Understanding settlement and demography dynamics in the Tiel micro-region: Combining Agent-Based Modelling, settlement and cemetery data

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Knowledge of past populations, their size and structure, is essential for interpretating patterns found in the archaeological record (Chamberlain 2006, 177; Schlicht and Diachenko 2023, 1070). However, disentangling historic demographic processes is far from easy, especially when census records are fragmented or missing. In such a case, we have to rely on settlement patterns, artefact distributions and cemetery data as proxies, with theory, anthropological insights and modelling to fill in the gaps.

In the case of the Lower Germanic Limes, the settlement record suggests a significant population in the period 25-150 CE, followed by a decline until the end of the 3rd century. However, the population dynamics behind this pattern remain somewhat elusive (Verhagen *et al.* 2016). In a previous study, we combined agent-based modeling and age-at-death distributions to gain a better understanding of demographic processes in the region. We used data from the Tiel-Passewaaij 'central' cemetery, one of the best excavated rural cemeteries in the region (Aarts and Heeren 2011). By extending a simple abstract ABM developed by Verhagen and colleagues (2015; 2019; 2016), it was found that a relatively low fertility, high mortality scenario best explained the age-at-death ratios found in this archaeological data.

However, a notable scale mismatch was also observed. The simulation's total population numbers far exceed those associated with the local community represented in the Tiel-Passewaaij cemetery record. This raises the question to what extent individual cemeteries, as records of local communities located in geographic space, reflect more global demographic processes in the wider region. In addition, the abstract scale of the simulation does not easily allow for a multi-proxy approach incorporating not just the cemetery record but also settlement patterns.

In order to address these limitations, the model was made spatially explicit to the Tiel micro-region. The demographic processes relating to mortality, fertility and nuptiality remain unchanged, but households settle over a semi-realistic landscape. Choice of settlement location is based on environmental attractiveness, preference for (lack of) crowding, and friction of distance. The evolution of the settlement landscape in the simulation model is compared against the archaeologically 'known' structure and development of the settlement landscape, based on a small number of well-known, excavated settlements and a reconstructed full settlement dataset based on aoristic analysis approaches to a large-scale archaeological find and site database (Lawrence, Verhagen and Groenhuijzen 2026).

Instead of generating a global cemetery record, cemeteries are located in space and only serve a select number of (nearby) households. With this, the model enables

the exploration of a wide-range of scenarios relating to household and cemetery location, allowing for a multi-proxy approach combining burial and settlement data. This study thus demonstrates that a more holistic approach to simulations of the settlement and burial landscape allows for a more refined understanding of the potential processes that formed these landscapes.

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