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Routes across the Civitas Menapiorum: using least cost paths and GIS to locate the Roman roads of Sandy Flanders

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ABSTRACT

Despite a long research history, little is known about the Roman road network in the northern part of the Civitas Menapiorum. In late nineteenth- and early twentieth-century publications researchers established the idea that Roman roads ended at the transition between the loamy and sandy areas. Others indicated that such roads were not yet located. During the last twenty years researchers have presumed the existence of five supralocal Roman roads in Sandy Flanders. However, their exact routes remained unclear. In this study a landscape archaeological approach is applied to study these roads and to suggest a series of possible routes. Based on recent LiDAR data and soil maps, least cost path analyses are performed in ArcGIS. Recent archaeological findings and double linear marks, visible on both oblique and vertical aerial photographs, are used to test the accuracy of the least cost paths. Finally, the names of present-day streets are used to clarify the continuity of Roman roads in the landscape.

Since the nineteenth century, numerous researchers and local historical societies have published on the supralocal Roman road network in Flanders. Reuvens, Leemans and Janssen concluded, based on their archaeological work during the Dutch period (1814–1830), that the former Roman fortress at Oudenburg would have been connected to the road network (see Fig. 1).[1] In 1877, in his *Topographie des voies romaines de la Belgique*, Van Dessel discussed the Roman origins of modern *heirwegen* (army roads) and *steenstraten* (paved streets).[2] Just a few years later, in 1882, Gauchez published his *Topographie des voies romaines de la Gaule-Belgique*, an extensive summary of knowledge of the Roman road network in northern Gaul.[3] At the beginning of the twentieth century interest in the subject decreased, and it is only since the work of Mertens in the 1950s that there has been a new bout of enthusiasm for these Roman roads. Mertens rejected the idea of a road connection to Oudenburg and concluded that Roman roads probably ended at the river Leie, on the transition between the loamy and sandy areas.[4]

Despite this long research tradition the routes of Roman roads in the Civitas Menapiorum – the Roman region covering what are now the Belgian provinces of West and East Flanders, the French Département du Nord and the Dutch province of Zealand – are still uncertain.[5] In contrast to other areas in the Roman provinces of Gallia (Gaul) and Britannia (Britain), the sandy areas of Flanders seem to have been inaccessible by road in Roman times.[6] The same might be true for the neighbouring coastal lowlands of the Netherlands, which van Lanen states to have mainly been accessed by water transport.[7] However, the absence of Roman roads in Sandy Flanders – the geographical region characterised by sandy soils covering the north of West and East Flanders and parts of Antwerp

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1 H. Thoen and S. Vanhoutte, De romeinse wegen in het Vlaamse kustgebied. Leiden alle wegen naar Oudenburg?, *Alle wegen leiden naar … Romeinse wegen in Vlaanderen. Kunsttijdschrift Vlaanderen* 301 (2004) 178–184.

2 C. Van Dessel, *Topographie des voies romaines de la Belgique*, Bruxelles, 1877.

3 V. Gauchez, *Topographie des voies romaines de la Gaule-Belgique*, Anvers, 1882.

4 J. Mertens, Les routes Romaines de la Belgique, *Archaeologia Belgica* 33 (1957) 1–45; J. Mertens, Oudenburg en de Vlaamse kustvlakte tijdens de romeinse periode, *Biekorf* 59 (1958) 321–340; J. Mertens, Oudenburg et le Litus Saxonicum en Belgique, *Archaeologica Belgica* 62 (1962) 51–62.

5 Thoen and Vanhoutte, De romeinse wegen in het Vlaamse kustgebied.

6 R. Chevallier, *Les Voies Romaines*, Paris, 1997; H. Davis, *Roads in Roman Britain*, Stroud, 2002.

7 R.J. van Lanen, M.C. Kosian, B.J. Groenewoudt, T. Spek and E. Jansma, Best travel options: modelling Roman and early-medieval routes in the Netherlands using a multi-proxy approach, *Journal of Archaeological Science: Reports* 3 (2015) 144–159.

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and Flemish Brabant – is unlikely to be a historical reality. Even though the first roads with military importance did not reach this region until about 20 BC, later fortresses like Oudenburg and Aardenburg must have had a connection with the hinterland, as the presence of all kinds of imported material, such as *terra sigillata* (a luxury clay slip ware) from eastern Gaul, North Menapian Reduced Ware and Pompeian Red Ware suggests.[8] The apparent absence of Roman roads can possibly be because they took forms other than the typical paved examples elsewhere. De Clercq presumes that the absence of natural stone in the northern part of the Civitas Menapiorum resulted in no or only local paving of roads, which complicates their identification during archaeological fieldwork.[9] A similar conclusion was formulated by van der Heijden concerning the Roman roads in the Netherlands. He states that the wide variation in attested physical appearances of Roman roads is an example of both the methodical and pragmatic attitude of Roman engineers.[10]

Moreover, research in Flanders was for a long time limited to the studies of classical texts, Roman milestones and itineraries, combined with sporadic finds of road segments.[11] In contrast, knowledge of Roman roads in the rest of Europe is extensive thanks to aerial photography,[12] the study of classical texts and road names, fieldwalking surveys,[13] the use of LiDAR[14] and geophysical survey techniques.[15] Interdisciplinary approaches have only been used successfully since the 1970s to study the supralocal Roman road network in Flanders. The archaeological, geographical and soil research by Thoen shed new light on the roads around Oudenburg.[16] The use of oblique aerial photographs, taken by Semey and the Department of Archaeology at Ghent University, was an important breakthrough as well, allowing the discovery and location of previously unknown sites.[17] However, it was not until the 1990s that these photographs were specifically used to study Roman roads.[18]

Five routes, as direct connections between broadly accepted junctions, are currently recognised as possible supralocal Roman roads in Sandy Flanders: *Zandstraat*, *Steenstraat*, *Zeeweg*, *Antwerpse Heirweg* and the road *Blicquy–Aardenburg* (see Fig. 1). These supralocal roads form the main regional connections between major centres of habitation, economy and the military.[19] Detailed topographical knowledge of the Roman road network, or the continuity of road segments in time and space, however, is still lacking. Indeed, for the Blicquy–Aardenburg road two different possible routes are currently suggested. The route via Aalter is favoured by De Clercq, based on the presence of a castellum (a small Roman fort) in Aalter and fortifications in Knesselare. In contrast, Vermeulen favors the route via Merendree, based on the vicus (a civilian settlement near a military fort) at this location.[20] Furthermore, the recent discovery of a Roman road segment at Kerkhove may also be part of the Blicquy to Aardenburg road, and another connection from Kerkhove to Oudenburg might also be plausible. Since further archaeological research on this site is in progress, this sixth trajectory, from Kerkhove to Oudenburg, has not been included in this study.[21]

The aim of this article is to reconstruct the supralocal Roman road network in the northern part of the Civitas Menapiorum based on recent landscape archaeological knowledge and new data. The use of LiDAR makes it possible to distinguish minor differences in height on detailed Digital Terrain Models (DTM), which is useful for tracing Roman roads, as shown by Toller in Yorkshire.[22] The link between the routes this suggests, via the analysis of least cost paths, and both archaeological sites and current roads will be examined. The latter focuses on *heirwegen* or *heerwegen* (army roads) and *steenwegen* (paved roads) because these are traditionally ascribed to the Roman period, although this assumption is currently questioned by archaeologists and historians.[23]

The study by Wiedemann, Antrop and Vermeulen is taken as the methodological example.[24] By using aerial photographs, GIS and archaeological data, they were the first and only researchers to reconstruct the possible main Roman road network in the southern part of the Civitas Menapiorum. Taking these two studies together, the conclusions and methods may be useful and applicable in other regions where the routes of Roman or later roads are not well known.

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8 S. Vanhoutte, W. Dhaeze and W. De Clercq, A pottery dump from AD *c.* 260–270 at the Roman coastal defence fort at Oudenburg (West-Flanders, Belgium). A study of military pottery consumption at the transition of the Middle to Late Roman period in Northern Gaul, *Journal of Roman Pottery Studies* 14 (2009) 95–141; W. Dhaeze, Studie van enkele volledige aardewerkcontexten uit het central nederzettingsareaal van Romeins Aardenburg, in: R.M. van Dierendonck and W.K. Vos (Eds), *De romeinse agglomeratie Aardenburg. Onderzoek naar de ontwikkeling, structuur en datering van de Romeinse castella en hun omgeving, opgegraven in de periode 1955 – heden*, Middelburg, 2013, 209–286.

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11 Van Dessel, *Topographie des Voies Romaines de la Belgique*; V. Gauchez, *Topographie des Voies Romaines de la Gaule-Belgique*; Mertens, Les routes Romaines de la Belgique; Mertens, Oudenburg en de Vlaamse kustvlakte tijdens de romeinse periode; Mertens, Oudenburg et le Litus Saxonicum en Belgique.

12 R. Agache, *La Somme Pre-Romaine*, Amiens, 1978.

13 I.D. Margary, *Roman Roads in Britain*, London, 1973; D.E. Johnston, *Roman Roads in Britain*, Bourne End, 1979; C. Taylor, *Roads and Tracks of Britain*, London, 1979; S.S. Frere and J.K.S. St. Joseph, *Roman Britain from the Air*, Cambridge, 1983; van der Heijden, Romeinse wegen in Nederland, 23–35.

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15 D. Powlesland, J. Lyall, G. Hopkinson, D. Donoghue, M. Beck, A. Harte and D. Stott, Beneath the sand – remote sensing, archaeology, aggregates and sustainability: a case study from Heslerton, the Vale of Pickering, North Yorkshire, UK, *Archaeological Prospection* 13 (2006) 291–299; G.N. Tsokas, P.I. Tsourlos, A. Stampolidis, D. Katsonopoulou and S. Soter, Tracing a major Roman road in the area of ancient Helike by resistivity tomography, *Archaeological Prospection* 16 (2009) 251–266.

16 Thoen and Vanhoutte, De romeinse wegen in het Vlaamse kustgebied.

17 J. Bourgeois, M. Meganck and J. Semey, Almost a century of aerial photography in Belgium. An overview, in: J. Bourgeois and J. Meganck (Eds), *Aerial Photography and Archaeology 2003. A Century of Information*, Gent, 2003, 37–48.

18 B. Hageman, Parallelle Sporen en Luchtfotografie: Inventarisatie, Terreinonderzoek en Interpretatie, unpublished Master's thesis, Ghent University, 1995; F. Vermeulen and M. Antrop, *Ancient Lines in the Landscape. A Geo-Archaeological Study of Protohistoric and Roman Roads and Field Systems in Northwestern Gaul*, Leuven, 2001.

19 Thoen and Vanhoutte, De romeinse wegen in het Vlaamse kustgebied; De Clercq, *Lokale Gemeenschappen in het Imperium Romanum*, 254–257.

20 De Clercq, *Lokale Gemeenschappen in het Imperium Romanum*, 254–257; Vermeulen and Antrop, *Ancient Lines in the Landscape*.

21 M. Rogge, Een Merovingische nederzetting te Avelgem-Kerkhove (West-Vlaanderen), in: A. Van Doorselaer (Ed.), *De Merovingische beschaving in de Scheldevallei. Westvlaamse Archaeologica Monografieën 2*, Kortrijk, 1981, 64–102; Van Bavay naar Aardenbrug? Even stoppen in Kerkhove, 2015, http://archeologie-kerkhove.be/2015/11/13/van-bavay-naar-aardenburg-even-stoppen-in-kerkhove/, last accessed 3 January 2017.

22 Toller, Current research into Roman roads in Yorkshire based on lidar evidence, 19–22.

23 L. Genicot, *Histoire des routes Belges depuis 1704*, Brussels, 1948; H. Thoen, Romeinen in de Vier Ambachten, in: A.M.J. de Kraker, H. Van Royen and M.E.E. De Smet (Eds), *Over den Vier Ambachten. 750 jaar Keure, 500 jaar Graaf Jansdijk*, Kloosterzande, 1993, 65–70; Thoen and Vanhoutte, De romeinse wegen in het Vlaamse kustgebied.

24 T. Wiedemann, M. Antrop and F. Vermeulen, Analysis of the Roman road system around Cassel and application of a GIS-model in Sandy Flanders, in: Vermeulen and Antrop, *Ancient Lines in the Landscape*, 83–96.

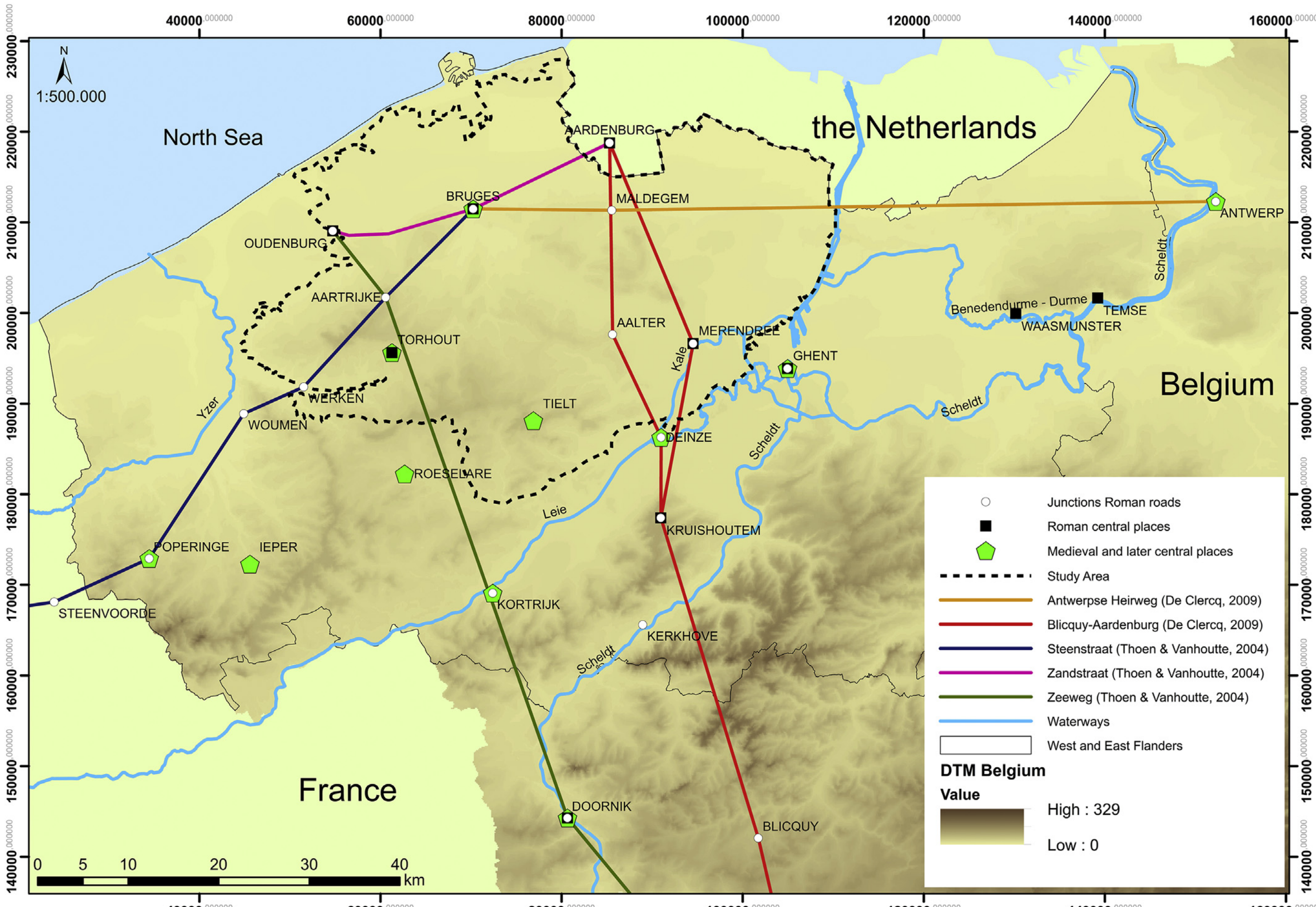

Fig. 1. Possible routes of Roman roads in Sandy Flanders in relation to known junctions, central places and the modern-day courses of the main waterways identified in Roman times.

Study area

The study area includes the northwestern part of the Civitas Menapiorum, stretching from the North Sea coast in the west to the river Scheldt in the east (see Fig. 2). This area was chosen because of the presumption that several supralocal Roman routes crossed the sandy area to Oudenburg, Bruges and Aardenburg. A second selection criterion was the archaeological knowledge for the area formed by both professional and amateur archaeological research.

The delineation of the study area was based on the availability of oblique aerial photographs and on the use of a classification of traditional landscapes in Flanders based on terrain, soil conditions, occupancy types, land use, field systems and landscape type.[25] The focus in this study is on the Flemish valley and Flemish cuestas to the west of the contemporary Ghent-Terneuzen canal. Adjacent traditional landscapes in the coastal polderland, alluvial valleys of the Scheldt and Yser rivers, sandy-loamy Flemish hills and urban-industrial regions were also included.[26]

Materials

The use of aerial photography in Flemish archaeology started in the 1970s. The pilot Semey noticed lines and discoloration in vegetation during his flights and started to photograph them. From the 1980s onward, the Department of Archaeology at Ghent University supported this research and hundreds of sites in West and East Flanders were located. Currently the collection comprises around seventy thousand photographs.[27]

The 2331 oblique aerial photographs available for the study area show marks over different years from 1983 until 2004. A first selection was based on visible crop and soil marks of road segments, which are characterised by double linear discolorations. Although the phenomenon of double ditched roads is not limited to the Roman period, research by Vermeulen and Hageman shows the potential of this type of marks to be of Roman origin.[28] Since only a limited number of double linear crop and soil marks have been excavated or surveyed through augering in the study area, all marks

[25] M. Antrop, V. Van Eetvelde, J. Janssens, I. Martens and S. Van Damme, *Traditionele landschappen van het Vlaamse Gewest*, Gent, 2002.

[26] V. Van Eetvelde and M. Antrop, The significance of landscape relic zones in relation to soil conditions, settlement pattern and territories in Flanders, *Landscape and Urban Planning* 70 (2005) 127–141.

[27] J. Bourgeois, M. Meganck and J. Semey, Aerial photography and the former landscape of Western Flanders, in: Vermeulen and Antrop, *Ancient Lines in the Landscape*, 27–40; Bourgeois, Meganck and Semey, Almost a century of aerial photography in Belgium, 37–48.

[28] F. Vermeulen and B. Hageman, Protohistoric and Roman roads, routes and tracks in Sandy Flanders: identification in the field, in: Vermeulen and Antrop, *Ancient Lines in the Landscape*, 97–113.

were considered in this research. The resulting 1404 photographs were georectified in ArcMap according to the Lambert 72 coordinate system using a second order polynomial transformation and bilinear interpolation. Due to lack of ground control points (GCP) and great distortion, only 544 photographs could be georectified. The visible linear marks from these were then drawn in ArcMap.

Besides aerial imagery with a specific archaeological purpose, interest in the archaeological potential of aerial photographs taken for military, mapping or public works is increasing. Those predating the large-scale landscape changes of the second half of the twentieth century may be particularly useful for revealing new information.[29] Therefore, vertical aerial photographs from the collection of the Geography Department at Ghent University were also used in this study. They were taken between 1950 and 1970 by the Military Geographical Institute and the Ministry of Public Building and Works. Only photographs with an oblique equivalent for the same location were selected, to allow comparison. This resulted in a selection of 386 photographs. Based on visible linear marks, this selection was further reduced to forty-eight photographs. The georectification and drawing was performed in the same way as for the oblique aerial photographs.[30]

The Central Archaeological Inventory (CAI) of Flanders, the online inventory of all known archaeological findspots in the region, was used to select all 189 known Roman archaeological sites in the study area. These include sites related to habitation (109), economy (21), burials (49), infrastructure (56) and fortification (9). More than one of these categories may be ascribed to individual sites, therefore no distinction or ranking of types or dating was undertaken for this analysis. Detailed excavation reports and maps of individual sites and locations were obtained by contacting respective excavators.

Methods

The main aim of this study was to create a cost surface in order to calculate least cost paths for possible Roman roads in the study area. A cost surface allows the modelling of the costs of traversing a landscape subdivided into grid cells on a map. Each individual cell is ascribed a cost, depending on the chosen cost attributes. Least cost paths then model the route with the lowest accumulated cost from A to B.[31] Several studies on the planning and topography of Roman roads indicate a wide array of possible cost attributes in choosing the location of a road, such as elevation of the terrain, preference for dry soils, slope, visibility, financial cost and travel time.[32] Since the study area is characterised by a large number of dry ridges and wet depressions, two cost surfaces were created based on an ASCII version of the DTM (cell size five metres) for Flanders (2001–2004) and a shapefile version of the Belgian soil map of 2001 (cell size five metres). The DTM was based on the first DEM for Flanders, created with LiDAR in rural areas and photogrammetry in urban areas. Interpolation was conducted by Inverse Distance Weighting and the average point density is one point per twenty square meters.[33] The cost ascribed to the DTM was based on the method used by Wiedemann, Antrop and Vermeulen.[34] They used the raster calculator in ArcGIS to give depressions (negative height values) and higher areas (positive height values) a respective high and low cost, since hilltops and ridges were favoured for routes. This argumentation was followed by applying the formula **Con("raster" < 0, Log10(("raster" * (−1)) + 1), Con("raster" ≥ 0, Log10("raster" + 1)))**. By doing so, extremely high or low values were adjusted. The resulting cost surface was afterwards inverted using the formula **(("raster" − Z_max) * −1) + Z_min** to give depressions and hilltops a respective high and low cost.

Subsequently, a cost surface based on the Belgian soil map was created. To represent the natural situation as closely as possible anthropogenic soils were replaced by surrounding values using a majority filter **Con(IsNull("raster"), FocalStatistics("raster", NbrRectangle(5,5, "CELL"), "MAJORITY"), "raster")**. The cost ascribed to the resulting map was based on a division into four soil types. Dry sand, dry soils, moist soils and wet soils were ascribed respectively costs of one, two, three and ten.[35] This modelled the (un)suitability of each soil type for road building in combination with the costs based on the DTM. For example, the high cost to run the least cost path along a depression would thus have been multiplied by ten if the soil conditions were wet.

Before multiplying both cost surfaces in the raster calculator, the cost surface based on the DTM was calibrated to a zero to ten scale by **("raster" − min("raster"))/(max("raster") − min("raster")) * 10**. In this way a continuous and consistent scale was obtained for both surfaces. Since no objective data on cost preferences in Roman decision making are available, no weights were ascribed to the calculated cost surfaces when combining them. After multiplying the cost surfaces, the resulting cost surface was calibrated in the same way, on a scale of zero to ten.[36]

To make it possible to calculate least cost paths to Aardenburg, now in the Netherlands, a cost surface for the area around this city was created based on height data from the elevation map of the Netherland, the AHN2 (cell size five metres). Despite a different reference level for Belgium (TAW) and the Netherlands (NAP), the elevation values of the AHN2 were not converted to the Flemish standards. This was based on the idea that the cost ratio would stay the same once the least cost path crossed the border between Flanders and the Netherlands. This theoretical assumption might cause inconsistencies when reference levels are substantially different. However, given that the area around Aardenburg is very flat and variations in height are small, the impact would be minimal. The cost surfaces for Flanders and Aardenburg were joined using the mosaic tool in ArcMap.

Calculations of least cost paths were based on the broadly accepted junctions of supralocal Roman roads in Flanders. Least cost

[29] D.C. Cowley and B.B. Stichelbaut, Historic aerial photographic archives for European archaeology, *European Journal of Archaeology* 15 (2012) 217–236.

[30] For both the oblique and vertical aerial photographs, orthophotos of West and East Flanders were used as master documents during georectification. The orthophotos date respectively from 2008 to 2006 and are available on geopunt.be.

[31] J. Conolly and M. Lake, *Geographical Information Systems in Archaeology*, Cambridge, 2006, 215 and 252.

[32] Chevallier, *Les Voies Romaines*, 98–99; J. Poulter, Surveying Roman military landscapes across northern Britain. The planning of Roman Dere Street, Hadrian's Wall and the Vallum, and the Antonine Wall in Scotland, *BAR British Series* 492 (2009) 3–31; P. Verhagen and K. Jeneson, A Roman puzzle. Trying to find the Via Belgica with GIS, *BAR International Series* 2344 (2012) 123–130; P. Verhagen, S. Polla and I. Frommer, Finding Byzantine junctions with Steiner trees, in: S. Polla and P. Verhagen (Eds.), *Computational Approaches to Movement in Archaeology. Theory, Practice and Interpretation of Factors and Effects of Long Term Landscape Formation and Transformation*, *Topoi Berlin Studies of the Ancient World 23*, Berlin, 2014, 73–97; van Lanen, Kosian, Groenewoudt, Spek and Jansma, Best travel options, 145.

[33] AGIV, *DHM-Vlaanderen I (2001–2004): Leesmij*, Brussel, 2004.

[34] Wiedemann, Antrop and Vermeulen, Analysis of the Roman road system around Cassel, 88.

[35] Wiedemann, Antrop and Vermeulen, Analysis of the Roman road system around Cassel, 92.

[36] J.K. Berry, *Optimal Path Analysis and Corridor Routing: Infusing Stakeholder Perspective in Calibration and Weighting of Model Criteria*, Denver, 2004, http://www.innovativegis.com/basis/present/GeoTec04/GIS04_Routing.htm, last accessed 3 January 2017; M.C.L. Howey, Using multi-criteria cost surface analysis to explore past regional landscapes: a case study of ritual activity and social interaction in Michigan, AD 1200–1600, *Journal of Archaeological Science* 34 (2007) 1830–1846; P. Verhagen, Quantifying the qualified: the use of multicriteria methods and bayesian statistics for the development of archaeological predictive models, in: P. Verhagen (Ed.), *Case Studies in Archaeological Predictive Modelling*, Leiden, 2007, 71–94.

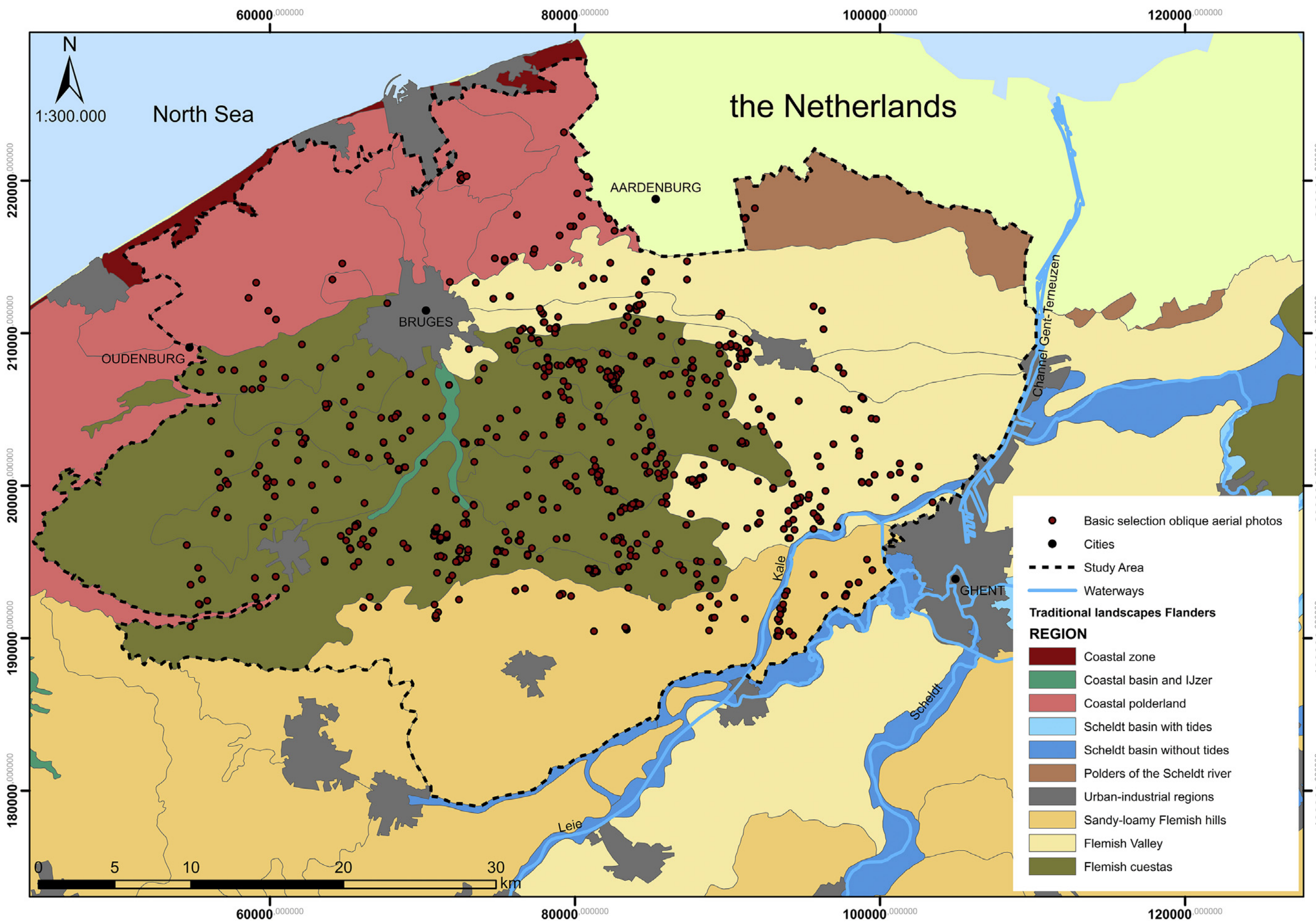

Fig. 2. Study area in relation to the available oblique aerial photographs, the traditional landscapes of Flanders and the modern-day courses of the main waterways identified in Roman times.

paths were calculated between consecutive junctions. Although this can impact on the calculated routes over longer distance, as indicated for the route from Oudenburg to Bruges on Fig. 3, this assumption follows Poulter's finding that supraregional routes were divided into several segments. Moreover, the end and starting points in this study are in themselves only junctions in the wider network of Roman roads. The least cost paths for the different possible supralocal Roman roads were calculated in ArcMap. The resulting raster data was transformed to polyline-shapefiles. Poulter noticed during his research on the planning of Roman roads in northern Britain that consecutive segments of consistently planned roads were laid out in opposite directions. Since a fixed direction for laying out roads seemed missing, and a similar study for Sandy Flanders was not available, the decision was made to calculate the least cost paths from the hinterland towards the coast. It was confirmed that this did not influence the resulting least cost paths by calculating three least cost paths in the opposite direction.[37]

Following the example of Wiedemann, Antrop and Vermeulen a buffer of 250 metres on each side of the least cost paths was calculated, resulting in a 500 metre-wide buffer.[38] The 250 metre distance was maintained in this study in order to test the calculated least cost paths. For a least cost path to represent a correct route it is assumed that it should run close to the parallel marks and sites identified by aerial photography and archaeology. As De Clercq and Van Thienen argue, late Roman settlements were located close to roads and rivers, and throughout the Roman period roads would have structured the landscape of settlements and their layout, a vision that is shared by Burghardt for the Roman province of Pannonia.[39] Using ‘select by location’, all marks and archaeological sites completely or partly within these buffers were selected. A comparison in orientation was visually made, based on the parallel course of the least cost paths, the marks and current roads.

Subsequently, the Kernel density of the Roman archaeological sites in the study area was calculated to compare with the least cost paths. The calculation was based on the point location of each site with a search distance of 1500 metres, an output in km^2 and an output cell size 100. A restriction in search distance to 250 metres, like the buffers, would have given limited site densities unusable

[37] Poulter, Surveying Roman military landscapes across northern Britain, 3–31; J. Poulter, Further discoveries about the surveying and planning of Roman roads in northern Britain. A sequel to BAR 492, *BAR British Series* 598 (2014) 3–16.

[38] Wiedemann, Antrop and Vermeulen, Analysis of the Roman road system around Cassel, 91.

[39] The Roman province of Pannonia covered parts of present-day Hungary, Austria, Croatia, Serbia, Slovenia, Slovakia and Bosnia and Herzegovina, A.F. Burghardt, The origin of the road and city network of Roman Pannonia, *Journal of Historical Geography* 5 (1979) 1–20; De Clercq, *Lokale Gemeenschappen in het Imperium Romanum*, 254–257; V. Van Thienen, Abandoned, neglected and revived: aspects of Late Roman society in Northern Gaul, unpublished PhD thesis, Ghent University, 2016, 56–58.

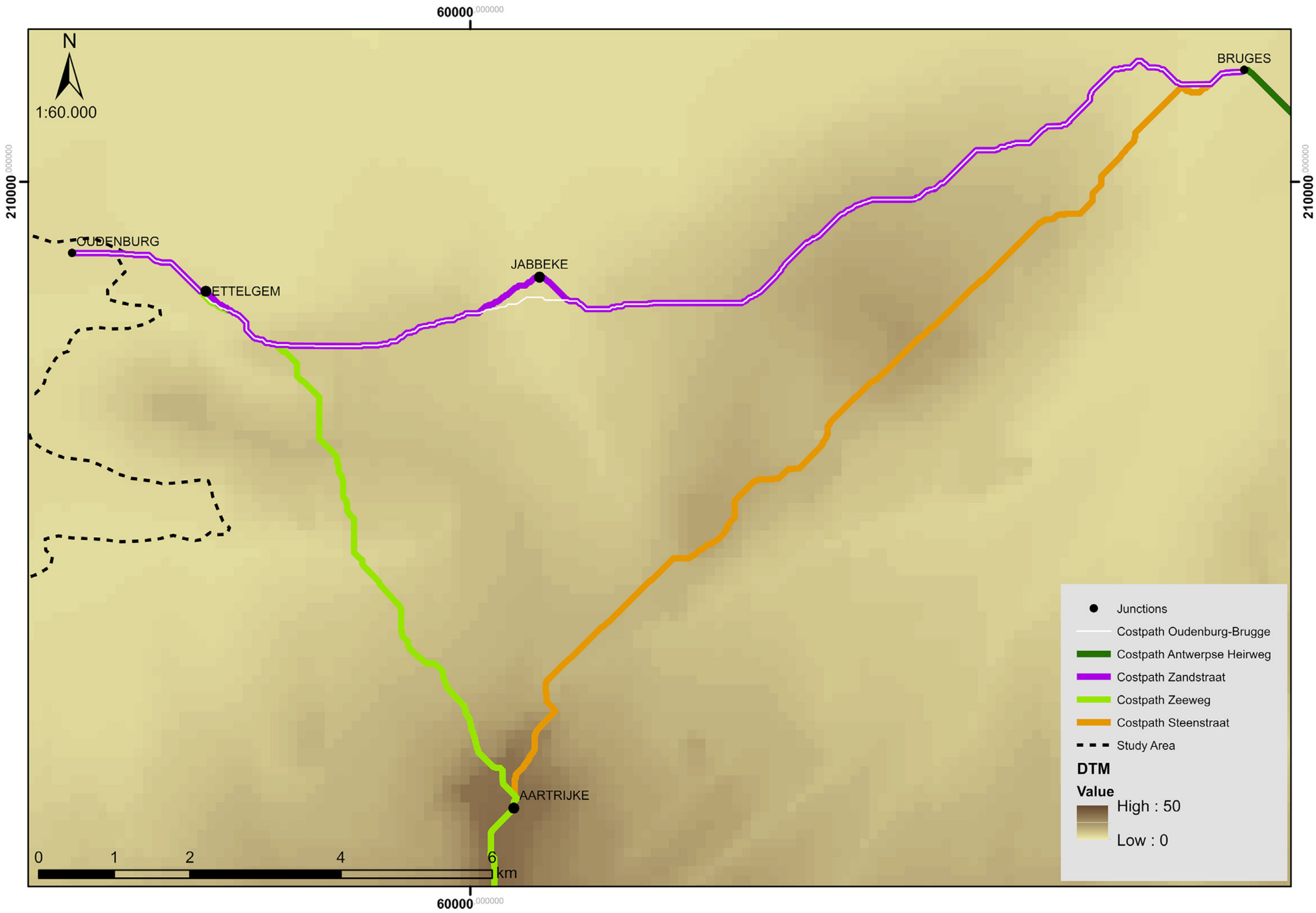

Fig. 3. Indication of difference between cost paths calculated over longer distance as a direct connection between Oudenburg and Bruges and in segments passing by Ettelgem and Jabbeke (Costpath Zandstraat).

for this supralocal research. The Kernel density was used to visualise and to assess the supralocal densities of archaeological sites.

After that, current roads with names referring to *heer*, *heir* (army) or *steen* (stone/paved) were selected from a shapefile of the modern-day road network and compared to the least cost paths, using a buffer of 250 metres around the latter. By means of 'select by location' overlapping parts of the buffers and the current roads were selected. A comparison in orientation was visually made.

Finally, the continuity of these current roads in time and space was studied by plotting them on recent orthophotos. We assume that modern-day interruptions in the use of the *heer*, *heir* and *steen* road names may refer to the obsolescence of a road segment; instances where the road has been partly deviated or moved and was given another name. The route of the original road segment may however still be visible in field systems or trackways and thus form a continuity in the landscape. Since it was impossible to study this for all the roads included in this research, the *Steenstraat* (paved street) was chosen as a case study, based on its striking rectilinearity and thereby possible Roman origin.

Results

The combination of cost surfaces based on the DTM and soil map for West and East Flanders and the AHN2 for Aardenburg resulted in a cost surface with costs between zero and ten (see Fig. 4). The calculation of least cost paths resulted in six routes for possible Roman roads (see Fig. 5). Although at first sight they run relatively directly between two junctions, these least cost paths do not tend to accord with the typical idea of dead straight Roman roads running through the landscape. Instead they follow the microtopography of small and large consecutive sand ridges, therefore bending through the landscape. This is demonstrated by the sinuosity index (Table 1), a measure of straightness of a linear element developed in the field of hydrology.[40] A straight line has a sinuosity of one. The closer to one, the straighter a line is. The *Zandweg* between Oudenburg and Bruges, for example, follows the great sand ridge Gistel-Maldegem-Stekene. The different segments of this road therefore have a sinuosity between 1.07 and 1.15. The least cost path between Poperinge and Woumen, on the other hand, deviates strongly from the direct connection between both places, indicated by a sinuosity of 2.85. Instead, it runs along the ridge of southern West Flanders thereby avoiding the Yser estuary. In order to interpret these values sinuosity indices for modern-day *steenweg* and *heirweg* roads were calculated. Due to the scattered and fragmented presence of these road names, four long segments of both types were selected as case studies. The *Gistelsesteenweg* (1.05), *Koolkerkesteenweg* (1.02), *Gentsesteenweg* (1.02) and *Brugsesteenweg* (1.00) have an average sinuosity of 1.02. The *Antwerpse*

[40] J. Mueller, An introduction to the Hydraulic and Topographic Sinuosity Indexes, *Annals of the Association of American Geographers* 58 (1968) 371–385; Verhagen, Polla and Frommer, Finding Byzantine junctions with Steiner trees, 81.

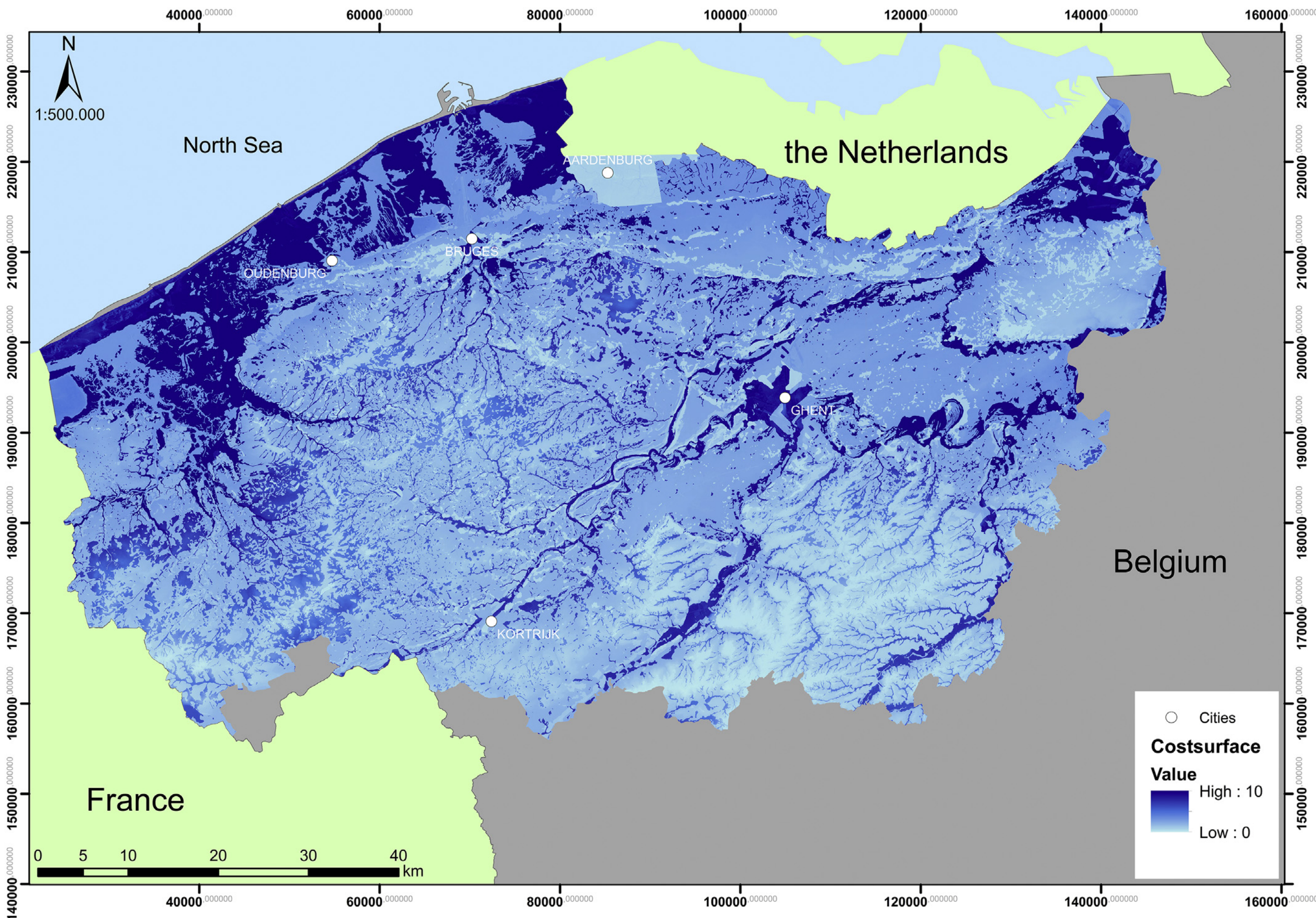

Fig. 4. Cost surface for West and East Flanders and the region around Aardenburg.

Heirweg (1.02), *Diksmuidse Heirweg* (1.03), *Heirweg* near Aalter (1.01) and *Oude Heirweg* (1.03) also have an average sinuosity of 1.02. A modern-day high way, such as the E40 from Bruges to Ghent, has a sinuosity of 1.005.

Comparison with marks and sites

After georectification, 326 double linear marks were drawn, of which 276 were found on oblique and fifty on vertical aerial photographs. 189 sites were selected from the CAI. The number of marks and sites within the calculated buffers varies for each least cost path (*Number of marks in buffer* and *Number of sites in buffer* in Table 2). In total, 36 (11.0%) different crop marks and 40 (21.2%) different sites lie within the buffers. Based on a χ^2 - test with $\chi^2{}_3 = 9.55$ and $\chi^2{}_{0.05} = 3.84$, we can conclude that this is not sufficient to draw conclusions on the correctness of the calculated least cost paths. Moreover, only 15 (41.7%) of the different marks within the buffer (*Number of parallel marks in buffer* in Table 2) have a parallel orientation relative to the least cost paths and there are no overlays. Based on a χ^2 - test with $\chi^2{}_3 = 58.9$ and $\chi^2{}_{0.05} = 3.84$, it is impossible to draw conclusions on the nature of these marks.[41]

Most of the sites only concentrate in parts of the routes, as shown by the lengths within the Kernel density (*m in Kernel density* in Table 2). Since the Kernel density was calculated based on sites within the study area, only the length of least cost paths within the study area was used as a total length reference. Five large site clusters are visible on Fig. 6, between Bruges and Oudenburg, between Bruges and Maldegem, east of Maldegem and around Aalter and Merendree. These clusters demonstrate a strong conformity with the least cost paths for the *Zandstraat* (73.8%), *Blicquy–Aardenburg 1* (63.6%) and *Blicquy–Aardenburg 2* (71.9%), as shown by the high percentage of least cost paths running through these clusters (*m in Kernel density* in Table 2).

Comparison with current roads

The number of modern day road segments with names referring to *heer*, *heir* (army) or *steen* (stone/paved) (see Fig. 7) within the buffers varies between the least cost paths (see Table 3). Overall, calculated least cost paths and current roads show low conformity. Modern-day roads with names referring to *steenstraat* and *steenweg* form an exception. The current *Steenstraat* has an overlap of 14.2% with the buffer for the calculated Roman *Steenstraat* least cost path. In total, 21.7% of its modern-day length lies within one of the calculated buffers. Roads with *steenweg* names, however, show an even higher overlap. Although only 5.4% of its total length lies within one of the buffers, this corresponds to 47,535 metres. The current *Steenstraat*, in contrast, has an overlap of 12,353 metres with the calculated buffers.

The total length of modern-day roads with names based on *heer*, *heir* (army) or *steen* (stone/paved) overlapping with each of the

[41] Conolly and Lake, *Geographical Information Systems in Archaeology*, 122–127.

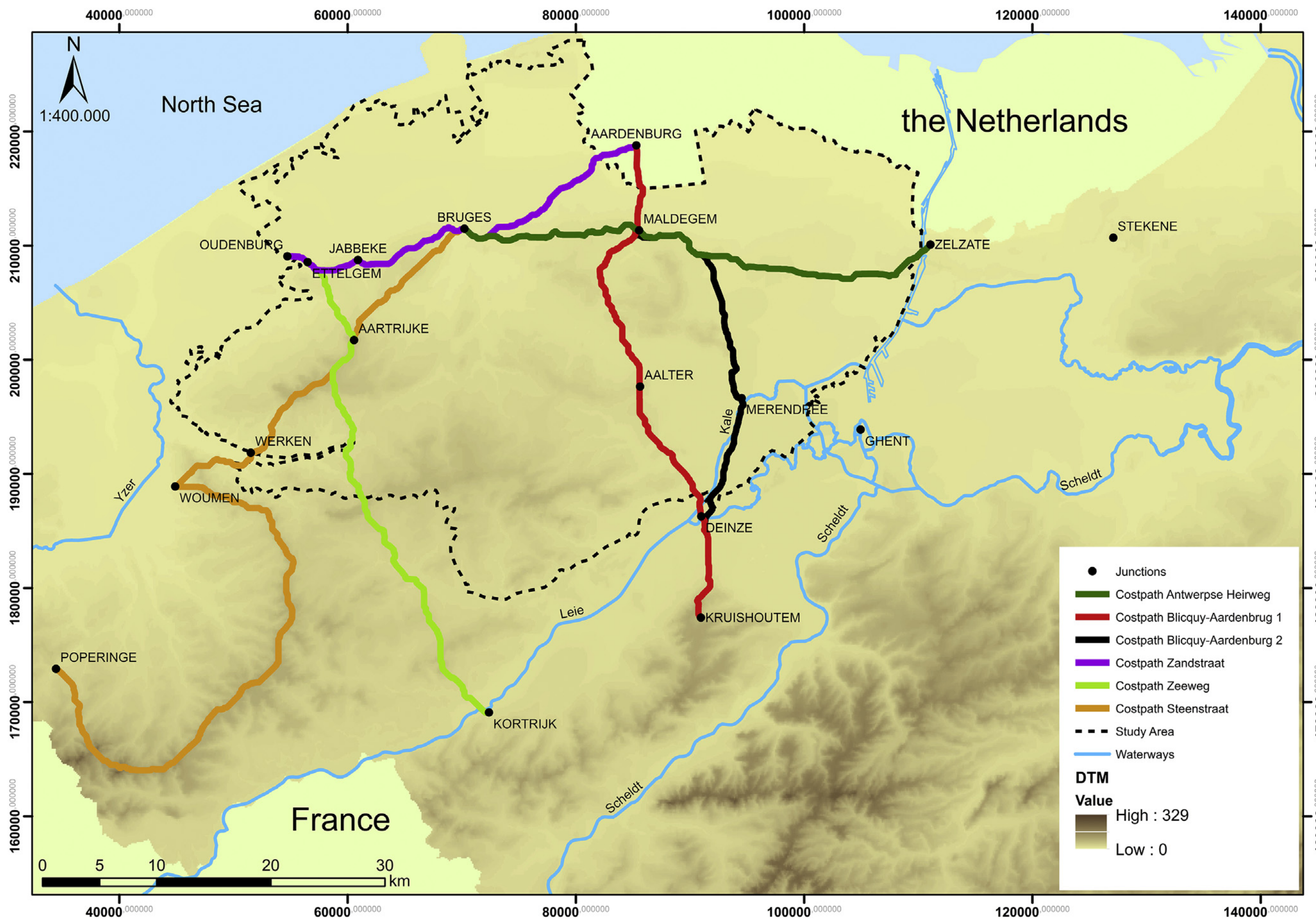

Fig. 5. Least cost paths for the probable Roman roads in Sandy Flanders, in relation to known junctions and the modern-day courses of the main waterways identified in Roman times.

calculated buffers is limited. The calculated least cost paths for the *Steenstraat* (1.6%), *Antwerpse Heirweg* (1.1%) and *Zandstraat* (1.3%) have in total the most overlap with current roads. The clusters of Roman sites based on the Kernel density indicate a limited relation with the current roads. In total, only 8.8% of modern roads with *heer*, *heir* (army) or *steen* (stone/paved) names run through concentrations of sites (*m in Kernel density* in Table 3).

Continuity

As described in the methodology, we assume that modern-day interruptions in the use of the *heer*, *heir* and *steen* names may refer to the obsolescence of a road segment. The route of the original road segment may however still be visible in field systems or trackways and thus form a continuity in the landscape.

Because of the extent of the study area, only one detailed example of continuity in space and time is given. The *Steenstraat* between Werken and Aartrijke has two discontinuities. One of them is situated to the southwest of Aartrijke, along the *Sparappelstraat* (see Fig. 8). At the crossing of the *Processieweg*, *Steenstraat* and *Sparappelstraat*, the *Steenstraat* name disappears. Around two kilometres to the northeast the *Steenstraat* reappears and enters the town of Aartrijke. Both segments of the *Steenstraat* are linked by the current *Sparappelstraat* and *Zeeweg Zuid*. In line with both segments, however, lies a trackway used by farmers. Since it is a straight connection between both segments of the *Steenstraat*, this trackway might be a continuation of an original route, which was abandoned in favor of the *Sparappelstraat* and *Zeeweg Zuid*. Its use as trackway thereby forms a continuity in the landscape.

Discussion

Reconstruction of the Roman road network

Van Lanen argues that the use of cost surfaces in low lying areas such as the Netherlands is of limited use since the relief differences are small.[42] Other landscape factors would have had a greater influence on the routes' locations. However, his study using a Network Friction Model shows that small levees might have been used as corridors across the landscape of these lower areas, which corresponds with the results of this study. The calculated least cost paths for possible supralocal roads do not seem to accord with the typical idea of straight Roman roads running through the landscape. They rather follow the microtopography of small and large consecutive sand ridges, resulting in a higher sinuosity index than modern-day roads. This is partly due to the chosen attributes and costing during the calculation of the cost surfaces, but does accord with findings from other researchers. Chevallier argues that, over long distances, Roman roads consisted of rectilinear segments which deviated from each other because of topography.[43]

[42] van Lanen, Kosian, Groenewoudt, Spek and Jansma, Best travel options, 145.

[43] Chevallier, *Les Voies Romaines*, 98–99.

Table 1
Sinuosity Index for individual segments of cost paths (straight line = 1).

Segment	Length cost path (m)	Length direct connection (m)	Sinuosity Index
Antwerpse Heirweg			
Bruges-Maldegem	17,383	15,310	1.14
Maldegem-Zelzate	29,285	25,549	1.15
Blicquy-Aardenburg1			
Kruishoutem-Deinze	9963	8871	1.12
Deinze-Aalter	13,857	12,575	1.10
Aalter-Aardenburg	24,767	21,136	1.17
Blicquy-Aardenburg2			
Kruishoutem-Merendree	21,671	19,560	1.11
Merendree-Aardenburg	29,677	23,991	1.24
Zandstraat			
Oudenburg-Ettelgem	1968	1842	1.07
Ettelgem-Jabbeke	5094	4418	1.15
Jabbeke-Bruges	11,069	9716	1.14
Bruges-Aardenburg	19,216	16,739	1.15
Steenstraat			
Poperinge-Woumen	54,382	19,091	2.85
Woumen-Werken	8701	7250	1.20
Werken-Aartrijke	15,119	13,392	1.13
Aartrijke-Bruges	15,015	13,734	1.09
Zeeweg			
Kortrijk-Aartrijke	41,375	34,702	1.19
Aartrijke-Oudenburg	10,766	9382	1.15

Preferably, they followed dry southern hillsides, avoiding damp and unstable areas. Especially in the coastal area, at the time consisting of estuaries, channels and tidal muds, sand ridges were probably used for traveling.[44] Poulter observed the same in the hills of Great Britain.[45] Roads were constructed by long distance alignments based on eyeshot, thereby meandering through the landscape, following ridges and watersheds. Examples of Byzantine road planning show that difficult topography was often favoured in contrast to wet conditions.[46]

The least cost path between Poperinge and Woumen, however, runs along the ridge of southern West Flanders instead of following the direct connection across smaller sand ridges in the Yser estuary. This major detour is strikingly different from the typical idea of straight Roman roads. This is also indicated by its high sinuosity in comparison to the other least cost paths and modern-day roads. Therefore, the least cost path for this segment was calculated in the opposite direction as well, giving the same result. This was to be expected, since the least cost path algorithm in ArcGIS is based on the Cost Distance and Cost Back Link, recording for each cell the accumulated cost and direction to the source cell.[47] Both would be the same in opposite directions. It is therefore unclear if this route is the rendering of a historical reality or should be ascribed to the cost surface. As Burghardt states, the construction of a road network since Roman times has been the result of considering a variety of possibilities and priorities. According to Verhagen, Polla and Frommer, the use of cost surfaces and least cost paths to locate Roman or later roads conflicts with the unpredictability of these historical decision-making processes. Since a wide array of possible attributes for road planning is suggested in the literature, a better understanding of these processes is of vital importance for constructing accurate cost surfaces. No detailed information is available for the Civitas Menapiorum. Therefore, based on the characteristic landscape of estuaries, channels and tidal muds, elevation and soil wetness were selected as attributes. However, the choice of route in Roman times could have been based on other cost attributes such as time, financial cost, visibility, slope or topographical index. Studies of Roman roads in Iberia and Roman-Byzantine roads in Turkey demonstrate that the use of different attributes, adding attributes and using different cost functions will affect the resulting least cost path. Only one possible route is thus represented, based on given attributes and costs.[48] Further research into these aspects for the Civitas Menapiorum will clarify if this has a major impact on the resulting least cost path for the road from Poperinge to Bruges.

The choice of costs is one of the explanations why only little similarity could be observed by comparing the buffers for the calculated least cost paths, the known archaeological sites from the CAI and the crop and soil marks on oblique and vertical photographs. Generally, only 21.2% of the archaeological sites lie within 250 metres of one of the least cost paths (*Number of sites in buffer* in Table 2), besides 11% of the marks on oblique and vertical aerial photographs (*Number of marks in buffer* in Table 2). Wiedemann, Antrop and Vermeulen concluded the same in their study of Roman roads around Cassel.[49] For the crop and soil marks this could mean that only a few such marks belong to supralocal Roman roads in Sandy Flanders. The crop and soil marks that do not seem to match the least cost paths or have another orientation could still be part of a Roman road network. These marks could be the remnants of local roads connecting and structuring the settlement or field systems.[50] This may also apply to archaeological sites that could not be linked with the supralocal road network. For the Blicquy–Aardenburg 1 road this could mean that the attested Roman roads on the Aalter-Oostmolenstraat and Aalter-Woestijne sites could be part of the supralocal road to Aardenburg or the local road network. Further detailed research on orientation, soil and topographic location and dating of crop and soil marks is necessary to study these possibilities. It is, however, not possible to prove this without identification in the field. This may be done by augering or excavation.[51]

Besides the choice of attributes, the reliability with which a least cost path represents the correct route of a Roman road depends on

44 C. Baeteman, *De holocene geologie van de Belgische kustvlakte*, *Geological Survey of Belgium* 304, Brussels, 2008, 7–18.

45 Poulter, Surveying Roman military landscapes across northern Britain, 3–31.

46 R.A. Hucker, How did the Romans achieve straight roads? Unpublished Paper FIG Working Week 2009: Surveyors Key role in Accelerated Development, Eilat, 2009; Verhagen, Polla and Frommer, Finding Byzantine junctions with Steiner trees, 80.

47 ESRI, Understanding cost distance analysis, http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/understanding-cost-distance-analysis.htm, last accessed 3 January 2017.

48 Burghardt, The origin of the road and city network of Roman Pannonia, 15; J. De Reu, Mind heterogeneous landscapes. A review of the 'Topographic Position Index', in: J. De Reu, *Land of the Dead: A Comprehensive Study of the Bronze Age Burial Landscape in North-Western Belgium*, Ghent, 2012, 155–174; Chevallier, *Les Voies Romaines*, 98–99; Poulter, Surveying Roman military landscapes across northern Britain, 3–31; Verhagen and Jeneson, A Roman puzzle, 123–130; Verhagen, Polla and Frommer, Finding Byzantine junctions with Steiner trees, 73–97; van Lanen, Kosian, Groenewoudt, Spek and Jansma, Best travel options, 144–159; A. Güimil-Farina and C. Parcero-Oubina, 'Dotting the joines': a non-reconstructive use of Least Cost Paths to approach ancient roads: the case of the Roman roads in the NW Iberian Peninsula, *Journal of Archaeological Science* 54 (2015) 31–44.

49 Wiedemann, Antrop and Vermeulen, Analysis of the Roman road system around Cassel, 90–91.

50 De Clercq, *Lokale Gemeenschappen in het Imperium Romanum*, 254–257.

51 Hageman, *Parallelle sporen en luchtfotografie*; F. Vermeulen, Field control and excavations, in: Vermeulen and Antrop, *Ancient Lines in the Landscape*, 67–74; M. Van De Vijver, K. Keppens, H. Vandendriessche, K. De Groote and W. De Clercq, Een Gallo-Romeins landschap van bewoning en begraving te Aalter Woestijne (O.-Vl.), een eerste stand van zaken, *Signa* 2 (2013) 152–157; J. Hoorne and A. De Logi, Aalter-Oostmolenstraat. Archeologisch vooronderzoek – maart 2013, unpublished report, De Logi and Hoorne, 2013.

Table 2
Results for comparison of cost paths, aerial photographs and archaeological sites.

Cost path	Length in m	m in Kernel density (% of length in study area)	Number of marks in buffer (% of total marks)	Number of sites in buffer (% of total sites)	Number of parallel marks in buffer (% of Number in buffer)
Antwerpse Heirweg	46,668	15,682 (34.4)	19 (5.8)	1 (0.5)	9 (47.3)
Blicquy-Aardenburg1	48,588	20,659 (63.6)	12 (3.7)	8 (4.2)	9 (75)
Blicquy-Aardenburg2	51,348	26,148 (71.9)	12 (3.6)	16 (8.5)	4 (33.3)
Zandstraat	37,349	24,385 (73.8)	2 (0.6)	27 (14.3)	2 (100)
Steenstraat	93,196	12,673 (40.2)	3 (0.9)	3 (1.6)	1 (33.3)
Zeeweg	52,142	9948 (37.7)	3 (0.9)	11 (5.8)	1 (33.3)
Total	329,291	109,495 (53.3)	36 (11.0)	40 (21.2)	15 (41.7)
	Length in m within study area	m outside Kernel density (% of length in study area)	Number of marks outside buffer (% of total marks)	Number of sites outside buffer (% of total sites)	Number of parallel marks outside buffer (% of Number outside buffer)
Antwerpse Heirweg	45,559	29,877 (65.6)	307 (94.2)	188 (99.5)	2 (0.7)
Blicquy-Aardenburg1	32,501	11,842 (36.7)	314 (96.3)	181 (95.8)	4 (1.4)
Blicquy-Aardenburg2	36,377	10,229 (28.1)	314 (96.3)	173 (91.5)	2 (0.7)
Zandstraat	33,027	8642 (26.2)	324 (99.4)	162 (85.7)	2 (0.7)
Steenstraat	31,552	18,879 (59.8)	323 (99.1)	186 (98.4)	1 (0.3)
Zeeweg	26,394	16,446 (62.3)	323 (99.1)	178 (94.2)	1 (0.3)
Total	205,410	95,915 (46.7)	290 (89.0)	149 (78.8)	12 (4.1)

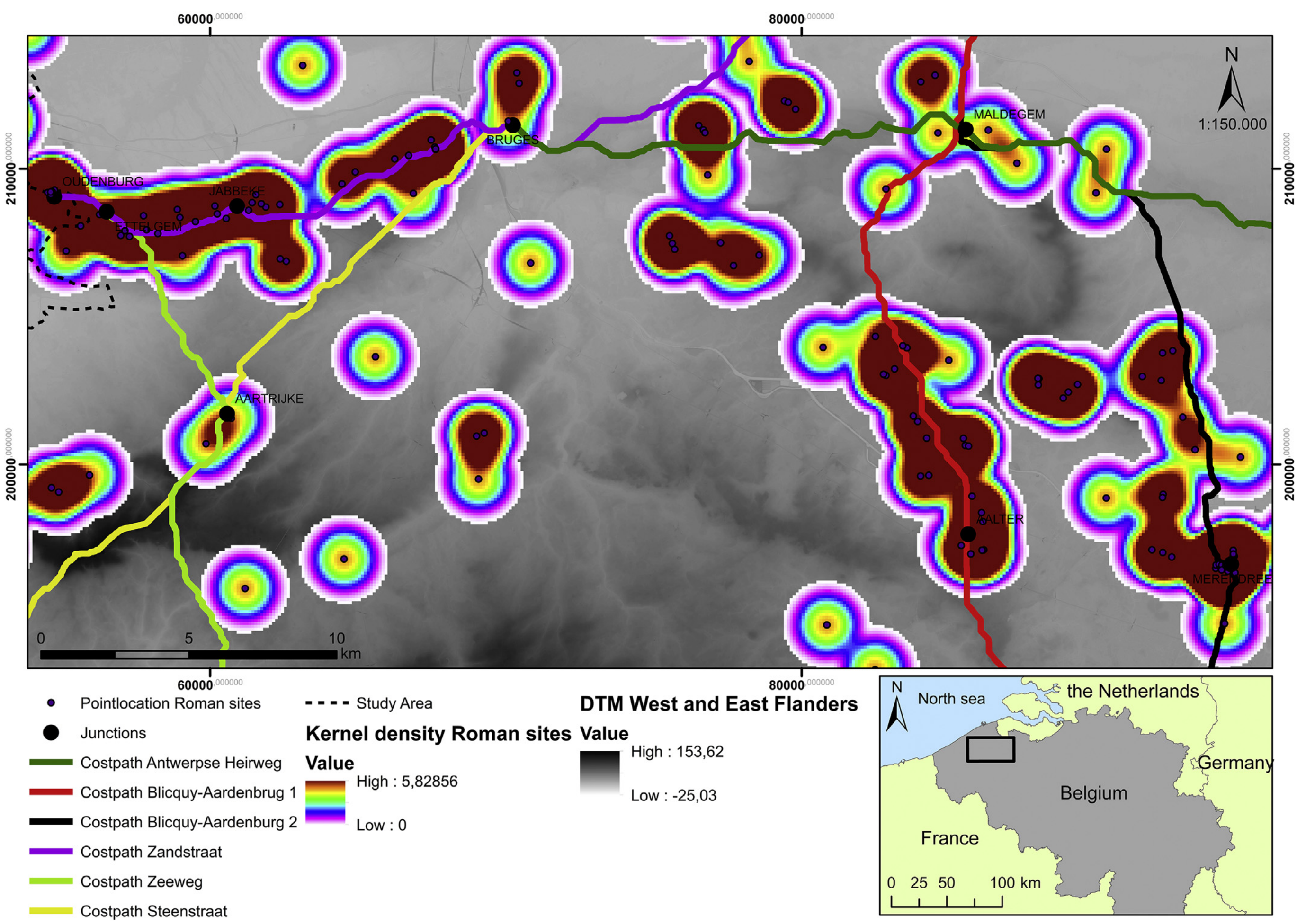

Fig. 6. Kernel density of archaeological sites in relation to some of the least cost paths in the study area.

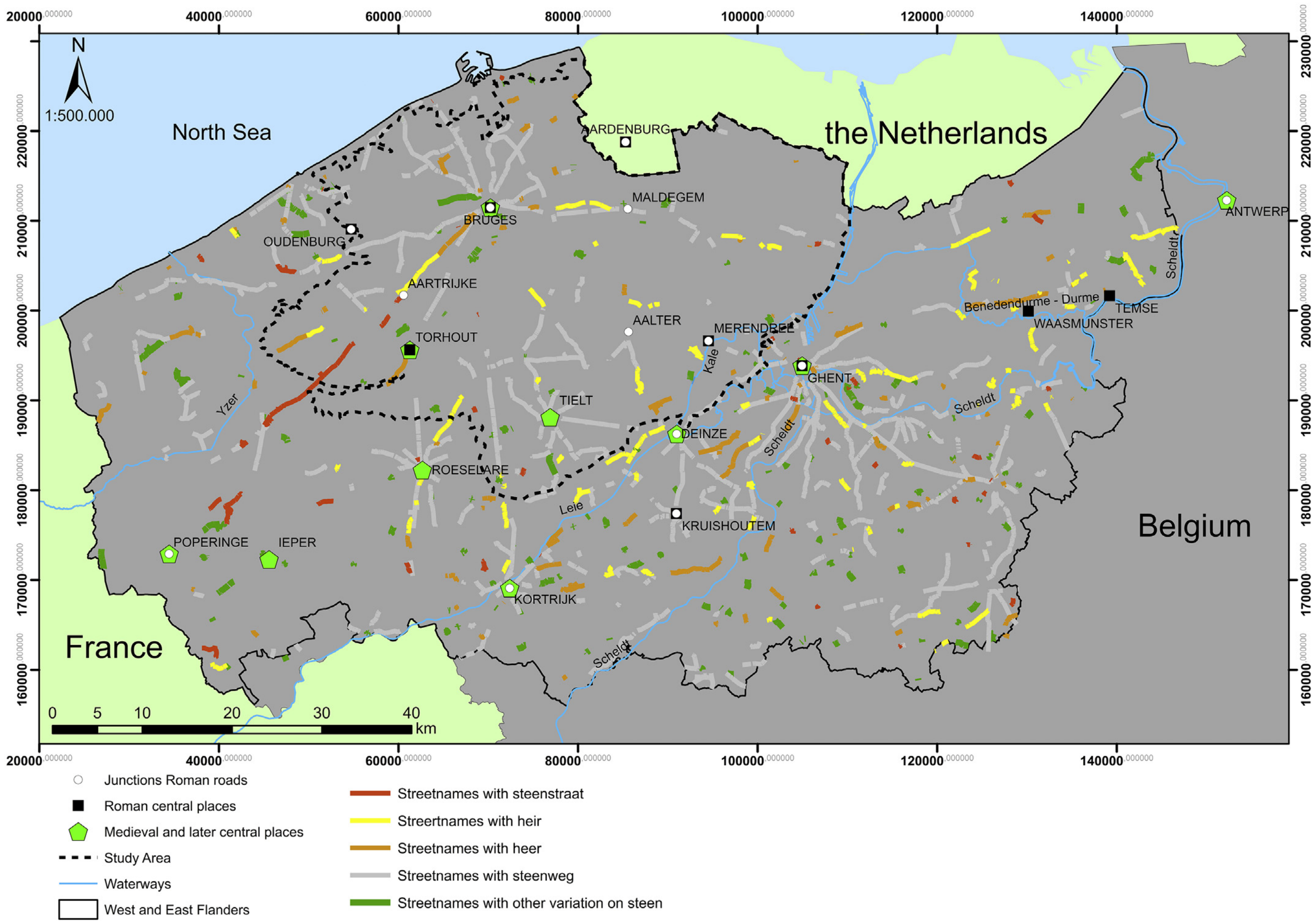

Fig. 7. Current roads in West and East Flanders with names referring to *heir*, *heer* or *steen* in relation to known junctions, central places and the modern-day courses of the main waterways identified in Roman times.

the data quality.[52] In contrast to the DEM with cell size five kilometres to five hundred metres used by Wiedemann, Antrop and Vermeulen, a LiDAR based DTM with cell size five metres was used in this study.[53] An even more recent and detailed LiDAR based DTM will allow the least cost paths to be refined further once data is available for the study area. However, the overall route will not change. In order to achieve more detailed routing extra attributes will need to be added to the calculations. On the other hand, several researchers state that Roman roads were not fixed to one single location because of seasonal conditions. In this context van Lanen speaks of a route zone instead of a route network.[54] This implies that a single least cost path cannot represent the exact route of a Roman road and that, based on seasonality, different attributes should be used to calculated several least cost paths instead. In this context, the crop and soil marks outside the buffers could be part of different routes of the same road. However, it needs to be studied to what extent roads would have been moved over more than 250 metres due to seasonal changes.

In contrast to the buffers around the least cost paths, the Kernel density shows a similarity between parts of the calculated least cost paths and concentrations of Roman sites. Based on De Clercq and Van Thienen's conclusion that roads structured the landscape of settlements, this may suggest that the least cost paths approach the routes of the supralocal Roman roads. For example, the least cost path Blicquy–Aardenburg 1 runs through the site concentration around Aalter. Combined with archaeological data from major road works in this area, this can indicate the presence of a supralocal Roman road from the south to the great sand ridge Maldegem-Stekene. It must be considered that, taking into account the rural character of the Civitas Menapiorum, not all aspects of society are archaeologically visible.[55] Therefore, the relatively limited number

[52] T. Bell and G. Lock, Topographic and cultural influences on walking the Ridgeway in later prehistoric times, in: G. Lock (Ed.), *Beyond the Map*, Amsterdam, 2000, 85–100; Wiedemann, Antrop and Vermeulen, Analysis of the Roman road system around Cassel, 90–91; K. Zakšek, E. Fovet, L. Nunniger and T. Podobnikar, Path modelling and settlement pattern, in: A. Posluschny, K. Lambers and I. Herzog (Eds), *Layers of Perception, Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA), Berlin, Germany, April 2–6 2007*, Berlin, 2008, 309–315; I. Herzog and A. Posluschny, Tilt-slope-dependent least cost path calculations revisited, in: E. Jerem, F. Redő and V. Szeverényi (Eds), *On the Road to Reconstructing the Past, Proceedings of the 36th CAA conference, Budapest, April 2-6 2008*, Budapest, 2011, 236–242; Conolly and Lake, *Geographical Information Systems in Archaeology*, 234–262; I. Herzog, Least-cost networks, in: G. Earl, T. Sly, A. Chrysanthi, P. Murrieta-Flores, C. Papadopoulos, I. Romanowska and D. Wheatley (Eds), *Archaeology in the Digital Era, CAA 2012 Proceedings of the 40th Conference in Computer Applications and Quantitative Methods in Archaeology, Southampton, United Kingdom, 26-30 March 2012*, Amsterdam, 2013, 237–248.

[53] Wiedemann, Antrop and Vermeulen, Analysis of the Roman road system around Cassel, 83–96.

[54] van der Heijden, Romeinse wegen in Nederland, 33; van Lanen, Kosian, Groenewoudt, Spek and Jansma, Best travel options, 144–159.

[55] De Clercq, *Lokale Gemeenschappen in het Imperium Romanum*, 254–257; Van Thienen, Abandoned, neglected and revived, 56–58.

Table 3
Results for comparison of cost paths and current roads with *heer*-, *heir*- and *steen* place names.

	Length in m	Antwerpse Heirweg (% of length)	*Blicquy-Aardenburg1* (% of length)	*Blicquy-Aardenburg2* (% of length)	*Zandstraat* (% of length)	*Steenstraat* (% of length)	*Zeeweg* (% of length)	Total (% of length)	m in Kernel density (% of length)
Heer	133,215	326 (0.2)	539 (0.4)	0 (0)	127 (0.1)	5687 (4.3)	1338 (1.0)	8017 (6.0)	10,702 (8.0)
Heir	146,792	3791 (2.6)	1132 (0.8)	0 (0)	0 (0)	3973 (2.7)	648 (0.4)	9544 (6.5)	13,482 (9.2)
Steenstraat	56,827	859 (1.5)	0 (0)	0 (0)	373 (0.7)	8078 (14.2)	3042 (5.4)	12,352 (21.7)	5477 (9.6)
Steenweg	878,253	9210 (1.1)	9040 (1)	7465 (0.9)	14,684 (1.7)	3153 (0.4)	3983 (0.5)	47,535 (5.4)	82,533 (9.4)
Variation on steen	123,726	675 (0.6)	10 (0.01)	10 (0.01)	1824 (1.5)	201 (0.2)	92 (0.1)	2812 (2.3)	5942 (4.4)
Total	1338,813	14,861 (1.1)	10,721 (0.8)	7475 (0.6)	17,008 (1.3)	21,092 (1.6)	9103 (0.7)		118,136 (8.8)

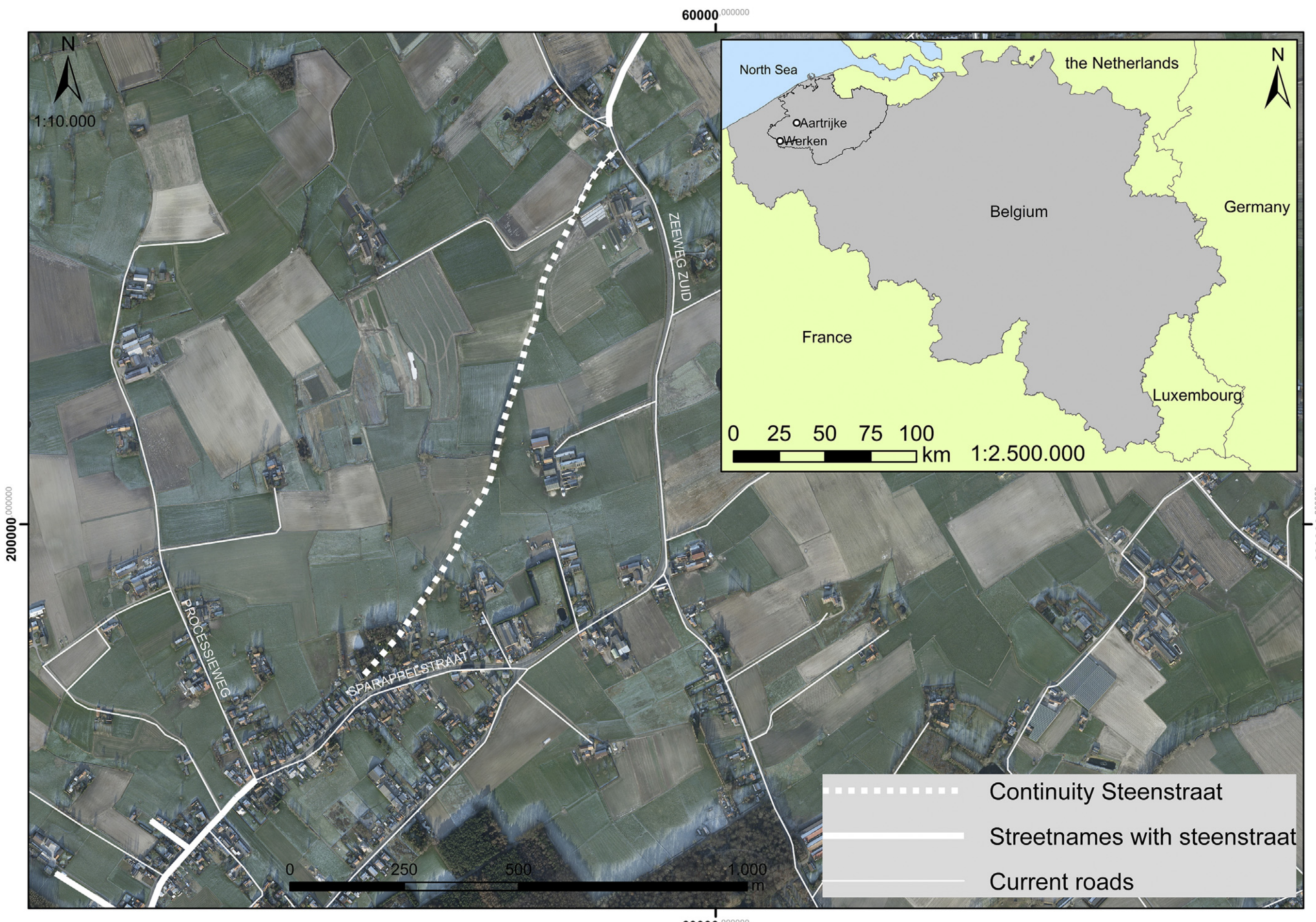

Fig. 8. Continuity of the *Steenstraat* near Aartrijke.

of available sites does not necessarily represents a correct clustering of settlements. Given that the Kernel density is both used to visualise and to assess clusters in Roman sites, it also must be considered that this may overestimate the site densities.

Contemporary routes

Comparing the least cost paths to contemporary roads with names based on *heir*, *heer* and *steen* shows a clear difference between *steenweg* (paved road) names and the other roads. As shown on Fig. 7, *steenweg* roads radiate from medieval or modern cities like Bruges, Tielt, Roeselare and Ghent, always connecting two cities. Roads with other names are less frequent and more fragmented, which makes it difficult to see their original routes. Moreover, most roads overlapping the calculated least cost paths have a *steenweg* name. It thus can be assumed that these roads follow the more optimal route through the landscape, which may indicate a more recent origin, since technological advances have improved road planning. This is confirmed by Verstraete and Genicot, who state that the *steenweg* roads were constructed between the sixteenth and eighteenth centuries to connect the cities with their hinterlands. For instance, the *steenweg* between Ghent and Bruges was built in 1782.[56] However, the sinuosity index shows little difference between roads with a name referring to *heir* or *heer* and those referring to *steen*, not allowing them to be ascribed a

[56] D. Verstraete, Oude wegen in het Meetjesland, *Appeltjes van het Meetjesland: jaarboek van het Heemkundig genootschap van het Meetjesland* 1 (1949) 49–57; Genicot, *Historie des routes Belges depuis 1704.*

different dating or origin.

Furthermore, the comparison with the Kernel density of archaeological sites shows that there is no clear link with the modern roads studied. The only exception is the *Gistelsesteenweg* with thirty-eight sites between Bruges and Oudenburg, thirty-six of which are located to the north of this road and appear to be linked to several smaller roads. Therefore, the more recent dating of *steenweg* roads is confirmed. The presence of individual Roman sites along and near the *Steenstraat* and several *heir* and *heerwegen*, however, may indicate a Roman dating. Thoen disagrees, based on an excavation on the *Antwerpse Heirweg* in Vrasene by the Archaeological Service of Waasland. Six road levels were excavated of which the oldest dated back to the eleventh century.[57] The *Antwerpse Heirweg* in Sint-Gilis-Waas, excavated by Van Roeyen, cut through Roman field systems. Roman tile-maker ovens in Temse were covered by the *Lage Heirweg*. The oldest phase of this road dates back to the twelfth century.[58] These examples counter a continuity between Roman roads and the *heir* or *heerwegen* as medieval roads. As stated by Thoen and Vanhoutte, some segments of these *heir* and *heerwegen* may yet date back to older roads.[59] This is very likely the case for the *Steenstraat* since traces of Roman infrastructure were found on the route of this road in Werken. In addition, the question may be asked what continuity of roads means. The absence of a Roman road in the stratigraphy of the *Antwerpse Heirweg* in Vrasene does not necessarily mean that there is a discontinuity. As illustrated by the example of the *Steenstraat* between Werken and Aartrijke, it is possible that a road was relocated at a certain moment in history. The roads before and after this relocation are discontinuous, but the route of both roads stays the same. The relevance of this statement for the *Antwerpse Heirweg* and other *heir* and *heerwegen* can only be attested by further landscape archaeological, historical and road name research.

Conclusion

The combined use of oblique and vertical aerial photography, archaeological knowledge, cost surfaces based on DTM and soil maps, least cost paths and road names, has resulted in a series of possible routes for Roman roads in the study area, where previously none or few were known. These routes will not always correspond to the exact roads, but contribute to the understanding of their location within corridors in the landscape. Moreover, it was possible to attest that current *steenwegen* do not have a Roman origin. For some segments of the *steenstraat*, *heir* and *heerwegen*, a continuity since Roman times may be possible. Further landscape archaeological, historic geographical and road name research is required to reconstruct Roman roads and their continuity in later periods in more detail. This study, however, shows that an interdisciplinary approach combining geography, archaeology and historical research can significantly contribute to the study of the Roman road network.

[57] Thoen, Romeinen in de Vier Ambachten, 65–70.
[58] Thoen and Vanhoutte, De romeinse wegen in het Vlaamse kustgebied.
[59] Thoen and Vanhoutte, De romeinse wegen in het Vlaamse kustgebied.