

## LATE HOLOCENE PALEOENVIRONMENTS AND HUMAN IMPACT IN FĂGĂRAȘ DEPRESSION (SOUTHERN TRANSYLVANIA, ROMANIA)

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**Abstract.** A 4800-year-long sequence of environmental change during the Late Holocene has been reconstructed for southern Transylvania (Romania). The research design used palynological methods to reconstruct vegetation history and human impact in the region. We present here the results of pollen analysis of one sequence of about 11.90 m length, originating from a peat bog near Avrig (113 pollen spectra). The vegetation record, which is supported by four <sup>14</sup>C dates, starts in the Subboreal with the *Carpinus* optimum. The first indications of human activities in the region appear at around 4600 cal yr BP. Some environmental changes were possibly linked with natural phenomena. A colder period that begins at about 600-700 cal yr BP could be correlated with the LIA event (Little Ice Age). However, the most significant changes were initiated between 2500 and 180 cal yr BP and were directly or indirectly associated with human occupation. These human-induced effects included major forest clearance, fire, agriculture and grazing.

**Keywords:** paleoenvironments, vegetation history, human impact, pollen analysis, Holocene, Transylvania.

### 1. INTRODUCTION

Palynological investigations are mainly used for the reconstruction of the vegetation history in the studied areas.

The evolution of the vegetation was influenced in principal by the climate changes, while more recently, starting with the Holocene, also by the human impact. The reaction of the vegetation to a certain human factor differed from a plant community to another, according to their resistance to changes.

During prehistoric age, the human impact on the natural vegetation was frequent but sometime, in pollen diagrams, it is difficult to separate them from the climatic modifications. On the contrary, within densely inhabited regions, human activity can mask the natural factors that affect vegetation evolution.

On a regional scale, the comparison between climate-induced and anthropogenic-induced impact on vegetation can be more easily done than on a

local scale. Also, climate changes can be better evidenced at higher altitudes, due to the fact that prehistoric cultures influences are poorly represented as compared to lowlands, as indicated by pollen diagrams.

If during Mesolithic age the human influence was restrained to the habitats and their surroundings, in Neolithic, more significant changes in vegetation occurred as a result of the immigration of the first farming cultures, due to clearances, forest grazing and fires.

Palynologists from Europe focused on such studies starting with last century (Iversen, 1949, 1973; Turner, 1964; Welten, 1967; Berglund, 1969; Ralska-Jasiewiczowa, 1977; Hicks, 1972; Behre, 1981, 1988; Pott et al., 1992; Rösch, 1992, 1998, etc.).

Proofs for the influence of human activity in Romanian Carpathians were identified for very early times, the area constituting an important center of civilization and culture (Fărcaș et al., 2003). The

earlier signs of anthropic impact in Romania were identified in Apuseni Mountains at about 7000 years BP (Bodnariuc et al., 2002).

Chronologically, these palynological data are consistent with the numerous archaeological data for the 8000-6000 years BP interval in the Balkans (Willis, 1994), as well as with the oldest <sup>14</sup>C data for the Neolithic age in northern Balkans (7500-7000 years BP) (Edwards & Halstead, 1996).

## 2. STUDY AREA

The Avrig peat bogs (45°43' N, 24°23'E, 400 m altitude) are situated in the southern part of Transylvanian Depression, near Avrig city (Fig. 1). This vast Cyperaceae and *Sphagnum* peat bog complex occupies an area of about 10 ha at the basis of an old terrace of the Olt River. The mires are settled in small depressions formed either by landslides or by the pre-Holocene meanders of the Olt River (Tantau et al., 2006).

The region is characterized by a temperate continental climate with moderate winters and cool summers. The annual precipitation level is above 600 mm. The mean annual temperature is 9°C and the mean summer temperature is 20°C.

From the phytogeographical point of view the peat bogs are located in the province of Transylvania (Ciocârlan, 2005), characterized by the presence of *Quercus robur* forests of the Centro-European- and Carpathian-type, and also by beech forests, which

alternate with oak plantations. *Quercus dalechampii*, *Q. polycarpa* and *Q. pubescens* are also present. Grazed lawns characterize the current landscape. The local vegetation type is assigned to the “*Caricetum rostratae*”, “*Caricetum lasiocarpae*” and “*Caricetum limosae*” plant communities, while the specific vegetation stage for this altitude (400 m) is typically characterized by the “*Carici elongatae-Alnetum glutinosae*” plant community (Coldea et al., 1997).

## 3. METHODOLOGY

The pollen spectra of the Avrig bogs were graphically represented using the GpalWin software (Goeury, 1997). The frequencies of pollen for each taxon were calculated as percentages of the total sum (AP + NAP). In the pollen diagram (Fig. 3), pollen values lower than 0.5 % is represented by dots.

To facilitate description and interpretation of the pollen diagram with respect to vegetation changes, Local Pollen Assemblage Zones (LPAZ) were established. These zones were established visually by comparing frequencies and dynamics of the principal taxa and each zone boundary denotes significant changes in pollen deposition and represents major changes in vegetation cover and in anthropogenic taxa presence.

The chronology was established by radiocarbon data at the Laboratory of the Radiocarbon in Poznan (Poland) (Tantau et al., 2006).

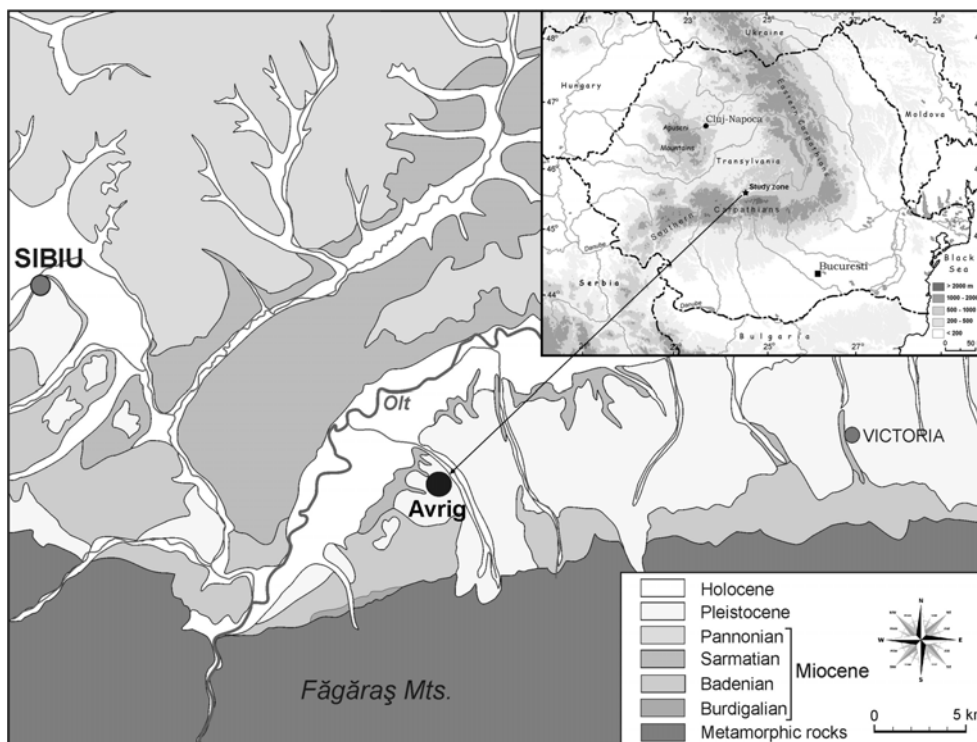


Figure 1. Location map of study zone in Făgăraș Depression and Romania

#### 4. ANTHROPOGENIC INDICATORS IN POLLEN DIAGRAMS

The anthropogenic indicators in pollen diagrams refer to the pollen types that reflect human activity and its impact on fossil vegetation (Behre, 1981).

The main anthropogenic indicators in pollen diagrams are grasses. Besides, the dynamics of certain arboreal taxa in time can provide important evidence on the human impact that influenced it. Thus, the decrease of values in the curves for certain arboreal taxa during Subboreal, and mainly during Subatlantic can be the result of fires produced by man in the forests, or of massive clearance during certain periods of time. If this trend is followed by sudden increase of other types of trees, it can be concluded that there were no natural causes involved. For example, the sudden increase of birch (*Betula*) curve during the Subboreal-Subatlantic interval evidenced by some pollen diagrams in Romania (Feurdean, 2005; Tantau et al., 2006, 2009) can be interpreted as a re-installation of this pioneer, heliophyle species on the location of former forests destroyed by man.

The increase/decrease of beech (*Fagus*) and hornbeam (*Carpinus*) percentages during the last stages of Subatlantic, followed by the relative increase of spruce fir (*Picea*) – phenomenon known in Romania as “the revival” of the spruce fir – is interpreted as an effect of human impact (Fărcaș et al., 2003).

On the location of the former cleared beech forests man planted spruce and fir, this being a more efficient species from an economic point of view, having a faster growth, or pine (*Pinus*). As a result, the pine pollen increases in participation in the surface pollen spectra of certain palynological sequences.

The pollen of cultivated plants is the best anthropogenic indicator. Its record in the pollen diagrams depends upon the species, due to the significant differences concerning the production and dispersal. Thus, *Secale* as an allogamous species shows a good productivity as well as a good dispersion capacity of its pollen, being easily distinguished from other cereals in the diagrams.

*Triticum*, *Hordeum* and *Avena* pollen cannot be differentiated without using phase contrast microscopy. They are autogamous species with high pollen productivity but showing a reduced dispersion. Thus they rarely are present in pollen spectra, even in the proximity of cultivated areas.

Pollen of some cereals (*Panicum* and *Setaria*) cannot be distinguished from pollen of non-

cultivated grasses, while *Cannabis* pollen cannot be separated from that of *Humulus*.

*Linum* and *Fagopyrum* pollen, while among leguminous plants, *Vicia faba* and *Pisum* pollen can be also identified in pollen spectra. In the same time, pollen of significant formerly cultivated species among Brassicaceae (such as *Camelina sativa*, *Isatis tinctoria*) can be distinguished only at a family level.

According to the previous observations, it can be stated that it is difficult to reconstruct cereal cultivation patterns in early times. This is due to the relatively broad range of variation of their pollen participation in cultivated areas and in human communities, as compared to their proximity (Welten, 1967). The same can be stated also for other cultivated plants of the Brassicaceae, Fabaceae, Cannabaceae, Linaceae, etc. families.

Besides the pollen of cultivated plants, some spontaneous species produce easily recognizable pollen that can serve as anthropogenic indicators: *Plantago lanceolata*, *Rumex acetosa*, *Centaurea cyanus*, Urticaceae, Chenopodiaceae, Apiaceae, etc.

The regional climate, edaphic, and floristic conditions must be taken into account, because they can substantially influence the record of vegetation and anthropogenic indicators within a certain area (Timar et al., 2010).

#### 5. VEGETATION HISTORY AND HUMAN IMPACT

For the Avrig sequence, 113 pollen spectra were analyzed and 91 taxa were identified. To facilitate description and interpretation of the pollen diagram, 11 Local Pollen Assemblage Zones (LPAZ 1-11) were established (Table 1, Fig. 2).

The forest succession begins in Subboreal with the *Carpinus* optimum and continue through the Subatlantic with the *Fagus* phase.

#### 6. DISCUSSIONS

The pollen record illustrates vegetation history and human impact during the Subboreal-Subatlantic period. The new results can be correlated successfully with the available data from other investigations in the Romanian Carpathians to give a general picture of the Late Holocene forest development in Romania.

#### 4800 – 4450 cal yrs BP

Climatic changes at the beginning of the Subboreal have caused the drastic decline of mixed-oak in favor of the hornbeam (*Carpinus*). *Carpinus*

attains maximum pollen percentages, which indicates that it became the major forest component. The dense and diverse forest dominated by *Carpinus* and *Quercus* also included *Corylus*, *Betula*, *Alnus*, *Ulmus*, *Picea* and *Tilia*. Changes in temperature and humidity trends between 5600 and 3500 cal yr BP may possibly have been important in enabling forest reorganization and expansion of *Carpinus* (Tantau et al., 2009;).

In the Romanian Carpathians, the major expansion of *Carpinus* is dated between approximately 6500-6700 years BP in Apuseni Mountains (Bodnariuc et al., 2002) and 5000 years BP in northern regions (Björkman et al., 2002, 2003; Feurdean, 2005). The event is dated at 6200 years BP (6700 cal yr BP) in the Avrig area (Tantau et al., 2006). This suggests that the expansion of *Carpinus* started from the populations located in the southern and southwestern parts of the Carpathian chain.

Throughout the Subboreal, anthropogenic actions grow, without multiply and the forest vegetation is not particularly affected (Tantau, 2006).

The first indications of human activity are observed at about 4200 years BP (4600 cal yr BP), with the first occurrence of cereal pollen.

#### 4450 – 4050 cal yrs BP

This period is characterized by dense forest dominated by *Carpinus*, *Fagus*, and *Quercus*.

Despite being locally replaced by *Fagus*, *Carpinus*, which is able to occupy areas with a greater exposure to the sun, remains regionally present. In Romania, the expansion of the forests dominated by *Fagus* occurred later than in Western Europe. It is generally dated at about 4500 years BP (Tantau et al., 2003, 2006; Feurdean, 2005). In the Apuseni Mountains this event occurs earlier, at about 5600 years BP (Bodnariuc et al., 2002; Feurdean & Willis, 2008).

Herbaceous values and some occurrences of cereals, *Secale* and *Plantago lanceolata* suggest an anthropogenic pressure.

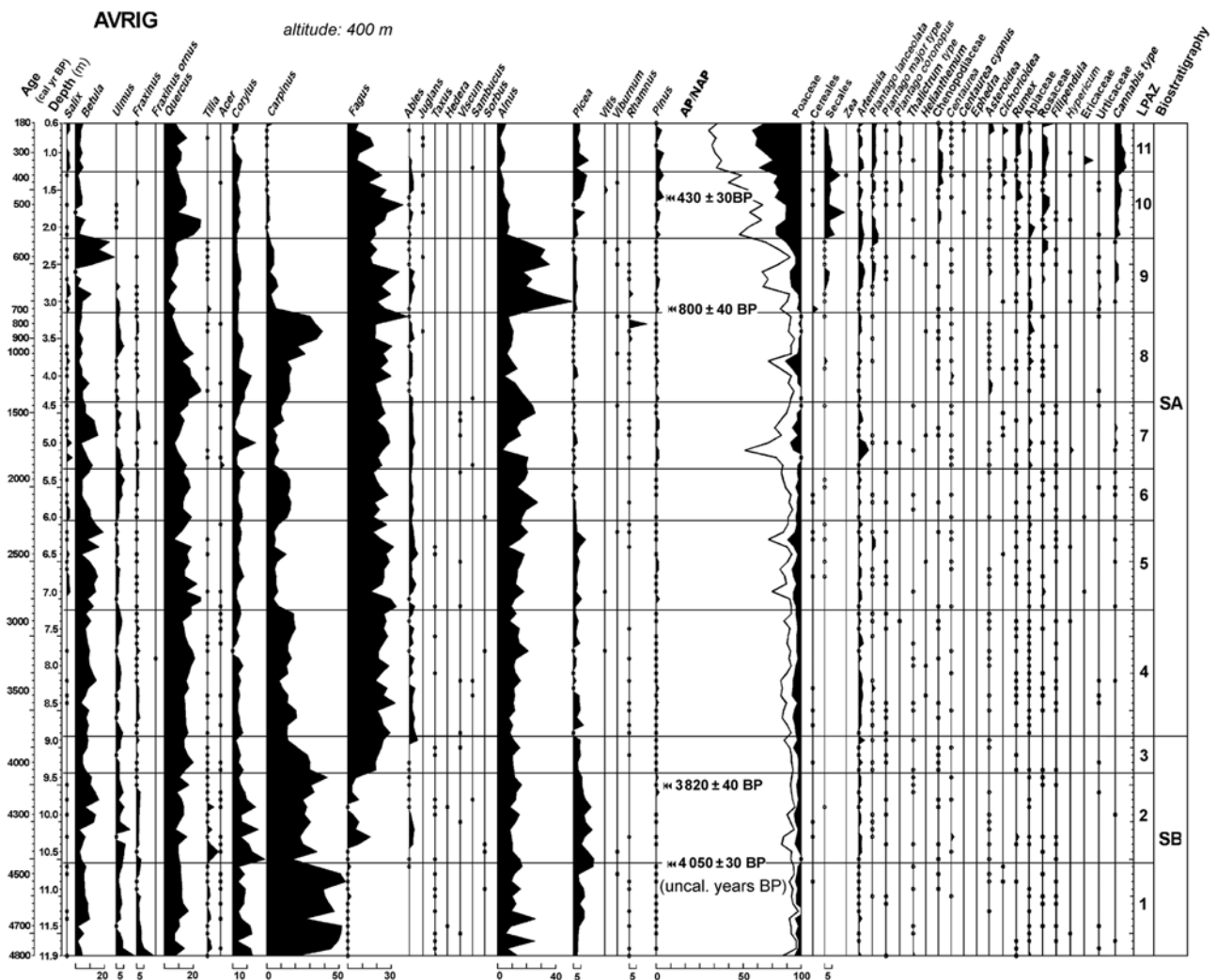


Figure 2. Simplified pollen diagram from Avrig (after Tantau et al., 2006, redraw) (SA-Subatlantic, SB-Subboreal)

Table 1. Summary of the pollen stratigraphy, chronology and vegetation history of Avrig (see Fig. 2 for pollen diagram).

<i>Depth (m)</i>	<i>Age (cal yr BP)</i>	<i>Description</i>	<i>Inferred local upland vegetation</i>
LPAZ 1 11.90- 10.65	4800-4430	The maximum of <i>Carpinus</i> (40-50%) occurs within this zone. The forest would have been dominated by <i>Carpinus</i> accompanied by <i>Corylus</i> , <i>Quercus</i> and, in smaller proportions, <i>Picea</i> , <i>Ulmus</i> , <i>Tilia</i> , and <i>Alnus</i> . A short rise of <i>Betula</i> occurs at the beginning of the zone. A significant characteristic of this zone is the presence of the cereal pollen, the first sign of agricultural activity in the vicinity of the site. The abrupt fall of <i>Carpinus</i> at the end this zone most probably indicates a hiatus.	Dense forest dominated by <i>Carpinus</i> . <i>Corylus</i> , <i>Quercus</i> , <i>Ulmus</i> , <i>Fraxinus</i> , <i>Tilia</i> , <i>Betula</i> , <i>Alnus</i> and <i>Picea</i> were also common. First occurrence of cereals.
LPAZ 2 10.65- 9.45	4430-4100	<i>Carpinus</i> values fall below 30%, while <i>Corylus</i> and <i>Tilia</i> values rise, indicating the existence of a local disturbance. There is also a marked increase of <i>Picea</i> , <i>Ulmus</i> and Poaceae, and the beginning of the continuous curve of <i>Fagus</i> and <i>Abies</i> . Herbaceous values and occurrences of cereals, <i>Secale</i> and <i>Plantago lanceolata</i> suggest an anthropogenic pressure.	Dense forest dominated by <i>Carpinus</i> , <i>Corylus</i> and <i>Quercus</i> . <i>Ulmus</i> , <i>Tilia</i> , <i>Alnus</i> , <i>Betula</i> , <i>Picea</i> were also common. Expansion of <i>Fagus</i> and <i>Abies</i> .
LPAZ 3 9.45- 8.95	4100-3800	<i>Carpinus</i> pollen values fall below 20% at the end of this zone, while <i>Fagus</i> values rise. Despite being locally replaced by <i>Fagus</i> , <i>Carpinus</i> , which is able to occupy areas with a greater exposure to the sun, remains regionally present. <i>Corylus</i> , <i>Ulmus</i> , <i>Fraxinus</i> and <i>Tilia</i> values all undergo a decline in this zone. Poaceae pollen is not abundant, but increase at the end of this zone. The human impact in the zone is indicated by occurrence of cereals pollen, <i>Plantago lanceolata</i> and <i>Rumex</i> .	Dense forest dominated by <i>Carpinus</i> , <i>Fagus</i> , and <i>Quercus</i> . <i>Corylus</i> , <i>Ulmus</i> , <i>Betula</i> , <i>Alnus</i> and <i>Picea</i> were also common. <i>Abies</i> almost disappear.
LPAZ 4 8.95- 7.25	3800-2870	This zone is dominated by <i>Fagus</i> with pollen values often higher than 30%. <i>Carpinus</i> pollen percentages fluctuate between 15-20%. During this period, the local vegetation consisted of a forest with <i>Fagus</i> and <i>Carpinus</i> , accompanied by <i>Quercus</i> , <i>Alnus</i> and <i>Betula</i> . <i>Tilia</i> and <i>Fraxinus</i> almost disappear from the local forests. At higher altitudes <i>Abies</i> and <i>Picea</i> were also present. The herbaceous taxa were not abundant during this period, but human activity is indicated by occurrences of cereals and <i>Plantago lanceolata</i> .	Dense forest dominated by <i>Fagus</i> , <i>Quercus</i> and <i>Carpinus</i> . <i>Corylus</i> , <i>Betula</i> , and <i>Alnus</i> were also common. Some arable fields were established at lower altitudes, where cereals were grown.
LPAZ 5 7.25- 6.05	2870-2250	<i>Carpinus</i> pollen values fall again (10%) in this zone, while <i>Fagus</i> , <i>Quercus</i> , <i>Betula</i> and Poaceae values rise. Despite being locally replaced by <i>Fagus</i> , this taxon, which is able to occupy areas with a greater exposure to the sun, remains regionally present. <i>Abies</i> plays a significant role in the local vegetation. The herbaceous taxa were not abundant during this period, but human activity is indicated by occurrences of cereals, <i>Secale</i> and <i>Plantago lanceolata</i> .	Dense forest dominated by <i>Fagus</i> and <i>Quercus</i> . Some arable fields were established at lower altitudes in the area, where cereals and <i>Secale</i> were grown.
LPAZ 6 6.05- 5.35	2250-1900	The vegetation is dominated by <i>Fagus</i> <i>Carpinus</i> pollen percentages are rather constant. During this period, the local vegetation consisted of a forest with <i>Fagus</i> and <i>Carpinus</i> , accompanied by <i>Quercus</i> , <i>Alnus</i> and <i>Betula</i> . Human activity is indicated by occurrences of cereals, <i>Secale</i> and <i>Plantago lanceolata</i> .	Dense forest dominated by <i>Fagus</i> , <i>Carpinus</i> , <i>Alnus</i> and <i>Quercus</i> . <i>Corylus</i> , <i>Betula</i> and <i>Alnus</i> were also common.
LPAZ 7 5.35- 4.45	1900-1360	<i>Carpinus</i> pollen values fall again (10%) in this zone, while <i>Fagus</i> , <i>Corylus</i> , <i>Betula</i> and Poaceae values rise. The herbaceous taxa values increase during this period, especially Poaceae and <i>Artemisia</i> . Human activity is indicated by occurrences of <i>Secale</i> , <i>Cannabis</i> type and <i>Plantago lanceolata</i> .	Dense forest dominated by <i>Fagus</i> and <i>Quercus</i> . <i>Betula</i> , <i>Alnus</i> and <i>Corylus</i> were also common. The grazing pressure in the forests had increased.

LPAZ 8 4.45- 3.15	1360-720	This zone is characterized by the recurrence of <i>Quercus</i> and <i>Corylus</i> and an increase of <i>Carpinus</i> percentages. Abrupt changes in the pollen spectra occur at the transition to the next zone: <i>Alnus</i> values increase and the percentages of <i>Carpinus</i> drop dramatically. At the end of the zone the first occurrence of <i>Juglans</i> is registered. Human activity is indicated by occurrences of <i>Secale</i> .	Dense forest dominated by <i>Fagus</i> . <i>Quercus</i> , <i>Corylus</i> and <i>Carpinus</i> were also common. Some arable fields with <i>Secale</i> were established.
LPAZ 9 3.15- 2.15	720-570	During the new decline of <i>Carpinus</i> , an increasing presence of <i>Alnus</i> , <i>Fagus</i> and Poaceae can be observed. This represents a new disturbance due to an anthropogenic pressure or climatic changes. <i>Carpinus</i> values fall below 10% and the pollen of herbaceous taxa (Poaceae and <i>Artemisia</i> ) progress. <i>Abies</i> plays a significant role in the local vegetation. The pollen of cereals, <i>Secale</i> , <i>Rumex</i> sp. and <i>Plantago lanceolata</i> , whose presence is continuous, often exceeds 1%.	Dense forest dominated by <i>Fagus</i> and <i>Alnus</i> . <i>Betula</i> and <i>Quercus</i> were also common. The grazing pressure in the forests had increased. Expansion of <i>Secale</i> .
LPAZ 10 2.15- 1.25	570-360	This zone is characterized by the recurrence of <i>Carpinus</i> and <i>Alnus</i> and an increase of <i>Quercus</i> and <i>Fagus</i> percentages. Continued anthropogenic action is indicated by more occurrences of <i>Juglans</i> and increase percentages of Poaceae and <i>Artemisia</i> . <i>Pinus</i> and <i>Picea</i> become more abundant while the decline of <i>Alnus</i> benefits <i>Fagus</i> and <i>Quercus</i> . The pollen of <i>Secale</i> , <i>Cannabis</i> type and <i>Plantago lanceolata</i> are present in continuous curves. The pollen of <i>Zea</i> is also present.	Rather open forest dominated by <i>Fagus</i> and <i>Quercus</i> . The grazing pressure in the forests increase. More arable fields were established, with cereals, <i>Secale</i> and <i>Zea</i> .
LPAZ 11 1.25- 0.60	360-180	This zone corresponding to a modern period is characterized by increasing human activity resulting in a change of vegetation. The rates of <i>Fagus</i> decrease gradually to values lower than 10%, but this taxon remains present. As the beech is absent from the surrounding vegetation today, we assume that the very recent past is not recorded in our cores. With the anthropogenic opening of the forest, there is strong increase of Poaceae. The pollen of <i>Secale</i> , <i>Cannabis</i> type and <i>Plantago lanceolata</i> are present in continuous curves.	Rather open forest dominated by <i>Fagus</i> and <i>Quercus</i> . <i>Carpinus</i> had disappeared from the local forests. More arable fields were established, where diverse cereals and <i>Secale</i> grown.

#### 4050 – 725 cal yrs BP

From 4050 cal yr BP onwards dense forests dominated by *Fagus* occurred in the area. *Quercus*, *Carpinus*, *Alnus*, *Betula* and *Abies* were also common.

The expansion of *Fagus* may have been a response to a combination of climatic changes, when average temperatures dropped and precipitation increased (Holzhauser et al., 2005), and human activity (Küster, 1997). In contrast to Western Europe, where beech replaces the former dominant *Quercetum mixtum*, here *Carpinus* decreases as *Fagus* increases (Tantau et al., 2009).

The optimum of beech occurs at the same time as an increase in markers of agricultural activities, around 3000 cal yr BP.

The first occurrence of *Juglans* is recorded only at 850 cal yr BP, later than in some studied sites from Romania (Tantau et al., 2003), but synchronous with others (Tantau et al., 2009).

The herbaceous plants are not abundant but agricultural activity is evidenced by the presence of cereals pollen (especially *Secale*) and *Plantago*

*lanceolata*. The few pollen grains of cereal-types and *Secale* are interpreted as originating from cultivated land at lower altitudes.

#### 725 – 180 cal yrs BP

During the last part of Subatlantic a new decline of *Carpinus*, an increasing presence of *Alnus*, *Fagus* and Poaceae can be observed. This represents a new disturbance due to an anthropogenic pressure or climatic changes.

A colder period could be indicated in LPAZ 9 and 10 by the abrupt decrease of tree pollen and increase in herbaceous taxa. *Carpinus* fall, *Ulmus*, *Tilia* and *Fraxinus* almost disappears from the local vegetation. This event could be correlated with the LIA event (Little Ice Age) (Man et al., 2009).

The last part of the Subatlantic is the optimal period for agriculture and grazing. Pollen of diverse cereals, *Secale*, *Plantago lanceolata* and *Cannabis* type is present in continuous curves. *Zea* is also present in arable fields. Poaceae progression is the sign of the grassland domination.

## 5. CONCLUSIONS

The peat sequence from Avrig provides a high-resolution record of Late Holocene forest, climate history and human impact in Făgăraş Depression.

The forest succession is as follow:

(1) The record begins in Subboreal with the *Carpinus* optimum. This was probably present in the forest after ca. 8000 cal yr BP.

(2) *Fagus* expanded only at 4400 cal yr BP, which may be explained by competition with previously established forest taxa.

(3) Human impact in the area is mainly related to forestry and forest grazing.

(4) The first indications of human activities are observed at about 4600 cal yr BP, with the first occurrences of cereal pollen.

(5) Cereals are recorded during the *Carpinus* optimum and throughout the *Fagus* phase, and they become more regular with the appearance of *Plantago lanceolata*.

(6) In the last part of the Subatlantic, the pollen of unspecified cereals, *Secale* and *Plantago lanceolata* is present in continuous curves.

(7) In historic times the changes in the natural forest cover were primarily caused by anthropogenic activities, namely animal husbandry and agriculture.

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