Geophysical Research Abstracts
Vol. 18, EGU2016-9695, 2016
EGU General Assembly 2016

Emergence patterns of novel vegetation assemblages over the past 15,000 years in Europe

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Plant communities are not stable over time and the development of so-called novel ecosystems, i.e. ecosystems that differ in composition from present and historical ecosystems, is inevitable. Ecological novelty may arise due to rapid climate changes, the introduction of exotic species, and human land-use changes. However, little is known as to when and at what velocity novel ecosystems emerged in the past. Here we use pollen sequences from the European Pollen Database (EPD) to explore the spatial and temporal patterns of emergence of novel plant communities over the past ca. 15,000 years.

The rationale behind this analysis is that just as modern communities are expected to differ fundamentally to those occurring in the future, this difference also occurred between past communities and their contingent future composition. Our aims are to explore the rate at which these past novel communities arose, and how these rates varied over time. Further, as land-cover composition has been significantly altered in comparison to the past, we explore the extent to which human-caused landscape changes accelerated the emergence of novel vegetation assemblages.

For each pollen record we collated pollen counts into 30 consecutive 500-year wide age bins centred on full 500-year intervals between 0 and 15,000 cal BP. We iteratively considered each age bin as describing a baseline condition in the past and searched for each assemblage in the baseline age bins the closest analogues among all assemblages in each future age bin (hereafter 'target age bin'). To identify assemblages lacking a close analogue in target age bins we determined for each reference age bin a critical dissimilarity score as the low quantile of the pair-wise dissimilarities observed. The rate of emergence of novel communities was estimated as the percentage of assemblages lacking a close analogue in target age bins per 500 years.

Rates of emergence of novel assemblages varied through time and highest rates occurred during periods of high within-site rate of vegetation change. For example, >50% of Younger Dryas steppe assemblages lost a close analogue after 500-1000 years due to the rapid range shifts and the disappearance of steppe environments. Within the Holocene, highest rates occurred in the early Holocene. Highest displacement velocities (km/year) at that time support the notion that rapid range shifts can lead to novel communities.

Rates of emergence were lowest between 7000 and 3000 cal yr BP and increased thereafter. During the past ca. 1500 years rates of emergence were up to 3 times higher than mid-Holocene rates and significantly lower than late-glacial and early-Holocene rates. Because during the past 1500 years novel assemblages mostly emerged in Southern and Central Europe, a region mostly impacted by anthropogenic activities, we interpret these results as the consequence of anthropogenic land-cover change that created novel landscapes. The proportion of assemblages having a close analogue in modern vegetation is higher for past communities located at high latitudes, indicating that communities at higher latitudes showed a longer persistence than communities in Southern and Central Europe.