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THE ROMAN *LIMES* IN *GERMANIA INFERIOR*: A GIS APPLICATION FOR THE RECONSTRUCTION OF LANDSCAPE

1. The Roman *limes* in the province of *Germania Inferior*

At the height of its expansion, during the first two decades of the 2nd century AD, the Roman Empire extended from the Iberian Peninsula to Arabia, and from North Africa to Britain (Grassi 2011). The Roman expansion was a long process that has in the defeat of Carthage, in the second Punic war, at the end of the 3rd century BC, a crucial turning point for Rome in acquiring a predominant role in the Mediterranean basin. The maximum expansion of the Roman sphere of influence was reached during the reign of the emperor Trajan, with the conquest of Dacia and Arabia provinces. It is this long process that resulted in the formation of the Roman *limes*, a frontier long more than ten thousand kilometers. The *limes* should not be considered as a permanent defensive barrier between the Roman and the barbaric world, or as the result of a deliberate political choice, rather it must be considered and studied as the result of fossilization of a contact line between two or more conflicting forces (Maggi 2011).

The *limes* system is focused both on the presence of natural physical barriers, such as the Rhine and Danube rivers in Europe and the Sahara Desert in North Africa, either on the presence of fortified sections such as the Hadrian's wall or the Germanic-Rhaetian *limes* (Barbero 2007). In the case of the province of the *Germania Inferior* (corresponding to today's Netherlands and part of North-West Germany), annexed between the half of the 1st century BC and the first decades of the 1st century AD, the Roman *limes* come to coincide with the course of the river Rhine (Fig. 1), a natural barrier capable of marking the division between the Roman domains and the Celtic-Germanic tribes not subjects to Rome (Visser 2015).

The Rhine area has undergone considerable environmental and anthropogenic change over the past 2000 years, leading to substantial modification in river courses, coastline, vegetation and land use. The Rhine diverted its main branch southward during the early Middle Ages, and the present shoreline dates from the late medieval period, changes that resulted in a considerable mutation of the geomorphological setting from the Roman period. A palaeogeographical map of the NW part of the *limes* zone was already assembled on the basis of an extensive database of geological bore holes collected by the University of Utrecht, and of detailed LiDAR-based elevation data (Van Dinter 2013; Verhagen, Jamie, Groenhuijzen 2019).

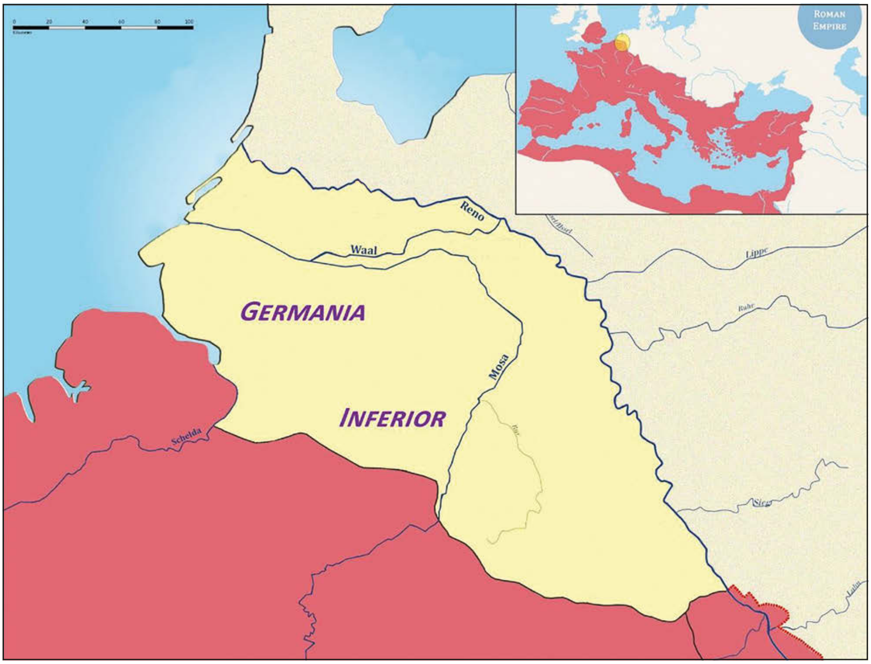

Fig. 1 – The Roman province of the *Germania Inferior*.

The archaeological research carried out in the area of the lower Rhine allowed the identification of the remains of the fortification system built by the Romans for the frontier control. In the area of Rhine-Meuse delta, by mid-1st century AD, a series of small auxiliary forts was built in the western part of this delta from the present-day city of Utrecht down to the North Sea, over a distance of about 60 km (Bosman, De Weerd 2004; Polak, Kloosterman, Niemeijer 2004; Polak 2009; Van Dinter 2013; Verhagen, Jamie, Groenhuijzen 2019). The fortifications were constructed on the left bank of the Lower Rhine. In 1970 in the city of Leiden, in the Roomburg district, thanks to the geo-radar survey, was discovered a fort with approx. size of 82×100 m. This is probably to be referred to a contingent of auxiliaries, probably on horseback, as the discovery in the area of a knight's parade mask seems to suggest. Also, thanks to the investigations conducted in the final years of the 20th century, the discovery of laterite stamps can be attributed to the contingents settled in the *castrum*. They are the *Cohors I Lucensium Hispanorum*, the *Cohors XV voluntarium civium Romanorum pia fidelis*, and the *Numerus exploratorum Batavorum* (Haalebos, Willems 1999).

In the center of Utrecht, below the square of St. Martin's Cathedral, the archaeological investigations have revealed the presence of two distinct phases of a second auxiliary encampment.

An early wooden structure, dated on the basis of materials found between AD 50 and AD 150, appears to have been overlaid by an encampment with stone structures measuring about 160×124 m. Such structure remained in use until AD 260, when the encampment, similar to other outposts on the Rhine was abandoned by Roman soldiers (Lendering, Bosman 2012). Another encampment for auxiliary troops was identified in the first half of 20th century near Vechten, where parts of the fortification perimeter and the soldiers' accommodation structures have emerged (Zandstra, Polak 2012; Polak 2014).

In the area of Nijmegen two distinct phases of a military settlement have been attested. The first is before the Batavian rebellion in AD 70 and consists of a large camp and a second small fort for an auxiliary contingent. Both were probably destroyed during the revolt, and in a later phase only one main legionary camp was erected (Willems Bradley 1992; Lendering, Bosman 2012). The numismatic and ceramics finds related to the first phase of occupation revealed the presence in the area of two main legions, the *I Germanica* and the *XIII Gemina*. Such evidence also made it possible to date the first phase of occupation of the site, between BC 19 and AD 12, probably related to the operations conducted by Drusus in the area in preparation for future Germanic campaigns (Willems 1990).

In the province of the *Germania Inferior* a second main legionary camp has been identified near Xanten, the site where in the AD 100 was established the Colonia *Ulpia Traiana*, in the place of an old settlement (Heimberg 1999). The earliest phases of the *castrum*, used by Drusus during his expeditions to *Germania Magna*, are still unknown to this day, as archaeological investigations in the past decades have focused mainly on Neronian-era structures. The first legion attested in the fort, known as *Vetera*, is the *legio XVIII* belonging to Varus' army, whose presence is documented by the cenotaph of centurion M. Caelius (Maggi 2011, 107). After the defeat of Teutoburg and the subsequent destruction of the three legions in the province, the consul Lucius Asprenate occupied the site to prevent the Germans from invading across the Rhine. In this phase the *castrum* was probably rebuilt by the future emperor Tiberius and the wooden fort was large enough to accommodate two legions, the *V Alaudae* and the *XXI Rapax*. Both later took part in Germanicus' campaigns between AD 14 and 16 (Lendering, Bosman 2012).

Around AD 30 the fort was demolished and rebuilt again. The reconstruction is traced back to AD 43, when the *legio XXI Rapax* was replaced by the *legio XV Primigenia*. The structures of the encampment were equipped

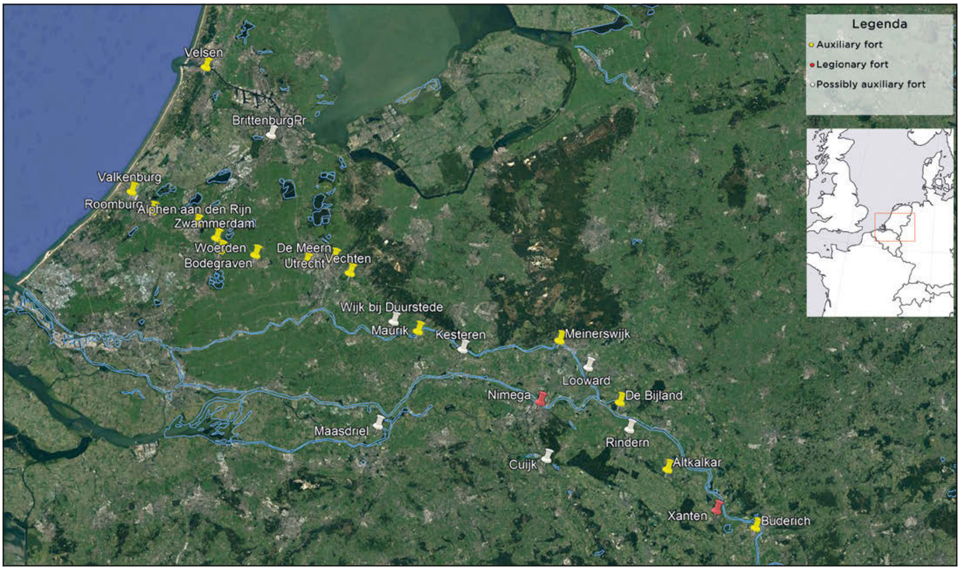

Fig. 2 – Location of the Roman forts across the Rhine *limes* system.

this time with local stone and brick foundations. A final rebuilding of the *castrum* was instead traced back to the sixth decade of the 1st century AD. This structure corresponds to the one razed to the ground by the Batavians during their revolt. The *castrum* was never rebuilt again by the Romans, just as the two legions that occupied it were never reconstituted. After quelling the Batavian uprising a new legionary base was built by *legio XXII Primigenia* in an area located in the immediate vicinity of the river, just over a kilometer from the previous one. The fort known as *Vetera II*, however, has never been archaeologically investigated, as it is now completely submerged by the modern course of the river Rhine. The site, extending roughly between 20 and 25 hectares was identified in 1960, by a group of underwater archaeologists, led by W. Piepers, at a depth of more than 10 meters (Lendering, Bosman 2012).

Thanks to the data collected in the course of the archaeological research conducted along the *limes* it has been possible to reconstruct how the system of Roman fortifications developed in the Rhine area. The Rhine *limes* was centered on a system of roads, initially used for the movement of troops, close to the river on which the various encampments were located, in a position to facilitate communication between them. Among these forts, numerous watchtowers had the role of patrolling the banks of the river and alerting the nearest encampment if the enemy approached. The camps could vary in size

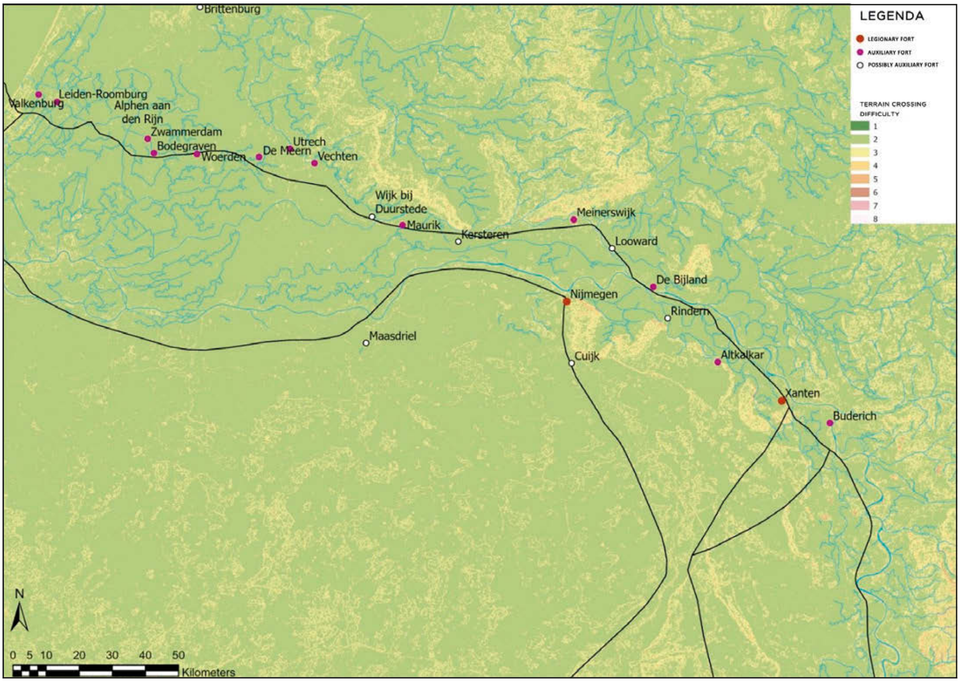

Fig. 3 – The Digital Terrain Model of the Rhine *limes* area.

according to the number of troops deployed inside, however they maintained a standardized structure in which we recognize the army headquarters, the warehouses and barracks.

The size of the forts varied, depending on whether the camp was intended to host a legion, the main unit of the Roman army, or auxiliary contingents, such as light troops, cavalry or skirmishers with supporting tasks. At present we count 17 military camps (Fig. 2). These including 2 for legions and 15 for auxiliary contingents. It is also assumed the presence of at least 6 other auxiliary camps in the area of lower Rhine.

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2. Spatial analysis applied at the Roman *limes* in *Germania Inferior*

In order to verify the position of these hypothetical forts, a visibility analysis and path distance analysis was carried out based on the location of certain sites and taking into account the ancient road routes and the geomorphology of the soil. For this purpose, has been created a raster cost surface (Fig. 3). A model of the terrain that expresses the difficulty of crossing, useful for spatial analysis of travel (Llobera 2000). The model is the sum of various factors like altimetry, slope, presence of streams, which hinders the crossing, and roads which instead facilitates it (De Silva, Pizziolo 2001; Citter, Arnoldus-Huyzendveld 2011). The visibility analysis allows to calculate the horizon visible by the human eye, taking into consideration the position of the observer, its height and the morphology of the landscape. This approach offers the possibility of simulating and reconstructing part of the complex relationship between the settlement systems and the morphology and landscape characteristics (Wheatley 1995). To calculate the area of visibility of each settlement it is necessary to define the parameters of the hypothetical observers. The height of the observer was estimated at 1.65 m, with a field of view of 18-20 km (Wheatley, Gillings 2002; Pecere 2006).

Thus, defined the observer, it is possible to perform the function of calculating visibility, which compares the characteristics of the observation point with the height of the surrounding areas, identifying on the basis of the dimensions what is visible. Intervisibility analyses have also been carried out between the various sites, to determine whether two observers were mutually visible and therefore in direct communication. On this basis, it was performed both a path distance analysis, recalibrated to represent the route taken in about 8 hours of a soldier's march, and the visibility analysis to determine what was visible from the various settlements, assuming an observer on a tower of approx. 5 m. The application of spatial analysis makes it possible to reproduce predictive models, assuming the presence of archaeological contexts through the study of known data, and to investigate the ancient landscape. Specifically, during this investigation, it was decided to apply visibility and distance analyses. Firstly, it was possible to demonstrate how the Roman forts located near the *limes* in *Germania Inferior* responded to specific requirements: 1) their position allowed an extensive visual control of the surrounding area, especially the main roads; 2) the distribution of the forts also seems to have been determined by the capacity and timing of movement.

As we have said, visibility analyses allow to determine the horizon visible to the human eye (Wheatley 1995). Their use in research has long been established, especially in relation to studies of cognitive archaeology. The visibility of a place is, in fact, one of the tools for creating a group's memory (Bradley 2002) and a powerful communication tool (Semeraro 2009).

In relation to this study, it is also important to underline how Polybius already mentioned the use of light signals in times of war, testifying to the importance and diffusion of these forms of distance communication (Pol., 10, 45-48).

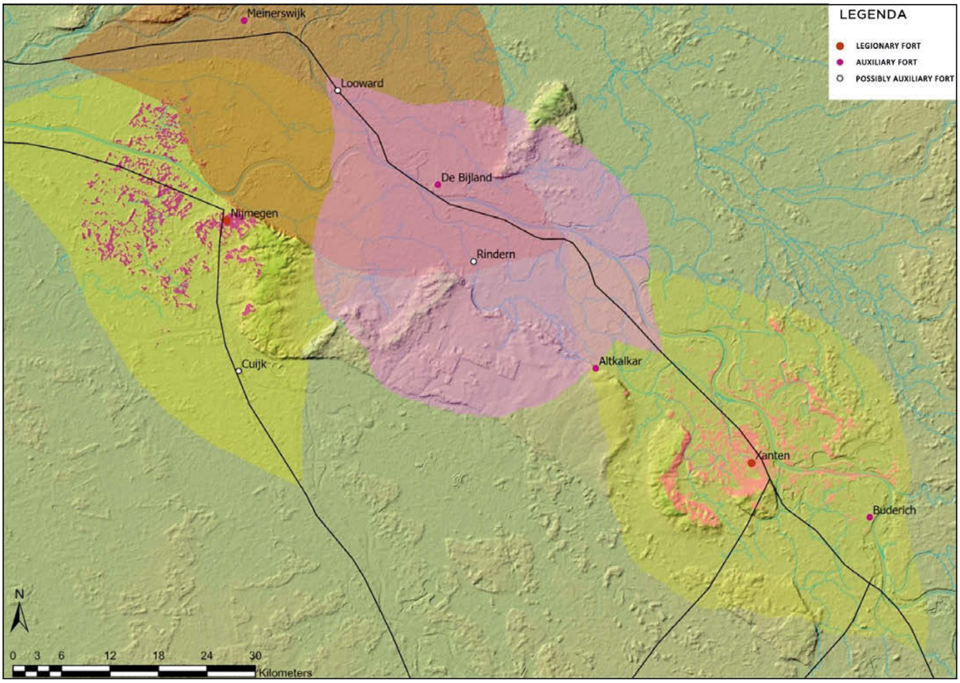

Fig. 4 – The Path Distance Analysis of the area between Nijmegen and Xanten.

For the analyses performed, an observer height of 1.65 m was estimated, to which 5 m were added to assume the presence of towers, while the visibility range was calculated to be 18-20 km (Wheatley, Gillings 2002; Pecere 2006). The ground elevation, on the other hand, is obtained from a DEM, i.e. a raster file in which each pixel represents the altimetric value of the ground with respect to sea level. To process the DEM of the area under examination, we chose to use the satellite images made available by the European Space Agency-ESA (https://www.esa.int/), processing the model using the specific software SNAP (https://step.esa.int/main/download/snap-download/). The SAR signal is determined by two main characteristics: "amplitude", which indicates the strength of the radar signal response, and "phase", a single wavelength due to the distance between the satellite and its target on the earth's surface, thanks to which a DEM can be derived (Bhattacharya, Arora, Sharma 2012).

The InSAR (Interferometric Synthetic Aperture Radar) technique allows to extrapolate a digital terrain model from these data. For the processing, the methodology recommended by the agency itself was followed (Braun

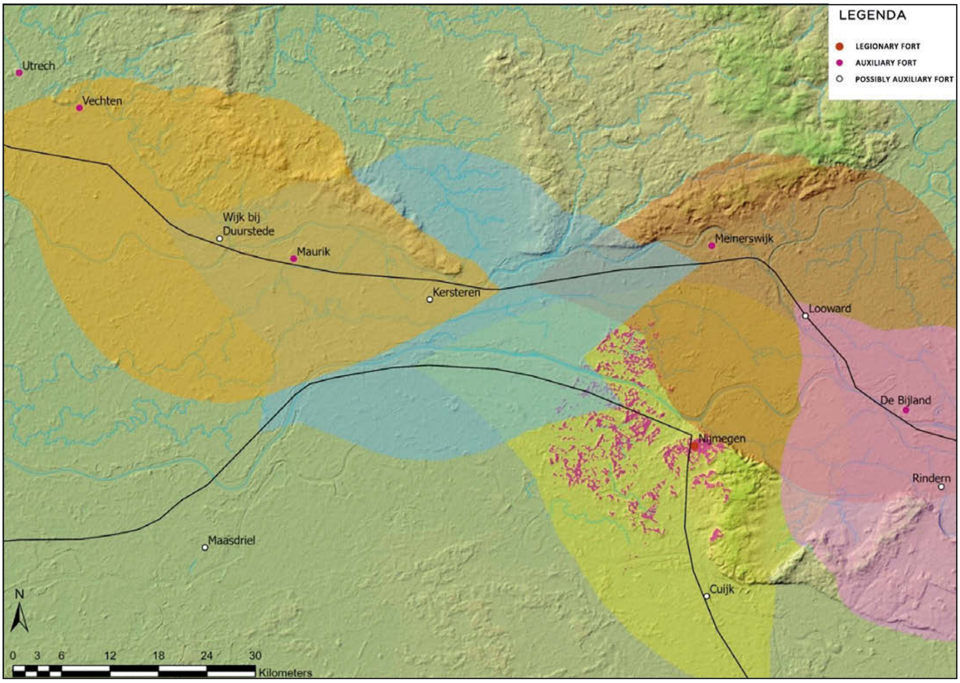

Fig. 5 – The Path Distance Analysis of the area between Wijk and Kersteren.

2021). On this basis, the position of each observer in the surrounding terrain is compared within a radius of approx. 20 km, highlighting the areas visible from it. In addition, intervisibility analysis has been carried out, in which it is shown whether two observers are mutually visible, thus reconstructing a communication network between the centers. The realization of the distance analyses, on the other hand, required the elaboration of a cost raster, in which each pixel corresponded to the crossing difficulty. For these reasons, different parameters were examined, to which different percentage weights were attributed. Specifically, data relating to the nature of the terrain, such as altimetry, slope or presence of watercourses, and data relating to human impact, such as the presence of roads or built elements, were processed (Tab. 1).

VARIABLES	OVERALL WEIGHT (in percent)
Slope	40
Altimetry	20
Environmental factors	20
Anthropic factors	20

Tab. 1

The factors under consideration were calculated on a scale of 1 to 8, with 1 being the lowest difficulty value. Slope was one of the factors with the greatest percentage weight, since up to 6° it is possible to take optimal routes in both directions (Llobera 2000), and up to 10° water stagnation is minimal (De Silva, Pizziolo 2001; Citter, Arnoldus-Huyzendveld 2011); a slope greater than 14°, on the other hand, significantly increases the cost of travel and does not offer good potential for human settlement (Van Luesen 1993; Minetti 1995).

The model obtained expresses, on a scale of 1 to 8, the difficulty of crossing the terrain. The distance analyses performed can be divided into two groups: the hypothetical reconstruction of the shortest path between two points and the calculation of the energy consumption or time spent by an individual to move through space (Forte 2002, Wheatley, Gillings 2002).

In archaeological research, the latter are often employed as catchment analysis (Vita Finzi, Higgs 1970), based on the methodological assumption that a community minimizes effort for its main subsistence activities. Based on anthropological and ethnographic studies, some general parameters have been provided for nomadic or sedentary groups (Chisholm 1962). In this analysis they were used to calculate the area accessible from the various centers in ca. 8 hours of walk, average walking time of a legionnaire. For example, in the area of Xanten-Nijmegen, where we see the area visible and reachable by both forts. Buderich is both visible and reachable from Xanten, while Altkalkar is not visible (Fig. 4). So, if there was a visual communication system between the different forts, it is possible to hypothesize an intermediate camp not yet known.

In this case the two hypothetical centers of Looward and Ridern would represent perfect points of conjunction of the network of Romans forts. Also, in the area between Wijk and Kersteren (Fig. 5) the distance analysis seems to confirm the excellent position of the sites to accommodate a fort. In both cases the visibility analysis and path distance prove to be a useful tool to verify the hypotheses about the location of forts, belonging to the *limes* system, which, at present day, is only assumed. A research methodology that, if applied to the entire limited system, could provide interesting information for the future research about a cultural heritage recognized in 2021 in the Unesco World Heritage List.

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ABSTRACT

The Roman Limes represents the border line of the Roman Empire at its greatest extent in the 2nd century AD. It stretched over 5,000 km from the Atlantic coast of northern Britain, through Europe to the Black Sea, and from there to the Red Sea and across North Africa to the Atlantic coast. The remains of the Limes today consist of vestiges of built walls, ditches, forts, fortresses, watchtowers and civilian settlements. The limes system is focused both on the presence of natural physical barriers, such as the Rhine and Danube rivers in Europe and the Sahara Desert in North Africa, either on the presence of fortified sections such as the Hadrian's wall or the Germanic-Rhaetian limes. The latter two are the best preserved and studied section.

However, the limes sections in which natural barriers were exploited to mark the boundary of the area under Roman control are less well known. Over the past two decades considerable progress has been made in the knowledge of limes areas such as the Rhine sector. In this area the river was exploited as a natural barrier, and control of the area was based on the presence of two larger legionary camps around which, along the southern course of the Rhine, small auxiliary camps gravitated. Only some of these encampments have been investigated and their position confirmed by archaeological excavations. The position of the other encampments is still speculated and awaiting verification. In this contribution, in order to verify the position of these hypothetical forts, through GIS systems a visibility analysis and path distance analysis were carried out based on the location of certain sites and taking into account the ancient road routes and the geomorphology of the soil.