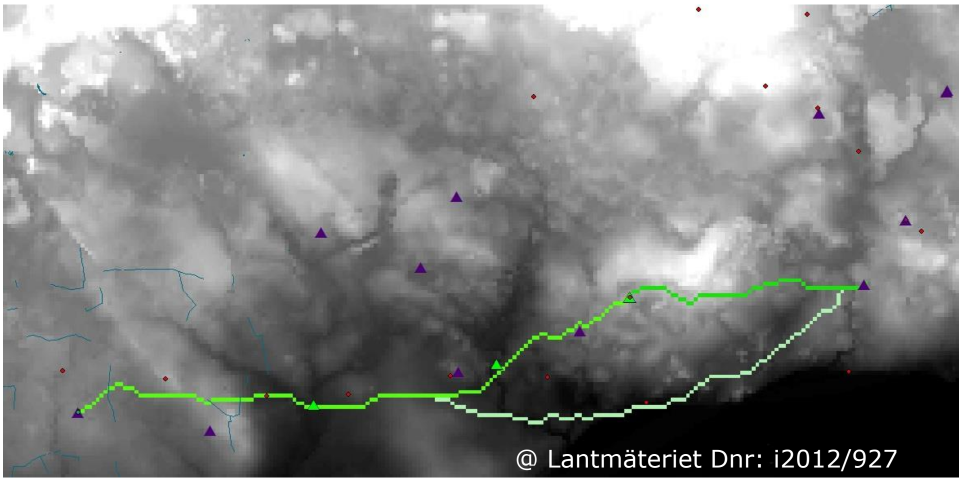
”In 100 meters turn left by the runestone”

-A least cost path and spatial statistics study, of the Scanian runestones;

in relation to Viking Age infrastructure.



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A son is better, though late he be born, And his father to death have fared;

Memory-stones seldom stand by the road, save when kinsman honors his kin.

—Hávamál 1:72

Abstract

This thesis concerns the patterns of organization visible within the context that is the Scanian runestones in relation to roads, organized clustering and energy-conservativity. As well as the digital methods increasingly used to analyze such patterns. Using FMIS databases and LIDAR-elevation data it analyses the long, spread out lines of runestones visible in the landscape through GIS spatial-statistics analysis, as well as least cost path analysis, and simultaneously evaluates the combination of the runestones and said tools, as a method for studying Viking Age infrastructure.

The statistical part of the analysis includes all of the Scanian runestones, and compares the organization grade (z-score and k-function) of the Scanian runestones to the organization grade of the Scanian milestones; the organization grade of the Gotland mile- and runestones are briefly discussed as a comparative material. The results of this analysis indicate a very high level of organized clustering within Scanian runestone context, one comparable to the level of organization we see among the Gotland Milestones.

The least cost path analysis focuses in on two smaller portions of Scania; the area in-between Källstorp and Bjäresjö (which have a large number of surviving runestones), as well as an area north of Lund, around Lödde å (where runestone material is less dense and linear, and is also subject to greater influence from surrounding features). The output of this analysis showed that most of the runestones in these regions seem to have been organized in relation to one single path of higher energy efficiency. In turn most likely indicating the presence of a larger body of Viking Age infrastructure, that may have stretched across most of Scania's south and west-coasts.

Key Words*:*

Runestone, Least Cost path, energy conservativity, Roads, Infrastructure, GIS, Average nearest Neighbor, Ripley's K, Viking Age, Early medieval, Iron Age

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1.0 Introduction

1.1 Why Vikings, Runestones and Roads?

The Viking and Early Medieval periods have been on my mind as long as I can remember, growing up every stick was a broadsword, every path was ancient and every mound held an ancient warlord. I can trace my choice of studying the Vikings all the way back to age 10, when my father handed me his copies of the works of J.R.R Tolkien and Frans G. Bengtsson. It sparked an interest in Old Norse history above all else, and the very same year in history class for my first ever history paper, I choose the Vikings. In a way I have never swayed from that choice, to this day, when given a choice; my studies always return to the Norse.

The choice of runestones and statistical analysis came to me around 2 years ago during studies in landscape archaeology. At the end of one lecture, I was given the instructions to run statistical tests on a material of landscape features within my own area of research; my choice more or less immediately fell on the runestones. What that very short and small scale experiment ended up showing me, was a pattern of greater organization within the runestone context. A result that made me lean away from the idea of runestones as simple boundary markers, and more towards the theories on runestones as road side monuments.

The third piece in the puzzle fell into place little over year ago, during my studies in digital archaeology. It was then that I for the first time gained a more in depth knowledge of digital elevation models and saw the potential of using them to further analyze the organization of the runestones within the landscape. This thesis thus deals with subjects and questions that I have pondered for a very long time, and this thesis simply marks my first chance to truly explore them at a reasonable depth.

1.2 The Runestones

For a longer time now there has been a general consensus of runestones as territorial markers, based primarily on the tendency of runestones to be found in the proximity to settlements and parish churches, as well as the texts on the stones themselves (e.g. Sawyer 2000). Using the texts of some of the more geographically informative inscriptions as well as current positions, some scholars have taken it further, suggesting that the stones' role as territorial markers where not boundary-related but rather primarily employed by placing them along infrastructure that intersected with the territory, such as bridges, main roads cross-provincial roads, burial sites and churches (e.g. Selinge 2010 p.67).

Initially most archaeologists and historians focused on the runestones as epigraphical monuments, mainly researching the texts and arts of the runestones, the size of the material also meant that most of these studies where regional in their focus. One of the cornerstones in all research dealing with runestones within the Danish sphere of influence is Erik Moltke's: *Runes and their Origin - Denmark and Elsewhere* (1985). Moltke covered most facets of runeology in his work. Starting from the ground up he analyses the Latin roots of the runes, their likely origin within Zealand or Scanian contacts with the continent, to then move on to translating and analyzing most of Denmark's and Scania's runic artifacts and monuments. The only thing Moltke did not really handle in depth was the Landscape aspect of the runestone context, but perhaps we shouldn't expect him to, as the Danish version was first published in 1976, when Landscape Archaeology was still a very young discipline.

More modern runestone research usually tries to include the landscape and monument aspects of runestones. Birgit Sawyer's *The Viking-age rune-stones: custom and commemoration in early medieval Scandinavia* from 2000 is quite significant here, in branching out across regions, as well as going more in depth in the spatial aspects of the Runestones. Unlike early researchers Sawyer focused less on art, linguistics, individual texts, and more on what you could call an anthropology of the runestones; drawing conclusions based on statistical surveys, that focused on aspects like location, religious indicators, re-occurring names, titles and phrases. Sawyer's surveys among other things concluded that the majority of runestones stand either by a road, or by structures that can be assumed to have been connected to some form of roads; such as parish churches and grave fields. Such conclusions have been drawn by others but mostly in regional studies (e.g. Selinge 2010, Hulting Lindgren 2003). What Sawyer's surveys really excelled at was thus highlighting cross-Scandinavian trends, as well as differences. At the same time it is important to note that while Sawyer's tables cover wider areas, the survey of each individual stone context was only local, in that the survey did not differentiate one type of road from another, nor did it set out to connect any of these isolated road contexts. Which results in the relationships of runestone locations being left out of the analysis completely, limiting the potential to evalute whether said locations are only central to the local population, or rather part of a wider network, central to the whole region.

Studies that use the runestones to connect these stretches of roads to one another seem to be lacking in landscape archaeology. Instead runestones are most often analyzed in relation to their immediate surroundings, and their relationships are mainly investigated based on the runic texts themselves. One example of this is Svanberg's map of the runestones around Lund in relation to known older Scanian infrastructure. Spatially the runestones are here only evaluated by proximity to known historical roads, while the runestones themselves are marked by text based bonds, not at all by any landscape based relationship to each other (see Svanberg & Söderberg 2000). While surveys like these show that some of the runestones have a cultural relationship to each other as well as a spatial relationship to stretches of old roads. Rather than evaluating whether the runestones that are not adjacent to the historical roads are part of an older road system, maps like these have a tendency to make it look like they represent a different context of runestones. In my mind avoiding such illusions can only be tackled by analyzing the runestones as their own landscape context, not as isolated islands near potentially younger roads. Such a perspective I feel is lacking in landscape archaeology relating to the runestones, at the very least in Scania where the runestones do not stand along easily recognizable ridges (as is the case in some parts of Sweden).

1.3 Tracking Roads – The aim of the thesis

The pre-industrial country roads of Sweden were often simple tracks of dirt, beaten up by hooves, boots and wagon wheels. At best they had been loosely graveled or spread with random temper to keep the mud at bay, making the tracking of any road that had passed out of use before the drawing of the first roadmaps easier said than done. Keeping this in mind, what would actually be a fruitful way of studying the runestones in relationship to Early Medieval roads? How can we move beyond the 17th century maps and relate the runestones to paths that now are invisible to the naked eye?

In other parts of the world, where clearly identifiable portions of paved or heavily graveled historical roads actually exist, GIS and digital archaeology is increasingly being used to study and map them. This has been done for many different reasons, which range from very basic motives such as the general management of cultural heritage or preservation through identification. But roads are also of huge importance when it comes to archaeological research and analysis. In modern archaeology we no longer only ask ourselves the questions of what and where but also the question of why. We speak a lot of agents and networks; we employ these wider perspectives as we try to find out what results in the birth of a settlement, the death of a settlement or even why it was situated where it was (Hodder 2012 pp. 27-39, Bell & Lock 2000). Roads as infrastructure, are structures that runs beneath other more stationary structures (by the very definition of the word), which means that they are a huge factor to all surrounding areas and communities. Roads, paths and waterways are what connect one site to another. If we claim to want to study the actors and networks of settlements, towns, other central structures, and not just sites as isolated moments in time, we need to study what bound the site together with the rest.

Beyond sub-structures and transportation networks, roads are also structures and networks of communication. Before the telegraph everything that needed to be communicated to a wider audience was simply placed were as many as possible would see it. This could mean placing a bulletin on a town square, raising a burial monument along a road leading to an important place or carving your name in stone on the road that crossed through your land. Our knowledge concerning the location and general path of infrastructure in the times we study is thus a huge factor not only in trying to place archaeological sites in a wider context but also in studying the roads themselves as structures of networking and structures of communication.

One interesting method has been to connect known segments of the roads, using so called *least cost path analysis*. In this 3D, GIS based method you start with a digital elevation model that you then convert to an energy cost raster. This raster map can then be used in calculating which route through the landscape costs the least amount of energy to traverse. This is used to calculate the most energy efficient path between to known points, thus calculating the most practical path for the road to take in the terrain. The use of this method can be summarized in three different scenarios. The first scenario is interpretive, here a more or less intact road is already known, and the low cost path analysis is used to investigate the degree of energy efficiency within said road. If the road is completely energy efficient it may indicate that the road is either older or simply a stronger agent than its surrounding features; as roads built to connect already active sites are not likely to be completely energy efficient. The second scenario is analytical, when there is a selection of sites or features that seem to line up in a network. A low cost path analysis is relevant here because it may show that the features are placed along the most energy efficient path in the area, and thus directly identify one of the main bases of said theorized networks. A significant example of cost path analysis being employed like this can be found in Bell & Lock's least cost path study from 2000. Wherein they employed this method on a cluster of Oxfordshire hill forts and showed that almost all of them was placed along the most energy conservative path across the local ridgeway.

The third way this analysis is interesting and useful in archaeology is its reconstructive capability, as the output of the algorithm actually includes a map of the most energy efficient path through the landscape. In the best case, dream-scenario, the fragments themselves tests as energy conservative in which calculating the most energy conservative path in-between them is likely to result in actual digital reconstruction of the road. And if not, that too is also useful data, as it may mean there are other unknown structures in-between, bending the road, or simply useful in providing general locations in which to look for more road fragments.

The aim of this thesis is to evaluate the potential for using this this kind of digital elevation and GIS analysis to test the theories of runestones as road side monuments; comparing the results of my analysis to the current theories and knowledge of the Viking Age road system. The fact that methods like these, to my knowledge are more or less untested when it comes to the runestones, means that devising my method will take up a considerable part of the project time; Making this as much of a landscape study as a methodological experiment. These two elements of the study are of course deeply entangled, as the results of a study like this must always be evaluated both through the nature of the method devised as well as the material used. At the end of a study like this you must also ask yourself if the material really was compatible with the devised method, as in my mind, in a study like this, the results hinge equally on the design of the method as the nature and quality of the material chosen as data.

The statistics of runestones locations is already out there; statistical studies on runestone locations all shows a clear trend towards runestones being located next to roads, churches, bridges, waterways and estate farms (Hulting Lindgren 2003 p. 60, Sawyer 2000 pp. 26ff, Selinge 2010). But in my mind there is a large difference between theorizing around the general locations of runestones and actually correlating them to networks of larger infrastructure. Proving that the runestones preferably should be placed next to a road is not the same thing as proving that they were placed next to the same road. And this detail, although it may seem minor to some, does have huge implications when it comes to our view of both Viking Age runestones as well as Viking Age infrastructure. If the runestones were only connected to smaller, mainly local paths, and not larger pieces of infrastructure; it would mean the messages they contained and communicated was mainly directed towards the local population. If the runestones on the other hand are mainly situated along central lines of larger infrastructure it could mean that the runestones were intended to reach a wide audience, and that Viking Age infrastructure did not only carry people and their goods. But could also have been carriers of information. In relevance to this study, larger roads are of course much easier to track by my method, as they cover greater areas leaving more sites and monuments to be used as hubs in the analysis.

My study analyses the relationship between the runestones themselves as one single infrastructural context, which is largely different from just comparing the general surroundings of one runestone to the next. My method also compares the runestones to other roadside structures as well as paths of energy-conservativity, evaluating the possibility of the Scanian runestones all relating to the same cross-provincial road system.

1.3.1 Questions

- Are the Scanian runestones organized in relation to each other in a statistically significant manner?
- Will a low cost path in-between runestones intersect with areas of already known roads?
- Will a low cost path between two runestones in well preserved parts of the landscape overlap with runestones located in-between?
- Can the methods tested in this study accurately track Viking Age infrastructure with the runestones as their only marker material?

2.0 Method and Theoretical Perspectives

2.1 Method and theory in Digital archaeology

Digital archaeology exists within the framework of the younger, more science oriented, and laborative-archaeologies. Like for example the laboratory parts of environmental archaeology, palynology or computational archaeology; it has been said to not be analytical rather than interpretive.

"Post-processual theory and digital technology are incompatible. Post-processual is interpretative, digital is analytic. Post-processual is deconstructive, digital is reconstructive. Post-processual is narrative, digital is measured." – Zubrow 2006 p.14

Of course the truth of this is largely reliant on the role the digital archeologist takes. Even if the digital archaeologists were to limit his role to recording and creating material, he would then still turn that material over to another specialist that would in the end interpret the material. The fact remains that even though many choose to interpret their material post-analysis; all digital archaeologists interpret their material in some minor way, regardless if they are trying to or not. Perhaps what you really should take out of such arguments is that the ideologies behind digital archaeology often build on more science oriented paradigms than say post-processual archaeology. Based on this you could say that the paradigms of many digital archaeologists lean closer to the values of processual archaeology or perhaps more fitting, the younger cognitive archaeology. Certainly there is a lot of digital archaeology within cognitive archaeology (Zubrow 1994).

Digital archaeology has also been argued to be more or less incompatible with the paradigms and methods of post-processual/interpretive archaeology (Zubrow 2006 p.14). The general argument here is that while clear cut post-processual archaeologists integrates interpretation into all stages of their methods. Digital archaeology is largely experiment and test-based, first analyzing data through the algorithms of software to let interpretation follow only after the result of said testing or building of a model (Zubrow 1994). Of course this is not representative of all digital archaeology, especially 3D GIS analysis have been used extensively by post-processual archaeologists; though mostly to aid them during their interpretation of the data, not in a quest for "testable models" (Chapman 2009).

To some extent I agree with this. At the very least the ideas of the scientific paradigms of recording and test based digital archaeology, as to some extent ideologically incompatible with the paradigms of clear cut post-processual/interpretive-archaeology. In more recent years many post-processualists have started calling themselves “interpretive archaeologists”, in an effort to highlight interpretation as the main pillar of post-processual methodology (Tilley 1994). Most likely this heightened focused on interpretation was a response to the critique of scholars like Colin Renfrew, who has argued that post-processual archaeology, really rests on the shoulders of processual archaeology (Renfrew & Bahn 2004).

By comparison my experience is that a good share of digital archaeologists seem to strive towards a fair level of positivism, or are at the very least, focus more on devising methods of more objective recording and testing of excavations and other material culture, than the interpretation itself. Among other things these trends manifest in the large amount of digital archaeology studies dealing mainly with the devising of new methods of detailed, digital excavation recording (e.g. Callieri et al. 2011), in studies seeking more automated recording processes (e.g. Grün, Remondino & Zhang 2004), or in the comparisons some scholars make between their analyses and the laboratory sciences (Zubrow 2006 p.9). The fact that so many digital archaeologists separate recording and interpretation I think is the least debatable break from older interpretative paradigms within the field. Yet at the same time Digital Archaeology is a very young discipline, and there is no unified theoretic paradigm shared by all digital archaeologists. In fact you could argue that digital archaeologists dealing primarily in reconstructive work, even though guided by analysis, primarily deal in interpretation, at the very least visual interpretation.

2.2 Analyzing Virtual Landscapes

In this project, I do in a way walk a narrow line in between the reconstructive and the recording/test based digital archaeology. I am not just reconstructing, I am also running statistical tests and I am analyzing data. Some landscape archaeologists use digital elevation models and landscape recreations not as an analytical tool but more as a visual tool for their phenomenological theories and interpretations. I am skeptic to this as I have been told by more than one environmental archaeologist that the spread pattern of vegetation based on pollen analysis is not near area specific enough to use landscape models as a material for phenomenology. When you only use the digital elevation model (DEM) visually, you don't really know what you would or would not have been able to see during the relevant time period. This is an example of not having a healthy give and take in between your reconstruction and your analysis. To me the reconstructive element of this method is not nearly as important as the data it results in, and thus I strive to have my perspective be as analytical as possible. As I believe that we can calculate how the road as a structure was likely to work into things like local economy, trade, communication and territoriality. But I also believe that a discussion of this should be based on the reconstruction, not the other way around. In my mind digital landscape archaeology should be used as an analytical tool, not as an illustration of manual analysis.

Virtual reality is not only a tool when it comes to digital archaeology; it is also an integral part of its theoretical perspectives. That is, many digital archaeologists acknowledge that the models they create does not really represent our reality but a different reality, just like the processes inside the test tube of chemist does not really correspond to surroundings of the effect he tries to study. While a Landscape Archaeologist will integrate his GIS material in a real life survey, this is not always the case in Digital Archaeology. In this study I will create a 3D Landscape in my computer, in doing this I am creating a testable virtual reality, in which to conduct my experiments. This is of course part of my perspective, not walking the landscape myself, imagining what would be the most likely path of an ancient cursus, but letting algorithms calculate this for me; attempting to shut the modern landscape out of my view and my mind, by eliminating it from the process as much as possible. In direct contrast to many post-processualist scholars (e.g. Tilley 1994), I aim to get my mind out of the modern landscape, as I believe that while out surveying in a real life landscape, our minds can never truly separate the landscapes of the past, from the modern landscape.

Of course it is impossible to completely take your mind out of the analysis, you have to tell the software what to do, and you yourself is selecting and gathering material. And even if the material you use to build your virtual reality from beyond all probability is complete and ready to insert into a database without sub selection, interpretations and conclusions can never be completely left out. Furthermore, in this study my material is far from complete; in fact the majority of it has been moved from its original context. For me this means a good deal of handling and sorting the material, long before the software gets to do its work; which in essence means employing another perspective: Hermeneutics. If you know from all other data than the geographical data itself that some of its points are not in their original position, of a later date, or even fictional, it simply is not (in my mind) scientific to enter that data into the analysis, as is.

2.3 Statistics and milestones as a benchmark

As part of my experiment in this thesis I have constructed databases of runestones still in their original hundred from FMIS data on two, well defined, Viking Age regions; Gotland and Scania. I compare their clustering and level of organizing in the landscape statistically, using milestones in the very same provinces as a standard for the organization level and pattern expected for a well-organized historical road sign system.

The milestones signify the first government mandated rural road signage in Swedish history; they appear in our landscape in the 1650's, after the first declaration of an official national mile (10 689 meters) in 1649. They were placed every mile (sometimes with smaller stones every half mile), along the so called "Landsvägar", which where the larger, officially mapped roads, that connected larger towns. In Scania around as many as 370 milestones are preserved, the oldest dating to 1691. Most of the stones though, where placed out gradually hundred (härad) by hundred during the 1700's the last of these was erected in 1780 in Villands Hundred (Söderpalm 1967 p.24-28). Being the oldest officially organized signage related to cross provincial roads, as well as of the same general date as the oldest Scanian provincial maps, it makes them a good statistical benchmark for the runestones.

Moving on from the statistics, on the basis of the spread pattern, I then selected portions of potential road in Scania and connect two rune stones in each area using low cost path analysis on a Digital Elevation model (DEM map), using detailed LIDAR (laser scanned) elevation data. I am doing this to construct hypothetical segments of road connecting the rune stones by the least terrain inhibited path, to use in my discussion of the potential of this infrastructure analysis method. I also compare this hypothetical road or path by one generated by instead using the milestones in the same area.

I also test the FMIS data statistically using the Ripley K and Average Nearest Neighbor spatial statistics (resources.arcgis.com/en/help/main/10.1/index.html#//005p00000008000000), to determine that these lines of rune stones can actually be said to be organized in relation to each other in a statistically significant way, that them being lined up in relation to each other is not just my potentially biased opinion.

The milestones are very fitting as a comparative material for this study, simply because we know, that they were made to provide roadside information. Unlike the rune stones there have never been any objections, to the fact that the milestones provided spatial points of reference for travelers on larger pieces of infrastructure. It is also a material that we know is organized and furthermore organized not only locally but corresponding to a cross provincial network of roads, some of which were in use all the way up to the introduction of paved roads. Furthermore it is a very large material, as well as a material that is much less fragmented and thus provides much shorter path sections to calculate and because of this is more reliable in my opinion. Though the most important thing to remember here is that milestones don’t just correspond to a network of roads, they are also a network in themselves.

As the name suggest the milestones where designed to stand within a mile to each other, which means that if all milestones of one generation was preserved and tested statistically, they should give an average mean distance of exactly 1 mile. To my knowledge the runestones have never been analyzed as an organized network within themselves before, or at least not in a comparative way. We relate the location of runestones to nearby estates, churches, rivers and roads, but when we relate runestones to each other, it quickly becomes a question of what they have in common, general trends in portrayal and surroundings; it quickly becomes an epigraphic study, or an art study, or a phenomenology of the runestones general locations. If larger pieces of infrastructure were the most common location for runestones, it can be argued that their spread pattern should not test as random. Instead they, as a uniform context of roadside monuments should have a certain level of organization within themselves, that every new stone was placed in relation to not only the land of the patron, but also the monuments already standing along that structure. The milestones are the ultimate example of such behavior, as we already know without doubt that every milestone was placed in relation to both the road as well as surrounding milestones. By comparing the organization level of the runestones to the organization level of the milestones we can determine if the choice of locations for each new runestones was based on similar criteria.

2.4 Least cost Path analysis

Energy path or "least cost paths" as it is called in Esri software is a GIS, 3D analysis tool. It builds on 3d elevation data to calculate the energy needed to traverse through the elevation in between two set points in the GIS map, which in turn allows it to illustrate the least energy consuming path in between those two points. The energy needed to cross an area, or the "cost" as it is called in the software, is calculated through the topographical data, by use of an algorithm built into the tool, the area is determined by the points or "targets" that you choose to have the algorithm calculate the path in between. In archaeology the data most often consist of slope raster elevation data or modeled elevation data (Bell & Lock 2000 p.85-88). This also means that you calculate the terrain only on ground level, not in terms of vegetation or buildings, this is also true for my study, I am building my height models on surface data alone.

Calculating movement cost like this can be used for a variety of different analysis. In their article from 2000, Terry Bell and Gary Lock, already having a general path in the Oxfordshire hill fort Ridgeway, employed a method that I in part test on the Scanian material in this study. They picked the outermost forts of the ridge (Barbury and Segsbury), and calculated their energy efficient path in-between to observe and analyze how it related to the other hill forts. Their first attempt resulted in the path completely diverging from the ridge, taking a lowland path, completely ignoring most of the sites that they had expected the path to pass through. Thinking that the idea to concentrate energy waste in a few though climbs by climbing down into the valley and then up again in the end, was only logical to a machine (Bell & Lock 2000 p.91-93), they modified the algorithm and introduced a bias, to make the algorithm less inclined to seek out downward slopes. The result was that the path instead followed a more evenly distributed path, along as even surfaces as possible, very close to the modern Ridgeway. Furthermore now it also passed through 3 hill forts and right outside a 4^{th}, only one hill fort diverged from this low energy cost path. The conclusion drawn was thus that the road was older than the hill forts, and had been created through a combination of energy conservation and a bias towards following the ridge instead of the vale and also that the hill forts was a network created around older infrastructure (Bell & Lock 2000 p.99).

Another way the tool has been used is to "patch up" roads whose path has already been more or less made clear by survey, excavation and historical maps or documents. A clear example here is Roman roads that often leave observable traces in the landscape. But even Roman roads have patches of unknown trajectory; we tend to think of them as clear, wide, straight, paved and almost modern infrastructure, but the reality is that less important roads, like some provincial roads, in part consisted of simple gravel roads. One example of a provincial road with less observable gravel segments, which very recently was subject to low cost path analysis, is the Via Belgica (Verhagen & Jeneson 2012). In this study they ran a variety of low cost path tests on a less well mapped portion of the Via Belgica stretching between Valkenburg-aan-de-Geul and Voerendaal, comparing the results to the proposed trajectory of other, non-digital studies based on assumed roadside structures.

Low cost path analysis can thus be used for a variety of reasons. It can evaluate, as in analyzing known paths in terms of their energy efficiency to determine how large a part it played in the paths origin. It can be evaluating, as in used as an argument for or against hypothetical stretches of road, or for that matter in times before real roads which path would have been most suitable for hunter gatherers to use through the terrain in search of material resources (e.g. Taliaferro et. al. 2010). It can of course also be reconstructive, as in how Bell and Lock's study determined where the road would most likely pass through the hill forts.

2.5 Least cost path – A cognitive archaeological method with a Darwinian perspective

If organization is the first key word for this study, the second is "energy-conservative". Humans are (beyond everything else) living creatures on a constant quest for a large variety of different resources, which regardless of their nature, psychological or physical, keep us going and in some cases keep us alive. By this I mean that when we leave the comfort of our home, to work or travel, we do this to acquire and collect; be it monetary capital, ideology based capital, religious capital or experience. In other words we are gatherers through and through, and in being gatherers I believe as a group that when we act to maximize said gathering, we do so through energy efficiency, maximizing the output of our ventures.

This does not mean I adhere to processual or deterministic ideas about human culture as predictable; deterministic processualist operated on an archaic and faded version of Darwinism, and is not compatible with modern Darwinian research. Darwin first stated the three fundaments of evolution (here summarized by Leonard 2001, p. 68) as:

1. **Variation**
2. **Heredity**
3. **Struggle for Existence**

Taking a determinist view, in my opinion means having to separate these three laws from each other, focusing on the third law and as a separate function working in a linear fashion towards being fitter and more efficient; modern Darwinism in contrast, has for a long time now focused on interplay in-between the three laws in what is called “niche differentiation”. The fact that endless variation in progression is a fundament in all continued existence, that there is no determined line of linear evolution that will render you objectively more fit to survive, but rather that we survive because we are different and as we progress in our differentiation we fill different gaps in system, be it a ecological system, an economical system or a cultural one. In my mind entangling culture and biology does not make culture any less individual or divergent in its progression (Hodder 2012, Leonard 2001).

When it comes to the roads themselves I do however not only look at them through a “fitness through efficiency” point of view, I also look at them through a heredity point of view. To do this I think very much in the lines of actor network theory, as well as cognitive, agency driven game-theory. Especially the “stag hunt” dilemma (to my knowledge first devised by Rousseau in the 18th century) has proved an excellent tool in looking at human cooperation in terms of how logical efficiency and structuralism, dogma are entwined in the birth of networks (Skryms 2004). Game theory studies the cognitive process as well as structures and agents through either real or AI population’s responses to carefully designed psychological games. In his book from 2004, Skryms writes about one such game “the stag hunt”, devised to study the origin and progression of human cooperation and networking, through the use of active agents. In the stag game, the population consists of hunters paired up two and two in pairs to hunt stag, and bringing down the stags requires cooperation and trust, the stag will not be caught if any of the hunters stray from the plan to catch smaller game (hare) by themselves, for themselves.

Testing shows that the vast majority of the population, when only guided by their own logical conclusions goes for the smaller game; they take the option that delivers capital right away. At the same time the tests show that when the tests incorporate influence, conversion and heredity, the stag hunters prosper in numbers. Implying that structures and agents that benefit the network rather than single cells, spread and grow not through logic or behavioristic traits, but through the ideas of agents and the heredity of the structures they build up. If a social-structure, landscape structure or the agency of an ideology is beneficial it spreads, as heredity is based on the collective success of a homogeneous group, not individual success (Skryms 2004). In my opinion, the stag-hunters though not reaping immediate personal gain of any higher caliber than the hare-hunters instead benefit the group and the agency grows stronger, and starts converting hare hunters who want to imitate their success. If cooperative hunting becomes a social structure by allowing the collective to prosper rather than single individual, the creation of trade and travel based infrastructure could be argued to likewise be guided in part by basic Darwinian urges of survival, in part by social structures and agencies that benefit the community as a whole.

Reading about these theories, and relating them to archaeology have greatly influenced my views on networks and infrastructure, and thus also my interpretation of the structures and networks I study in this thesis. Strengthening my conviction that infrastructure, in its function of connecting large and advanced structures, are not likely to be energy efficient in its entirety, but only in-between the main hubs of the network. As structures that benefits the whole network seems to be more hereditary than actions that at first glance seems more logic to the individual (like choosing to hunt the hare because it gives you the same individual payout with a lessened probability of failure, or travelling from point A to C without going past point B, since it would demand more energy), as they do not aid the group or network as a whole, and unless the network is feudal, not even the individual himself in the long run. You could compare this to the route of a paperboy; during his training he will be taught a pre-defined route, but as his knowledge of the route, the clients and the urban landscape grow. He will use that knowledge to modify the route for greater efficiency in his venture. But his route can only be modified in relation to the locations of the clients or clients will not benefit from being a client, resulting in them severing themselves from the network in turn diminishing the income and resources of the paperboy.

I view roads as a network of paths, running beneath structures, both connecting old ones as well as creating new. Being guided by structures and constructing a network of resources and heightened efficiency, roads in their entirety are thus (as already mentioned in relation to the stag hunt and the evolution of cooperative behavior/structures) not likely to correspond to the most energy efficient path. Especially not if spanning through an area the size of Scania. Energy efficient or not, a path will never become infrastructure until it acts in a wider network, connecting used structures, or as the name suggests, becomes a fundament that interlinks structures and agents. Energy by path analysis thus needs structures or "hubs" if you will, as to be used in a favorable way. The analysis requires points that accurately represent the structures connected by the network, the more hubs representative of road side structures that you can provide; the more likely it is that you are analyzing infrastructure and not simply an energy conservative path, e.g. Bell Lock's study low cost path study, where hill fort locations were used as hubs (Bell & Lock 2000).

3.0Material

3.1 FMIS DATA

FMIS and the online version Fornsök, is a GIS based archive of monuments, cultural heritage sites, in the format of vector points, lines and polygons, topographic and orthographic maps, as well as corresponding summaries of survey and excavation documentation. The database is owned and managed by the Swedish National Heritage Board RAÄ (Riksantikvarieämbetet), who supplies the database in two versions, one restricted version for the general public and one complete version for researchers and professionals. During my time in the masters-program I gained temporary access to the non-restricted database and downloaded the GIS shapefiles used in this thesis; the survey files where instead accessed continually through the online version during the writing of this thesis.

As the data is managed by RAÄ this generally means you can usually trust it to have overall good degree of credibility; Though at the same time, with RAÄ being a public organ of cultural heritage management, it would not look good if RAÄ as a public organization appeared to choose sides in any ongoing archeological debates. This trait of theirs, along with the time it takes to manage and update a database the size of FMIS. Means that the site and monument information following with the shapefiles, can often be either short cut or not up to date with current archaeological research or debates. Most of the files I read for this thesis in-fact displayed a warning label of potentially being outdated, as they hold the distinction of not having been updated since the late 80's. When dealing in artifacts and monuments that very rarely are discovered (like runestones), this is in my opinion not a very large factor, and for this study FMIS has proved a good tool for acquiring relevant location data, as well as summaries of the monuments general context. That being said, because FMIS data has the tendency of not being completely up to date, I feel you do have to cross match the survey entries most fundamental with your study with newer bodies of research when you use it. Had I not done this, I would for example have been ignorant of the Färlöv stones discovery in the late 90's.

3.2 LIDAR & Orthographic Data

All elevation and orthographic data in this thesis have been downloaded from the National Land Survey of Sweden (Lantmäteriet) through the GET database hosted by SLU (Swedish University of Agricultural Sciences). The LIDAR data is scanned by laser radar mounted on aircrafts flying over areas of about 25x50 kilometers at a time, and then digitally split up into tiles of 2, 5x2, 5 kilometers before download. The resulting point-cloud (3D model consisting only of vertexes), that on clear scans has an average density of one point every 1 to 2 square meters, with an average distance error of 40 centimeters and average height error of 10 cm. In essence this means in areas of decent quality any landscape feature that is 2 square meters or larger will show up in the model, obviously this also means that larger features will appear the most detailed. The quality of each tile can be seen in attached meta-data files.

The scans are delivered through the online GET tool in an LAS format; the data now covers almost the entire southern half of Sweden as well as the northern coast. The orthographic maps consist of orthographic photo mosaics also captured by aircraft, with a resolution of 25 centimeters per pixel. Highly developed areas are updated every 2 to 4 years (http://www.lantmateriet.se).

Even though the numbers of accuracy provided by National Land Survey of Sweden are very good indeed, it is important to note that the data is not delivered as a finished DEM (elevation model). Before running the actual analysis point clouds are cropped down to the area of study, often not taking lines of shifting quality into consideration. It is then filtered to remove points designated as vegetation or buildings, potentially lowering the point density further. Finally it is triangulated into a mesh, and in this case going further the mesh DEM is transformed into a raster

DEM. This means that every time you use this kind of data, you change it and the elevation model you create will not be the same as the original data you built it from. While still an excellent tool with huge potential one should remember that the elevation models built by a researcher, is not only the output of the data and the algorithms, they are also in part the creative output of the researcher.

3.3 Maps

Historical and orthographic maps were used in the process of selecting the areas for my case studies. The historical maps I used where all from the online archive of Military Archives of Sweden (Krigsarkivet), where several provincial maps of Scania from the 17th and 18th century can be inspected for free in PDF format. The earliest maps stem from the time of the Swedish conquest of Scania, about 600 years after the Viking Age, which means they don't provide a completely reliable material. However, as they show a Scania before truly large scale deforestation and trenching of the wetlands, they do provide a general idea of which areas would be harder to traverse. They also show more or less the same roads as the Milestones, which allowed me to get a more visual view of how those roads related to aspects like forestation.

Orthographic maps where very useful in surveying the areas surrounding the runestones. The Orthographic mosaic maps provided by SLU are as previously mentioned of a very high resolution. But using a mosaic of photographs will mean not having a uniform lighting across the landscape, which can provide problems when looking for things like old boundaries, mounds and crop-marks, which can cause you to second guess if what you see really are what you think you see. Because of this several providers of photographic maps where used as comparison, mainly Google earth, but also the orthographic function in FMIS as it allowed for the highlighting of relevant sites in the landscape.

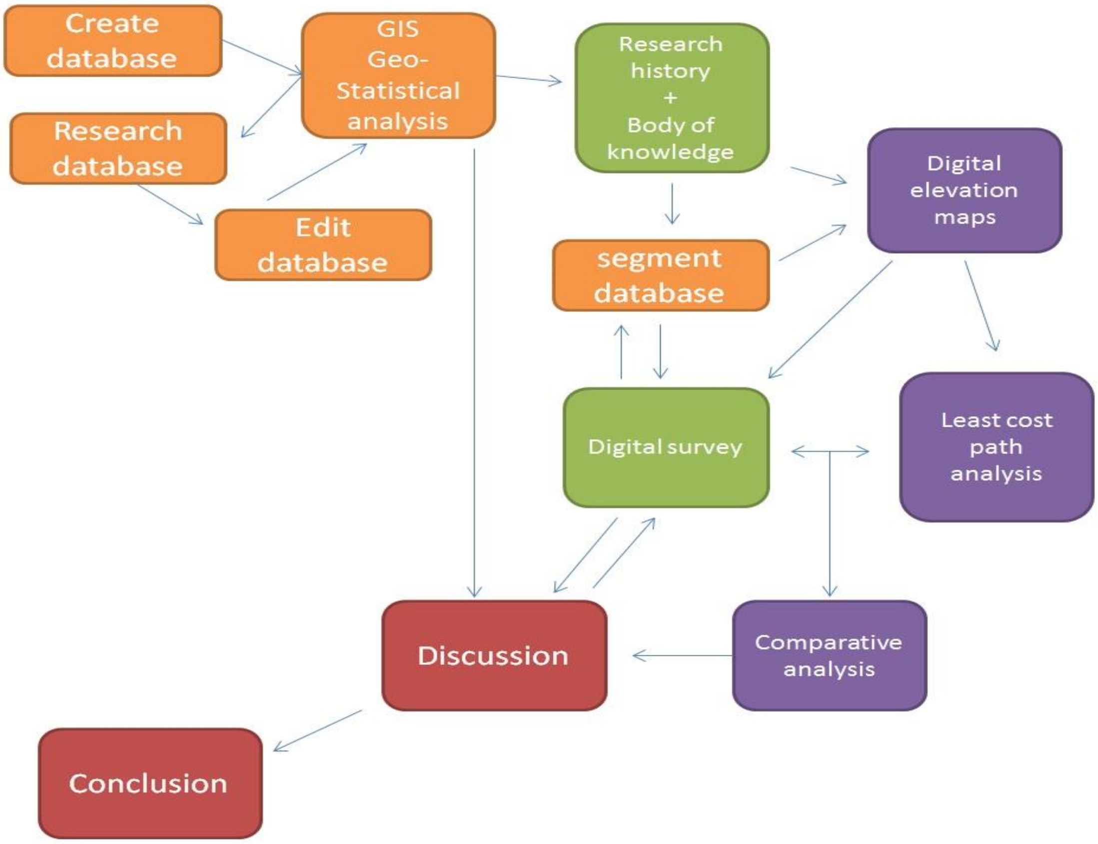
During the interpretation I used maps in a similar way, but instead of historical maps the results where instead compared to paleo-ecological maps of the case study areas for greater reliability. For the southern case study the ecological maps from the Ystad Project was used for a clearer view of the landscape (Berglund 1991). For the northern case study, I could find no truly detail maps of the Viking Age ecology and instead had to use more general maps of ecology, settled areas and places of burial (Callmer 1991, Svanberg 2003 and Svanberg & Söderberg 2000). Keeping in mind that maps based on pollen-analysis can never be completely accurate in their borders (because of the fact that pollen transports by both wind and water), and the fact that vegetation is not a focus in my thesis, I only used these maps as a tool in my interpretation.

3.4 Primary sources

Primary sources take a small but significant part in my method by being used in the interpretation of the results. When you ask yourself why a runestone location may be more important than others, why it might even represent a powerful agent in the landscape, it is very important to remember than the runestones themselves are primary sources. Their location, their art and their texts may all be combined with the revelations of a test result in search for a well-grounded interpretation, it is important to remember this and not be blinded by the seemingly endless new possibilities of digital technology. At the same time runestones can be cryptic and writes to a contemporary audience, so not having a background in their text-based research I tried to keep such parallels on a healthy level.

3.5 Method workflow

The chart below illustrates my own method, or rather my combination of already in-use archaeological low cost path analysis and statistical analysis, devised to allow a more fragmented material, such as the Scandinavian material; to be interpreted with a high degree of confidence. The statistical part of the method might seem a bit odd to some; why run the tests twice, why once without categorization and then again once more after categorization? This is simply because of the rather small time frame in which I have conducted this analysis; I simply did not have time do go through the comparative Gotland material with the same level of detail as the Scanian material that is the focus of the analysis. In order to not portray a skewed view of the materials In my statistical analysis I thus run the Scanian tests twice, first like with the Gotland material on an unedited FMIS selection, and then again with an edited selection. In the ideal employment of this method of course every single part of the material should be studied, interpreted and segmented pre-analysis, creating a more streamlined as well as relevant flow through the pipeline of analysis.



4.0 Analysis

4.1 Statistical Analysis

Stare at any surface or item long enough and you will start seeing lines, symmetry, hints of order and clustering; even the clouds will take shapes if you stare long enough. I can look at my maps of GIS points and tell you that to me they look organized, but my feelings or hunches can never really be said to be objective or for that matter perhaps not even persuasive. So in this part of my analysis I employed two different 3D spatial tests on the data to test if I was simply seeing things, or if the rune stone indeed where organized on a significant level. The tests I employed here were the average nearest neighbor test and the Multi-Distance Spatial Cluster Analysis (Ripley's K Function), both as found in ArcMap 10.0.

The average nearest neighbor test is a spatial-statistic test used to measure first of all level of organization, from clustered to dispersed, but also the statistical relevance of said clustering, which is if the material is clustered in a way that is not likely to happen by chance. It does this (as the name suggests), by calculating the collectively average distance in-between each selected spatial feature. From this it gets the “Observed Mean Distance” which it then compares to the “Expected Mean Distance”. The algorithm also produces a “Z-score” and a P-value. P stands for probability and Z for standard deviations, extraordinarily High Z-scores thus signify that the points are too evenly dispersed across the area to be randomly distributed, and low means they are too evenly clustered to have been created randomly in relation to each other. The P-value is always low when showing a significant result, regardless if the rest of the test shows clustering or dispersion. (help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//005p00000008000000).

Why is the observed mean distance relevant in discussing the runestones in relation to infrastructure? Many of the Scanian runestones have as already mentioned been mapped in relation to the larger provincial roads of Scania (e.g. Svanberg & Söderberg 2000 p.24), the very same roads which the milestones originally stood along, by an average mean distance of 1 mile from every stone to its nearest neighbor. Which means even now circa 300 years later, one should expect the milestones to hold a very low Z-score, comparing the runestones to this score thus indicates if the runestones are organized in a similar manner as known main road signage, along the very same stretches of road that the runestones have been associated with.

It is also relevant because this tool is very different from previously used methods in not comparing the material visually. Drawing maps is very useful, but comparing the runestones to early roads by way of maps only answers which runestones relates to the roads still in use in later periods, and it does not indicate if their relationship with the rest of the stones. If the Scanian runestones have a significantly low z-score, one comparable to that of the milestones, then the rest of the runestones should be part of the same network of organization, and may in fact indicate Viking Age roads no longer in use by the drawing of the first detailed provincial road maps.

Ripley's K-function, is also a test of randomization and clustering, so in essence I ran the Multi-Distance Spatial Cluster Analysis just to confirm that other tests against the null hypothesis would give me the same result. But there is one large difference between the tests. While average nearest neighbor deals with the expected mean-distance, Ripley's K-function is measured in permutations; that is to say the test is run several times on several distances to establish if the features are as organized on all distances or different scales of analysis. The result is a graph with a red line of observed distribution, and a blue line for expected random distribution. If the red line maps significantly lower or higher than expected, it in most cases mean you can reject the null hypothesis. Significantly higher (measured by the size of the confidence envelope) means the material is significantly clustered and lower means it is significantly dispersed (help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Multi_Distance_Spatial_Cluster_Analysis _Ripley_s_K_Function/005p0000000m000000/).

Generally the confidence envelope is supposed to surround the expected K factor; with an exception for more none homogenously shaped study areas. Apparently a bug exists in ArcGIS 10.0 making this trait appear also in homogenous areas; however this does not really matter for my analysis as I use two different materials to compare rune stone randomization to expected level of randomization for a roadside marker system (the mile stone system) rather than a detailed level analysis of randomization.

(http://forums.arcgis.com/threads/39549-Ripley-s-K-Confidence-Envelope-doesn-t-follow-the-blue-expected-line)

Ripley K analysis is relevant as a method of analyzing this material for much the same reasons as it measures the same basic aspects of large scale organization (organized clustering and dispersion). Scania might be quite a square and uniform province, but in the Viking Age the settlement pattern consisted of a thin and coastal main space of habitation of an almost peninsular shape, connected to smaller satellite areas around lakes and rivers on the inland (Svanberg 2003 p.153). The uneven, clustered spread of Viking Age habitation of course have the potential to skew the results of a method that always compares a feature to its closest neighbor, as runestones in isolated areas with multiple runestone locations would always have each other as their nearest neighbor. The fact that Ripley K analysis measures over a variety of distances instead of the shortest one available makes it an excellent complement to Average Nearest Neighbor analysis, in being able to disprove the null hypothesis (that everything is random), regardless of whether parts of the material is spatially isolated.

4.1.1 Gotland Data

The Gotland runestone material was the first FMIS material I studied for myself outside of a GIS course exercise, but the first time I ran these tests were actually as part of a free lab in computational archaeology. The tutor had given us the instructions to after finishing our exercises, download new FMIS material, more related to our interests and specializations, so that we could practice spatial analysis testing on materials from which we could draw deeper conclusions and interpretations. On more or less of a whim I queried the FMIS database for rune and picture stones on Gotland, and what I witnessed were more or less the inspiration for this project. Baffled by the straight lines and paths Gotland's runestones seemed to be organized in, I proceeded with running the ArcGIS Multi-Distance Spatial Cluster analysis to confirm that they were indeed organized. After doing this it was Torbjörn Ahlström, who suggested I should run the same tests on the Gotland milestones for comparison. When deciding to do an analysis of the Scania material in relation to known roads in western Scania, I re-ran the tests along with Average Nearest Neighbor tests for comparison.

It would be silly to assume that all road systems would test as having the same level of organization, especially when the marker system you are testing it through, have been out of use for 200 years. With this in mind it is always useful to use test results from reliable material of more than one region. One should not take for granted that the road system that has most in common with that of Viking Age Scania is the one of 17th and 18th century Scania. Gotland was chosen to weigh this problem for a couple of reasons. I knew its material would probably test quite well as others other researchers seems to have good results analyzing the Gotland picture stones based on similar questions (Alexander Andreeff is currently working on a doctoral thesis on the organization of Gotland's picture stones in relation to an organized landscape). There was also the fact that my quick and very basic testing of this material during my landscape archaeology studies had given very good results.

The second reason was the shape of the province. As already mentioned the main area of habitation and travel in Scania during the Viking Period was much smaller than that of 18th century Scania, evens though they technically are the same province, the significantly different shapes and spread of the areas tested, could raise questions of representativity. Gotland on the other hand being an island, still had a road system that shared Viking Age Scania's nature as an elongated, costal centered society.

As expected the Gotland Milestones test like one might assume a pan-regional system of road signage would test. As the provided graph shows (Figure 1.), the results lands not only in the significantly clustered range but in the outermost field of this range, meaning that it is not only significantly clustered it is extremely clustered by comparison to a randomly distributed set of features in the same area. The Z-score was -7.538312, which by the software's built in scale equals a less than 1% chance of random clustering. For the automated graph to display this less than 1% chance randomization message, you must get a Z-score of at least -2.58, which makes -7.53 and extremely good result. The P-value was 0.00000; again this is lower than the 99% accuracy limit which for the P-value starts at 0.01. In essence this confirms what we already know, that the milestones as a context consists of a highly organized network, distributed evenly by every metric mile. If this test would have been run 300 years ago, it would have shown than every single milestone had more or less the exact same distance to its nearest neighbor as the others. What the figures mentioned above show, is that even now there are enough milestone in their original position for the algorithm to determine that the odds for them having been erected in a random pattern to be significantly lower than 1%. The Z-score of -7.53 in turn, provides a benchmark for how a highly organized, coastal network of road signage may test after a few hundred years.

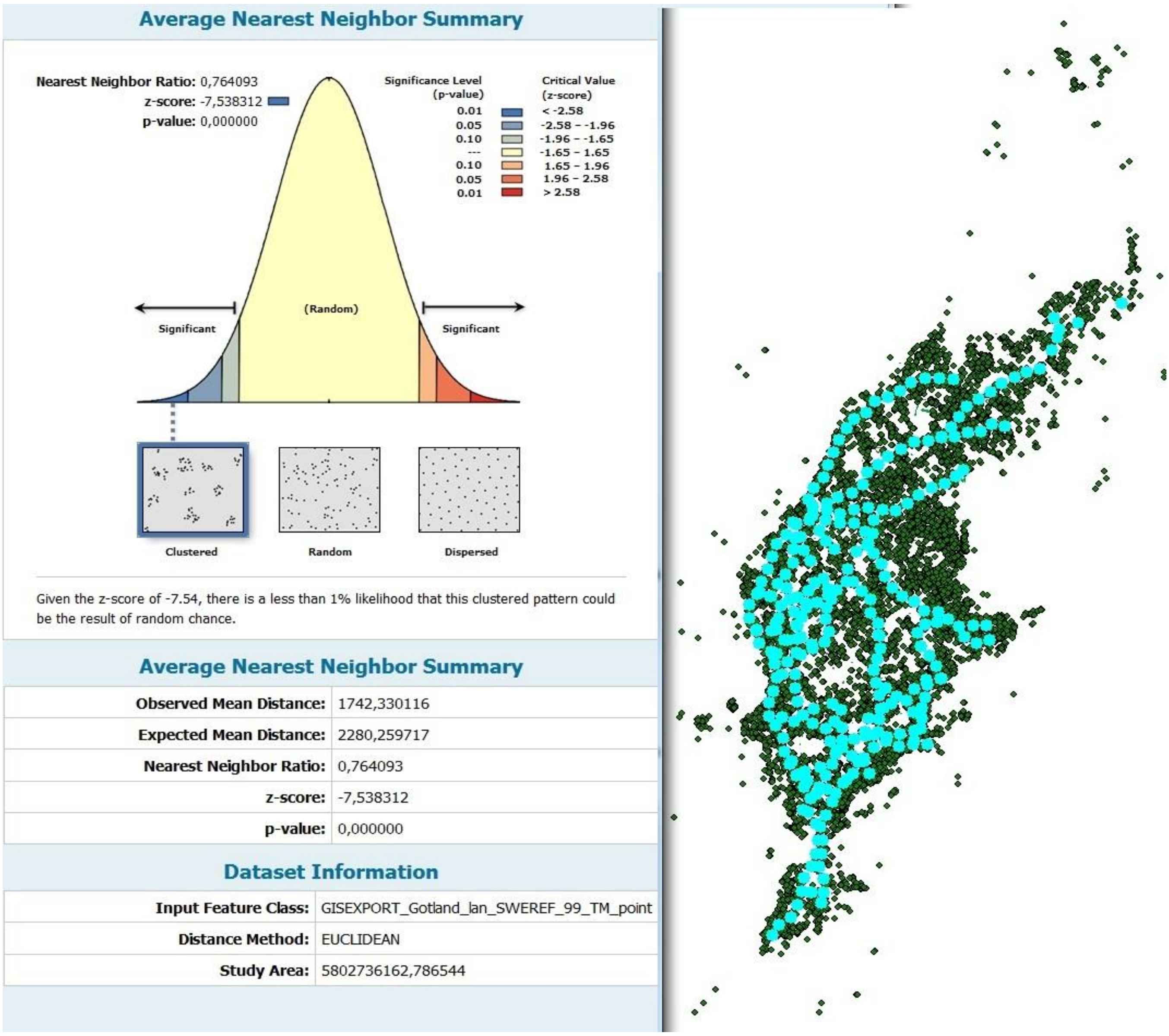


Fig. 1. Average Nearest neighbor: Gotland Milestones. To the right you see Gotland's milestones marked in blue against the green dots that signify archaeological sites on Gotland. To the left you see the test results in both graph format as well as the actual statistics.

What could be said to be rather surprising is that the Gotland Rune carving material beats that score, which in the same software, with the very same setting on the Average Nearest Neighbor tool, delivered something as amazing as a -21.946808 Z-score as well as the same lowest of low P-value (figure 2.). Personally I would not take too much out of the fact that the rune stones got a better Z-score; though I am not a mathematician I would make the educated guess that this is because of the fact that the runestone points are less linear while still being evenly distributed across the island. This means that they also cover a larger percentage of the island, literally giving each rune stone more near neighbors; though these results should still not be underrated. It does not take a very long inspection of the two contexts to see quite a few correlating lines in their point spreads (Figure 3). And the fact still remains that the average distance in-between the rune stone is more even than the average distance in-between milestones when measured by the Euclidian principle. Furthermore I would not be surprised if a careful categorization was made to remove all stones with an uncertain original context, if it were to result in clearer paths that corresponds even further to the mile stone paths (as below is shown to be the case with the Scania material).

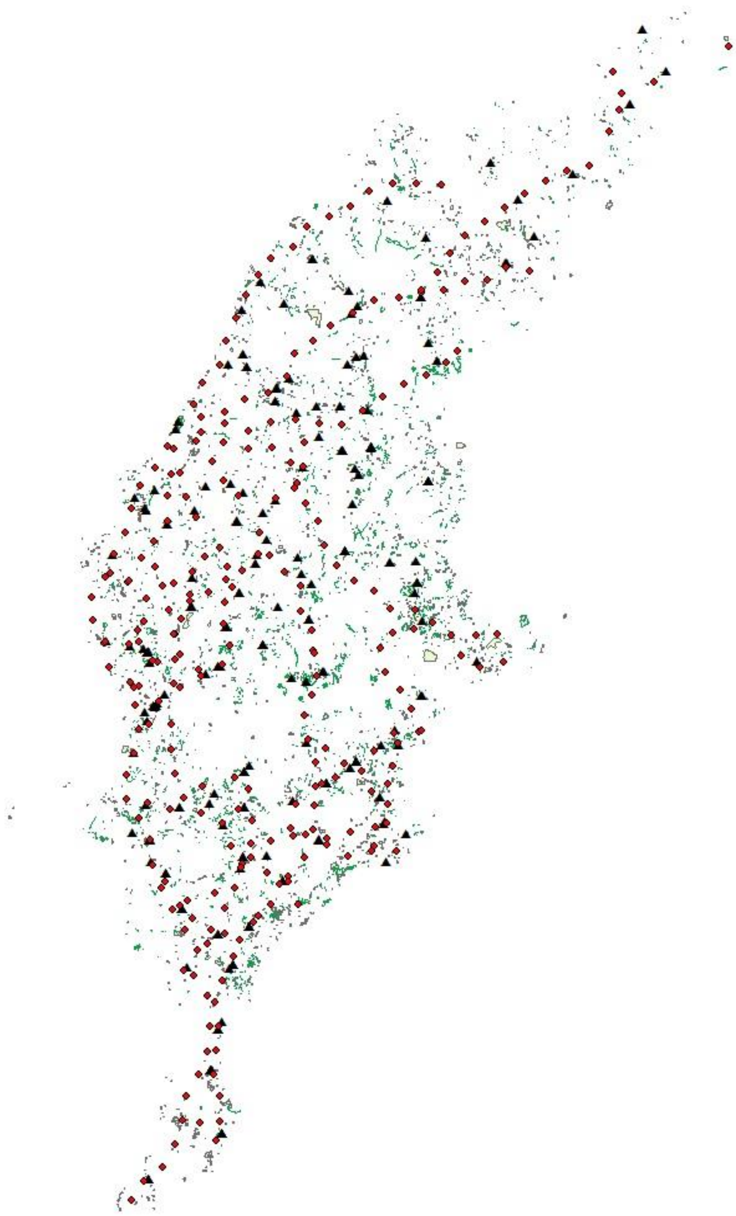


Figure 3. When the milestones (red) and runestones/picture stones (black) of Gotland are mapped out together, you can clearly see that they seem to be placed along very similar networks of straight lines.

The Ripley K test, the one that first sparked my interest did not disappoint the 2nd time either, this time run by 999 permutations for 99% accuracy the observed K-functions of the two materials was still extraordinarily similar. As you can see on figure 4, both materials keep above the expected K-function, displaying a very similar level of clustering until reaching a distance of 30000 where the both take a sharp turn and become significantly dispersed. That is, to the software the runestones as well as the milestones appear significantly clustered for 3/5 of the total distance, after which they mathematically become significantly dispersed.

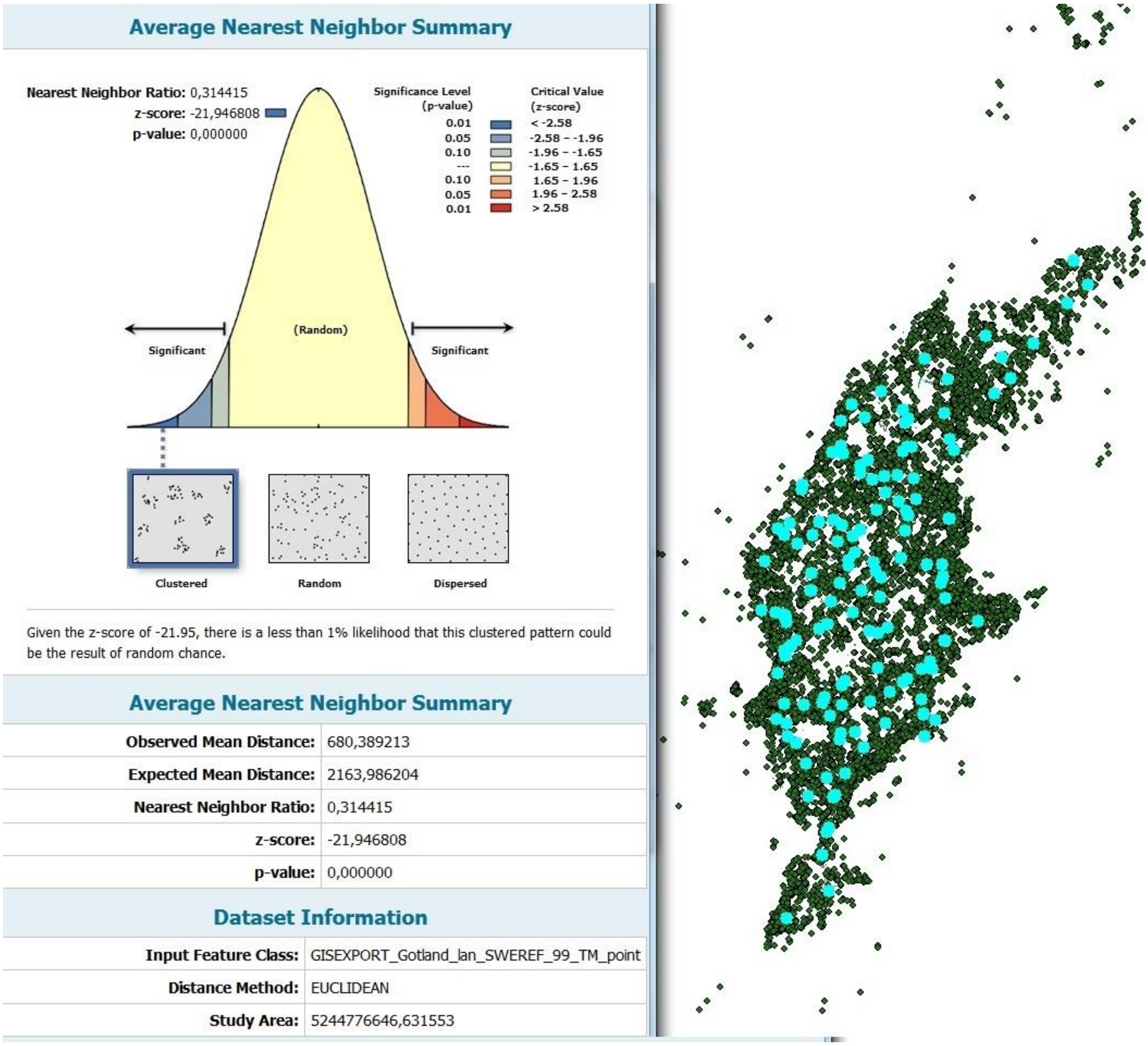


Fig. 2: Gotland rune and picture stones. Again the material (the rune and picture stones of Gotland), are highlighted in blue to the right. While to the left we have the results of test. P-value and Z-score both display extraordinarily low values, indicating very organized clustering.

What does this mean? First of all it means that not even confirmed and well-structured systems of road signage are clustered when each feature is compared to the next over the entire map, and not just to its nearest neighbors. The fact that they both become mathematically dispersed at the very same distance of analysis could thus be seen as an argument for the fact that the rune stones on Gotland indeed are lined up in a linear pattern of infrastructure. We can also see that the main difference between the two graphs is that the runestones observed a less static K-function, which means it is slightly less regular in its clustering. Perhaps this could be attributed to the fact that I did not have time to go sort through the FMIS files on rune stones, again if one where to study the Gotland material in detail, and not only as a comparative model, I expect the graph resulting from a sorted material to be slightly more uniform in its curve.

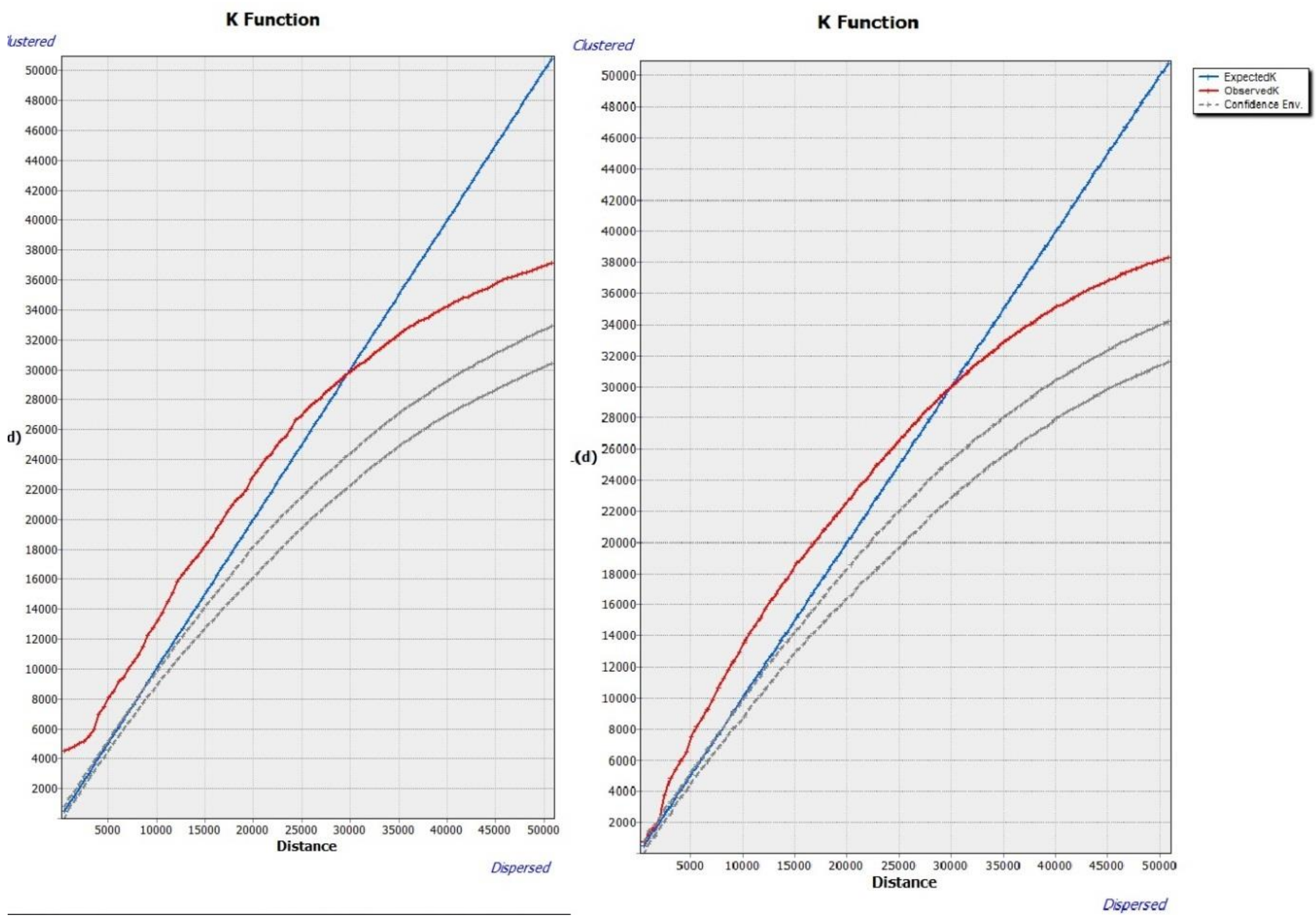


Fig. 4. Ripley's K factor. Slightly more uneaven rune stone graph to the left, and the milestone graph to the right. The graphs show that the milestones and runestones holds very similar levels of organisation on all permutations. The more steady graph to the right most likely means the milestones are slightly more homogenic across the board.

4.1.2 Scania Data

4.1.2.1 Average nearest Neighbor Analysis

After doing the work of going through every single FMIS post on Scanian rune carvings and realizing that up to a third of them was either out of context or created after the Viking Age, I decided to run all the tests on the Scanian runestones twice. First, like with the Gotland data, I ran all the tests on all features registered as rune carvings or picture stones in FMIS, to get a comparable result to the Gotland material. Then after segmenting the Scanian runestones into a database of reliability I ran the tests again for a more relevant output.

I also created a separate selection table for the Scanian milestones, the result was a map (Figure 5.), that in my view correspond really well to the early maps we do have of Scania's road system, I think here primarily of maps like "*General Charta Öfwer Hertigdömet Skåne*" from the late 1600's (see http://www.riksarkivet.se) and Gerhard Buhrmanns map from 1684 (http://www2.ra.se/kra/ bilder/galleri/kb1.pdf). A generally high level of preservation for the Scanian milestone system is also confirmed by the statistics. The Scanian material also scores within the 99% accuracy limit for significantly clustered with a Z-score of -12.608110, slightly better than the Gotland but still not as significantly clustered as the Gotland rune stone material. The P-value of 0.000 again confirms the result.

If working from the theory that the runestones should somewhat mirror the larger historical infrastructure, in comparison to the Scanian milestones as well as the Gotland material, the Scanian rune stone material does appear considerably fragmented (even through visual inspection only). Though a quick query in FMIS will tell you that there actually are as many as 87 posts of Scanian rune stones in FMIS, some of these are duplicate, moved or simply medieval/early modern carvings, and they are all more or less centered around the western and southern coast. The good news is that they even in this state appear to be clustered around three paths (clearly visible on the figure 6). One long path stretching from Ängelholm in the North, or possibly from the Småland border as indicated by the most northern point, through Lund, Uppåkra, Trelleborg to finally stop in the Österlen/Ystad area. A second possible path stretches off after Uppåkra, taking the inland path through Österlen to the east coast, and a third path is visible sweeping of the main path just north of Lund by Lödde å and stretching of into north-east Scania; though clearly these two bi-paths are considerably less even.

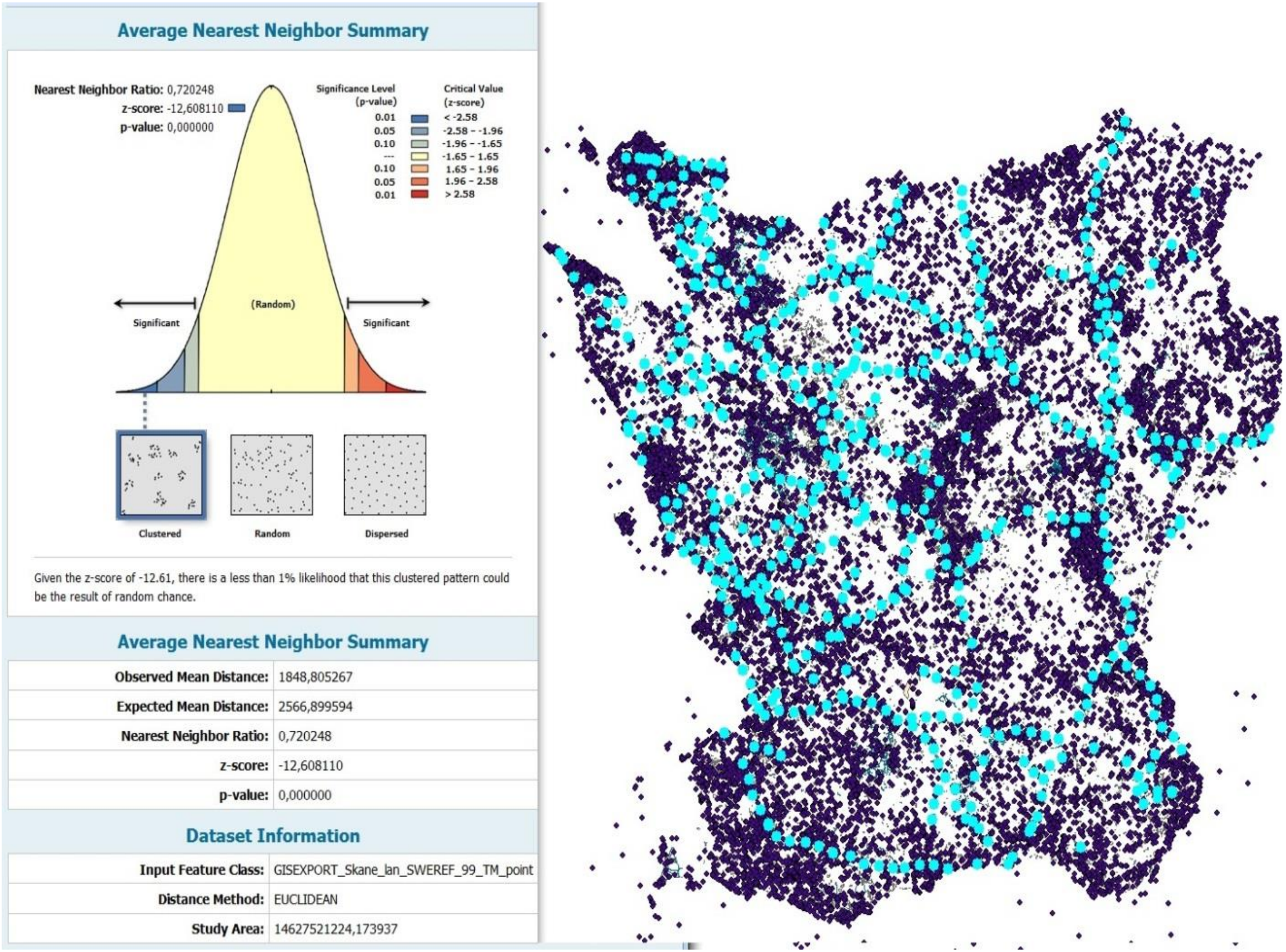
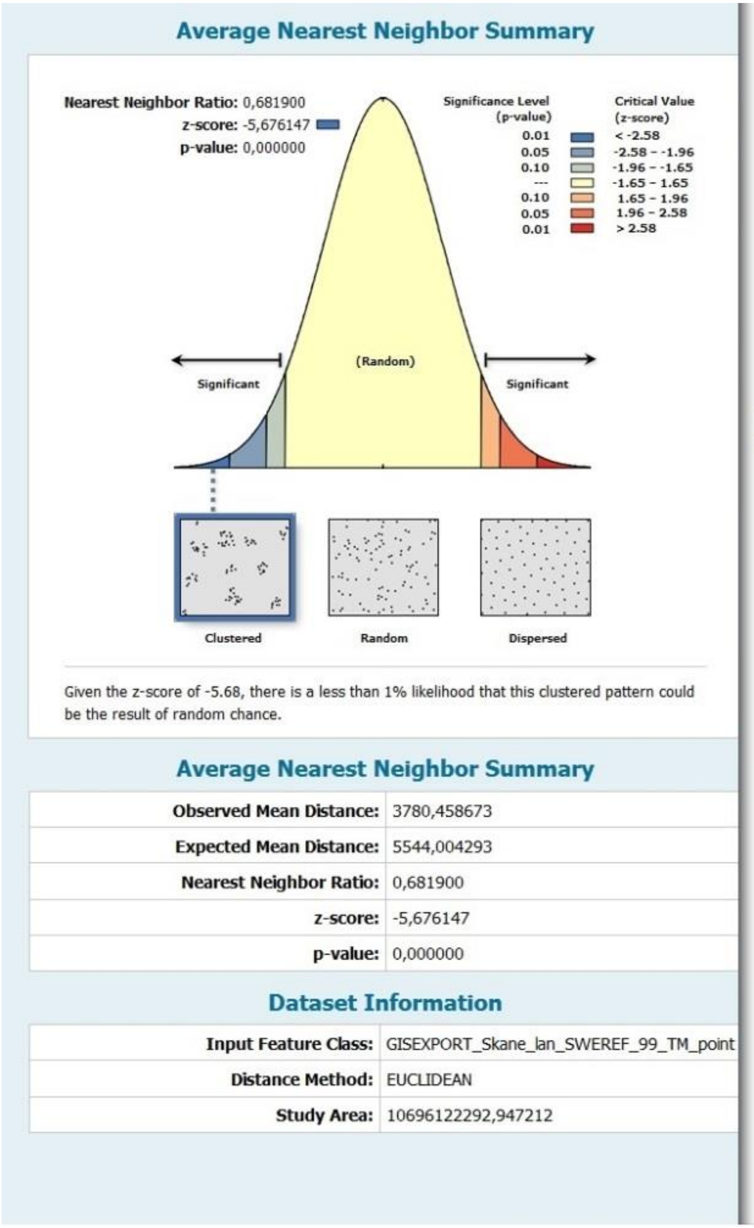


Figure 5. Average nearest neighboor test, Scanian Milestones. The analysed material is highlighted in light blue to the right. To the left are the test result disscussed in the text. Again the z-score is one of a very organised material



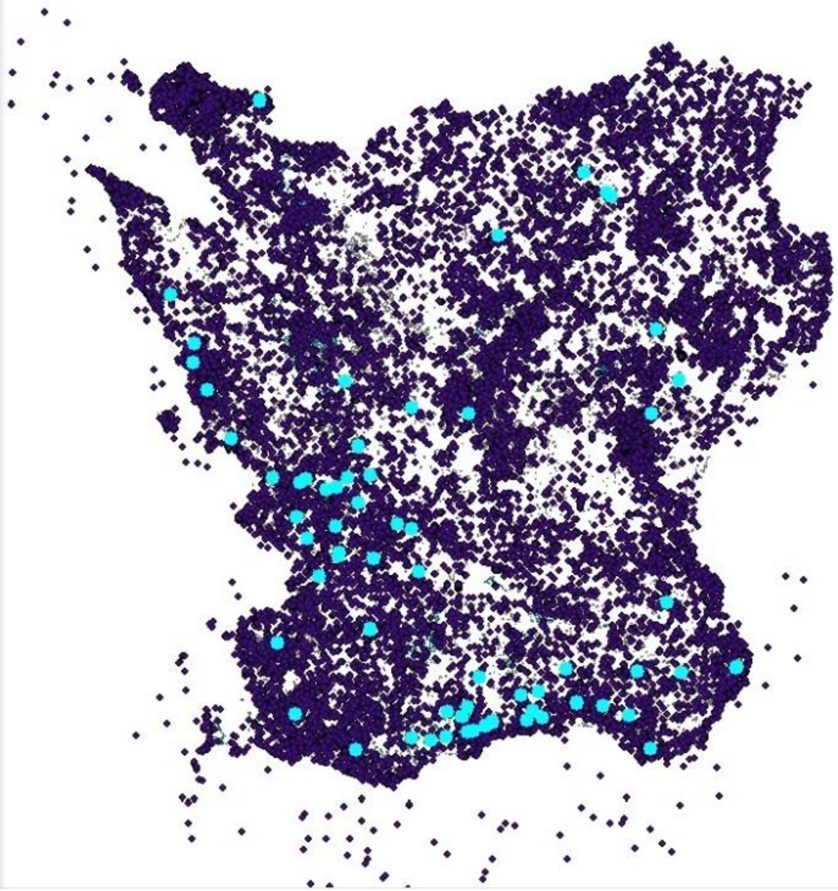


Fig. 6: FMIS'S Scanian runestone material un-edited. To the right all features in FMIS categorised as Scanian runic stones. To the left the results of testing the material. The z-score of -5,6 is more similar to that of the Gotland Milestones than that of the Scanian Milestones

Perhaps to be expected, the Scanian rune stones did not test as good as the Gotland stones as the Z-score for the unedited material test was -5.676147 (figure 6). Although remember, as the limit for 99% accuracy is -2.58, this is still a very good score. It is also significant because it is quite close to the Gotland milestones Z- score of -7.53, which after all is a system of roadside signage I think no one would question. Again the P-value lands at 0.000. It seems that the Scanian runestones indeed does have a lot in common with coast-centered systems of road signage.

After running these tests I went on to sort through all the FMIS rune stone files. Initially I was doing this to determine which parts of the observable rune stone paths had the highest concentration of rune stones still standing in their original context. However rather quickly I realized that a large number of the stones that deviated from the paths were either post-Viking period carvings or removed from their original surroundings in the early modern period. This is when I decided to run the Scania tests again. So before running the tests again I did a new selection based on this research (summarized in appendix). The new selection consisted of the 10 Scanian rune stones with a more or less confirmed original position, the 5 accounts of no longer standing stones I found most trustworthy and lastly a large number of rune stones that have only been moved locally e.g. from a field to a farm or to early Romanesque churches. Based on having read all survey files in FMIS, I have concluded this last group of stones that have been moved to a new local context is by far the largest of all devisable categories. Most of these were also in some way connected to a church, either built into the wall of the church, standing in the grounds, or built into the wall of the surrounding graveyard.

While delimiting the material further turned out to create far more homogenous paths visually, the software quickly determined that the material was even more fragmented and handed me the worst Z-score to date -3.045928; though still within the 99% margin both for Z-score and the P-value which lands at 0.002320 (Figure 7). In other words the Z-value rose ca. 2.6 units with the removal of the features I judged to be out of context. However, a good chunk of those stones where real rune stones with unknown origin, so a slight drop might not really indicate anything substantial when based on a material that just became ca. 18% more fragmented (judged by out of context stones in the FMIS database; look to the appendix for further details). Another possibility is that some of the locations of the out-of context stones correspond better with the clustering than some of those judged as closer to their original position. So I continued on, running tests with fewer of my categories activated, by the logic that if removing one category would result in a higher Z-score, it could be said to confirm the idea that I had a few bad apples in my so called "safer categories".

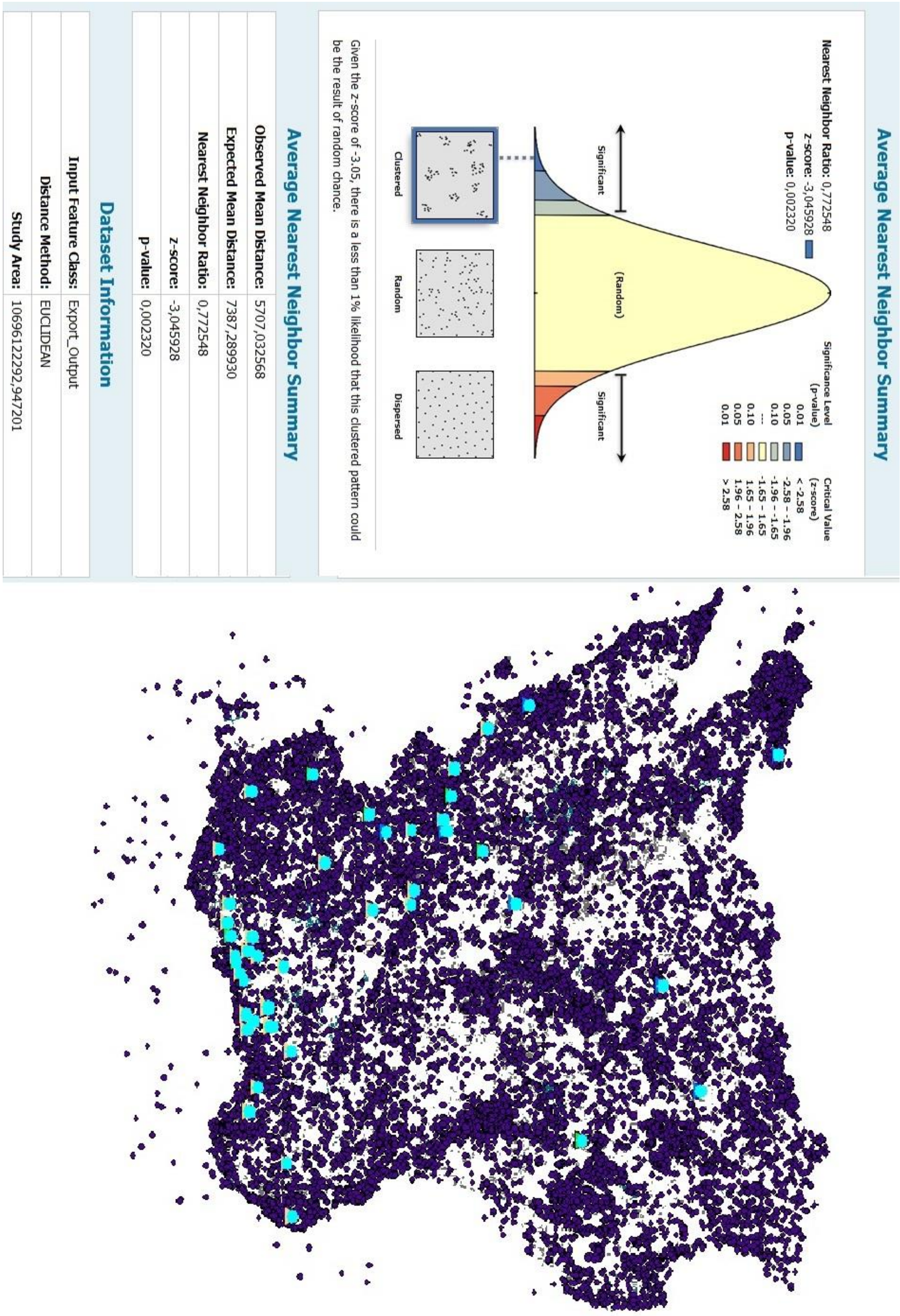
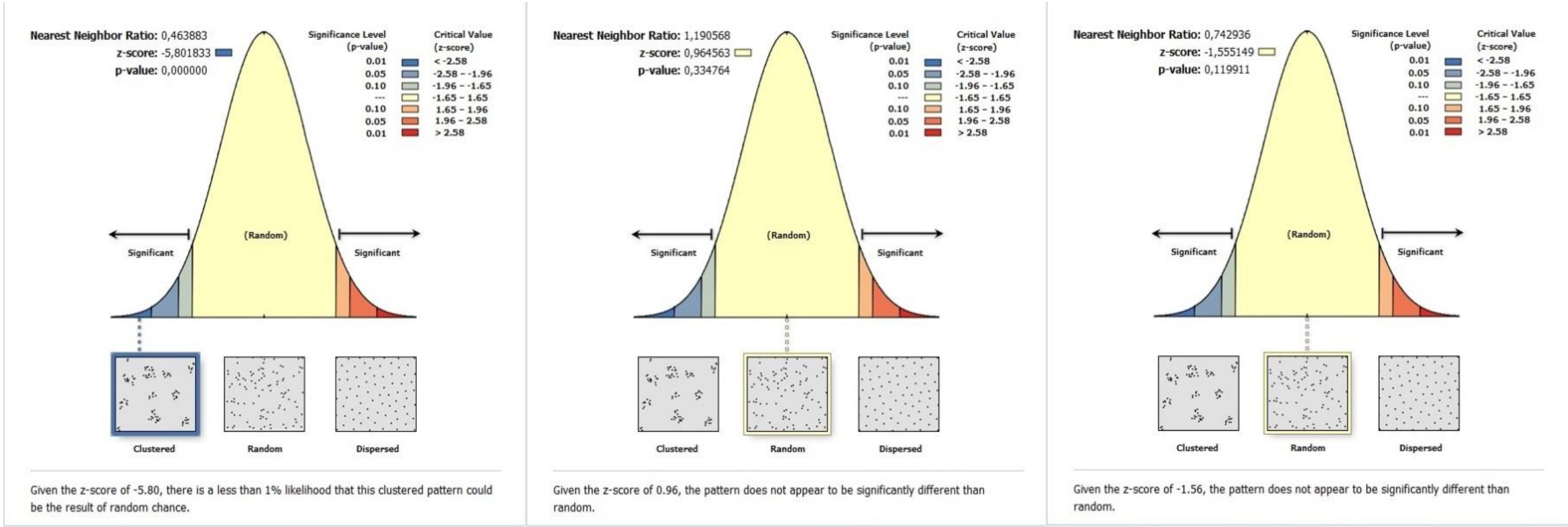


Figure 7. Scanian rune stone material, edited. This test included all runestone locations judged to be close to or identical with the stones original position (highlighted in light blue). While visually the result is something that looks more like roads. The Z-score shows a lower grade of organization than when including runestones that have been moved longer distances, as well as stones that are not from the Viking age.

The results of this 2nd round of edited material tests in part confirmed both my suggested explanations for the slightly worse Z-score (all results in figure 8.). Testing the location points based on written and oral sources together with the ones for stones believed to be in their original position resulted in a Z-score within the randomized spectrum of 0.964563. Testing only the stones that are suggested to be in their original context in the FMIS survey files also resulted in a result with the randomized spectrum, with a Z-score of -1.555149. This could be said to confirm two things: a) the Scanian material is so fragmented that cleaning the databases too hard can result in a drop in statistical significance b) as the source based files and the files for original stone locations tested worse together than the in context stones did alone, it is quite possible that some of points based on historical sources are not reliable (even though I had already weeded out the ones I found to fantastical, again look to the appendix for details).

This was in part also confirmed in the next test, where I removed both the out of context features and the features based on historical sources and finally got an edited Z-score that was lower than the unedited Z-score. Using only the stones in their original context, as well as the ones that appear to have been only locally moved, turned out to result in the best numbers for the Scanian material overall, with a Z-score of -5.801833 and P-value of 0.000. This also proves that the low Z-score of the unedited material was not reliant on its larger database, as a cleanup cutting away as much as 51.7 % of the original database resulted in a lower Z-score.



Average Nearest Neighbor Summary

	a)	b)	c)
Observed Mean Distance:	4240,498460	23269,577685	12148,835533
Expected Mean Distance:	9141,304908	19544,932018	16352,463341
Nearest Neighbor Ratio:	0,463883	1,190568	0,742936
z-score:	-5,801833	0,964563	-1,555149
p-value:	0,000000	0,334764	0,119911

Dataset Information

	a)	b)	c)
Input Feature Class:	GISEXPORT_Skane_lan_SWEREF_99_TM_point	GISEXPORT_Skane_lan_SWEREF_99_TM_point	original_position
Distance Method:	EUCLIDEAN	EUCLIDEAN	EUCLIDEAN
Study Area:	10696122292,947201	10696122292,947201	10696122292,947201

Figure 8. From left a) In context + locally moved stones b) In context + Source based stone locations c) In context stones only. This figure shows three different groupings of tests based on the categories in figure 10. In essence it shows that while analyzing to few stones will corrupt the pattern and test as random, the runestones test as most organized when only testing the standing stones still close to their original context.

4.1.2.2 Multi-Distance Spatial Cluster Analysis (Ripley's K Function)

The Ripley K - Multi-Distance Spatial Cluster Analysis progressed very much in the same manner, although it can be said to have had an easier time identifying the Scanian materials vertical nature as a result of organization (most likely because it measures on all distance and not just closest mean-distance); the effect of this is clearly visible in the graph summary. As you can see in figure 9, the Scanian runestones tested significantly different from the Gotland material. While the Gotland material was significantly clustered at 2/3rds of the total distance, the Scanian material was significantly clustered at the majority of all instances. The runestones databases also tested slightly different in these test, compared to have they tested in the nearest neighbor test. Here (clearly visible on figure 9's upper row), the first version of the edited database clearly tests as sharing most similarities with the Scanian milestones. Though not as similar as the Gotland test results , they both start rising significantly at around 5000, peak in the middle around 23000 and then dip down toward towards less significant results at the larger distances; the shape of which they bend towards the expected randomization line is also the most similar of all my Scanian based tests.

The Ripley K algorithm, measuring over larger distances, thus had no problem seeing the relationship between the runestone-points based on historical sources and two other categories of runestones, which should mean that most of them are genuine after all. Based on these results you could read the corresponding results from figure 7 to mean that the stone locations based on written sources, could simply be located in areas of poor preservation. Looking at the map (figure 11) you will see that most of these points stand in the north of Scania, where runestones are both more sparse and stand further apart, which really would lower the statistics of a test based on average mean distance in between features. This could also be said to be confirmed by graph 9F, which shows that removing the points based on historical sources does not result in higher levels of clustering when measuring over larger distances. The portion of the graph that gives a clustered result, hugs the confidence envelope for the randomized blue line for its entire duration, at least by comparison to the test that included the source based stones. It then sweeps off into the dispersion field in the same manner as the Gotland stones, though perhaps this is simply to be expected from a rather thin and vertical spread of features (though this does in no way discredit the portion where it actually tests as clustered).

The important part here is that both the edited tests of Scanian runestones resulted in graphs that corresponded better to the milestone graphs than the graphs for the unedited Scanian material, suggesting that there is rhyme and reason to the way the runestones are placed in relation to each other. Together with the results of average mean distance tests the runes stones across the board, give a good result of significant organization within the spread pattern, as long as tested in decent numbers. And in the case of the edited Scania databases, on a level that is comparable to the milestones.

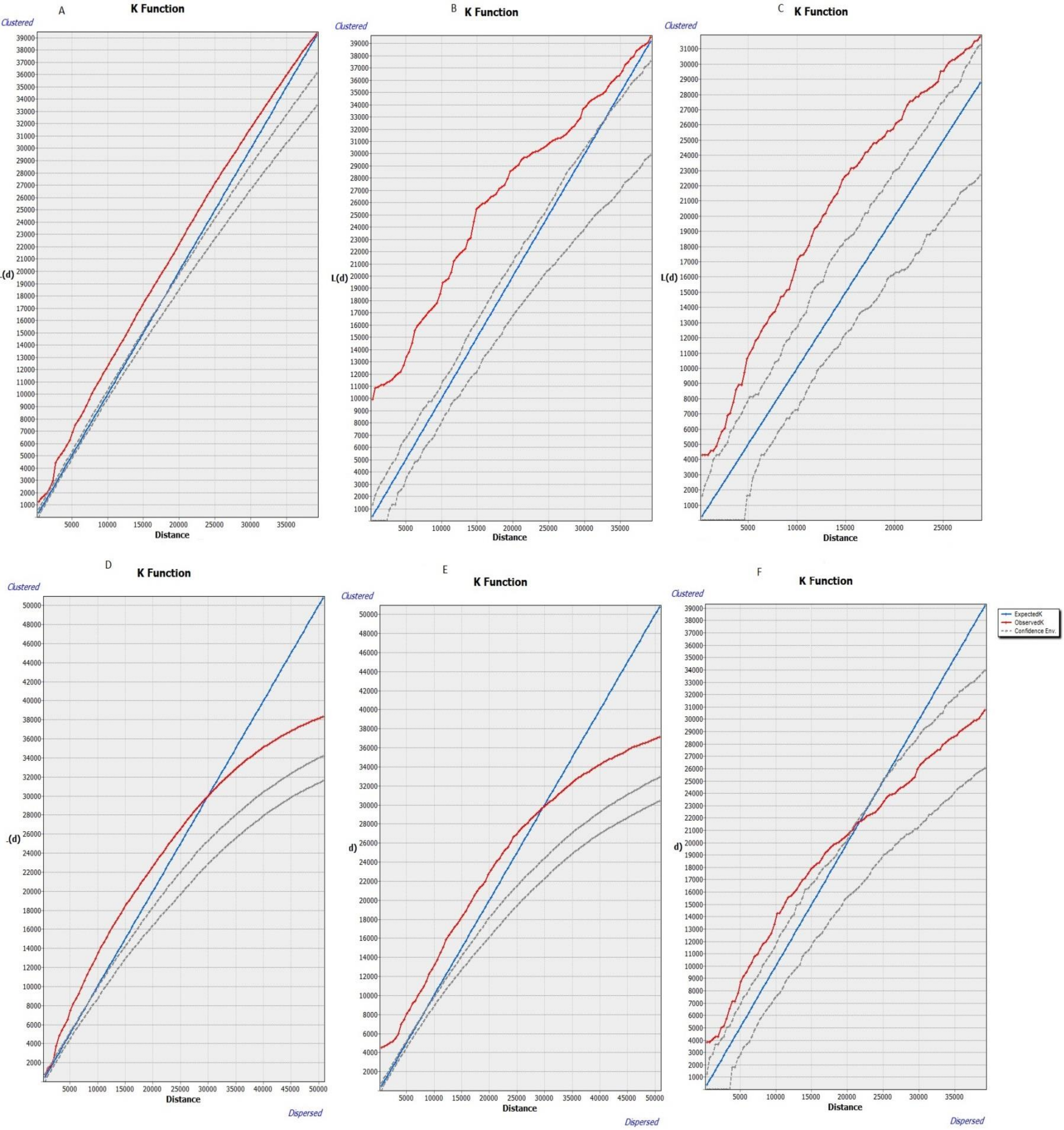


Figure 9.

A) Scania milestones B) Entire Scanian runestone database

C) Edited Scanian runestone database D) Gotland mile stones

E) Entire Gotland runestone database F) Scanian runestones in original and semi-original context.

4.2 Low cost path Analysis

4.2.1 Material

The categorization of the FMIS database used in the statistical testing was initially simply meant to aid me in selecting suitable targets (start and end points for the path) for the low cost path analysis, but doing this work changed both my view of the material itself and correspondingly its limits, potential and my plans for how the analysis should be conducted. Both the process of doing this research and in turn categorizing the material based of it, also took a lot longer than I had planned for. Largely because of the poor state of the FMIS runestone survey records on Scanian runestones, or at least the transferred accounts of them in the database; in the end I estimate I've put almost 4 weeks into researching and categorizing the Scanian runestones. The level of research done on each stone in the official surveys (or at least the level of presentation of it), was embarrassingly un-even. There are even files for fragments in museum collection, where the surveyor didn't bother to identify them, and simply wrote down how many stones there where in the collection (e.g. RAÄ Lund 86:3).

While reading and making notes one every single file on Scanian rune and picture-stone carvings in FMIS, I sorted these under 5 categories: post-Viking Age stones, stone locations based on historical records and oral traditions, stones moved completely out of their contexts, stones judged to be in their original context by the Swedish National Heritage Board and one last category of stones that has been moved only locally (for example built into an early church wall). For the sake of the GIS analysis I then merged these into 4 categories based and level of reliance, and created 4 corresponding color shapefiles for these categories in ArcGIS, creating a base map for the cost path analysis (the milestones where put in as a 5th category for visual comparison to the mid 1700's road system :

- **Green triangle - Original Context Stones**. Stones deemed by the Swedish National Heritage Board to stand more or less in their original position, or very close to it.
- **Purple triangle - Moved Stones.** Stones who have been moved locally, e.g. to the local church, estate, or from a field to a nearby farmhouse for protection.
- **Blue triangle - Lost Stones.** Stones only known to FMIS surveyors through written source material, or primary oral sources.
- **Red triangle - Out of Context stones.** These include medieval rune carvings, less believable claims of stone locations in written sources, and current locations for stones that have been moved far from their original context (e.g. coordinates for stones that are now in museum collections). These stones are not used in the least cost path analysis.
- **Red circle – Mile stones.**

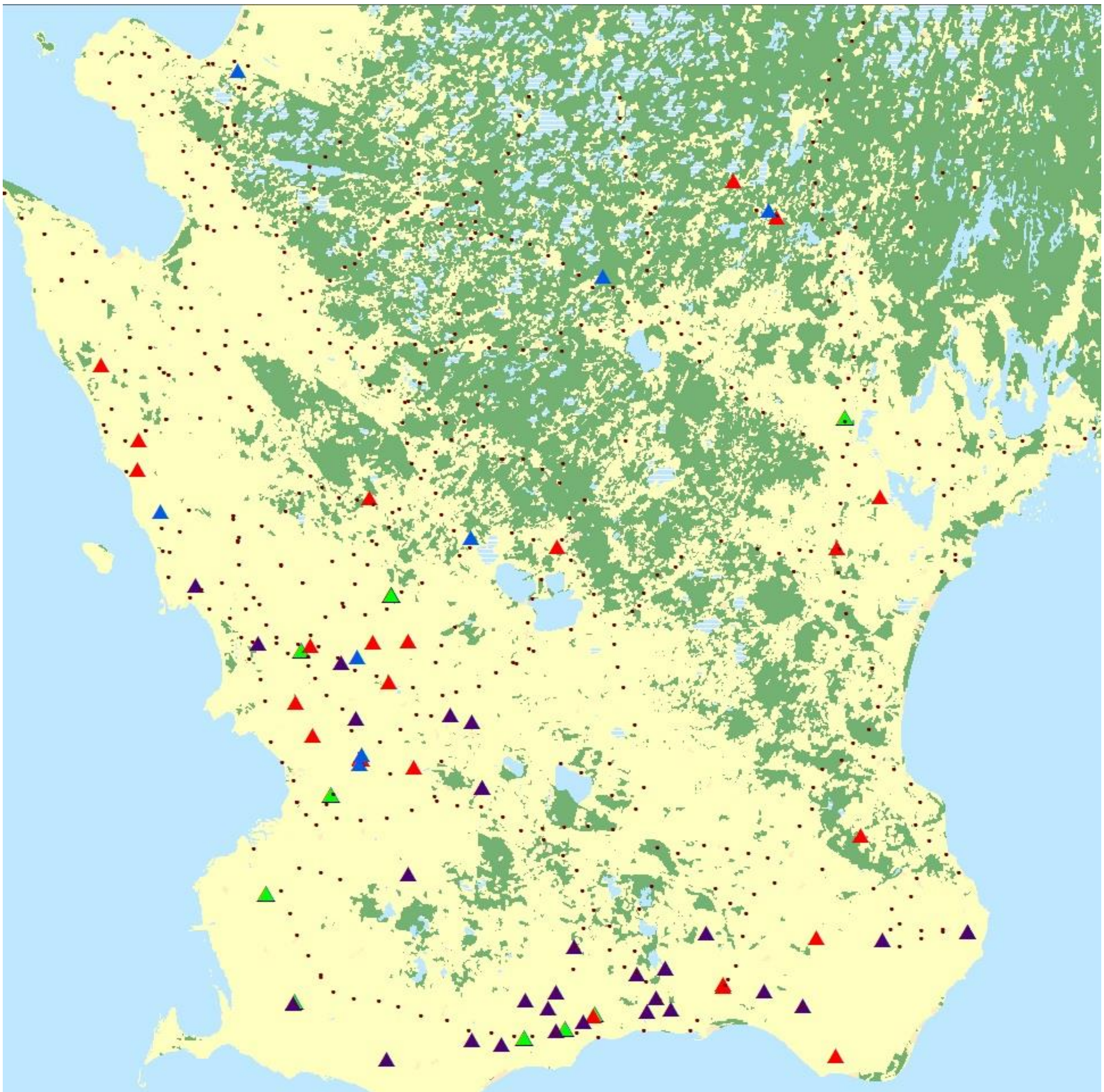


Figure 10. All the Scanian runestones and milestones by category

Figure 11. All the runestones and milestones taking into consideration for the least cost path analysis, by category. The two areas chosen for the analysis itself are marked in red polygons.

The next step of the method pipeline (see chapter 3.5 *Method workflow*), was to remove all stones that where not trustworthy, creating a new landscape of only stones likely to belong in the runestone paths. All data pointed to the fact that the majority of runestones in the category marked by a red triangle on the map (figure 10), are not likely to be part of the context behind the organization pattern of the runestones. This is based on research made in the FMIS files that judged many of them to be either post-Viking Age in date, or simply moved larger distances in early modern time, and based on the statistical analysis who indicated a level of organization less correspondent with infrastructure when they were included. But also based on visual inspections of the map material, where clearly the red triangles represent a larger percentage of the locations that deviate from the otherwise very linear runestone clusters than any other category. Visually they are also the category of runestones who overlaps the least with the milestone-paths. Based on all this, I made the choice to remove this category from my virtual landscape completely before starting the least cost path analysis.

Removing this segment of the data resulted in the new landscape you see in figure 11, which just like the almost identical point selections used in the statistical analysis portray very road-like, organized, linear clusters of runestones along the coasts facing the Öresund strait and the Baltic Sea. At the same time you can see that some areas (like the area in-between Uppåkra and Trelleborg, see figure 11) are considerably sparser on runestones than others, in fact probably to sparse to use as a material without taking other factors like central places, land-use, wetlands and forestation into account. And as the computers available to me are not powerful to handle a LIDAR based digital elevation model the size of Scania anyway, the logical conclusion, was create two different case studies, by picking two segments of the landscape with a larger number of runestones, as well as elements relevant to my ideas on the creation of semi-energy conservative infrastructure (see method and theory chapter). This involved fitting the areas showing the less dispersed runestone clustering with orthographic satellite photographs with a 1m resolution (acquired from Lantmäteriet through the SLU Geographic Extraction Tool service), as well as all other corresponding FMIS data, to employ together with the now color coded runestone material in a form of digital landscape survey, to determine suitable areas for building digital elevation models. Based on this digital landscape survey I ended up choosing the two areas marked in red on graph 10.

Along the south coast I found my first area, in the stretch of land in-between the Källstorp Runestone (RAÄ Källstorp 2:1) and the Bjäresjö runestones (RAÄ Bjäresjö 4:1, 72:1); this area was chosen for its lack of obvious, potentially road manipulating agents (e.g. well established central places) or landscape structures (such as large bodies of water or high potential for heavy forestation). It was also chosen due to its seemingly high level of landscape conservation, judged by a correlation between a high number of runestones standing close to their original position in very tight linear clusters, as well as the high preservation of other landscape features, like the village separating cairn walls that here looks extraordinarily well preserved compared to the rest of Scania (visible in the thin blue lines on figures 13, 15, 16 and 17), and because it has a large number of well-preserved mounds. In other words, I choose this area because the material and landscape is optimal for testing if all my theoretical assumptions about the runestones, early infrastructure, as well as my categorization of the runestones, are indeed correct. In opposite, the second area (the marked area around Lödde å), was chosen as a material to test the other side of the coin. While my digital landscape survey of this area showed many promising features (e.g. in some areas field boundaries in-between some of the runestones where a lot straighter than surrounding field boundaries), I believe that structures like the river, it is potential offloading points and Lund, represent such strong agencies that the paths represented by the milestones and runestones are likely to strongly deviate from the least cost path.

The last part of material in this segment of the analysis is LIDAR-data elevation data. In Sweden there is a more or less nation-wide LIDAR coverage, created by Lantmäteriet through aerial laser-scanning, with an average point space of 0.5 meters. Like the orthographic satellite photos, elevation data corresponding to the two areas of case-study was acquired from the National Land Survey of Sweden through the SLU GET tool. The elevation data is delivered in an LAS format, which for ArcGIS 10.0 means first converting said LAS files into Multipoint files, which in turn (for the sake of the analysis) was converted into a DEM (digital elevation model), TIN files (vector based, triangulated DEM), raster (pixel) based DEM's, and slope-rasters. The slope rasters are what the Least Cost Path tools actually use for the calculation of energy conservativity, by the logic that the more vertical a slope, the more costly it is to traverse.

4.2.2 Southern Case study

As previously described this case-study analysis focuses on the area along the southern coast of Scania, more specifically in the area in-between Källstorp and Bjäresjö; runestone locations that ended up being part of the calculated paths include the runestones at: Källstorp, Tullstorp, Östra-Vemmenhög, Skivarp, Västra-Nöbbelöv, Sjörup, as well the two runestones in Bjäresjö. The mid-18th century road represented by red circles on the image (figure 15) are used as a comparative material, and as you can see it is a road still in use today, on modern maps called "Landsvägen".

Cost Path Analysis, though named like it would be one, singular analysis, actually consists of larger number of processes and sub-analysis, for greater efficiency these are often pipelined into one analysis toolbox matrix. This is so that the output of each part of sub analysis can feed into the next automatically, creating one uniform tool, where only the material for the path at hand need to be switched out between the calculation of different paths; an example of this can be seen in figure 12, which display the ArcGIS 3D-analysis toolbox/matrix I created and employed in this analysis. In this graph blue shapes display data input, green display data output, yellow symbolize tools of sub-analysis and the arrows show the feeding of data in-between said stages of analysis, ending with the final output: the generated least cost path. The graph shows the whole process, which involves converting raster DEM into a slope calculated raster surface of analysis, re-classifying the different levels of slopes into even categories of depth and height, assigning proportional cost values to said categories by way of an weight overlay, and then finally using calculating cost distance in relation to the now weighted categories of slopes between the chosen markers on the raster surface (in this case the Dagstorp and Lund Runestones).

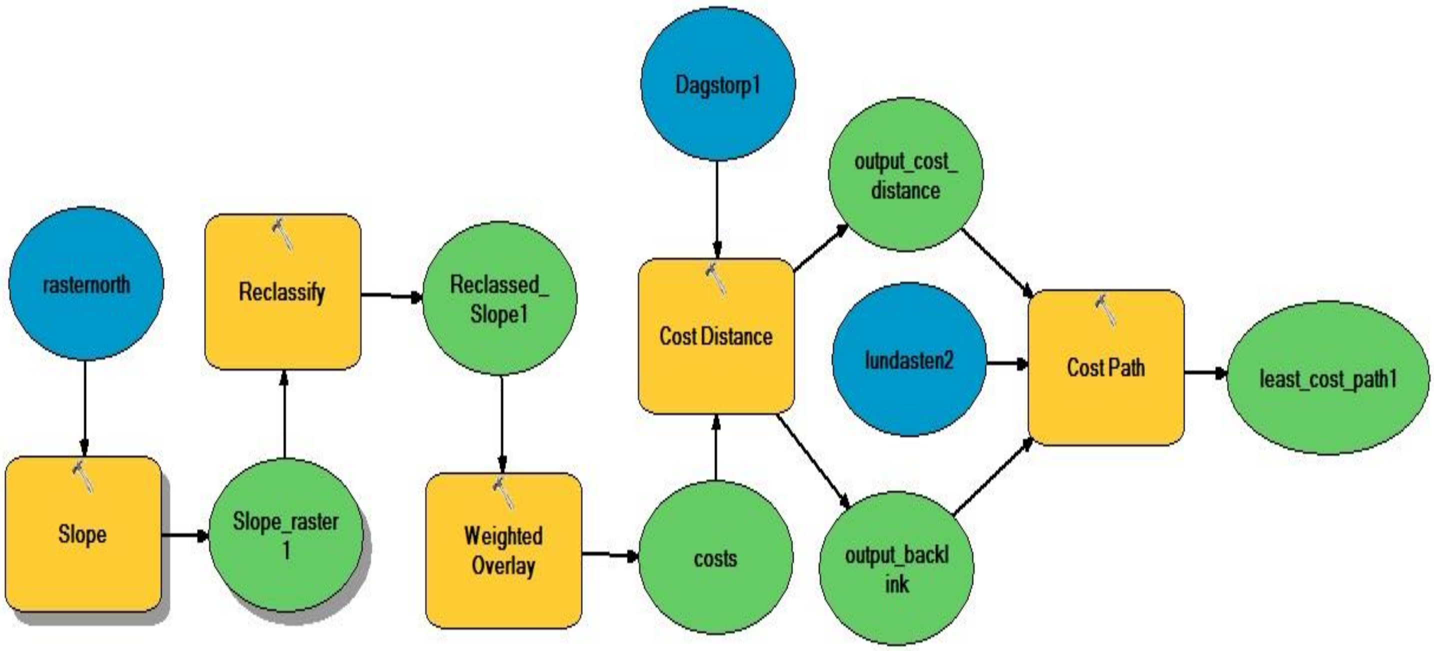


Figure 12: Least cost path toolbox: Blue = input, Green = output, Yellow = tools of sub-analysis.

4.2.2.1 Testing & Results

The image below shows the 5 paths I generated for the southern case study, each path color represents individually calculated least cost path run in the order from bottom to top: in-between each cost path calculation, adjustments were made in either weighted overlay or choice of runestones to use as hubs/targets. The purple line indicate the first/test run of the analysis run with the Källstorp runestone and the southern Bjäresjö runestones as targets, here the energy costs is only in proportion to the steepness of the slope (no land-use is taken into account); as a result the algorithm quickly identifies the portion of sea-bottom captured by the laser as the most easily traversed part of the DEM (much like Bell & Lock's initial problem in their study from 2000, with their path climbing down the ridge, into their lowland, and then up again, rather than keeping an even energy distribution). Changing the algorithm calculation the way Bell & Lock (2000) did was beyond my capabilities at the time, and building a new weigh-overlay including detailed land-use (like known Viking Age bodies of water and wetlands) was simply outside of my remaining time frame; my more primitive solution instead consisted of re-assigning the weights of the deepest slopes in the elevation model. The path is instead briefly discussed in relation to topography in chapter 5.1.2, through the Iron Age topography maps of the Ystad project (Berglund 1991).

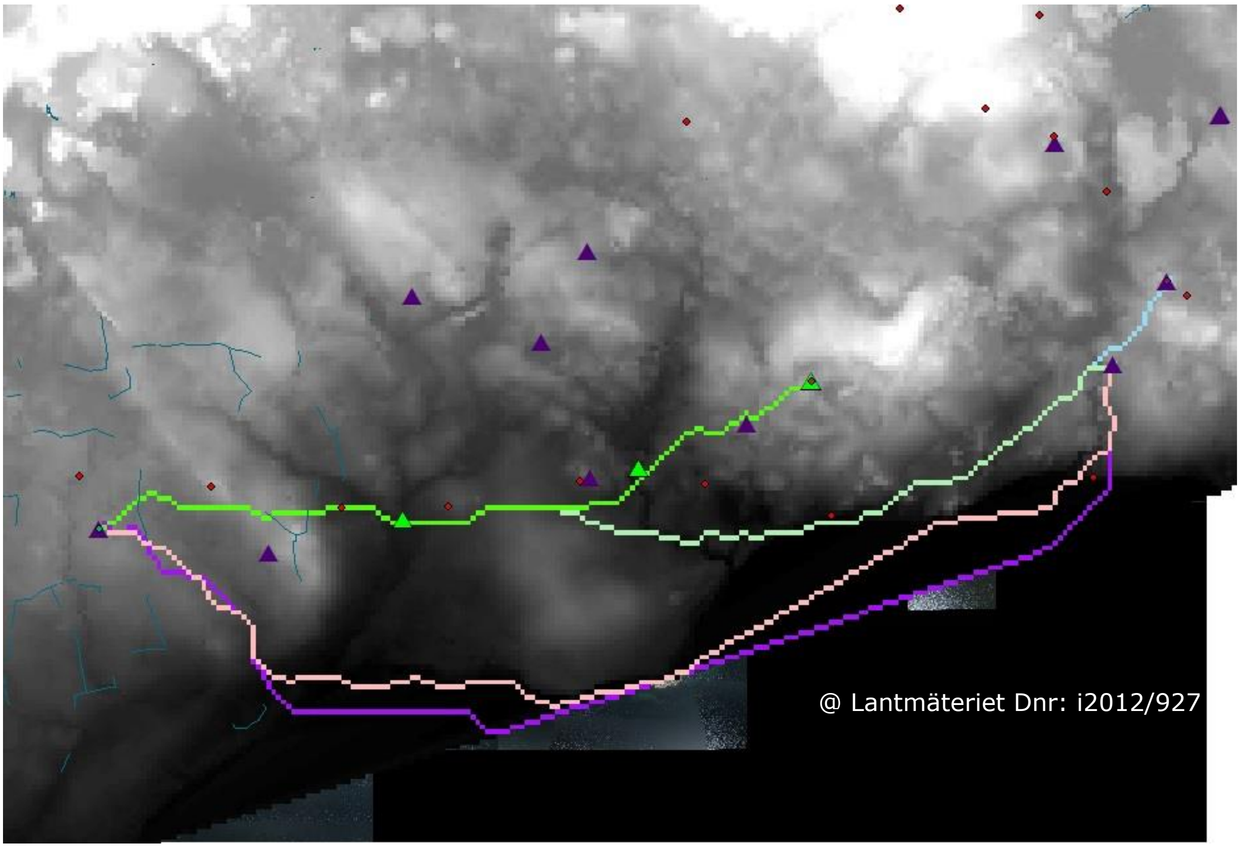


Figure 13. Least cost paths with different cost distribution and targets, in order of trial and error: purple, pink, light green, blue and neon-green. The background shows the raster DEM used as the surface for the path analysis.

The 2nd path (generated as a pink line on figure 13), thus differs from the 1st path in that the deepest 10% of slopes in the landscape have now been given an identical cost weight, as the highest 10% of slopes (by the logic that crossing deep waters should be at least as costly as traversing steep slopes). The result is a path that for the most part follows the modern coastline, but as you can see the bay at Abbekås (marked on figure 14) is just shallow enough to remain outside of these 10%. Because of this and the fact that the water levels was higher in the Viking Age than now, I modified the weight overlay again, now making the lowest 20% as costly to traverse as steep hills. The sea level was only slightly higher, but lakes and their rivers see a significant rise around 750 AD, and the area still had large areas of fens and waterlogged fields (see Berglund 1991 pp.82-85). With the added cost of traversing through areas that are likely to have been flooded or marshy, the 3rd path (light green), hugs close to the 18th century road, and actually cuts straight through the location of the Östra Vemmenhög runestone. This of course means that Östra Vemmenhög is the most conservative place to traverse the possible river depression cutting through this area of the raster DEM (black areas marked in orange on figure 14).

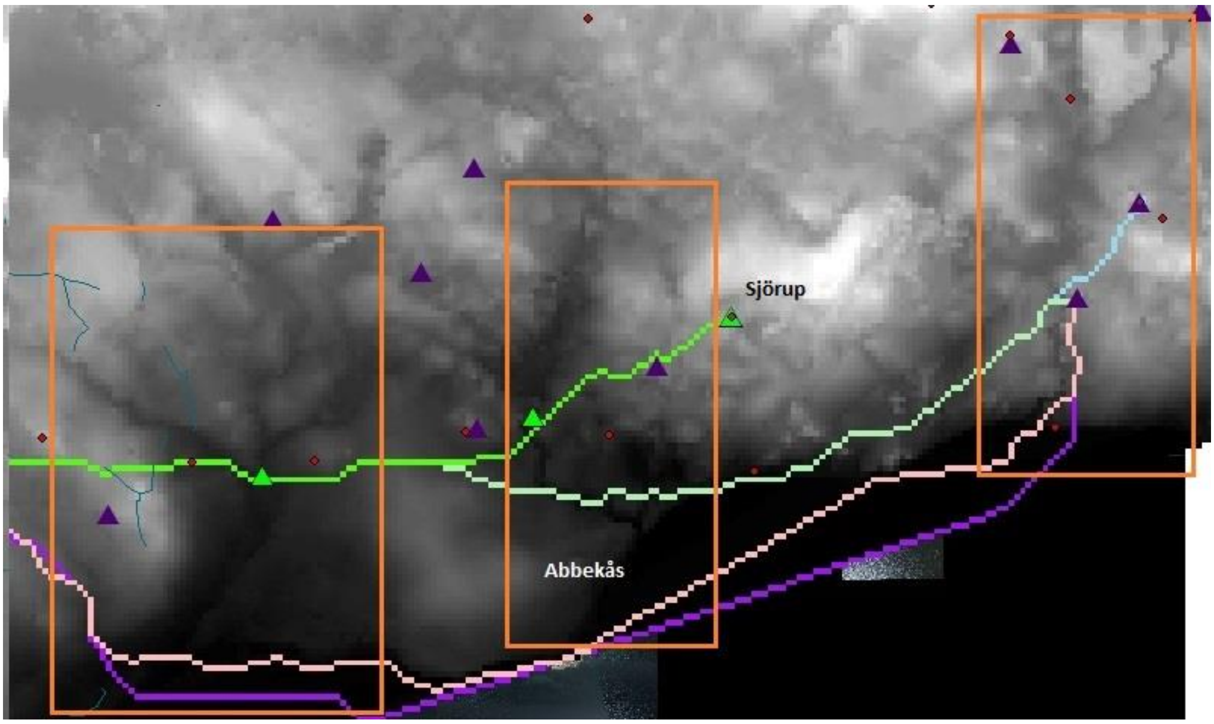


Figure 14. The orange squares, marks river-like depressions in the landscape that seem to affect both the 18th century road and the least cost path.

The most eastern of the in-context runestones (the Sjörup runestone), is clearly visible as standing by the top of a hill on the raster model (the model consists of a pixel based grid, where high points in the landscape are shown in white, while low points are shown in black). While the Skivarp, Nöbbelöv and Sjörup stones all stand on the nothern side of the hill, the 3rd path passes by southern edge of it. Hoping that this simply was because of me choosing a target stone that stands south of said hill, I ran the same path analysis again, this time with the nothern Bjäresjö stone as end destination; this is the 4th path, the blue line which as you can see does not deviate from the 3rd path until it arrives in the area of Bjäresjö. What does this mean? It means the Skivarp, Nöbbelöv and Sjörup stones does not stand on the most energy conservative path inbetween Källstorp and Bjäresjö, though as already discussed in the chapter 2.5 *Least cost path – A cognitive archaeological method with a Darwinian perspective*, this does not necessarily mean that the runestones were not roadside monuments.

Based on the idea that one of the runestones could actually represent the Agency that bends this potential streatch of road from it is most energy conservative path I decided to run a 5th and final path analysis (the neon green line); as the u for this line I choose Sjörup. I choose Sjörup primarily becaused it is the most eastern stone in the study area judged to stand in the general vecinity of it is original position, but also because it is the only stone in the study area to not stand by a corridor of lowland. The result is a positive one, as visible in the 5th path on figures 13 and 15, when setting the precondition that the path must pass through Sjörup, all in-context runestones lay on the least cost path, and all the runstones inbetween that are judged to be moved only in realtion to the local parish, stand on, or very close to the least cost path. Suggesting that not only were the majority of the runestones in this area placed along a path of energy efficiency, but also that said path was subject to the influence of a structure or agent within the area of Sjörup.

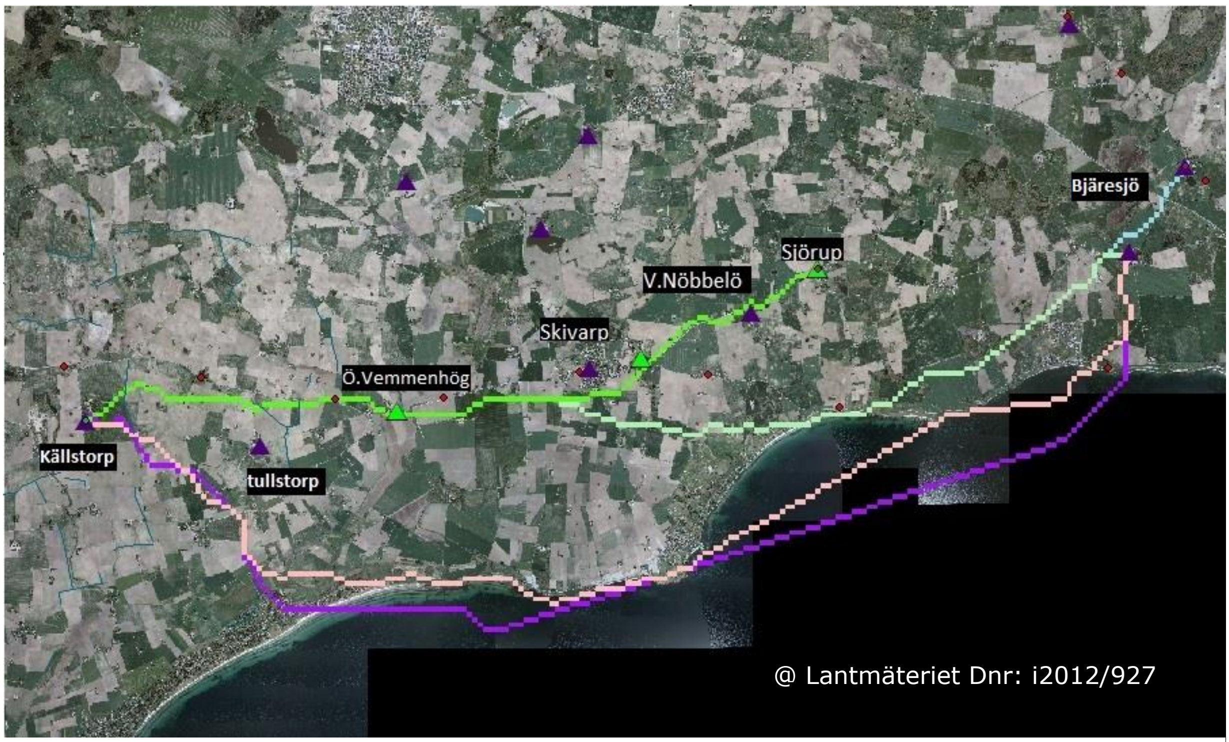


figure 15. All 5 calculated paths, geo-referenced to satellite photography of the area.

4.2.3 Northern Case study

Geographically the northern area of case study is really more central than northern but it is still northern as the Scanian runestone material goes. This also means that by comparison to the southern material it is considerably more sparse, which was one of the reason I choose it as my second area of study. The other reasons (as mentioned earlier), were the two gigantic anomalies visible on the raster elevation grid said study area (Figure 16); that is Lödde å and its surrounding river depressions (black and dark gray lines in the center of the image), and the hill that Lund stands upon (the large white field in the bottom-right corner of figure 16). Both are costly to cross by foot, while at the same time being hugely important to the early medieval and late-Viking Age trade-network (Svanberg & Söderberg 2000 pp. 258f). These considerably more problematic circumstances makes the area North of Lund a good are to test the method under less favorable circumstances.

The nature of the testing was more or less identical to the southern case study, and the toolbox visible in in figure 12 was in fact constructed for this test. The only difference between said toolbox and the toolbox used for the southern test, is that it is cost-weight overlay is divided into groups of 5% instead of 10%, as I suspected the northern raster grid could need more detailed adjustments.

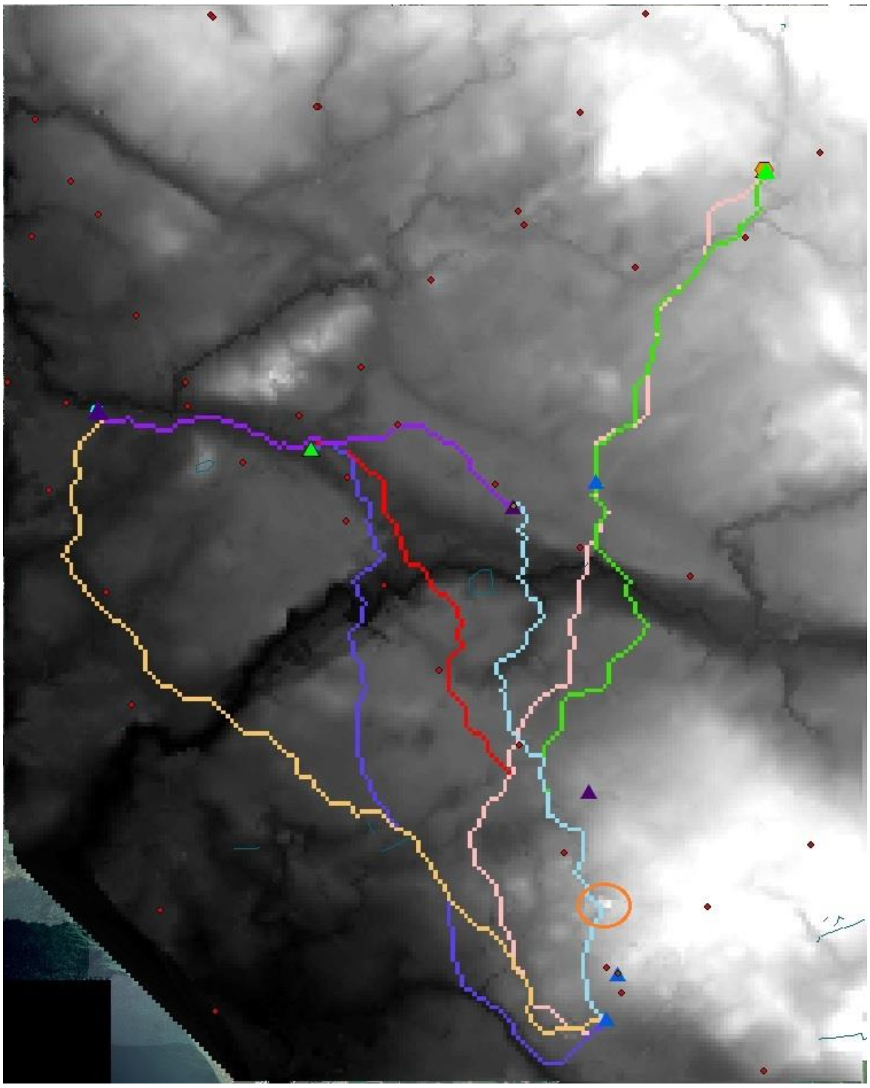


Figure 16. The 7 generated paths in the northern case study highlighted in different colors. Again the map beneath show the DEM grid used for the analysis. The red dots signify the milestone road system.

4.2.3.1 Testing & Results

The northern case-study was conducted in the same stages as the southern case-study, except that 7 paths were done instead of 5 due to the fact that the paths here line up in a road-fork. Just like the southern case study I started with conducting tests with energy costs only proportional to the steepness of the slope (not accounting for water etc.). The results of these are the pink line in between Lund and Västra Strö and the purple line in between Lund and Dagstorp (marked on figure 17); as visible this again resulted in unfavorable paths. First of all, the LAS conversion tool used in building the northern DEM (mentioned in chapter 4.2.1 *material*), failed in any attempts to completely remove the urban landscape of Lund. Resulting in a section of land that is very uneven and full of building fundaments of very sharp slopes that the path avoided like poison. There was also a problem with the earthworks in and around St. Hans Backar (a former, modern waste disposal site, marked as an orange circle in figure 16), which cuts of two natural depressions/passages in the landscape, as well as the fact that the path again tried to maximize it is time spent crossing areas that in reality consists of larger bodies of water.

I corrected this in much the same way as in the southern case-study, by making the deepest 20% of slopes more costly to traverse. Except for the fact this time I also had to adjust the weight cost of the upper 15% of sharpest slopes, to do away with the anomaly of St. Hans Backar; the number of 15% as a correct representation of non-natural Scanian earth works, was chosen through a series of experiments. The paths calculated post this modification is shown in the green, blue, yellow and electric indigo colored lines (figures 16 and 17).

The green line (Lund->Västra Strö), now follow the borders of medieval Lund, exits the hill through the more eastern of the depression, and follows the hill of the Vallkärra stones first recorded position much closer. It then crosses Lödde å in a more narrow area, passes by the ditch (identified in FMIS) where the now lost Lilla Harrie runestone once stood, and then continue to follow straight field boundaries, continued by a visible depression all the way up to Västra Strö. The path in-between Västra Karaby and Lund does not fall into the fork pattern of the runestones at all, showing that the organization pattern of the runestones as well as the milestone path that runs from Lund to V. Karaby through Kävlinge are subject to path influence in-between. Having 3 runestones in between I again tried to identify this hub of influence (like I did in the 5th path of the southern case study), this time dividing the path into two separate calculations (blue and indigo).

The blue line (Lund->Stora Harrie) follows the same pattern first, until cutting of in the direction of the 18th century road and bridge, though heading for St. Harrie it instead makes a right turn, down through a Depression in Kävlinge, where it crosses the river and continues straight for St. Harrie. The Indigo line (Store Harrie->Västra Karaby), then continues forward along two milestones, before bending south to cross the Dagstorp runestone, to then follow the depression around Saxån for the remaining stretch to V. Karaby. For greater confidence in these result I then continued to calculate a path with the same setting in-between, Lund and Dagstorp (the red line).

To sum up, the analysis of this case-study shows that when calculating a forked path from Lund to Västra Karaby and Västra Strö that also has to pass through Stora Harrie, the least cost path connects all the runestones in their original position as well pass through or very near to the runestones that have been either lost or who have been judged to only have been moved within their local context. This suggests that both Viking Age Lund as well as some sort of structure or agency in the area around Stora Harrie; subjects the organization of the runestones to heavy influence.

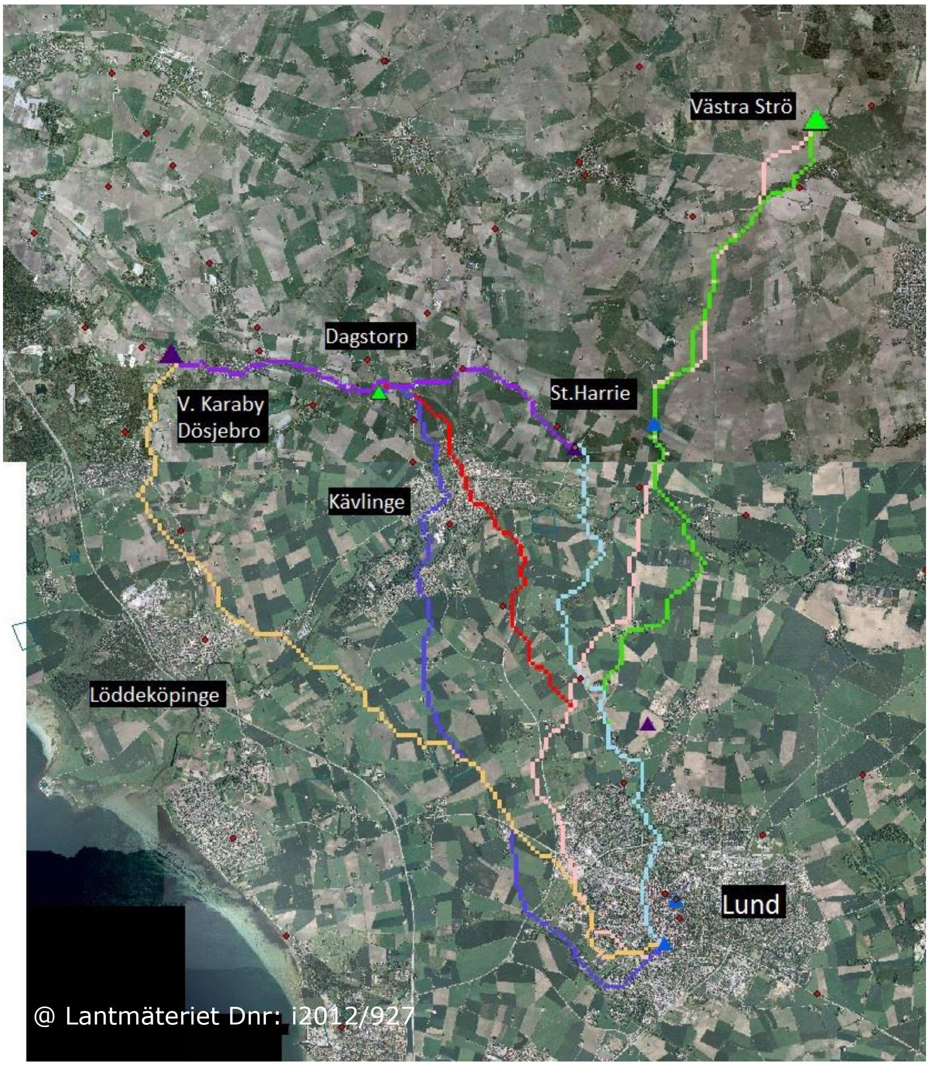


Figure 17. The 7 generated paths in the northern case study highlighted in different colors and geo-referenced to an orthographic map of the area.

5.0 Discussion

Completely in line with the statistical testing, the least cost path analysis suggested a linear, common reference of organization for the runestones, and furthermore it showed that this common reference consists of energy conservative paths, that in part overlap with stretches of known historical roads. However it also showed that these paths are not the most energy conservative way to cross the research areas, but rather the most energy conservative paths in relation to a few key areas in the landscape. So in this chapter I discuss these results and relate them to their archaeological and Late Iron Age contexts. I also discuss the output, success and potential of methods tested in the analysis.

5.1 Continued habitation and warrior aristocracy? The bump in the road by Sjörup…

The analysis showed that while some of the runestones where situated on the natural path of energy conservation through the center of the study area, 33% of the studied stones where situated only along the most energy conservative path if you were heading for Sjörup. Suggesting that something (ritual, ideological, economical or hierarchical), in the vicinity of Sjörup old church, held enormous influence over the surrounding landscape.

The Sjörup runestone itself is really quite famous, partly because it has been known to academia since the 1620's when it was drawn by a Jon Skonvig for the Danish work *Monumenta Danica,* but perhaps primarily because the text on the stone speak of a battle at Uppsala often interpreted as the famous battle of Fýrisvellnir. It is also a quite early stone, and has no sign of Christian impact within the original carvings (Moltke 1985). According to *Monumenta Danica,* when the Danish antiquarians came to inspect it, they found it being used as a bridge over a small creek, according to their information it had previously been standing by a mound "an arrow shot" north of the church (e.g. see FMIS survey file for Sjörup 3:2). Only one of the Sjörup mounds is known to stand in that general area (Sjörup 20:1) which stands right by the side of the country road marked by its current milestones in the mid-18th century, which the Danish antiquarians most likely would have come travelling down 100 years earlier. It was with a certain degree of doubt that I categorized the Sjörup stone as being in its original context based on this, but in hindsight, with least cost path lining up with said road on its way up to Sjörup, I feel like it is indeed quite likely that the antiquarian Ole Worm knew what he was talking about; Sjörup 20:1, (only 200 meters from its current position) could very well be the original position of this runestone. The text on the Sjörup runestone reads as follows…

"Saxe placed this stone in memory of Asbjörn, his partner, Toke's son. He did not flee at Uppsala, but fought as long as he had a weapon" (Moltke 1985).

The text about the battle at Uppsala and the mentioning of warriors by the name of Asbjörn and Toke has caused them to be connected to the Hällestad runestones (Moltke 1985 pp. 294ff), which also mention Asbjörn and Toke, as well as other warriors who "did not run at Uppsala". The Toke on the Hällestad stones had the peculiarity of also having his name written in full form "Toke Gormsson", and on Hällestad 1 as "Gorm's Toke", stressing the relationship with his father. He is also mentioned as having huscarls ("heimþegi") on 2 of the stones, as well as being a "lovable Lord" ("Drótt"). Two of the stones at Hällestad also bare resemblance to the smaller Jelling stone, and Hällestad 1 is rather unique in having been used as the cornerstone of the church. All has led to the theory that this Lord Toke Gormsson was a brother or nephew of King Harald "Bluetooth" Gormsson, who escaped the chronicles by dying on a battlefield in Uppsala (Lihammer 2003 p. 103, Randsborg 1980 pp.40ff).

Prince or no prince, what is clear from simply compiling the texts, is that this Toke Gormsson was a very powerful and rich man who died on a battlefield surrounded by henchmen, somewhere in the area of Uppsala. And while stones like Västra Nöbbelöv mentions a Toke as the brother of the deceased Thegn (most likely brother in arms), the Sjörup stone is the only one where the deceased is mention as Toke's son, and the only Scanian stone, not dedicated to Toke, that says "he did not flee". The distance between Hällestad and Sjörup is quite far, but at the very least this opens up for the possibility that the Sjörup stone, at the very least, is a memorial to the son of one of the most powerful individuals in Scania at the time.

Figure 21. The Sjörup runestone seems to stand in a location that influenced much of the infrastructure around it. It has been speculated that the memorialized was a member of the Danish royal family at the time.

As already briefly mentioned, the runestone custom appears in Scania rather late in the game, with the oldest stones; the Örja stone (Moltke 1985 p.151-165), and the recently discovered Färlöv-stone (RAÄ Färlöv: 166), both most likely being transitional pieces at best. This makes the fact that the Sjörup stone stands in the central region of what looks to have been the most runestone dense area in all of Scania (Figure 11) a very relevant aspect. A higher runestone cluster density could of course simply be the result of an area having a larger host of upper strata individuals, exploiting and marking smaller regions of land. But a slightly larger literate population does not necessarily equal a faster spread of new cultural practices. The older runic alphabet may actually be of Scanian origin in the first place (Moltke 1985), yet the early presence of literate individuals does not seem to hasten the adoption of the runestone custom. Fast, large scale adoption of a new practice is thus perhaps also a sign of a very active and connected region, the complete opposite of a cultural backwater.

5.1.1 A mix of magnate clans and royal servants?

In her contextual analysis of the Scanian runestone material Hulting Lindgren (2003) notes that beyond being hosting the largest number of runestones, this area is also the only Scanian area were the memorialized are called "Thegn". The word Thegn is a title with the simple meaning "one who serves", a title that survived long past the Viking Age as the title for an aristocratic retainer. Both Moltke and Sawyer argue that the Viking Age Thegn should be seen as a senior, distinguished member of the elite, while the Thegn we know through, while the later tradition of a Thegn as a young nobleman in the service of a more distinguished nobleman, actually has more in common with the Viking Age titles of Drengr and Svenni. Moltke stresses a military definition of these titles, by comparing the runestone texts to the Anglo-Saxon definitions of Thegn, here Thengs originally were a sort of proto-counts and barons. He identifies these titles as those of upper-strata warriors of two different classes, with Thegn as a senior level, officers of sorts within the king's war machine. Adding to that a further level of command in warlords (Drotts) like Toke Gormsson who in turn just like the King could command both Thengs and Drengr (Moltke 1985 pp.284-316).

Moltke's description of the Viking Age title system actually runs very close to that of late-medieval Sweden, which consisted of the three classes: Svenne (the knightly class), Friherre ("free lord", head of one or multiple estates) and Greve (head of a county). Moltke does not argue that the Viking Age titles would have been hereditary, but rather dependent on the level of responsibility one was entrusted with by the local ruler. An interpretation that basically imply that the Scanian east coast with its Drott and his Drengr and the Scanian south coast with its 5 Thengs and their Drengr, represent a stratified system of vassals and royal servants through which the Danish monarchy might have ruled Scania.

The fact that we have 5 supposed Thegns on the Scanian south coast may thus be another possible answer to why we see the road bend away from its optimal path within the southern study area. To say so for sure, the test area would have to be widened to give room for all title stones of higher significance, but we might still have an indication in the Sjörup stone's neighboring stone; the V. Nöbbelöv stone. This stone was erected by a man called Toke and though the last word of the text is damaged, Moltke suggested that it most likely reads as Thegn. As shown in the analysis this stone only falls on the least cost path if it has to pass the Sjörup stone. If the V. Nöbbelöv stone stands on this less conservative path because of a significant estate of some sort, it would speak in favor of Moltke interpretation that the man Toke memorialized there actually was a Thegn. If the Toke of these two stones was the same man as Toke Gormsson, this would perhaps also explain why a Thegn stone would be placed along the road to another estate, as Asbjörn then would have been the son of an even more distinguished vassal.

Another possible vassal estate is found just east of the study area. In her Thesis from 2003, Caroline Hulting Lindgren mapped out a likely genealogy for the Hunnestad Monument and other stones connected to it by the names of the memorialized. The result is what looks as very powerful dynasty stemming from a man called "Gunne Hånd", who seems to have ruled multiple estates (at least the areas of Hunnestad and Gusnava), who then divided these estates among his sons. This monument has been moved, but as the general whereabouts of its original position is known, it might be interesting to in the future run a least cost path through this area as well. In part to evaluate suggested original positions, but knowing that there probably is a Viking Age estate in this area it would also be interesting to compare paths calculated in the Hunnestad area to the one around Sjörup.

Anglert pin-points the so called family stones of this region (those with texts primarily dealing in inheritance and family connections), as being primarily spread out north of the more dense clusters of stones in line with our calculated path (Anglert 1995); on figure 15 we see 4 stones displaying the same behavior. The fact that several of these more isolated stones along the south coast primarily relates to inheritance and ownership, perhaps speak to the fact that Scania as part of the forming Danish state, is less a kingdom of borders, and more one of which local lord is loyal to what overlord. More isolated, and seemingly more interested in tagging their land than connecting to a network of infrastructure, these stones perhaps represent the older local powers, rather than vassals of Sweyn, Harald or Canute. Scholars like Klavs Randsborg have suggested that the Danish Thegns could indeed have been very similar to the Anglo-Saxon Thegns. Which would mean that their ownership of land, though hereditary would have been dependent on their standing with the king, he goes on to argue that some of the post-Jelling period runestones marks the first successions in this new system of royal vassalage based on inheritance of royal land. He puts these supposed vassal stones in contrast to the family stones, arguing that these stones more focused on inheritance and ownership than titles represent a group of people that actually owned their land independent of the crown (Randsborg 1980 pp. 31-43). This scenario could explain why a probable vassal stone like the V. Nöbbelöv stone connects directly to the main runestone path, while more family oriented stones at times can stand several kilometers north of the path.

5.1.2 The Landscape

On figure 14, we see the remains of what looks like large river deltas highlighted within the orange squares, some of these depressions still contain streams to this day. These depressions are in turn surrounded by lowlands seen in the dark areas on the map; the path seems to for the most part stay away from these lowlands as well as hills (white areas), svirving through corridors of moderate slope in-between. The paleo-ecological maps of the Ystad project (Berglund 1991 p. 83) include the most eastern part of the study area (the area of Sjörup and Bjäresjö), based on this maps it seems that in the late Viking Age these lowlands were covered in patches of fens and wet-meadows, spread out in between more dry meadows and arable fields. Based on Berglund's ecology map it seems that these wetlands, were mainly situated in the area in-between the green lines on figure 13. This means that the wetlands would probably not have been the deciding factor that steers the runestone path off the most energy conservative path; as the coastal area where the 3rd path (light green) would seem to have been reasonably dry, at least not during the Viking Age. The wetlands may however explain why the Sjörup stone stand further up the hill than the V. Nöbbelöv stone, at least if we expect these roads to be used all year round and not just in the winter.

On the other hand if the road is significantly older than the Viking Age, the wetlands could have been a deciding factor. Moving backward through the periods from the Viking Age to the Mesolithic, the area around Sjörup fills up with more and more wetlands. But standing on one of the higher hills in the region, the Sjörup area is one of the few that seem to have had clear passage to the sea without having to cross any wetlands, even all they back in the Mesolithic period.

It has been known for some time that Sjörup may be host to an Iron Age site of even greater archaeological importance. The "Sjörup Find", dating to the late Migration Period and containing a larger number of broaches, sword details, scabbard mounts and riding gear in silver and gold, was discovered by a local lake by a farmer, and then sold to the Historical Museum in Stockholm in 1853 (see online catalog for 2663). There are also some late bronze age finds from Sjörup in the Museum catalog (e.g. SHM 9822:791), and an early medieval spear (SHM 11094:16). During the Ystad Project a Roman Iron Age settlement was suggested to be situated in Sjörup, due to an survey just east of the village, resulting in the finding of pottery and hearths (RAÄ Sjörup 23:1). There are still large, perfectly square crop marks around the area of the excavation (visible in de orthographic data from Lantmäteriet, as well as FMIS and Google Maps), to me suggesting that the actual site is much larger than the area that was investigated. Even further to the east there is also an excavated site from the Neolithic, and another Stone Age settlement west of the church, by the least cost path.

So we have Neolithic habitation, fine burial jewelry from the late Bronze Age, a settlement from (at the very least) the roman Iron Age, a rich hoard from the Migration Period, 3 mounds (likely Bronze or Iron Age), a warrior's memorial from the Viking Age, a stone church, and a spear from the early medieval period. It would be hard to argue that this continuous choice to settle on this dry hill would have had nothing to do with its favorable position in the landscape. At the same time there is no denying that we seem to have very powerful individuals living here in the early medieval period, individuals who doubtlessly would have shaped the landscape around them.

In my mind the findings of the southern case study should be placed in this discussion. As I see the fact that the low cost paths bends to go over a hill at Sjörup, instead of going below it (like the initial least cost path), just like the 18th century road bends to the manipulation of towns like Skivarp in the historical period (figure 18), as further evidence of Sjörup as an important prehistoric site of continual habitation, and the original position of its runestone. There is perhaps no real need to draw a clear line between the presence of powerful individuals In Sjörup and a favorable topology. As the land itself probably contributed to the rise of the Viking and Migration period magnate farmers and warlords, combining to the areas seemingly strong agency.

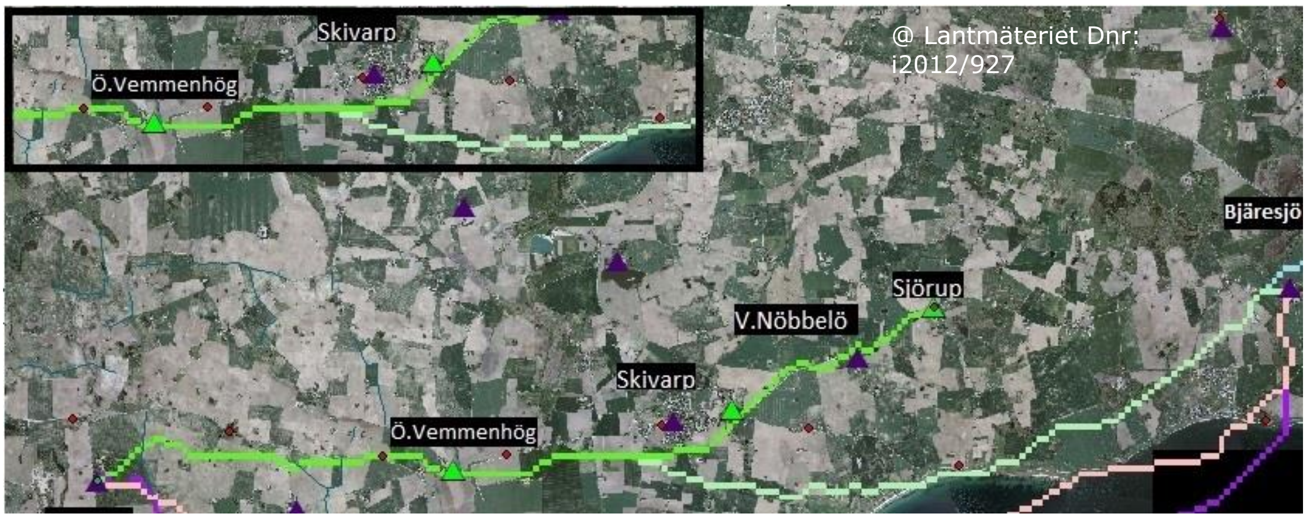


Figure 18. Main picture: runestone low energy path bends from the least cost path to pass over the hill at Sjörup. Black square: 1700's road bends from least cost path to pass by Skivarp.

5.2 The river, the Knytlinga clan, and the fork in the road…

Like expected the northern case study, proved a lot more complex, as not one but two potential areas of road manipulation agencies was seen in the analysis. Had there been more runestones in context runestones in the area I don't doubt that even further deviations could have been discovered. This and the fact that further cost manipulation had to be done to combat problems with the elevation data, as well as the river where other factors than path efficiency that may have gone into the building of a bridge across the river, makes the results of the northern case study more problematic and not as clear.

5.2.1 Lund, the town that caused Vikings to walk up-hill

The deviation around Lund is perhaps the least problematic. Lund was founded in the late 10th century and most likely by King Sweyn "Forkbeard" Haraldsson (Hårdh 2010 p.302), which makes it a strong royal presence at the same time as the Viking Age runestone custom spreads from Denmark to Scania (Randsborg 1980). It is not hard to imagine why Sweyn would have chosen the next hill north of Uppåkra for his new Scanian headquarters, if there indeed was a road running by it is foot. Nor is it necessary to assume that a very long period of time would have gone by, before Lund's royal connections caused merchants to walk up the hill instead of around it, and the road started following the top of the hill instead of on the plane below it. When you add to that the clerical and monastic characteristics of Lund, the Occam's razor lands quite close to my discussion about the bump in the road near Sjörup; in one word: power. The real difference being that in Sjörup we cannot say for certain that power and religion was present in the Viking Age, while these are more or less unquestioned in the case of Lund.

The only thing this deviation in my mind ads to the discussion is the fact that Lund was not really created on an optimal route of travel, but rather on an optimal place to control a route of travel. The oldest Scanian churches to have been excavated and dated are found here, the oldest church dates to around 990 which make it contemporary with the reign of Sweyn Forkbeard (Anglert 1995 p.66). It also makes the very first Scanian churches contemporary with the largest category of Scanian runestones, those of the so called "post-Jelling Period".

Christianity in the Viking Age is often related to authority, it spread with the King and those close to the king, while the majority of the population was most likely only Christian in name, by royal decree (As discussed further below, Scanian churches was not a common sight before the rise of the Estridsen dynasty, who rose to power at the very end of the Viking Age). It has been argued that the Christian runestones show the early hubs of religious influence through the higher aristocracy in the Christianization of Scandinavia (Sawyer 2000 p.17ff). The Lundagårdstone (RAÄ Lund 44:1, a post-jelling type), though not Christian in its iconography has been argued to have this function of portraying the will and influence of the king's vassals, cementing this new strengthened Danish power in the Scanian landscape in the minds of its people (Svanberg & Söderberg 2000 p.19). It was first discovered lying in the ruins of the Allahelgona monastery, in what during the Medieval Period would have been the most northern outskirts of the town, though still close to the central main street. During the Viking Age, this area could even be argued to have been outside of the town borders, making it plausible that the stone originally stood by the road leading down into the town's northern point of entry. Today the stone stands in the entry hall of Lund University's main library, very close to the location of the monastic ruins where the stone was found.

Moltke also discussed the impressive nature of the Lundagårdstone, though instead of focusing on its sheer size and obelisk nature, he focuses more on the art and the text. Within the text Moltke emphasized that the runes say "stones", plural not singular, meaning that the Lundagårdstone was part of a larger monument, perhaps comparable to other impressive runestone monuments like Västra Strö or Hunnestad (RAÄ Västra Strö 2:3, 2:4 and RAÄ Skårby 7:1). Moltke also mentioned the iconography of the Lundagårdstone, consisting of four-legged beasts and face mask, as aspects that should be interpreted as signs of power, protection and respect (Moltke 1985).

The face-masks are almost always argued to be connected to the very elite within Viking society, either by signifying Odin the god of lords and war, or Jesus Christ and the new religion of the Danish monarchy; either way most researchers seem to agree that the face masks signify power (Hulting Lindgren 2003 pp. 13ff). Hulting Lindgren makes another god point about the text, in the fact that the patron mentions his grandfather "Esge Björn", but not his father, highlighting that the patron's grandfather probably was a very important man. This could be compared to how the Stones mentioning Lord Toke Gormsson (Primarily the Hällestad runestones), almost always mentions that Toke was the son of Gorm, or even "Gorm's Toke". Furthermore we also have the Danish Grensten stone, were the patron also found it important to convey that he was the grandson of an "Esge Björn" (Moltke 1985). It would seem that once again we are dealing with a patron who while clearly commanding a lot of power of his own, is descended from men of even more

Figure 20. The Lundagårdstone, commonly mentioned as a memorial raised by vassals of either king Sweyn I or Canute the great.

absolute power. Hulting Lindgren also notes that the facemask of the Lundagårdstone seems to be wearing a crown, though details like that are of course always hard to prove (see figure 20). The title used for the memorialized "land-men" have been tied to royal vassals in control of large areas of land (Moltke 1985 p. 297, Anglert 1995 p. 154, Randsborg 1980).

> *"Thorgisl, son of Esge Björn's son, set up these stones in memory of both his brothers, Olav and Ottar, good "land-men" (lanmitr)"*
>
> *(Translation of the Lundagårdstone, as in Moltke 1985)*

Moltke interpreted the Lundagårdstone having both a facemask, beasts carrying weapons as well as crosses; as carrying a mixture of Christian and Pagan references, all relating to power. This is something that is not entirely uncommon in items related to newly Christianized monarchies, certainly there are a variety of Viking Age items from elite workshops that carry this duality (such as minted coins with both crosses and hammers). It has been argued that a similar phenomenon is visible in princely burials during the Christianization of England. Hines boils it down to tension in-between a new religion spreading amongst the upper strata of society being afraid to clash with tradition, their subjects, and time tested norms for signifying power (Hines 1984). In a similar way, the fact that only 13% of Scanian stones are outright Christian, and stones like the Lundagårdstone, or the Hunnestad monument, holds a duality within their iconographic message, could be interpreted as there being a new power in Scania. That the Scanian elite now serve two masters: their own local interests as well as the Christian kings of Denmark.

At the same time this power does in no shape or form appear to be absolute, or border based. I say this because we don't see any real Scanian church expansion before the second half of the 11th century (Anglert 1995 pp. 66ff), by the time of which Sweyn and the other candidates for Scania's first Danish kings are long gone. One would imagine this very slow and initially quite sporadic pattern of churches spreading out of a clearly Danish town like Lund, signify power being wielded through a network of Danish islands of influence and choke holds on the region, rather than by having conquered or converted actual land. Lund as the apparent headquarters of the Danish monarchy in Scania (Randsborg 1980 p. 75-84), would most likely have acted as a central node of this network, that at least by the looks of the least cost path, seem to have maintained its network of vassals through main roads and larger rivers. The church building expansion of the late 11th century could represent a 2nd face of this network.

None of the least cost paths calculated really crosses through early medieval Lund, the closest path instead graces the borders west of it (figure 17). This is largely in line with Maria Åkesson's maps of the early road networks, which shows a network of Iron Age farms and smaller roads west of Lund (Åkesson 2012 p.40). Yet the least cost paths also show that even after the Höjebro river-crossing, and the road that connects it to Lund would have started to be employed, the optimal path would still have been to turn west at the end of this road and not actually pass through the medieval town center. This does not mean that the road did not pass through Lund, The archaeological evidence of a steadily increasing presence of religious and royal power, as well as the more dense building patterns; makes it more than likely that it did. With that in mind, all the factors showing Lund as a settlement that Is not very likely to have been created on the optimal path of travel, should perhaps instead be seen as a testament to the power Lund wielded over its surrounding, as the central node of royal network branching out into Scania.

5.2.2 Lödde å - a major intersection?

It is really the deviation around the river that may require further analysis and discussion. Lödde å and its Viking Age harbor-settlement of Löddeköpinge have been well known for the last 50 years or so, and have often been discussed in relation to infrastructure. The trade settlement at Löddeköpinge has been known since 1964, and the habitations hosted a large plethora of finds from both the Viking Age and the early medieval period (Svanberg & Söderberg 2000). So perhaps it is not at all surprising that the waterway, which this harbor emporia would have been likely to use as its main trade-route into central Scania, should prove to have a large effect on other Viking Age infrastructure in the area. In fact the runestones have already been mapped in relation to early roads and the three waterways in the area; Saxån, Lödde å and Höje å (Svanberg & Söderberg 2000 p.22). The real center of discussion in relation to the river is thus the area around Kävlinge and Stora Harrie where the line of runestones splits into what looks like a fork shaped intersection (the most visible in figure 11). The analysis showed that all 3 parts of this fork in the road was part of energy conservative paths, the problem is the that the paths split before crossing the river, and I find it quite unlikely that the Viking Age road would split before the river as it would include the building of two bridges unnecessarily close to one another. In my opinion it is far more likely that the fork in the runestone path represents a natural offloading station, connecting Lödde å to a road intersection where transportations could continue by foot, north-east, north-west, or across one single bridge straight down to Lund.

The Stora Harrie runestone (if not moved to far) is the most southern runestone north of the river, and is thus worth discussing in relation to said fork in the road. The stone today only exists of a fragment of a once larger stone. Erected over a man named Toke by his brother-in-law Berle; it was first discovered in 1851, placed in the floor of Stora Harrie Kyrka, which was itself built around the year 1200 as part of the Lund Cathedral diocese (RAÄ Stora Harrie 2:1). The stone is one of very few that show strong signs of the Christian religion in its disproportionally large and very stylized Latin-cross. Only 12 Scanian runestones have visible Christian connotations to start with (Anglert 1995 p. 41), which is not that large a proportion compared to the 47% of all Scandinavian runestones that hold clear Christian influence (Sawyer 2000). And yet within this small category, St Harrie together with Sölvestad 1 remains the only runestone-crosses that are seemingly devoid of inspiration from Norse art, due to their straight, yet contoured shapes, Moltke categorized this cross under Maltese crosses (Moltke 1985 p.272). On his comparison on the same page you can clearly see that the Maltese rune-crosses have most in common with those portrayed as part of a papal ferula (e.g. Sövestad 1). Another Christian connotation could be argued to exist in the fact that the stone was integrated into the floor of a medieval church, a custom otherwise mainly reserved for the tombstones of the local nobility.

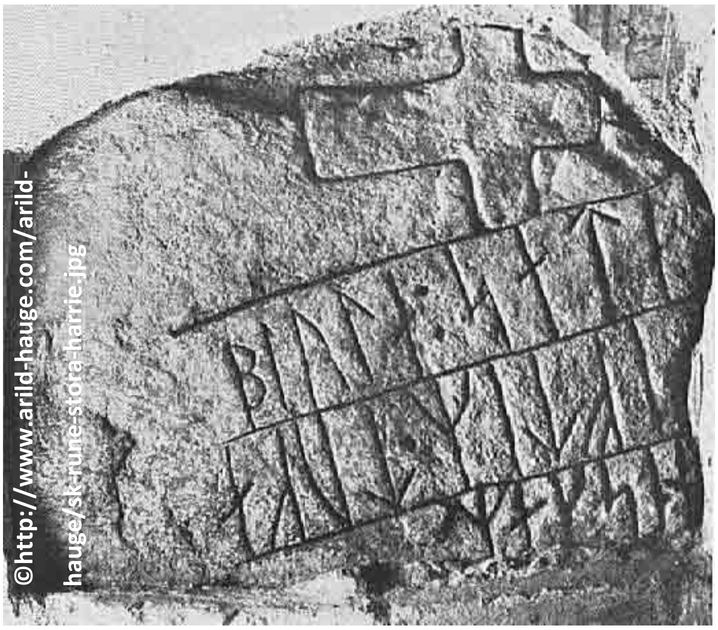


Figure 22. The Stora Harrie runestone could mark a major intersection in Scania's Viking Age Infrastructure. The stone displays a disproportionately large Latin-cross.

According to Samnordisk-Runtextsdatabas, the stone is an early type (RAK), dated to the Post-Jelling period of ca.1000-1050 CE, which would fit in nicely with a Danish post-conquest control-point. Stora Harrie, among the three lowest stones in the fork, is also alone in having not 1 but 2 Viking Age settlements in its vicinity, partly excavated through rescue-archaeology (Jacobsson 2000). Based on what I have read in the FMIS files, both these settlements seem to be in their prime within the Roman Iron Age to then be re-settled in the Viking-Age. Placed in the context of the discussion above regarding Christian influence of the Danish monarchy, this does not exactly work against the idea of Stora Harrie natural control-point in the Scanian infrastructure, re-settled in a time of increased centralization. Thinking of Stora Harrie as a Lundensian satellite is tempting, though the idea remains largely a speculative one as the Viking Age finds from St. Harrie at this point mainly consists of artifacts, with only one smaller building excavated.

Though the archaeological evidence in the area can generate vague theories at best, the analysis itself leaves me quite convinced that if one would want to find an intersection between these three paths, he/she should still search in this general area. Even though the least cost paths did cross before the river and not after, there are actually two perfectly good depressions visible in the DEM; depressions that could represent a path joint in-between Stora and Lilla Harrie. In figure 19, you can see this depression highlighted in lighter red on the left image, as well as corresponding straight lines in-between the field boundaries marked in yellow on the orthographic satellite-images to the right.

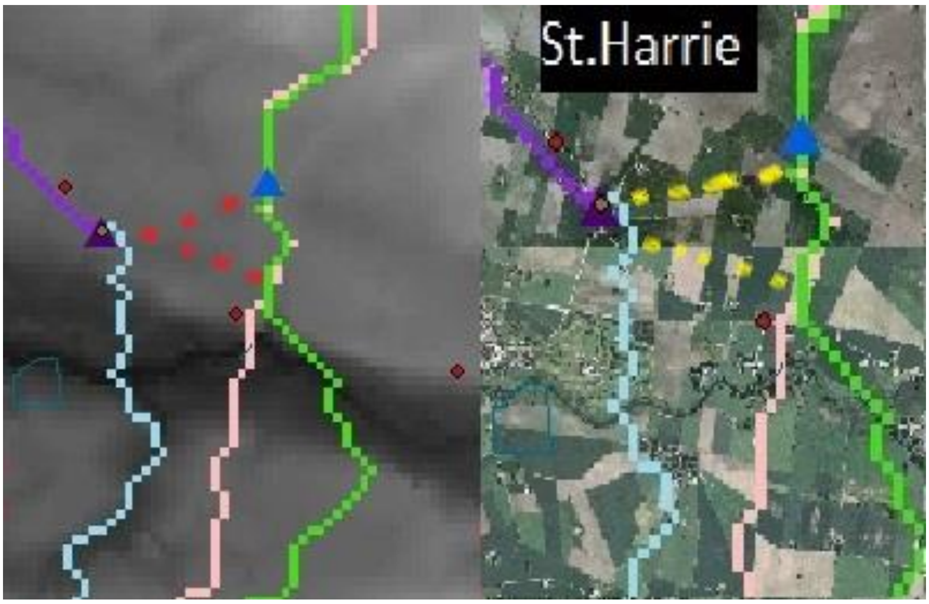


Figure 19. The red lines highlights visible, straight depressions in-between the two northern paths of energy efficiency, the yellow highlights corresponding straight lines in the field boundaries. The most eastern milestone on the image to the right (red dot) marks the known crossing point of the river.

Though I am convinced that one of the depressions highlighted in graph 18, together with the low cost energy paths represent a Viking Age intersection and a logical hub in the network of infrastructure along with the river, I see no way of concluding which of the potential road segments are more likely to represent the Viking Age reality. On one hand, the lower line starts from the Pink cost path, which actually crosses the river in the same spot as the milestones as well as our earliest provincial maps of Scania. On the other hand we have the upper, which is situated in Harrie, that hosts an in my mind much more significant runestone, as well as known Viking Age habitation. There is also the fact that the purple and blue energy lines fill out 2/3rds of an in use, but narrower, contemporary fork in the road by St. Harrie church.

The results of the northern case study thus remain inconclusive when it comes to the section of road around the river crossing, but as discussed above; the results of the analysis did provide a lot of other valid data. First of all, if calculated by the precondition of passing through Stora Harrie parish, all runestones line up along a forked path of energy conservativity; furthermore, the start of Viking Age Lund may have affected the infrastructure in its surrounding very quickly; and lastly the fact that there may be a very important site in either Stora or Lilla Harrie parish, which acted as an agent on the system.

5. 3 Trees, LIDAR, statistics and excavation records; an evaluation of the method…

The method used in this thesis proved a lot more effective than I had dared to hope for, at least in relation to employing it within the given time frame. At the same time it displayed several of the pitfalls that I had feared in advance, as well as some that I had not expected. The southern case study, and the fact that the first path calculations headed straight into open sea, highlighted one important factor that I would in hindsight argue needs to be part of this method, and that is "land-use". In the end I went around this problem by changing parts of the weight overlay, but dividing the study areas into sections of land-use would not only have allowed me to have more confidence in the output of the analysis, it could also be a helpful tool.

Least-cost path analysis is off course not only used within digital and landscape archaeology, it also used in a variation of other professions, for example by geographical researchers as well as government and town planners. When the latter mentioned use it to plan or re-route existing pieces of infrastructure they also use something called “land-use rasters”. Land-use rasters are polygon-shaped raster-overlays that are used to highlight the properties of different areas of the map. Within least cost-analysis these overlays can be assigned different energy-cost weights, causing the paths to avoid for example wetlands, urban sites and areas of heavy forestation, in favor of areas with not only easily traversed slopes, but also easily crossed vegetation.

In hindsight land-use rasters could also be an important factor if applying the method to areas of less dense runestone paths. The stretch of runestones in-between Uppåkra and Trelleborg for example was evaluated as a potential area of case study, but discarded because a) the distance in-between each stone was quite substantial, and b) though following the same general shape and curvature as the milestone path, there runestones here does not overlap with it. Instead their path seems to take a more coastal route, leaving the analysis with few points of reference (as visible on figure 11). However during the final phases of this project, I have come to realize that this gap in-between the two paths, could perhaps be explained by retracting forestation, as maps showing research into Viking Period habitation and forestation of these areas (e.g. Svanberg 2003, Calmer 1991) seem to follow the general shape of the runestone path in this area (at least when comparing the graphs with the naked eye). The effect of forestation on Viking Age least cost paths were not included in the method evaluated in this study but if it had been, it could have allowed for larger areas of case study.

Originally I had planned to move beyond the milestones as a representative of the 18th century road pattern and also compare the least cost paths to stretches of road identified within field archaeology. Due to time restraints and technical issues, I ended up having to streamline the method and this very time consuming part of the post-analysis went out the window. Yet evaluating the results of the method, especially the northern case-study, I am now even more convinced that field-archaeology has a natural relationship to these kinds of remote sensing methods. In the future the use of this method should include deeper correlation to excavation records, and optimally perhaps archaeological users of least cost analysis should even incorporate field-archaeology of their own into their study of the paths as to either evaluate the reliance of the method or simply gain more data on areas with complicated path trajectories.

The statistical analysis, though largely silent in the discussion of the results so far, remains a hugely successful part of this study, and a component of the method one should think twice before discarding. Before one goes about explaining deviations from the path by active agents in the landscape one first has to crunch the numbers and prove for certain that the targets within the analysis are organized in relation to each other on a higher level of statistical significance. Because if the material does not prove to be organized within itself, you will never know if a target's deviation from the least cost path is the result of contemporary influence on the infrastructure, or if the target simply does not belong in the context. Without the statistical analysis I could not have justified the discarding of runestones from the database pre cost path analysis, and it would have been much harder to interpret the results post cost path analysis.

Finally I think there is something to be said about LIDAR data in relation to the evaluation of this method. LIDAR data, having a high resolution, as well as being acquired by directly scanning the landscape (in contrast to older forms of elevation data acquired by the conversion of topographical maps), has to be argued to be among the best kinds of elevation data you can use for this method (at current time). This does not mean it is without pitfalls; at present day the point spread of the LIDAR data remains un-even, and though the nature of such deviations are always disclosed in the metadata, it did hinder remote sensing in some parts of the digital elevation models I built. There were also problems with the categorization of the elevation layers used to filter away vegetation and urbanization, even though attempts were made to filter the LIDAR data based on both the manual from Lantmäteriet as well as the international standards for categorization of LIDAR data. The end result was still a DEM that still contained sections of buildings, several building fundaments where for example visible in central Lund post filtering.

Still, the resolution and potential of LIDAR data is great compared to other elevation data used by researchers in the past. The fact that a national coverage of LIDAR data is now available to wide array of researchers based in Sweden is a huge benefit that greatly adds to the potential of this method. In my mind, as the resolution of the Swedish LIDAR grid grows more even and the capabilities of our hardware keep growing and can handle larger and larger sections of detailed elevation data, the capabilities of this method will grow as well.

6.0 Conclusions

At the start of the thesis I asked a number of questions, which general themes the later analysis and discussions have followed. In this concluding chapter I tie this metaphorical sack of questions back together by summarizing what the study showed in relation to these questions.

- *Are the Scanian runestones organized in relation to each other in a statistically significant manner?*

Yes, the statistical portion of the method showed that the Scanian runestones are placed in a highly organized pattern, and that locations for erecting runestones has thus most likely been chosen either in relation to other runestones, or in relation to a cross provincial feature. It also showed that the statistical significance of this pattern rose when not including stones that have been moved from their local area, giving further weight to the organization level of the runestones that still stand in their local context. And lastly it showed that the level of organization within the runestone-context is on a similar level of organization of historical road side markers (the milestones), suggesting that the runestones display the level of spatial organization you would expect to see in a context of main-road monuments.

- *Will a low cost path in-between rune stones, intersect with areas of already known roads?*

Yes, the low cost paths generated across runestones intersected with both sections of more modern roads as well as sections of roads that correspond to earlier networks of road visible through the milestones. Though to answer if these historical roads in turn correspond to sections of Viking Age roads other methods of investigation might be required. The present study at least gives credence to the idea that the least cost paths actually represent paths of transportation.

- *Will a low cost path between two rune stones in well conserved parts of the landscape overlap with runestones located in-between?*

The low cost analysis showed that not all of the studied runestones stand along the natural path of energy efficiency through the landscape, but rather on a path of general energy conservativity in relation to places of importance during the early medieval period. In the southern case-study, all the studied runestones where placed in relation to the path when Sjörup was used as a 3rd marker, and correspondingly all stones in the northern case where situated by the low cost path when using Stora or Lilla Harrie as a 3rd marker.

The very low requirement of one point of influence in each study area, in my opinion, speaks in favor of these paths being genuine, in turn an indicator of the quite large influence larger Iron Age settlements and central places could potentially have had on their surroundings, in what (through the lens of this analysis) looks like a very large scale effects on regional infrastructure. It perhaps also speaks to the very old age of the cross-provincial roads, as it would have been very hard to plan an energy-efficient road without the use of advanced cartography

- *Can the methods tested in this study accurately track Viking Age infrastructure with the runestones as their only marker material?*

As a method based on calculation and statistics deal mostly in odds and likelihood, rather than any truly empirical observations, I am tempted to say that the answer is no. But as the statistical significance of the spatial analysis was so high, and all of the in-context runestones within the case studies where connected through low cost paths, I would argue that the odds for these paths representing Viking Age infrastructure are very high.

At the same time I would argue that though the method tested generated results that would have been very positive in relation to tracking Viking Age infrastructure, the method would have to first be modified further, before one could claim any detail accuracy in relation to remote sensing. This would include previously discussed components like actual field work, more detailed study of previous fieldwork as well as land-use analysis. Though on a personal note, I don't see how the Scanian runestones could be so highly organized both in relation to each other as well as paths of energy conservativity, if they were not connected by one piece of very large, and very ancient infrastructure.

7.0 Summary

In this thesis I tested least cost path and spatial statistics as methods of tracking Viking Age infrastructure by way of runestones, and through that also in part the theories concerning the runestones as roadside monuments. I did so through two case studies; one along the south coast of Scania and one in the area north of Lund around the river of Lödde å. The goals were methodological but also in part theoretical.

The first part of the analysis consisted of categorizing the Scanian runestones into different levels of reliability as least cost path markers, calculating the Z-score and K-functions of these groups of runestones as to compare them to those of milestones. The results show that the Scanian runestones categorized as still standing in or within a few kilometers of their original context, had a similar Z-score to that of Gotland's milestones, indicating that the Scanian runestones are organized in relation to each other in a similar way to other roadside monuments. At the very least the analysis concluded that runestones were not set out by a random pattern, but that their locations were probably chosen along a common frame of reference, for example a network of connected roads.

In the second part of the analysis, the runestones within the case study areas were then placed within a 3d-model of the landscape based on LIDAR elevation scans, to be subjected to least cost path analysis. The results showed that while the runestones don't always stand along the most energy efficient path through their area, they do stand on routes of high energy efficiency in relation to powerful agents in the landscape. This was then discussed in relation to authority, topography, urban-centers, the new monarchy and other forms of infrastructure such as larger rivers.

Through the analysis I conclude that this method, with a few minor alterations, may be a very potent tool for analyzing Viking Age infrastructure, and that the results seem to confirm the idea of runestones as roadside memorial monuments, raised in the wake of the consolidation of Danish royal power in Scania.

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9.0 APPENDIX

Out of context / post-Viking Age	
Valleberga 26:2	written source, existence doubtful
Fjelie 43:1	oral source, existence doubtful
Hästveda 24:1	post Viking Age
Stora Herrestad 4:2	post Viking Age
Lund 11:6	out of context
Lund 9:4	out of context
Lund 9:5	out of context
Helsingborg 50:1	post Viking Age
Farstorp 142:1	post Viking Age
Lund 11:3	out of context
Örtofta 40:1	post Viking Age
Stora Herrestad 4:1	post Viking Age
Lund 9:6	out of context
Sjörup 3:2	out of context
Lilla Harrie 25:2	out of context
Lund 9:2	out of context
Lund 11:4	out of context
Västra Sallerup 45:1	post Viking Age
Allerum 119:1	post Viking Age
Stävie 15:1	post Viking Age
Simris 76	out of context
Södervidinge 41:1	post Viking Age
Lyngsjö 95:1	historical source, existence likely, though post Viking Age origin
Lund 11:7	out of context
Kristianstad 203:1	post Viking Age
Hardeberga 32:1	post Viking Age
Lund 9:3	out of context
Lund 11:1	out of context
Kverrestad 4:1	post Viking Age
Lund 86:3	out of context
Höör 160:1	post Viking Age
Lund 11:2	out of context
Sankt Olof 69:1	post Viking Age
Välluv 32:1	post Viking Age

Konga 24:1	post Viking Age
Simris 75	out of context
Lund 9:1	out of context
Lund 11:5	out of context
Historical source	
Lund 43:2	historical source 1700's , stone now In Denmark
Stehag 2:1	historical sources 1800's, existence plausible
Östra Karup 147:1	oral sources, existence likely
Hörja 135:1	oral sources, existence likely
Hästveda 99:1	historical sources, existence likely
Glumslöv 36:1	historical source 1700's, existence plausible
Lilla Harrie 25:1	drawings and surveys from the 1700's and 1800's, existence very likely
Locally Moved	
Glemminge 2:1	moved, probably ca. 200 meters
Simris 1:2	moved
Holmby 1:1	moved, probably ca. 1 km
Baldringe 2:1	moved
Skivarp 123:1	moved
Simris 1:1	moved
Hassle-Bösarp 13:1	moved, probably ca. 500 meters
Västra Karaby 10:1	moved
Vallkärra 6:1	moved
Örja 3:1	moved
Stora Köpinge 22:1	moved, line of mounds 1 km away
Bösarp 40:2	moved
Bjäresjö 4:1	moved, from one of the local mounds between 500 m and 1,6 km away
Hyby 8:1	moved
Östra Herrestad 5:1	moved, ca. 500 meters to closest Iron Age site
Hällestad 2:3	moved, according to runes placed by the hill (500m)
Tullstorp 1:1	moved, rich pre-historic landscape, mounds ca. 500 m in any direction
Bjäresjö 72:1	moved, line of mounds and milestones ca 400 meters away
Sövestad 2:1	moved, from local grove
Skårby 4:1	moved, milestone 130 m, mound 350 m.
Hällestad 2:1	moved – originally placed by the "brother stone, by the mound/hill" ca. 800 m.
Hällestad 2:2	moved, next to 65
Bjäresjö 21:1	moved, found I unknown nearby field. Closest known Iron Age local ca 400 meters
Västra Nöbbelöv 2:1	moved, line of mound, medieval keep 250 meters.
Solberga 2:1	moved, line of mounds 500 meter, castle ruin
Örsjö 6:1	moved, from farm with mound 1800's
Villie 4:1	moved, probably ca. 2km
Källstorp 2:1	moved – runes mention bridge and memorial, river + mounds ca 1km
Fuglie 1:1	moved, corresponding name mound 200 meters
Sövestad 2:2	moved from farm ca. 500 meter.
Holmby 10:1	moved, according to tradition 4 km
Stora Harrie 2:1	moved, line of mound 900 meters
Lund 44:1	moved, found in the ruins of the Allahegona monastery in northern Lund
Original Position	
Dagstorp 9:1	original position
Färlöv 166	original position
Uppåkra 2:1	semi original position
Fuglie 2:2	original position
Skivarp 25:1	original position
Östra Vemmenhög 3:1	original position
Västra Strö 2:4	original position

Fosie 3:1	semi original position
Västra Strö 2:3	original position
Sjörup 52	semi original position