to rise, altering the mixed deciduous component.

A more suitable comparison would be with a willow xeric variant (Table 9):

Table 9

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
2b. Willow Xeric variant	<5		<10b	>10	< 50	>10	> 50	>5	
cluster 3	>5		<10b	>10	< 50	>10	> 50	>5	<10

— Jessen and Mitchell chronosequence: **Zone III** - younger *Salix herbacea* period.

— Vegetational characteristics of cluster 3: a xeric variant of a relatively closed willow forest, made up of *Salix*, *Juniperus* and *Corylus* shrubs. NAP values have dropped significantly, and *Betula* continues to be present with values around 10%. Compared to the previous millennia, the formation has begun to develop vertically, with an greater number of arboreal individuals present in the vegetation.

Juniperus is not considered in Jessen and Mitchell's chronosequences.

3.1.3 Comparison 3

Dominance structure of cluster 1:

Table 10

cluster 1	COR	ULM	BET	SAL
mean	51.41	21.81	6.60	4.80

Cluster 1 is recorded at Weir's Lough and Sluggen Moss.

— Comparison with Huntley and Birks' vegetation types (see Table 11):

Table 11

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
4. Northern mixed conifer-deciduous	>5		>10b				> 50		<10
cluster 1	>5		<10b	<10	< 50	<10	> 50	>5	<10

The coniferous element of vegetation type 4 (*Picea* and *Pinus*) is incomplete in cluster 1:
- *Picea* is not a native arboreal species in Great Britain and Ireland;
- *Pinus* value on average reach 4%.

A more suitable comparison would be with a northern mixed deciduous variant which compensates for the absence of *Picea* from the pollen record (see Table 12):

Table12

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
4b. Northern mixed deciduous variant	>5		<10				> 50		<10
cluster 1	>5		<10b	<10	< 50	<10	> 50	>5	<10

— Jessen and Mitchell chronosequence: **Zones IV-V** - post-glacial and Boreal periods.

— Vegetational characteristics of cluster 1: a closed deciduous forest with xeric elements still persists. Deciduous species make up 70% of the total pollen count, the xeric elements around 11%.

Betula and *Salix* are probably present along forest margins and in natural clearances, and are a vestige of older vegetational units. It is possible that competition forces these species to occupy niches more in line with modern analogues.

3.2 Phytogeographical recostruction: 12,000 ÷ 9,000 yrs BP

Arboreal species present or migrating into the area during this time period, as identified by Huntley & Birks (1982) and Birks (1990), are quoted in Table 13.

Table 13

Period	Species	Distribution
13,000 BP	*Salix* sp	throughout N Ireland
13,000 BP	*Betula* sp	throughout N Ireland
12,000 BP	*Juniperus* sp	in SW Scotland and N Ireland low values in S Ireland
9,500 BP	*Corylus*-type	in SW Scotland along northern coast and centre of N Ireland in southern Ireland
9,000 BP	*Corylus*-type	throughout N Ireland
9,000 BP	*Ulmus* sp	in S Ireland advancing along an EW front in SW Scotland

3.2.1 Period: 12,000 ÷ 11,000 yrs BP

Vegetation is characterized by an open *Salix-Betula* formation, made up of stunted trees or shrubby individuals. Information is not available for all sites, but it is plausible to assume that vegetational homogeneity throughout Ireland is a characteristic feature of this period. Vegetational cover is probably limited in Northern Ireland by the expansion of ice-sheets from SW Scotland between 13,000÷12,000 yrs BP (Bølling glaciation episode), followed by a southward retreat of existing Irish ice-sheets (stage D - Synge, 1970), coinciding with the warm interglacial period (Allerød interglacial) in the rest of Europe (Dansgaard *et al.*,1989).

3.2.2 Period: 11,000 ÷ 10,000 yrs BP

This millennium is cooler than the preceding one, with a decrease of *Betula* and a rise in *Juniperus* values; *Salix* dominates the vegetation. This may be registering the cooler climatic conditions of the Younger Dryas III glacial expansion event: this ends abruptly at 10,720±150 radiocarbon yrs BP (Dansgaard *et al.*,1989) in Greenland; a more recent dendro-date of 10,970 yrs BP has been suggested for central Europe (Becker *et al.*, 1991). $\partial^{18}O$ and continental dust data from Greenland ice and Swiss lake-sediment cores register, within ~20 yr from the first suggested date, a 7°C rise in temperature due to increased summer solar radiation at high altitudes. Shifts in wood $\partial^{13}C$ levels from a Late-Glacial/Holocene tree-ring sequence recently developed in Germany also point to a rapid climate change from dry cold conditions to warmer, more humid conditions following a 5°C rise in air temperature (Becker *et al.*, 1991). *Corylus* values increase along the E coast of Northern Ireland, possibly indicating migration from SW Scotland and successive colonization of these areas, rather than a northward movement along the eastern coasts of Ireland of relict *Corylus* populations present in Southern Ireland (Birks, 1990) before 9,500 BP. Expansion may have been favoured by a retreat of ice-sheets into the areas south of Belfast and Newry (Synge, 1970) at the Younger Dryas-Holocene transition. *Pinus* may have followed a similar route into the island, but data is ambiguous. More recent evidence would suggest its northward migration from southern Ireland (Birks, 1990); however the spatial lag in the expansion rate between England and Ireland during the 8th millennium and the lack of data from central Ireland does not aid interpretation. Recent evidence for the upland vegetation of the South Pennines (Tallis & Switzur, 1990), dates 5% *Pinus* values to 9,000 BP; this may be suggestive of an earlier and more northward expansion in England than previously hypothesized. The *Salix-Juniperus* formation (cluster 2) is restricted to lowland sites, indicating that conditions were milder than in upland areas during the glacial expansion. This vegetational type marks an initial vertical evolution of vegetation; essential soil formation processes and the accumulation of nutrients and organic matter had been carried out by the dominant non-arboreal species of the previous millennium (Pennington, 1986).

3.2.3 Period: 10,000 ÷ 9,000 yrs BP

Vegetational diversification begins during this period, a feature which becomes characteristic as a result of the migration of new species into the area.

Ulmus is the most recent arrival and appears to be migrating from SW Scotland; by 9,000 BP it has moved inland into lowland areas only from the E coast. The *Corylus-Ulmus* formation (cluster 1) represents a closed mixed deciduous formation which still contains certain xeric elements, such as *Betula* and *Salix*, relicts of older formations. This type marks a further vertical evolution of the forest.

Four features are characteristic of the 12,000 - 9,000 yrs BP period:

a) the migration of new species, which cross over into Northern Ireland from SW Scotland, and possiby from southern Ireland;
b) the development of new vegetation types as a result of these migrations, starting off from the E coast. This would be indicative of a migration of some taxa from Scotland;
c) newly arrived species spread initially into lowland areas. Vegetation in these areas is characterized by increasing vertical complexity and resulting competition processes;
d) upland sites maintain older and structurally less complex vegetation types for longer periods.

3.3 Period: 9,000 ÷ 4,000 yrs BP

The following clusters have been identified in this period:

Table 14

Period yrs BP	Identified clusters
9,000 - 8,000	1, 2, 3, 4
8,000 - 7,000	1, 2, 3, 7
7,000 - 6,000	1, 2, 3, 5, 7
6,000 - 5,000	1, 2, 3, 7
5,000 - 4,000	1, 2, 3, 7

3.3.1 Comparison 4

Dominance structure of cluster 2:

Table 15

cluster 2	COR	NAP	ALN	BET
mean	28.80	23.01	10.05	9.43

Cluster 2 is recorded at Killymaddy (?), Gortcorbies core 2 (?), Altnahinch (?), Slieve Gallion (?), Ballynagilly (?) and Meenadoan (?); (?) indicates sporadic or joint presence of clusters.

— Comparison with Huntley and Birks' vegetation types:

Table 16

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
5. Mixed deciduous	>5		<10a				> 50		>10
cluster 2	>5		<10b	>10	< 50	<10	> 50	>5	>10

Overall similarity with the mixed deciduous forest type is close. However:

- *Fraxinus excelsior*-type values for cluster 2 are very low (3%), and values below 5% are recorded for all sites prior to 5,000 yrs BP (Smith & Pilcher, 1973).

— Jessen and Mitchell chronosequence: **Zone VIa** - *Corylus-Pinus* dominance during the Boreal period.

Comparison between cluster 2 and the Jessen and Mitchell chronosequences highlights a different evaluation of the rôle of *Pinus*: in the latter the average score is less than 5%. In the former emphasis may have been placed on its rôle as an indicator species rather than as a dominant element of the vegetation, since the numerical classification indicates that this is clearly not the case.

— Vegetational characteristics of cluster 2: a relatively open mixed deciduous forest, with *Betula* still present at values of 10%, occupying a position along forest margins and in clearances.

3.3.2 Comparison 5

Dominance structure of cluster 7:

Table 17

cluster 7	NAP	COR	ALN	BET
mean	47.10	19.53	9.21	6.13

Cluster 7 is recorded at Altnahinch (?), Slieve Gallion (?) and Ballynagilly; (?) indicates sporadic or joint presence of clusters.

— Comparison with Huntley and Birks' vegetation types:

Table 18

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
4b. Northern mixed deciduous variant	>5		<10				> 50		<10
cluster 7	>5		<10b	>10	< 50	<10	> 50	>5	<10

Overall similarity is close with the previously used variant 4b of the Northern mixed deciduous forest:

- *Picea* is absent from Northern Ireland;
- *Pinus* values remain at 1%.

— Jessen and Mitchell chronosequence: **Zone VIb** - *Corylus-Pinus* dominance during the Boreal period.

— Vegetational characteristics of cluster 7: an open mixed deciduous formation, with relict xeric elements such as *Betula* (6%) still persisting. In this formation NAP values are lower than in cluster 2, possibly indicating colder climatic conditions between upland and lowland sites.

3.3.3 Comparison 6

Dominance structure of cluster 5:

Table 19

cluster 5	COR	ALN	QUE	ULM
mean	38.09	20.28	14.22	8.10

Cluster 5 is recorded at Killymaddy, Weir's Lough and Sluggen Moss.

— Comparison with Huntley and Birks' vegetation types:

Overall similarity is close, although:

- *Fraxinus excelsior*-type values in cluster 5 remain below 1%.

— Jessen and Mitchell chronosequence: **Zone VII** - *Alnus-Quercus* dominance during the Atlantic period.

— Vegetational characteristics of cluster 5: a mixed and closed deciduous forest dominated by *Corylus*.

Table 20

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
5b. Mixed deciduous hazel variant	>5		<10a				> 50		>10
cluster 5	>5		<10b	<10	< 50	<10	> 50	>5	>10

Quercus values begin to increase, indicating further vertical evolution of the formations.

3.4 Phytogeographical recostruction: 9,000 ÷ 4,000 yrs BP

Arboreal species present or migrating into the area during this time period, as identified by Huntley & Birks (1982) and Birks (1990), are:

Table 21

Period	Species	Distribution
9,000 BP	*Alnus* sp	in S England
8,500 BP		disappears from S England
8,000 BP		present in SW Scotland
7,500 BP		disappears from SW Scotland and reappears in S England
7,000 BP		present in SW Scotland
6,500 BP		along E and N coasts of N Ireland
6,000 BP		throughout N Ireland
10,500 BP	*Pinus sylvestris*	present in SW Scotland
10,000 BP		along W coast of N Ireland
9,000 BP		disappears from N Ireland
8,500 BP		present in S Ireland
8,000 BP		throughout N Ireland (Huntley and Birks)
7,500 BP		in southern N Ireland (Birks, 1990)
7,000 BP		throughout N Ireland (Birks 1990)
9,000 BP	*Quercus* (deciduous)	in S Ireland advancing along an EW front
8,000 BP		in SW Ireland and eastern N I reland
7,500 BP		in western N Ireland

There is some discrepancy as to the distribution of *Pinus* in Ireland, with a 1,000 year difference concerning its presence in Northern Ireland. The data used in the present study would seem to indicate that *Pinus* may have been present along the eastern coast of Northern Ireland around 10,000 yrs BP.

A second discrepancy is highlighted for *Alnus*: Huntley and Birks indicate that alder arrives in Northern Ireland around 6,500 yrs BP, while the Northern Ireland data set unambiguously records its presence along the northern coasts around 9,000 yrs BP.

Evidence of the migration pattern of *Quercus* is also not clear: Birks (1990) indicates a common migration front in Ireland and England; however only two sites are available to record its presence in the central Ireland between 9,000÷8,000 yrs BP. Birks dates its arrival in Northern Ireland to the 8,500÷8,000 yrs BP period. Data used in this study suggests that *Quercus* may have been present along the northern coasts of Northern Ireland in the 9,000÷8,000 yrs BP period with values of 3÷4 %. Values of 15% are clearly documented for the 7,000÷6,000 yrs BP period for sites along the eastern coasts of Northern Ireland, suggesting a migration from SW Scotland, rather than a northward movement from south-central Ireland.

3.4.1 Period: 9,000 ÷ 8,000 yrs BP

Vegetation in Northern Ireland begins to be characterized by the simultaneous presence of different vegetation types.

Alder and possibly oak may be migrating into Northern Ireland from SW Scotland, although *Quercus* is registered in southern Ireland at 9,000 yrs BP (Birks, 1990).

Vegetation along the E Coast is characterized by a *Corylus-Ulmus* formation continuing through from the previous millennium. The new *Corylus-Alnus* vegetation type formed along the N coast replaces an older *Salix-Betula* formation. The vegetation of both lowland and upland sites in this area changes; lack of species diversification and reduced vertical development of the older formation may not be able to sustain the competitive superiority of the deciduous formation.

3.4.2 Period: 8,000 ÷ 7,000 yrs BP

The *Corylus-Ulmus* formation (cluster 1), a northern mixed deciduous vegetation type, spreads into the W replacing the older *Salix-Juniperus* formation (cluster 3), in both lowland and upland sites.

The *Corylus-Alnus* formation (cluster 7), another mixed deciduous type, moves from the N to the W, replacing an open *Salix-Juniperus* formation. Elements of the latter persist in the new vegetation type, such as high NAP values and the presence of *Betula*: these are drastically reduced in successive periods when the competitive *Corylus-Ulmus* formation (cluster 1) moves into the area.

3.4.3 Period: 7,000 ÷ 6,000 yrs B P

The northern mixed deciduous type dominated by *Corylus-Ulmus* (cluster 1) is replaced in lowland sites along the E coast by the more mesophylous deciduous variant characterized by *Corylus-Alnus* (cluster 5). The *Corylus-Ulmus* formation is in turn concentrated along the W coast.

Quercus values increase, possibly because of a new influx of migrating individuals from SW Scotland; a southward expansion from the N coast, or a northward migration from southern Ireland cannot be excluded.

Alnus replaces *Ulmus* as a dominant species, because of a raising of the water-tables and the exposition of wetter soils (Smith, 1970). *Corylus* values drop while still maintaining a dominant rôle in vegetation.

The *Corylus-Ulmus* (cluster 1) deciduous formation replaces the existing *Corylus-Alnus* type along the N coast; change is only minimal, and represents a closing up of the forest with further vertical evolution. As a result *Betula* is restricted to niches in line with current ones.

3.4.4 Period: 6,000 ÷ 5,000 yrs B P

This period is characterized by relative stability, with the sole exception of a W expansion of the northern mixed deciduous forest formations (cluster 2 and cluster 7); the oldest xeric formation in Northern Ireland is replaced after 3,000 years.

This is also the period of the elm decline, the single best radiocarbon dated episode in the vegetational history of the British Isles; the phenomenon appears to be synchronous and dates to bewteen 5,300 and 5,100 yrs BP (Smith & Pilcher, 1973). In terms of vegetational structure this episode is marginal, given that average pre-decline *Ulmus* values are around 8%. Post-decline values pick up to around 4% in Northern Ireland. In compositional terms the event is of little importance; its value as a temporal marker remains unaltered.

3.4.5 Period: 5,000 ÷ 4,000 yrs B P

The closed mixed deciduous *Corylus-Alnus* formation (cluster 5) replaces the *Corylus-Ulmus* formation along the W coast, replicating the pattern observed in the 7,000÷6,000 yrs BP period.

The northern mixed deciduous *Corylus-Ulmus* formation (cluster 2 and cluster 7) present along the N coasts remains stable.

A number of features characterize the 9,000÷4,000 yrs BP period:

a) the simultaneous presence of different vegetation types in the various areas of Northern Ireland;
b) 2 spatial patterns become established: (i) vegetational units move in a clockwise direction, from E to W to N coasts, and from lowland to upland sites; (ii) vegetational units move in an anti-clockwise direction, from N to W coasts, and, to a limited extent only, to the E coast. This pattern in part reflects the impact of migrating species and the formation of new vegetation types;
c) structurally more complex formations replace older, simpler vegetation types, at first along the N coast, and later in the W coastal area, which becomes the final outposts for structurally simpler formations.

3.5 Period: 4,000 ÷ 1,000 yrs B P

Table 22

Period BP	Identified clusters
4,000 - 3,000	2, 5, 6, 7
3,000 - 2,000	2, 5, 7
2,000 - 1,000	2, 5, 6, 7

3.5.1 Comparison 7

Dominance structure of cluster 6:

Table 23

cluster 6	FRA	COR	ALN	NAP
mean	35.81	20.13	13.13	9.44

Cluster 6 is recorded at Kimmyaddy (?), Gortcorbies core 2, Altnahinch, Sluggen Moss (?) and Meenadoan (?); (?) indicates sporadic or joint presence of clusters.

— Comparison with Huntley and Birks' vegetation types:

Table 24

Comparison	Mixed deciduous	Mediterranean	Montane - Boreal	Steppe	Betula	Salix	APC1	APC2	Alnus
5c. Mixed deciduous ash variant	>5		<10a				> 50		>10
cluster 6	>5		<10b	<10	< 50	<10	> 50	>5	>10

Overall similarity with the mixed deciduous forest type is close; *Fraxinus excelsior*-type dominates with values around 35%. This taxon has been recorded in preceding periods with values below 5% (Smith & Pilcher, 1973).

— Jessen and Mitchell chronosequence: **Zone VIII-IX** - *Alnus-Quercus* dominance during the Sub-Boreal and Sub-Atlantic periods. *Fraxinus* is not included in the Jessen and Mitchell chronosequences, although overall structural similarity with Zones VIII and IX is evident.

— Vegetational characteristics: a mixed and closed deciduous forest dominated by *Fraxinus*, reflecting forest clearance and post-clearance colonization of this taxon, characteristic of secondary woodland vegetation (Smith & Pilcher, 1973).

3.6 Phytogeographical recostruction: 4,000 ÷ 1,000 yrs B P

Fraxinus excelsior-type is the only species first migrating, and later spreading into the area during this period, as identified by Huntley and Birks:

Table 25

Period	Species	Distribution
5,000 BP 4,000 BP	*Fraxinus excelsior*	S of SW Scotland in N and E coasts and centre of N Ireland

3.6.1 Period: 4,000 ÷ 3,000 yrs B P

The *Fraxinus*-dominated mixed deciduous forest (cluster 6) characterizes the E coast, replacing the *Corylus-Alnus* (cluster 5) formation, which retreats to the W coast.

Widespread 'landnam type clearance' (Smith, 1970) resulting from human activity begins to take place around 2750 BC; this in turn favours expansion of *Fraxinus* into secondary woodland. *Corylus* values drop to 20%, but hazel continues to act as the main taxon involved in post-clearance woodland regeneration.

NAP values increase, indicating a shift towards a more open vegetation, as shown by the persistence of structurally stable open northern mixed deciduous forests.

3.6.2 Period: 3,000 ÷ 2,000 yrs B P

The *Fraxinus*-dominated mixed deciduous forest (cluster 6) spreads from E to W and combines, on lowland sites, with the open *Corylus-Ulmus* (cluster 2) formation; the latter maintains its hold on upland areas.

Anthropic forest clearance, as shown by the steady rise in NAP values, and the formation of secondary woodland favours the spread of*Fraxinus. Corylus* persists as a dominant element in woodland vegetation.

3.6.3 Period: 2,000 ÷ 1,000 yrs B P

This period is marked by an significant contraction of forested areas; NAP values of 50% reflect widespread deforestation and clearance for agricultural purposes. Localized forest regeneration takes place in W and central Northern Ireland in later centuries.

Two features are characteristic of this period:

a) large-scale and long-term anthropic impact on primary formations;
b) the spread of *Fraxinus*, dominant element of secondary woodland vegetation, reflecting man-induced changes.

4. CONCLUSIONS

Comparison between the vegetation types resulting from the clustering procedure with both traditional chronosequences and the European vegetational types highlights a broad basis of agreement, as summarized in Table 26.

Table 26 - Comparison between Jessen and Mitchell's chronosequences, clusters and Huntley and Birks' vegetation types.
Confronto tra le cronosequenze di Jessen e Mitchell, i raggruppamenti ed i tipi vegetazionali di Huntley e Birks.

Cluster number	Jessen and Mitchell's chronosequences	Huntley and Birks's vegetation types
cluster 4	zone II	xeric variant of an open birch forest
cluster 3	zone III	xeric variant of a willow forest
cluster 1	zones IV-V	northern mixed deciduous forest
cluster 2	zone VIa	mixed deciduous forest
cluster 7	zone VIb	open northern mixed deciduous forest
cluster 5	zone VII	hazel variant of a lixed deciduous forest
cluster 6	zone VIII-IX	ash variant of a mixed deciduous forest

Closer inspection reveals a number of significant differences. Pre-1960s chronosequences could not rely on absolute radiocarbon dating; this inevitably flattened out of any geographical difference in the vegetation which may have been present in the pollen signal for different time periods. Furthermore, the emphasis placed on a single species as a means of registering changes in vegetation through time inevitably leads to a confusion between local and larger scale changes. This in part explains the split in Jessen and Mitchell's schemes at the Boreal-Atlantic transition.

— Comparison with Huntley and Birks' numerically-derived European vegetation types indicates that a continental-scale approach may mask local patterns in vegetation. Different vegetation types are in fact be present during any one period, as shown in Table 27.

Table 27 - Summary of vegetation types in Northern Ireland. The area of dominance of each unit is identified. Indication of possible source areas of migrating species as identified from the cluster analysis are given.

Riassunto dei tipi vegetazionali nell'Irlanda del Nord. Viene identificata l'area di dominanza di ciascun tipo. Vengono fornite indicazioni sulle possibili aree di provenienza di specie migranti sulla base dei risultati della cluster analysis.

Years BP	Clusters per area of N Ireland East	West	North	Species migrating from SW Scotland	Cluster characteristics for each area on N Ireland East	West	North
1000	7	7	-		NAP-COR-ALN	NAP-COR-ALN	?
2000	7	5-6	2		NAP-COR-ALN COR-NAP-ALN	FRA-COR-ALN	COR-NAP-ALN
3000	6-2	6-2	2-7		FRA-COR-ALN COR-NAP-ALN	FRA-COR-ALN COR-NAP-ALN	COR-NAP-ALN
4000	6	5-2	2-7	*Fraxinus*	FRA-COR-ALN	COR-ALN-QUE	COR-NAP-ALN
5000	5	5	2-7		COR-ALN-QUE	COR-ULM-BET	COR-NAP-ALN
6000	5	1	2-7		COR-ALN-QUE	COR-ULM-BET	COR-NAP-ALN
7000	5	1	2-3	*Quercus?*	COR-ALN-QUE	COR-ULM-BET	COR-NAP-ALN
8000	1	4	2-7, 3		COR-ULM-BET COR-NAP-ALN	NAP-SAL-BET	SAL-JUN-NAP
9000	1	3	2-7	*Alnus Quercus?*	COR-ULM-BET	SAL-JUN-NAP	COR-NAP-ALN
10000	1	4	4	*Corylus? Ulmus*	COR-ULM-BET	NAP-SAL-BET	NAP-SAL-BET
11000	3	4	4	*Pinus? Corylus?*	SAL-JUN-NAP	NAP=SAL-BET	NAP-SAL-BET
12000	4	4	4?		NAP-SAL-BET	NAP-SAL-BET	NAP-SAL-BET

Identification of the source areas of migrating species is problematic for a number of species. There is a gap in the information currently available for central Ireland; new information may clarify whether species migrate at the same rate as in England, as hypothesized by Birks (1990). It is clear that a number of species are crossing over from SW Scotland and colonizing the E coast of Northern Ireland. Glacial *refugiæ* in southern Ireland for a number of species (*e.g. Corylus*) are not to be excluded, given its more oceanic climate. This area (as well as the coastal atlantic-facing areas from Wales up to Scotland) would have been the first to benefit from the milder climate resulting from the fluctuations in the production of North Atlantic Deep Water (NADW) formation at to the Yonger Dryas III/Holocene transition. North Atlantic (Jansen & Veum, 1990) and South Ocean (Charles & Fairbanks, 1992) sea cores clearly indicate the formation of a poleward transport stream of oceanic heat during this period. Diffusion from these sites perhaps in coastal areas at first and later into central Ireland, during the early -middle Holocene may have contributed to the colonization pattern of Northern Ireland.

The simultaneous presence of different types of vegetation at the local scale poses interesting questions as to whether Holocene vegetation in this area is in dynamic equilibrium with climate or not (Prentice, 1986; Birks, 1990). Diffusion of species and vegetation types does not appear to be limited solely by the absence of favourable climatic conditions, certainly essential, but which act together with a number of factors: the position and distance of glacial *refugiæ*, spreading rates, pedogenic development, contraction of glaciers (at least until 9,000 yrs BP), individual plant characteristics and reproduction rates, ecological factors such as competition and human influence (Pennington, 1986; Ritchie, 1986; Behre, 1988; Davis, 1989; Birks, 1990). An approach focussing on the behaviour of vegetational units at the local scale in conjunction with the diffusion rates of single species may help to clarify some of these points.

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