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## **Potential paths and historical road network between Italy and Egypt: from predictive to postdictive approach.**

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### **Abstract**

In this paper we aim to present the preliminary result of two cases studies focused on the predictive and postdictive approach to historical routes. We developed and tested the procedure in two different geographical areas: northern Lazio and the valley of the Kings in Egypt. Our work is based on three steps. The first one is predictive. We evaluated the movement in a given geographical context and period. In this phase we produced several potential paths between two known settlements, by changing the weight of the environmental and cultural factors. In the second step we verified the prediction directly on the field. The last step is postdictive. We change the question and we ask why did they use exactly those paths. We modelled several cumulative cost surfaces to produce a simulation that overlaps as much as possible the historical paths. Thus, we can understand and evaluate which were the key factors that constrained the route network.

Keywords: Predictive and postdictive method, Least cost path, Mobility in archaeology, Historical roads.

### **1. Introduction**

Recently, predictive models in archaeology have been critically debated (Verhagen, Whitley 2011, Casarotto, Kamermans 2013; Verhagen 2013). The increasing awareness is that we are not able to reconstruct precisely the palaeoenvironment in a given period, but especially the difficulty to process the cultural aspects, may lead to avoid GIS tools. But we think we are not obliged to choose between enthusiastic acceptance and paralysing scepticism. We can use these tools as simple tools, among a set of many. In addition, they constitute a prediction, though they do not deal with site location. In fact, the forecast of potential paths in a given geographical space and historic period is itself a prediction. The approach we propose is based on the idea to join predictivity with postdictivity. It gives us a flexible tool [669] and an alternative between inductive - deductive method (for a first consideration see Citter, Arnoldus-Huyzendveld 2014, see also Arnoldus-Huyzendveld, Citter, Pizziolo in this volume). Our procedure is based on three steps. The first is predictive. In this case the questions

are all related to a forecast. Was there a connection among the point A and B in that context and period? Was there only one possible connection? The latter raises a further question. Was it the result of a single action or a long lasting process? In the second step we verified the forecast directly on the field. Fieldwork is a crucial step to get the necessary information to establish the reliability of the processed simulations. The last step is postdictive. In this phase we reverse the process and we also change the questions. Why did they move exactly along those paths? Which were the factors that attracted the movement in that area? Were they environmental or cultural factors? The two theoretical phases take into account a circular interaction between deductive and inductive approaches, in a potentially endless cycle (fig.1). Of course, although our procedure uses numbers (which are not the answer, but only a helpful tool), we can think that the outputs are driven by the archaeologist. He works on the algorithm or, as in our case, on the cost surface, he changes values and variables until he gets the result he likes more. This criticism is correct if the values and [670] the parameters are not explicit. Moreo-

ver, if we limit our work only on the predictive phase (for more details see Citter, Patacchini in press). The first test developed with this approach produced encouraging results (Patacchini, Moretti in press; Citter, Patacchini in press). In these case studies we went a step further, because we evaluated the slope frequency along the historical routes we are dealing with. This estimation allows us to improve and calibrate the slopes' weight by creating more accurate raster maps (fig. 2). A brief remark is essential about the least cost path algorithm too. All the GIS packages, no matter the operator's skills (Gietl et alii 2008; Herzog, Posluschny 2011), force the computer to choose the cells that have a lower cost within a neighbourhood of the given cell, despite how much lower it is. This detail is crucial when we work on a postdictive level, because humans, unlike the algorithm, do not feel small value changes, so they prefer to walk as much as possible along a straight line. To avoid this trouble, we chose to evaluate the overlay between the known historical route and the predicted one within a 100 m buffer. We also tried a slightly larger buffer (125 m) to incorporate errors generated by the least cost path algorithm.

## 2. Northern Lazio

The starting point for both case studies (fig.3) was the reconstruction of the historical route network that joined the two settlements we chose for the evaluation. In northern Lazio we focused on the area between Veii and Ferento, where we reconstructed the main historical paths using traditional sources: itineraries (Tabula Peutingeriana and *Itinerarium provinciarum*), aerial photographs, historical maps and archaeological data (fig.4). This step is relevant during the postdictive phase, because it allows us to compare the expected route with the historical one. In addition, it permits to calibrate more accurately the weight of each parameter. All the potential paths generated by this procedure are based on environmental and cultural factors (fig. 5 and 6). They can be considered as attractors (like springs or central places), detractors (like lagoons or low draining soils), facilitators (like gentle slopes or water crossings), and obstacle (like rivers, streams or ravines). The first two act at the distance, the latter directly on the ground (Citter, Arnoldus-Huyzendveld, Maccani 2013). The resulting cumulative cost surface is, thus, a raster map, whose cells express the degree of advantage or disadvantage to moving in that context. Using some of the parameters shown in figures 5 and 6 we generated several balanced potential paths between Veii and Ferento. In this phase we weighted the slope (to create this raster

we used a 10 m. resolution DEM, see Tarquini and others 2007 and 2012) as environmental factor and as parameter driven by human choice. For instance: obviously a gentle slope is easier to traverse than a steep slope, but sometimes the natural choice can be overwhelmed by a cultural consideration such as the need to have shorter route. Everything was related to needs of travellers. So, we calibrated some of them to facilitate the movement on a gentle slope (0-5%), and rest to favour the movement on a rather higher slope, though still accessible (5-10%). As one can see in figure 7, the potential paths define four different strips that have the same direction of the historical routes. This is a very important result, because it means that the predictive step already got the main factors and their reciprocal weight. The field survey can be considered the heart of this procedure. First, we focused on those areas where the evaluated path runs far from the historical one. The aim was to look for possible traces of ancient roads nearby. In the surveyed areas we got no positive feedback. Though caution is always welcome, we thought that this is not a bias, but a real lack of datum. After, we verified every critical point raised by the evaluation process. In this case we had have the chance to examine the real morphology of the landscape (slope, hydrography, soil type, etc.), but, above all, to evaluate the historical routes in relationship to the environment, in particular, when they run through the geographical constrained (fig.8). After the fieldwork we worked on the postdictive side of the procedure, by integrating all the available data, including survey. Thus, we calibrated the former forecast, asking which were the factors that had more influence on the four main historic roads between Veii and Ferento. To answer these question we modelled several cumulative cost surfaces to produce a simulation that overlaps as much as possible the historical paths (fig.9). As we can see in the chart (fig.10), the overlap of 50% in the first buffer is reached only by the path 4. On the contrary, almost all the potential paths reach this threshold if we extend to the second buffer. The low overlay within the 100 m buffer is caused by the algorithm, as we just said. The slope frequency calculation was almost useless. It only increased a little the overlay between the two paths, confirming it is one of the key factors involved in this case study. To conclude, we would like to make a short reflection on path 4, that seems one of the most interesting. We can see in the figure 9 that this simulation connects Veii to Ferento through a stretch of the Roman Cimina road, which was considered in the Middle Ages a variant of the Francigena (Corsi, De Minicis, 2012: p. 75-81). The Bronze age settlements uploaded into the for-

mula as attractors allowed us to achieve a high level overlay. So, according to this evaluation, this route seems to be the most ancient and stratified route of the area, also because it is still used. However, it's just an hypothesis, any proof may come out only thanks to archaeological excavations of parts of the road.

Andrea Patacchini

### 3. The Valley of the Kings (Egypt)

From a morphological point of view, the Egyptian case shows remarkable differences compared to the Latial one. By the way, even in Egypt we have focused on the study of an historical path between two known points. The path we have chosen still exists today and in ancient times Egyptian workmen between 1450 and 1100 BC used it daily. They started from Deir el Medina to go to the Valley of the Kings, where they took part in the construction of the royal tombs. The goal of our analysis was to evaluate the factors that may have influenced its shape, to understand, which were the reasons that led the workers to prefer that path. We need a brief introduction. In Egypt, it is not always possible to do researches using the accurate database available in Italy or in Europe. The datasets are always very scanty; satellite images, aerial photographs, detailed geological, soils, and topographic maps are rare too. From this point of view, there are still too few archaeological missions that use the most updated technological tools, mainly due to economic reasons. The few exceptions are limited to the area of [671] the Delta, and (luckily) to the Theban necropolis, thanks to the Theban Mapping Project ([www.thebanmappingproject.com](http://www.thebanmappingproject.com)). In addition, we noted that the availability of updated and freely downloadable data is much lower than that in any European country. This led us to improve the potential of our dataset: such as the DEM, downloaded from ASTER GDEM (<http://gdem.ersdac.jspacesystems.or.jp/>), with a cell size of 27 metres, that has been refined through interpolation with contour lines (with a pace of 10 m) increasing the resolution up to 10 metres. Obviously, this “new” DEM has not actually a cell size of 10, because we did not upload further elevations, so we can consider only a sort of approximation to 10 metres. However, this allows us to draw a slightly more detailed slopes map (fig.11). Therefore, to study the potential paths that during the so-called New Kingdom linked Deir el Medina to the Valley of the Kings, it is necessary to start from literature, but also from a survey. Whereas the available material on the subject [675] is virtually non-existent, the best way to get an

idea of the area is to go in situ and walk the trails on which still Egyptians and adventurous tourists can travel. Moreover, the field work allows us to understand not only the morphology, but also which could be the factors that most influenced ancient Egyptians, both, to build the settlement and to connect it (fig.12). We must remind that the village was made with the sole purpose to hosting the community of artisans in charge of the construction of the royal tombs. The examined area, the Theban hills on the west bank of the Nile, then and now has no vegetation, there are no sources of fresh water and the temperature can go up to 45° C, making the desert and stony terrain unsuitable even for walking after 11 AM. Therefore, the knowledge of the landscape combined with the survey is crucial to evaluate the simulations of the predictive [676] phase. As we can see in figure 14, the predictive paths generated using slope, exposure and potential hydrography (fig.13) are too long and do not coincide with the “philosophy” of the historical route, which passes over the elevations to shorten the travel time. Please note that we have consciously overlooked the geological map we got, because geology and soil composition, although interesting, did not seem to have any influence on the choice of a particular route. We can say the same for the temples, which we did not consider as attractors, because in this case the aim of the artisans was to reach the working site as quickly as possible. The only potential paths that run close to the town are those shown in letter C: in this case we decided to consider the slopes [678] as if they were a cultural factor, assuming that the Egyptian artisans have consciously chosen, a shortest, but harder route. The result turned out to be interesting for another reason, precisely because the path 1 reflects a current road visible from satellite and mapped on IGN as well. Obviously, this has no link with any ancient route between the two points, but it tells us that the weighing choices to process the paths are in some way related to the reality. However, the direct knowledge of the area and the survey lead directly to the next step, namely postdictive. At this point, we have digitized the aforementioned historical path, which run through the village du Col, a small settlement intermediate sometimes used by the workers to rest. The data we have are almost certain, since this is the only way a craftsman could walk through in the morning and in the evening (perhaps with tools and burden), willing to make his trip quicker and easier. In fact, this way seems the only possible, because the other options to cross the heights in safety, avoiding steep slopes are rare. Once gathered all available information (ASTER GDEM, a French IGN in scale 1:

10,000, a topographical map and a hydrographic one of the Valley of the Kings produced by the Theban Mapping Project and found at the TMP Library), we tested, whether the slopes really influenced the [680] performance of the historical path, as indeed it was already clear when we developed the predictive path 3, letter C, and already shown in figure 14. The calculation of the frequency of slopes spread over the historic route gave us an important confirmation, indicating a preference for those slopes between 10 and 50%. These data, combined with those collected on the field, allowed us to reclassify the slope raster assigning a lower weight (therefore more advantageous in terms

of cost) to that particular range of values just mentioned, thus generating a postdictive path that reaches 100% overlap with the historical one, in a buffer of 100 m from the latter (fig.14, letter D). In conclusion, we can say that the historical path has been strongly influenced by slope, which in this part of Egypt seems to be predominant when we think in terms of ancient roads. Moreover, the traces of ancient paths, were often related to the morphology of the territory and to the friction on the traveller. Of course, this was not the only parameter considered when planning a path (hydrography, fords, springs, etc. were not undervalued at all), but it was certainly one of the most important.

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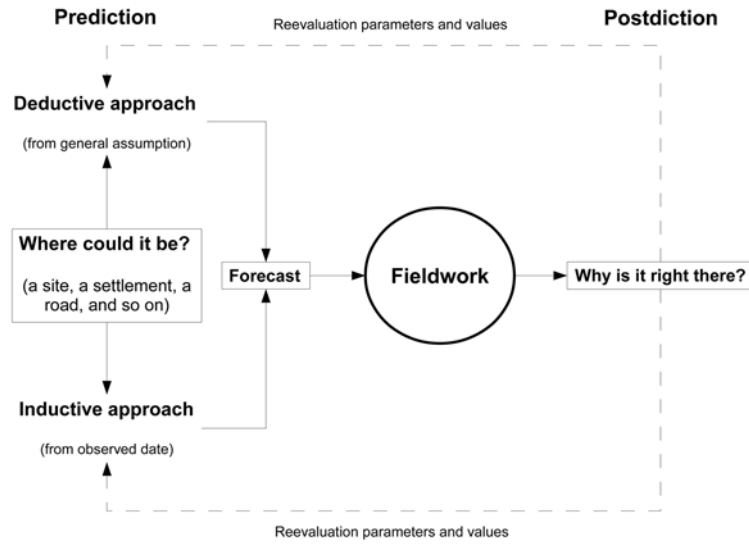


Figure 1 The predictive and postdictive work flow [669].

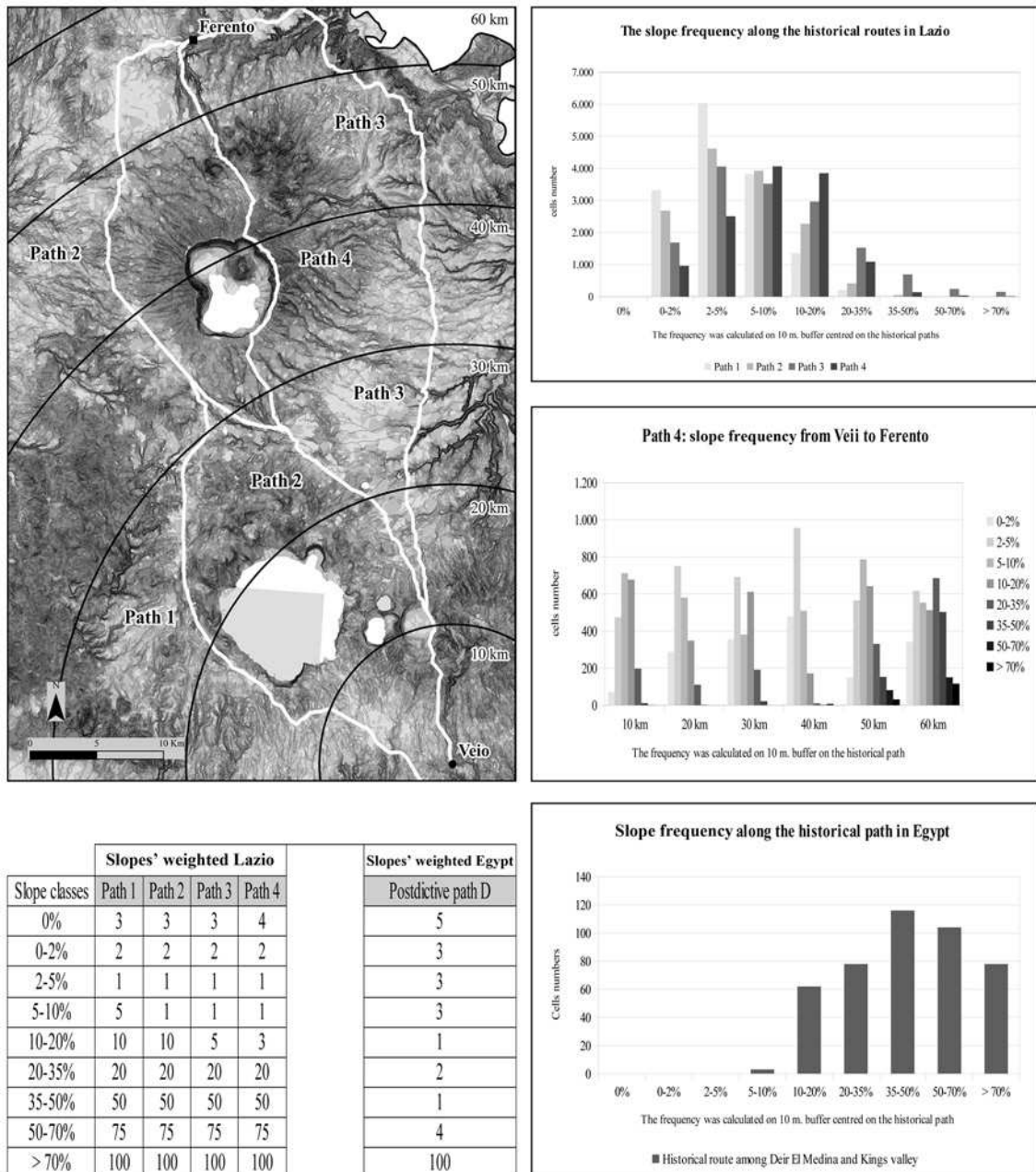


Figure 2 The slope frequency and the slopes' weights after the frequency calculation [670].

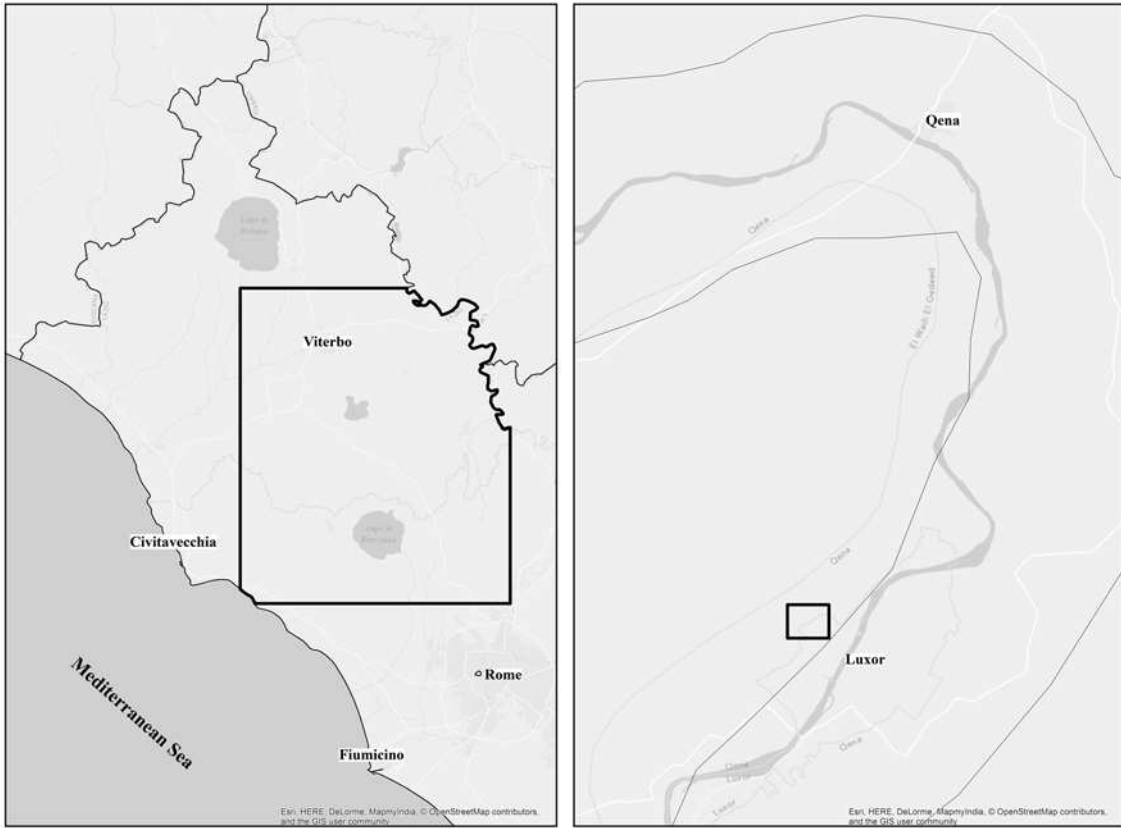


Figure 3 Location of our studies areas: northern Lazio on the left and the Valley of the Kings in Egypt on the right [672].

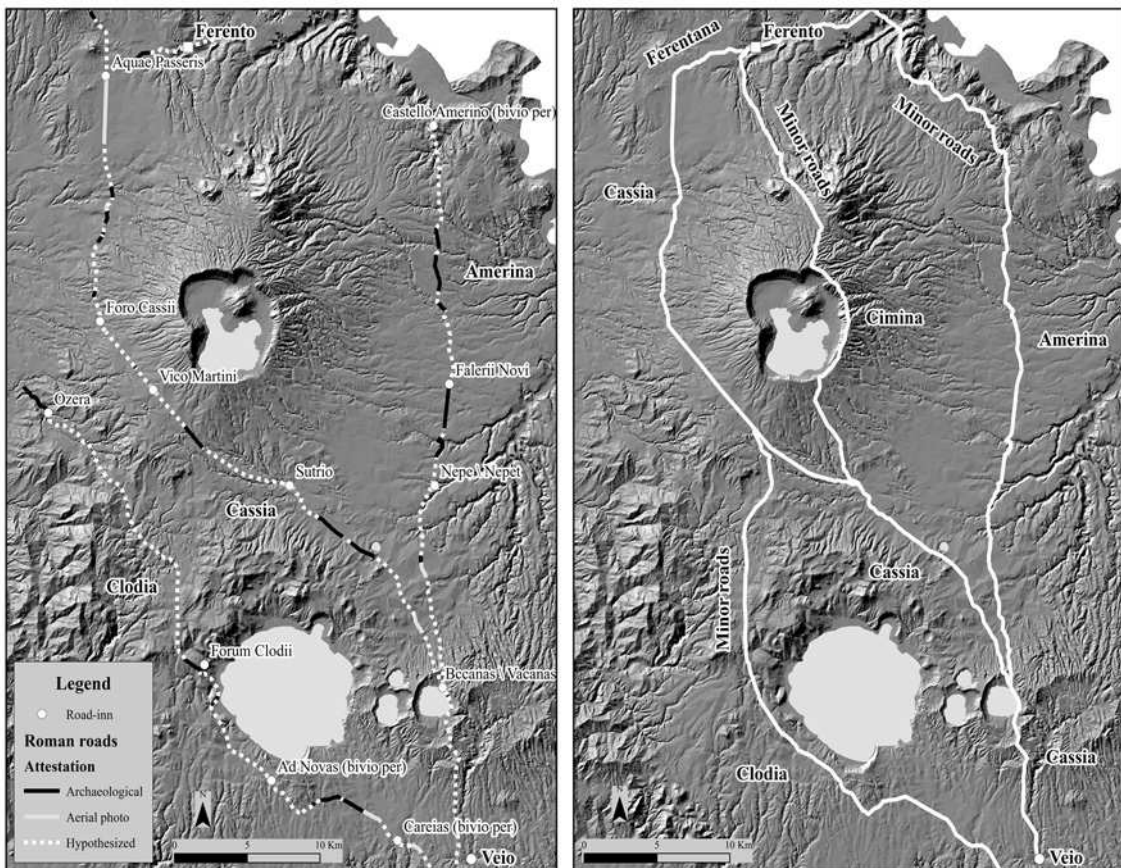


Figure 4 On the left the main roman roads: Clodia, Cassia and Amerina (white dots = road-inn, black line = road stretch reconstructed by archaeological source, light gray = road stretch reconstructed by aerial photo and white dashed line = road stretch hypothesized). On the opposite side the historical road network that connected Veii to Ferento [672].

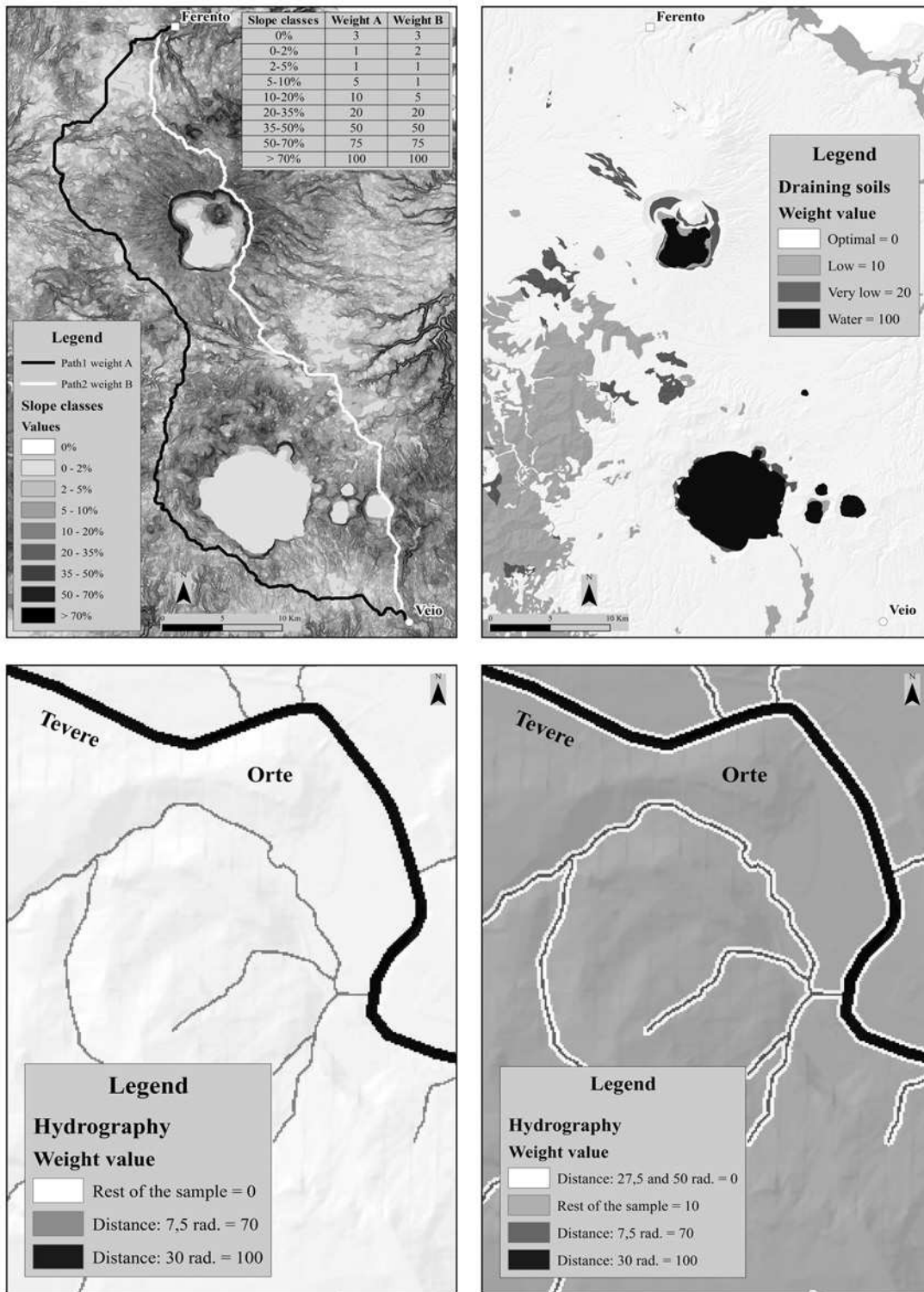


Figure 5 The four images show some parameters and weighing take into account during the elaborations. The slope on the top right, the soils drainage on top left, the hydrography, like obstacle, on bottom right and the hydrography, like attractor, on the opposite side [673].



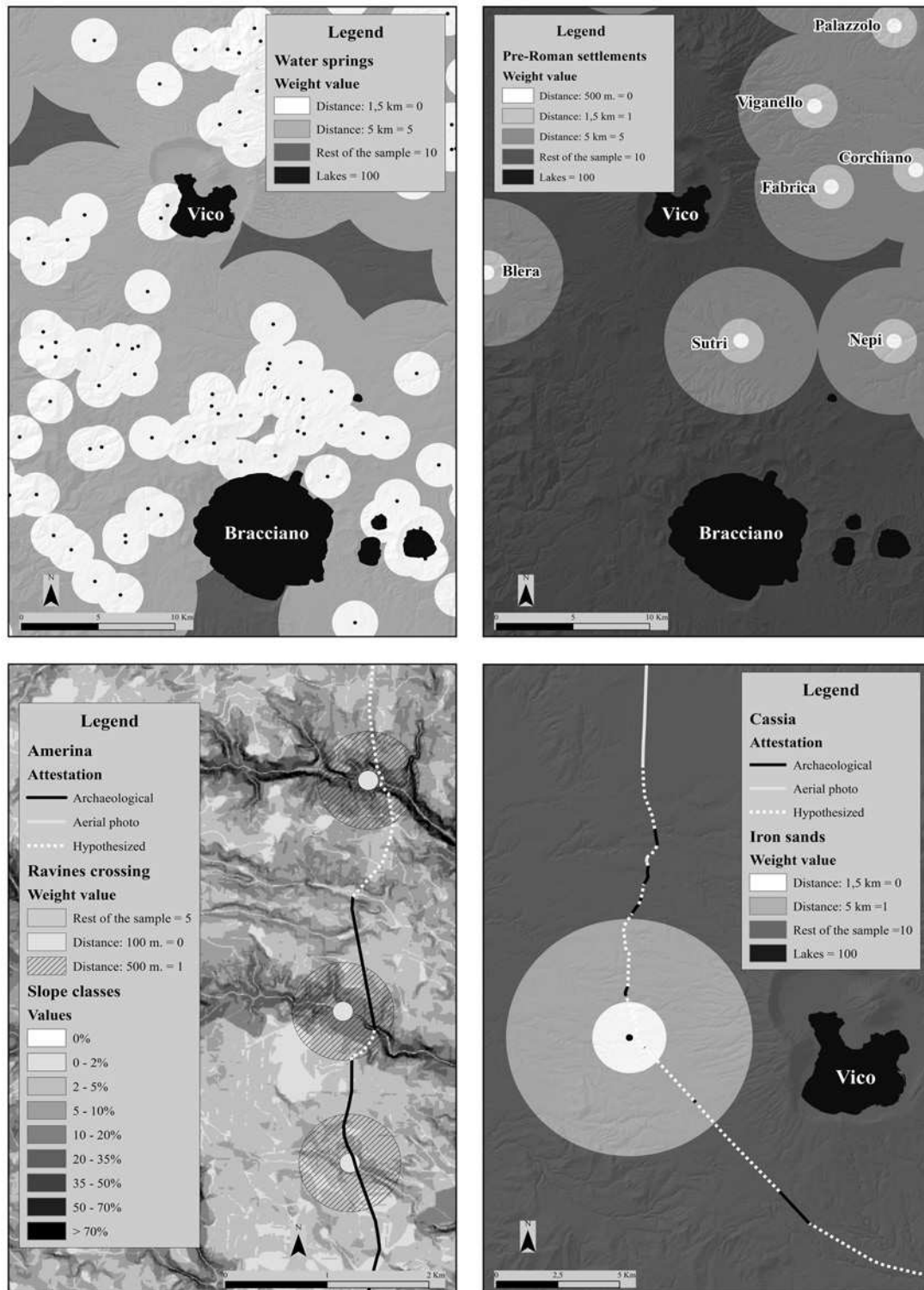
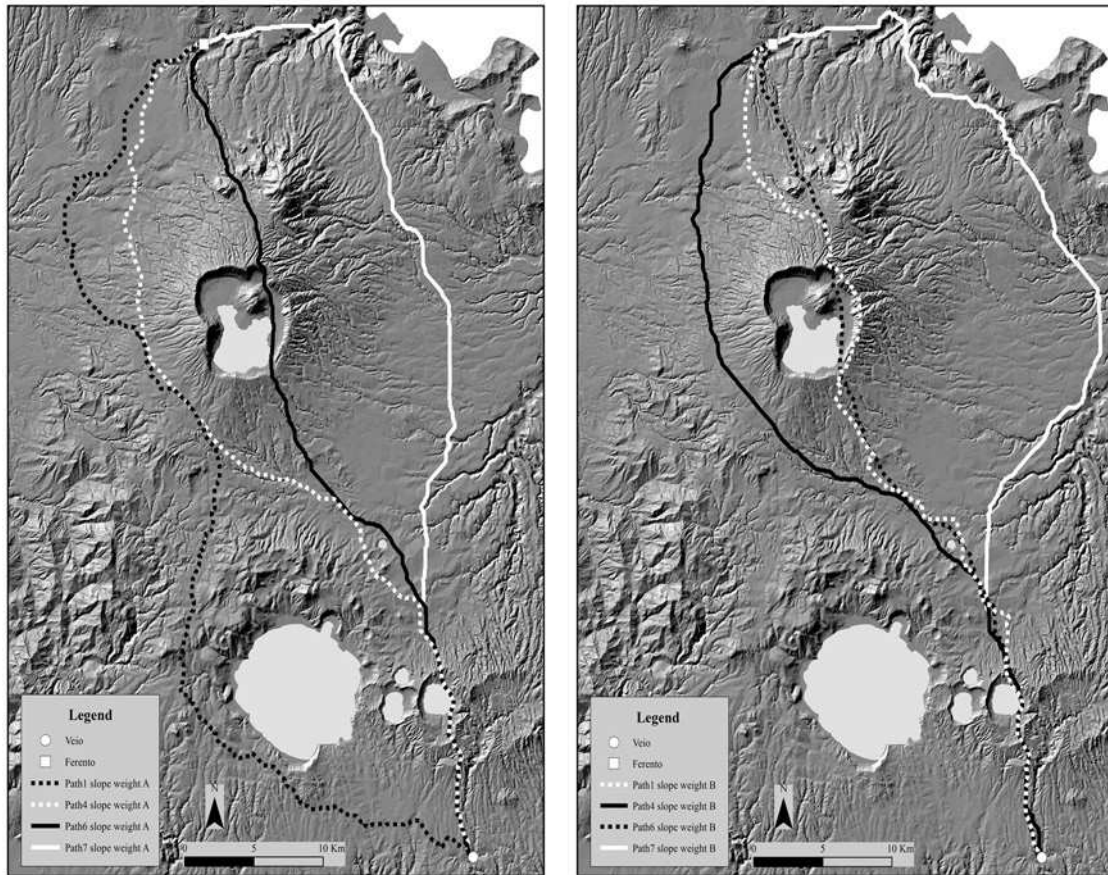


Figure 6 Other four examples of parameters and weighing. The water springs (like attractors) on the top right, the Pre-Roman settlements (like attractors) on the top left, the ravines crossing (like facilitators) on bottom left and the iron sands (like attractor) on the opposite side [674].



Paths	Formulas
1	Slope 50% - Hydrography 50%
2	Slope 50% - Hydrography (as attractors) 50%
3	Slope 35% - Hydrography 35% - Water springs 30%
4	Slope 25% - Hydrography 25% - Water springs 25% - Hot springs 25%
5	Slope 20% - Hydrography 20% - Water springs 20% - Hot springs 20% - Draining soils 20%
6	Slope 20% - Hydrography 20% - Water springs 20% - Hot springs 20% - Final Bronze age settlements 20%
7	Slope 25% - Hydrography 25% - Water springs 25% - Pre-Roman settlements 25%
8	Slope 25% - Hydrography 25% - Water springs 25% - Pre-Roman and roman settlements 25%
9	Slope 25% - Hydrography 25% - Water springs 25% - Main roman settlements 25%

Figure 7 In both images we can see some predictive paths evaluated among Veii and Ferento. On the left the potential paths take into account such as facilitator a slope range from 0 to 5% (weight A). Instead on the right, we can observe the same paths, but in this case the simulations take into account like a facilitator a slope between 5 and 10% (weight B). In the table we have highlighted the formulas used for generated the potential paths displayed on the two pictures above [675].

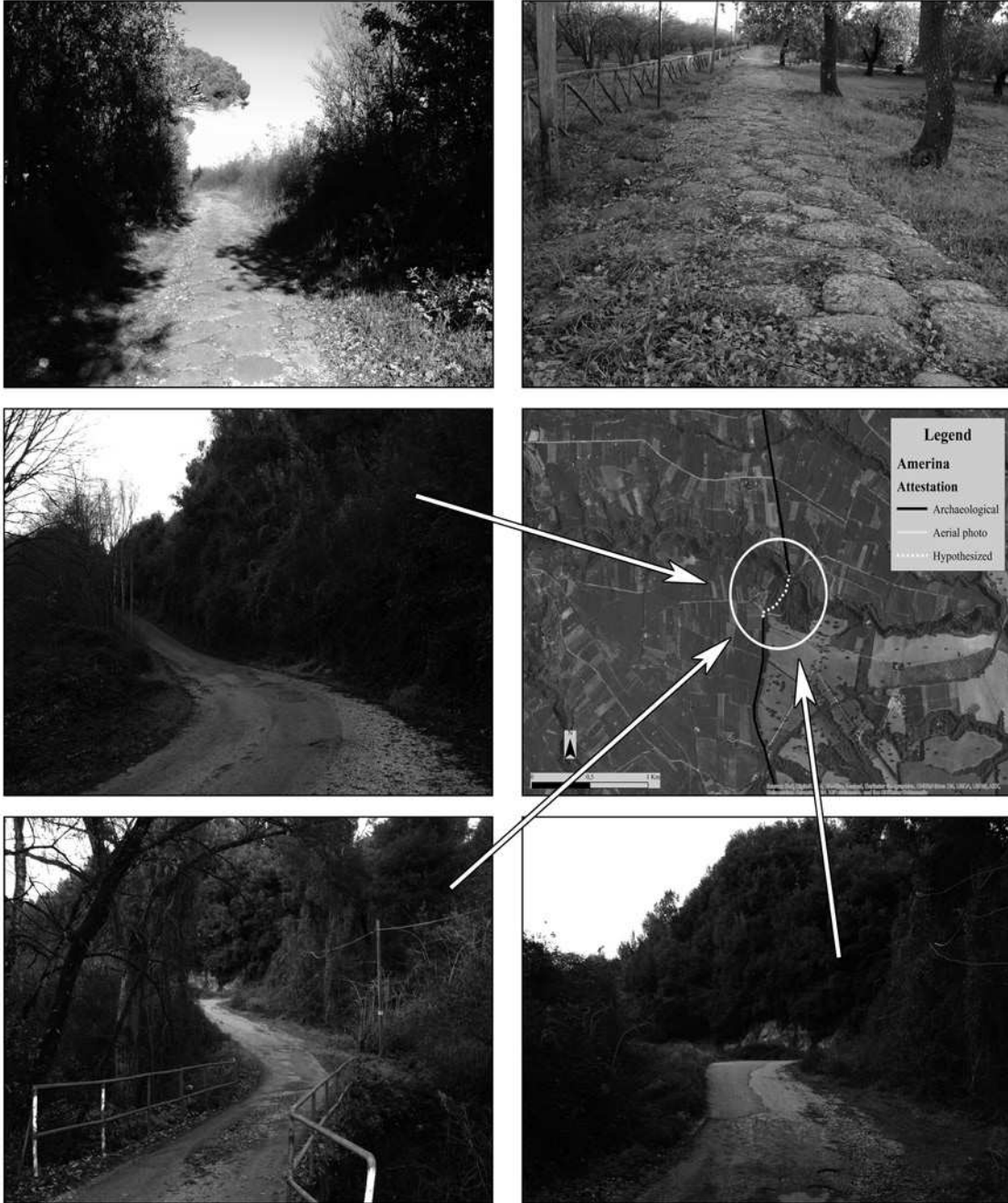


Figure 8 Some photos taken during the field survey in Lazio. On the top the morphology along the Cassia and Amerina paths. In the four pictures below we can see a kind of ravine crossing on the Amerina path. We point out how the modern road still pass through this area [676].

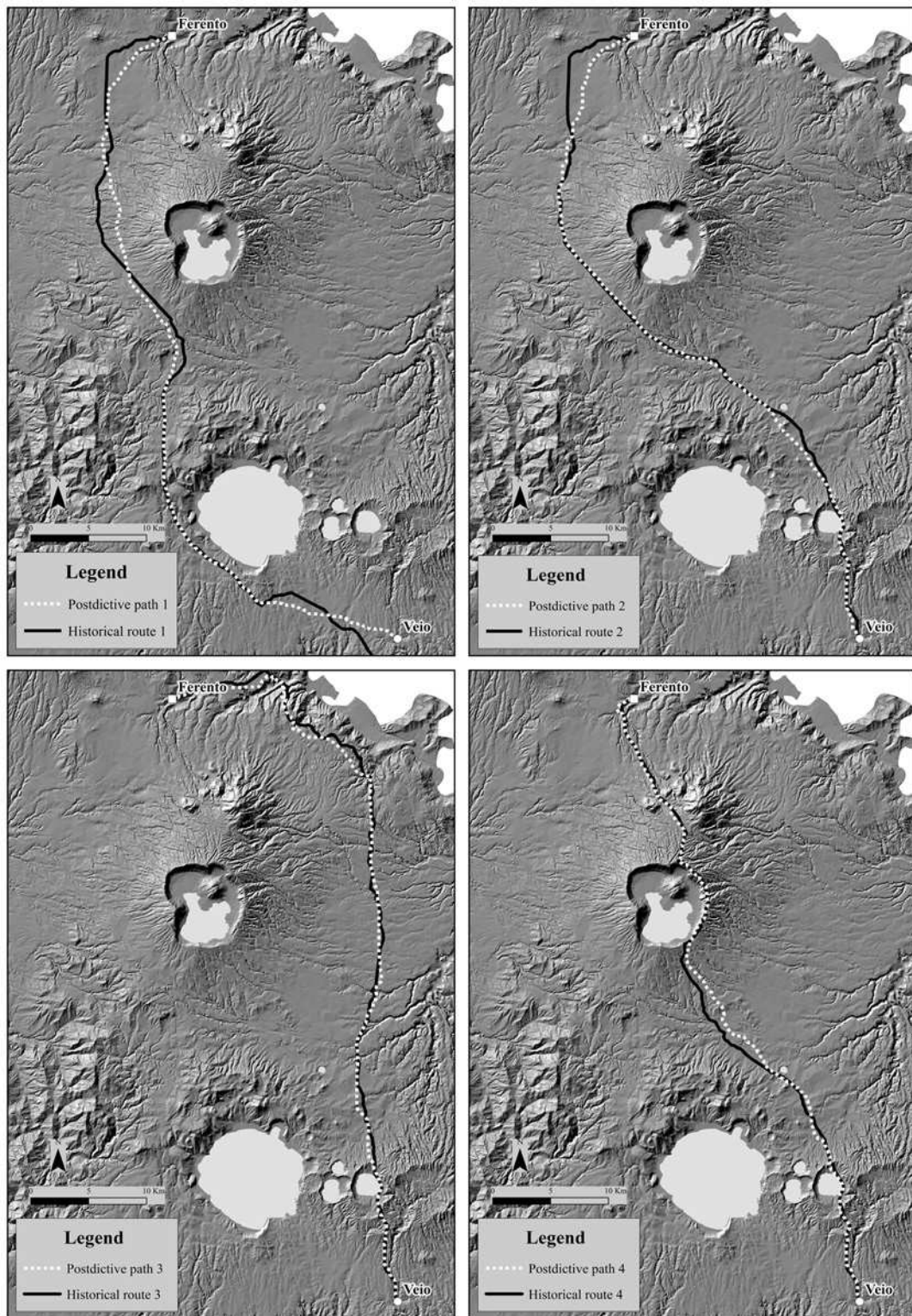


Figure 9 The paths that connected Veii to Ferento in relationship to our four postdictive simulations. Follow we explicit the formulas used in each one evaluation: Path 1: slopes' calibrated 35%, hydrography 35%, selected mines 20%, selected hot springs 10%. Path 2: slopes' calibrated 25%, hydrography 15%, water springs 20%, hot springs 20%, iron sands 20%. Path 3: slopes' calibrated 20%, hydrography 20%, water springs 20%, ravine crossing 10%, Pre-Roman settlements 30%. Path 4: slopes' calibrated 35%, hydrography 30%, water springs 30%, final bronze age settlements 5%. The word “selected” means a selection of the available data to attract the path in that zone. Same things for “calibrated”, which means the weight giving on the slope frequency calculated each on the historical routes [677].

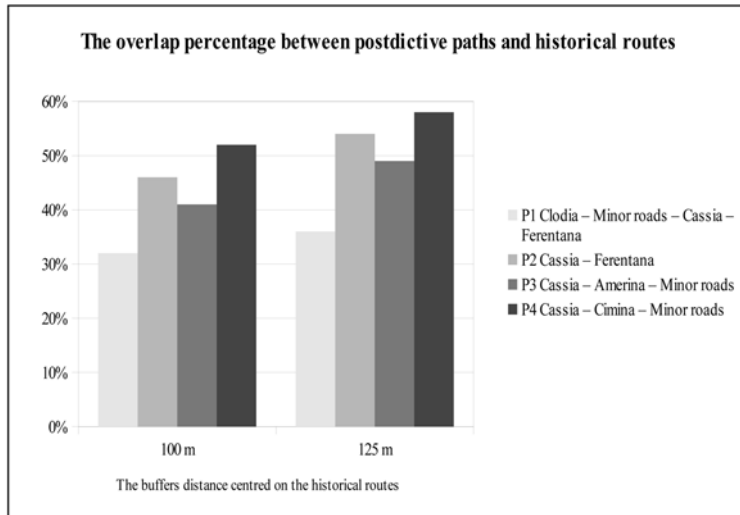


Figure 10 The chart show the overlap percentage among the postdictive paths and historical routes from Veii to Ferento [678].

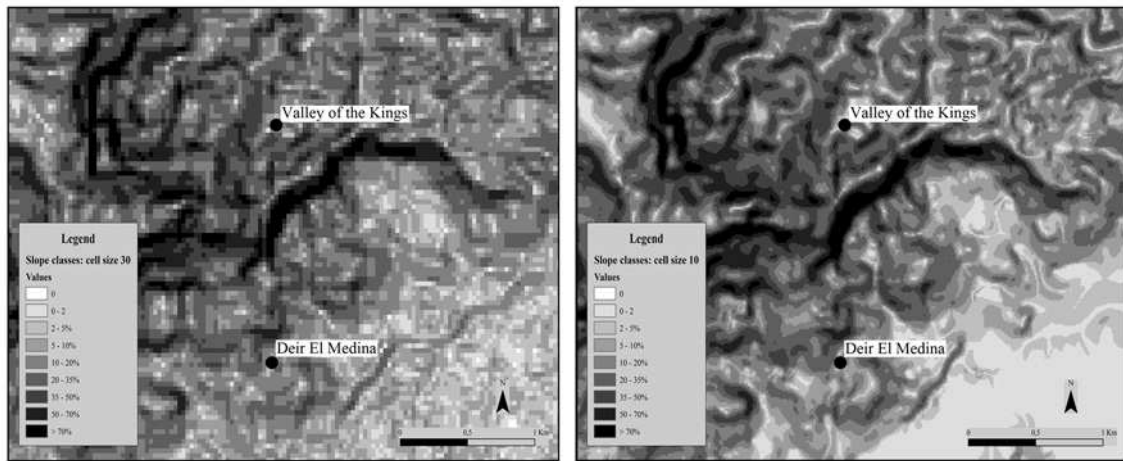


Figure 11 The refined DEM, we point out the difference between the old slope raster (left) and the new one (right) [678].



Figure 12 The historical path survey. In both images we can see the many slope changes along the road [679].

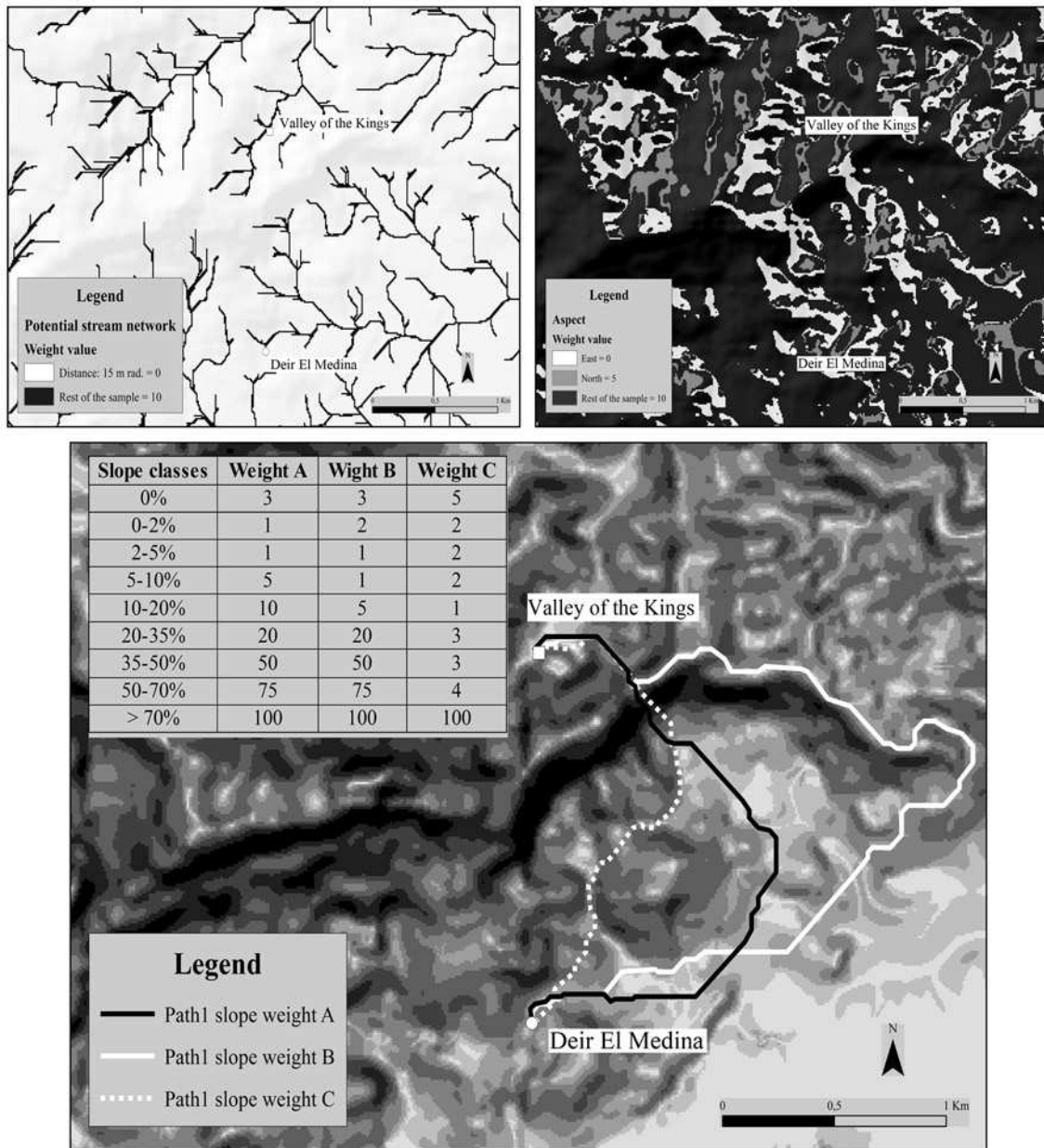


Figure 13 The all parameters and weighing values used in Egypt. The potential stream network on the top left, the aspect on the top right and the slope below [680].

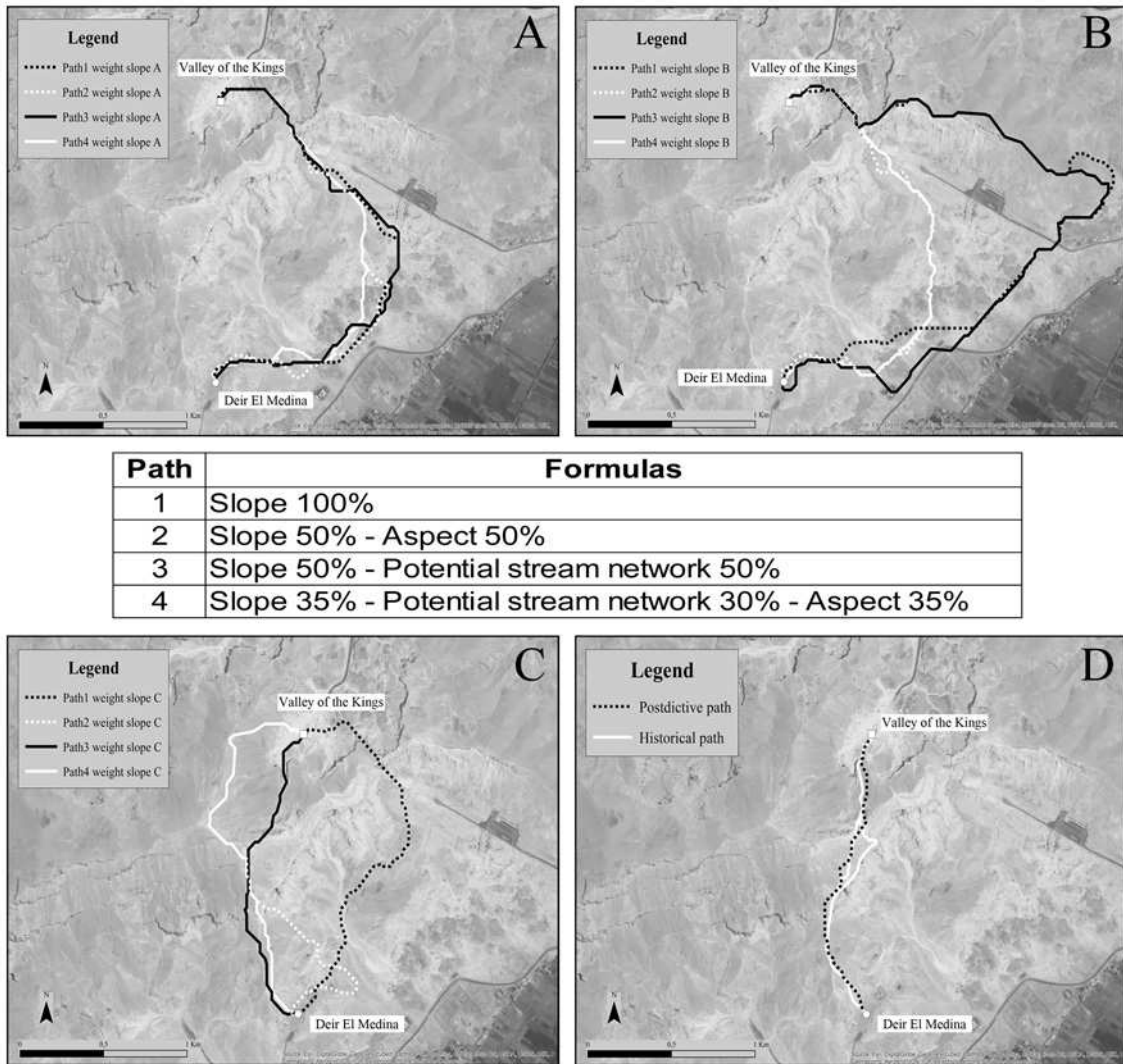


Figure 14 The predictive paths on the top and bottom left (letters: A, B and C). The postdictive path on the bottom right (letter D). For reach this overlap we worked on a slope values, giving a lesser weight on those slopes between 10 and 50% [679].