# Anthropogenic landscapes? Modelling the role of hunter-gatherers in interglacial ecosystems in Europe

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# SUMMARY


## English

Human impact on the environment has extended over millennia, with evidence of anthropogenic landscape changes before the emergence of agriculture. Review of available archaeological evidence from both the Last Interglacial (LIG, ~130,000–116,000 BP; Neanderthals) and Early Holocene (~11,700–8000 BP; Mesolithic humans) archaeological contexts shows that a similar set of proxies is available for both periods. Despite available case studies and ethnographic observations of anthropogenic burning by hunter-gatherers, it remains challenging to ascertain whether these local-scale activities caused landscape changes at regional or even (sub-)continental scales.

To address this, a new spatially explicit open agent-based model (ABM) called HUMan impact on LANDcapes (HUMLAND) was developed to investigate the impact of hunter-gatherer activities on vegetation in Europe during the LIG and the Early Holocene. This model incorporates several sources of impact on vegetation: natural and anthropogenic fires, megafauna plant consumption, and climatic impact. The developed ABM integrates various datasets, including estimates of potential maximal megafauna plant consumption, digital elevation model, and distribution of large water bodies.

The developed ABM uses outputs from the CARbon Assimilation In the Biosphere (CARAIB) and Regional Estimates of VEgetation Abundance from Large Sites (REVEALS) models. CARAIB, driven by climate forcings and by assumptions about dynamics of vegetation, provides potential natural vegetation cover used as a starting point for simulation runs. REVEALS provides quantitative pollen-based regional vegetation abundance estimates. This dataset is used as target for HUMLAND runs. Comparing these datasets revealed significant differences, indicating that climate alone did not shape European landscapes during the study periods.

Sensitivity analysis showed that the intensity of human-induced vegetation changes depended on the number of forager groups, their vegetation preferences around campsites, and the size of impacted areas. HUMLAND was then combined with a genetic algorithm to generate scenarios of past vegetation change, using parameters identified by the sensitivity analysis, and an additional parameter for human-induced hunting pressure on megafauna. Finally, HUMLAND tracked and quantified the impact of humans, natural fires, climate and megafauna in the most common scenarios.

Comparisons between CARAIB–REVEALS data and genetic algorithm scenarios suggest that climate and megafauna were not the only factors determining

interglacial vegetation. Fires, specifically those caused by hunter-gatherers and their hunting impacts on megafauna, influenced European ecosystems. Ethnographic, archaeological, and modelling evidence indicates similarities in landscape impacts by Neanderthals and Mesolithic humans. Specifically, both groups impacted an area of similar size around their campsites and had comparable vegetation openness preferences. Additionally, minimum population estimates required to match HUMLAND outputs with REVEALS for the LIG are comparable to those of the Early Holocene.

This study provides the first quantification of Neanderthal and Mesolithic human impacts on interglacial vegetation, showing that both groups substantially shaped European landscapes. Although megafauna and climate were major factors during the LIG, Neanderthals influenced vegetation through fire use, making certain areas more attractive to herbivores because of increased nutrition and palatability of new plants. In the Early Holocene, humans directly transformed approximately 8–26% (with a maximum of 14–47%) of landscapes through burning, alongside indirect effects from hunting. Thus, European landscapes were shaped by human agency before the emergence of agriculture, highlighting the integral role of people and fires in interglacial ecosystems.