Beyond Replication: The Quantification of Route Models in the North Jazira, Iraq

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Abstract

The primary aim of this paper is to present a solution to the issue of the statistical validation of route models. In addition, it introduces a body of theory taken from the broader field of route studies, isolates individual physical variables commonly used to predict route locations and quantifies them against the preserved hollow ways in the North Jazira Survey area, ending with a discussion of the complexity of human travel and the paramount importance of cultural variables.

Keywords: GIS, Route Analysis, Quantification, Mesopotamia, North Jazira

Introduction

Quantification of route models opens up routes as a new source of evidence. Quantification of route models also reveals a new, yet-unexplored aspect of pre- or proto-culture: route choice. Understanding what made people travel to one place and not another at any particular time has the potential to inform about socio-political and economic relations, past commodity chains, and to fill in gaps in route preservation, possibly even predicting the location of crossroads and key junctions where archaeologists may expect to find important, as yet-undiscovered sites.

Archaeologists have sought to understand ancient travel and routes through many means:

- historic texts, maps, and ethnography (Daryaee 2010: 406-409, Hendrickson 2011, Reynolds and Langlands 2011, Ristvet 2011, Sheets 2009),
- the reconstruction of routes based on assumptions or informed guesses on the importance of individual or multiple variables (hydrology – Allen 1990, time – Contreras 2011, access to good pasture or ease – Franchetti 2005: 140-145, vegetation, waterways, and slope – Howey 2007),
- visual comparison of such models to preserved route ways (Daly and Lock 2004: 360-362, Kantner 1997, 2004, 2012, Llobera 1996),
- and even typologies and comparative approaches (Earle 2009a, b, Snead et.al. 2009 a, b).

Those working in Northern Mesopotamia, have paid considerable attention to the numerous hollow ways preserved across the landscape, a feature type that was first noticed nearly 100 years ago in aerial photographs (for a brief history see Wilkinson et.al. 2010: 748, see also: Wilkinson 2003: 111-120, Ur 2003, Ur and Wilkinson 2008: 309-312, Ur 2009, Menze and Ur 2012: E785-E787, Casana 2013). Over the last 20 years, Wilkinson (1993, 2003: 111-117) has successfully argued, in support of van Liere and Lauffray (1954/55) that these hollow ways represent a palimpsest of features recording the past movements of people and animals rather than irrigation features (as argued previously by McClellan and Porter 1995, and McClellan et.al. 2000).

The hollow ways in Northern Mesopotamia have been grouped into three categories:

1. those which lead to the agricultural fields outside tell settlements,
2. those leading to the open steppe and pasture grounds, and
3. some long distance hollow ways which connect sites (Wilkinson 2003: 114-117, Ur 2003: 109-112, Casana 2013).

It is the last of these that is the focus of this paper. The results presented are from ongoing GIS-based research using routes as a means for providing a new line of evidence for understanding a much-debated cultural expansion that took place at the end of the fourth millennium B.C. in Mesopotamia (Algaze 1993, 2008; Stein 1999; Stein and Özbal 2007). However, this necessitates overcoming what John Kantner (2012: 236) terms the issue of statistical validation. How is it possible to quantitatively compare a route model to a preserved route system?

The key to solving this question is realizing that statistical validation of routes is not a problem of comparing two lines, but of turning those lines into data that can be placed meaningfully into a table.

Theory and Methodology

Theory

Route Studies an interdisciplinary field with its own vast body of literature that extends beyond archaeology and anthropology to fields like sociobiology and neuroscience, engineering and mathematics, and emergency planning. From this wealth of literature come a few important points to consider when looking at route systems archaeologically.

First, there are some human universals in navigation and wayfinding. The part of the human brain responsible for this task is also one of the most primitive parts of the brain (Burgess 2002). Like mice, we have three types of brain cells associated with these tasks nicknamed 'grid cells', 'place cells', and 'direction cells' (Burgess 2011). Grid cells allow us to know where we are in space relative to boundaries, be they a cliff or a wall, by firing signals in overlapping triangular grids as we move around. Place and direction cells inform us of our egocentric location within this grid (*ibid.*). Like mice and even insects such as ants and wasps, humans make use of dead reckoning or getting to a known location by heading straight in its direction (Shettleworth 2010, Müller and Wehner 1988). Like chimpanzees, humans also make use of landmarks to learn new routes and find their way along them (Normand and Boesch 2009, Normand 2010). These universals, however, can hardly account for the locations and plans of the many paths, routes, and roads humans have built around the world throughout history.

Second, the use of cardinal directions is not a human universal and people are able to navigate across long distances even to places they have never been before without the invention of the map through use of topographic gossip and the association of locations either to important resources for their culture's economy or stories from their culture's ideology (Widlok 1997, Lewis 1976). This is an important point for studying cultures such as that of Northern Mesopotamia in the third and fourth millennia B.C, because it demonstrates the plausibility of planned long distance overland travel centuries or even millennia before the Babylonians began drawing maps on clay tablets (see object ME 92687 at the British Museum, popularly known as "The Babylonian World Map").

The third and final point to consider relates to the concepts of 'optimizing' as opposed to 'satisficing'. Whether humans optimize or satisfice is a question that remains open about human nature.

The exact term 'satisices' first appears in the third edition of *Administrative Behavior* in an added introduction in which satisficing is described both as '[looking] for a course of action that is satisfactory or "good enough"' (Simon 1976: xxv) and making 'choices without first examining all possible behavior alternatives and without ascertaining that these *are* in fact all the alternatives' (*ibid.* xxvi). In all editions of *Administrative Behavior*, Simon argues in the fourth and fifth chapters that people have bounded rationality and it is this argument for bounded rationality that leads to the conclusion that people are satisficers rather than optimizers (Simon 1945, 1957, 1976, 1997).

Bounded rationality is exemplified in Simon's Administrative Man (Simon 1976: xxviii-xxxi). Administrative Man serves as a contrast to Economic Man, the perfectly optimal man who makes his decisions completely rationally (*ibid.* xxix-xxx). Simon describes the theories of rationality in social sciences at the time as 'schizophrenic' with economic theories assuming optimal behavior and psychological theory emphasizing the outside influences and external pressures that influence a person's thought and decision-making (*ibid.* xxvi-xxvii). Administrative Man is in the middle: boundedly rational. He makes decisions that are 'good enough' in that the decisions are effective in achieving the main goal of the task at hand, but not necessarily in the fastest, most efficient, or best (optimal) manner (*ibid.* xxix-xxxi).

The term satisficing is applied to archaeological route studies in a chapter of the volume *Least Cost Analysis of Social Landscapes* (Branting 2012). The section of the chapter on satisficing begins by stating: 'People, even when they have significant knowledge of part or all of the system, tend to make decisions on where to go and what to do in less than optimal ways' (Branting 2012: 214). This is followed by the advice that 'an important distinction should be made in least cost analysis between optimizing, or finding the absolute best path according to criteria employed, and satisficing, or finding a path that would meet the need(s) behind the movement of the individual' (*ibid.* 215). An example is provided of a person that needs to be at a meeting in an hour, but it only takes about 20 minutes to get to the meeting from their current location (*ibid.*). This allows the person 'the flexibility to choose not only the optimal path but also a wide range of alternative paths that would suffice' to get them to the meeting on time (*ibid.*). One example alternative path is a slightly longer (time) path would allow the person to stop by 'a favorite coffee shop' on the way where they can 'get the coffee [they] have been craving' (*ibid.*). Branting points out that this option would 'fulfill two tasks with the same trip' (*ibid.*). The other example alternative path provided is again a slightly longer (time) path that passes through a beautiful park (*ibid.*).

In this paper, it is argued that humans do optimize, but not always to a single variable. Single variable optimization, is not a difficult task in terms of cognitive ability: ants, a wasps, mice, and chimpanzees are all capable of the skill – as already discussed. There is no reason, therefore, to assume that a person is not also capable of route optimization. Take Branting's (2012: 214-215) example above about a person who needs to get to a meeting in an hour. Is getting to the meeting *and* obtaining a favorite coffee not more optimal to than simply getting to the meeting? Is the (presumably most) beautiful path to the meeting through the park not simply another form of optimal path?

Contrary to Simon's argument and what may seem intuitive, one recent study in human navigation suggests that people do, over time and with increasing familiarity of an area, gradually optimize their routes (Kneidl and Borrman 2011). In this study by Kneidl and Borrman, groups of 2-4 students were started from one of four corners of their university campus and told to go to a well-known landmark without the aid of a map, but recording each street as they travelled. Once they returned to campus, they were asked in a survey how familiar they are with the city center, recorded if they felt they had taken the shortest (time) route (89.54% believed they had), and were asked to draw their route on a map. The researchers were able to distinguish between three types of pedestrian to inform their simulation model whose ultimate aim is to inform emergency planning:

- 'Pedestrians who are familiar with the location and know the best way to their destination
- Pedestrians who are not familiar with the location, but try to keep as close as possible to the airline to their destination
- Pedestrians who are not familiar with the location and make their decisions based on local criteria'

(Kneidl and Borrmann 2011: 3)

Another experiment, specifically looking at the human ability to optimize in a traveling salesperson problem found people were significantly better and faster at optimizing shortest tours than "pessimizing" longest tours (Chronicle et.al. 2006). The travelling salesperson problem has several variations. In this experiment, the participants were specifically asked to generate a circuit-type tour in which no location is visited more than once. At the end of the experiment 31 of the 100 shortest tours produced were optimal, while none of the longest tours succeeded in maximizing the total length of the tour (*ibid.*).

More studies are needed to properly assess whether people optimize or satisfice, but it also needs to be kept in mind that there are multiple variables a person can select from when optimizing and people may in fact optimize according to multiple variables at the same time. Some of the added preferences noted in the study by Kneidl and Borrman were travelling along main roads and taking fewer turns (2011:5).

Together these three points illustrate that people have the mental capability to optimize their travel, aided by social and linguistic devices, even across longer distances in prehistoric or protohistoric time periods without maps; but there is still no reason to expect that clicking the Cost Path function in ArcMap to generate a least cost path, or the equivalent in other programs, will produce anything that resembles the actual routes taken by any given group of people. There are many kinds of optimal: fastest, easiest, shortest, shortest route between a specified set of locations (the traveling salesman problem), safest, most beautiful, and so on. In modern western society, time is an important variable, but without specific evidence there is no reason to assume that time or any other single variable play(ed) a significant role to other cultures. It is entirely possible that people, such as those in the third and fourth millennia B.C. in Northern Mesopotamia, optimized their travel according to different or even multiple variables, the relative importance of which varied along any given stretch of route.

Methodology

While my larger hypothesis is that people in my study area (and more generally) optimize according to many variables, this study breaks this hypothesis down and asks how much any single variable could account for a route location during a given time in the North Jazira of Iraq. The significance of the method described in this article is that it does not *assume* anything about human rationality or behavior. It simply asks to what degree any single variable matches.

1. Generating Route Models

A series of optimal route models, each modeling a single variable, are constructed for two blocks of time: the fourth millennium and the early third millennium BC. It is not expected that any of these route models will accurately and precisely match the preserved hollow way system where people actually walked; each of the models simply represent what the route system of hollow ways would look like *if* travelers had optimized to the variable modeled one hundred percent of the time. In this paper, these optimal route models were constructed using: ESRI ArcMap 10.0 Cost Path (easiest route), GRASS R.Drain with R.Walk for the cost layer (fastest route), and by manually drawing straight lines between sites (shortest route).

2. Converting Lines into Numbers

While it is already possible to visually examine the proximity between the optimal route models and the preserved routes in GIS at this stage, the optimal route model lines must be converted into numbers that are placed into a table for quantitative analysis. This can be achieved by two methods. The first involves constructing a series of buffers around the hollow ways, converting the optimal route model into a point shapefile, and counting how many points lie within each buffer. The second method still involves converting the optimal route model into a point shapefile, but then a select-by-location tool is used with a search radius to find all points within the first pixel distance, second pixel distance, and so on. In this study, only overlap within a single pixel distance is considered[1].

The point spacing of the optimal route model should reflect the quality of the underlying data[2], with a single point per pixel. This occurs automatically when using ESRI ArcMap to convert from a raster to a point shapefile. Likewise, the buffers should also reflect the quality of the underlying model data.

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[1] This approach assumes the optimization of routes is a spatial problem. This is not always the case, particularly in mountainous terrain. Anonymous Reviewer 2 correctly points out that the fastest route and the second fastest route to a location may be spatially distant to each other. The best example of this scenario is a mountainous area where two parallel valleys lead to the same destination in nearly the same amount of time. If a researcher is interested in finding out how much a preserved route overlaps the optimal route model (*k*) *and* the nearly optimal route models (*k*-1, *k*-2,…, *k*-*n*) then it will be necessary to construct these precise models, use the method described here to record the overlap of the preserved routes to each of the constructed models, then add the rates together for a total rate overlap for *k* to *k*-*n*. In some cases, as Anonymous Reviewer 2 critiqued, the difference between optimal route model (*k*) and the slightly less optimal model (*k*-*n*) may be insignificant, for example: a route that is 5 hours and 23 minutes long compared to a route that is 5 hours and 21 minutes long.

[2] In this case the underlying data is an SRTM (version 2) DEM projected using WGS_1984.

While each idealized route model will *usually* have a resolution based on the data used to inform it, sometimes this is not the case. In this paper, this exceptional scenario is exemplified by the shortest route models. Simply a straight lines drawn between sites, there is no underlying resolution to the data. Nevertheless, it is necessary to convert these models into point shapefiles with *n* points, spaced *d* distance apart. For this reason, it is remembered that hollow ways are tangible features with real dimensions, including width. For this paper's study area, Wilkinson et.al. (2010: 748) observed the hollow ways are 'generally on the order of 70-120m wide.' Therefore, it is necessary to assess overlap between the model and the digitized route locations with a search radius of at least 35 meters. Otherwise, it is possible the model will occupy the same space as a hollow way and falsely give the impression of no overlap simply because the infinitely tiny points in each respective shapefile do not exactly overlap, resulting in a Type I error. Considering this and the choice to use the most conservative (smallest) values for my route analysis, I chose a point distance of 70 meters for my shortest route models.

3. Generating a Population Sample

In order to determine the statistical significance of any individual optimal route model, a sample population of random models must be constructed with the same specifications (*n* points, spaced *d* distance apart) as the optimal route model. These are constructed here by using the Create Random Point tool in ESRI ArcMap 10.0. This process does not assume normality, but simply places dots randomly across the map (ESRI 2014). The full population sample of random models is constructed using sequential sampling for a mean to determine how many random models are 'enough' (see figure 1 for an example). As each model is constructed, the amount of overlap between each random model and the preserved routes is recorded using the same method for recording the overlap between the optimal route model and the preserved routes.

4. Significance

For each model, the null hypothesis states that the overlap between the optimal route model of that variable and the preserved route system is the same as the overlap between any random model with the same specifications and the preserved route system. The alternate hypothesis is that the optimal route model overlaps the preserved route system either significantly more often or significantly less often than any random model with the same specifications. It is possible to use a two-tailed Z-Test[3] in this paper, since the data is normal in the following case studies (figure 2); but if this is not the case in a future study, bootstrapping is an alternative method of determining significance provided it is remembered that bootstrapping can overstate significance[4] (Efron and Tibshirani 1993: 224-227). As will be seen in the case studies with normal-shaped data, two-tailed Z-Testing and bootstrapping provide similar results.

Case Study: The North Jazira in the Third and Fourth Millennia B.C.

Third Millennium

During the third millennium B.C., settlement was concentrated entirely in the northeastern half of the North Jazira Survey area (figure 3a). Therefore, only this portion is included in the present study area. Some space around the area of the sites is also included (so that it is possible for a route to take a slight left then right to avoid an obstacle, for example, when traveling west between two southernmost sites). This extra space is the combined additional space used by all of the optimal route models under study. Therefore the total study area is the combined area of all of the sites inhabited in the North Jazira Survey Area during the third millennium plus the combined area of all of the optimal route models (figure 3a). All the long distance hollow ways in the defined study area are included (figure 3b), while the other two types of hollow ways, which lead to agricultural fields around tell settlements or to the open steppe and pasture grounds adjacent to those fields are excluded

[3] A two-tailed Z-test is useful, because it not only informs if the model variable significantly accounts for the location of the hollow ways, but also if it significantly does not account for their location. The latter is informative for thinking of other variables to test that might have played a (positively) significant role.

[4] Bootstrapping advice provided in the Stats4Grads seminar series at the Mathematics Department, Durham University.

from analysis. There are many variables that could be tested, but three physical variables were chosen for this article: physical ease (easiest), time (fastest), and distance (shortest). For the easiest model, least cost paths were generated between each site and every other site using the cost distance, cost backlink, and cost path functions of ArcMap 10.0. Comparing the model to the hollow ways, as described above, it is found that 9.3 percent of the locations of the preserved hollow ways can be explained by the variable 'ease'. Using sequential sampling to determine how many models are 'enough' (figure 1), a sample population of 110 models with the same parameters as the easiest route model matched an average of 11.6 percent of the hollow ways with standard deviation of 1.2 percent. The resulting two-tailed Z-Test reveals that the probability of the optimal model matching the location 9.3 percent of the hollow ways is 5.5 percent, and it is not possible to reject the null hypothesis at the 95 percent level that the easiest route model is any different than any random model with the same specifications. Bootstrapping, which overstates significance, yields a probability of 3.60 percent, which is not significant at the 95 percent level.

Repeating this method, the R.Walk function based on Naismith's Rule was used to create a fastest optimal route model (Flor and Neteler 2012, Aitkin 1977, Langmuir 1984, Naismith 1892). This optimal route model overlapped 16.5 percent of the hollow ways. Then 160 random models with the same parameters were created to test the significance of this overlap. This sample population overlapped, on average, 20.0 percent of the hollow ways with standard deviation of 1.7 percent. The two-tailed Z-Test indicated that the probability of the optimal route model overlapping only 16.5 percent of the hollow ways is 3.9 percent, which is significant at the 95 percent level – in the wrong direction! Similarly, bootstrapping indicated a probability of 2.48 percent, which also demonstrates significance at the 95 percent level. This suggests that one or more different variables that acted against an efficiency of time may have been important for early third millennium travelers, if they were optimizing their travel. This is the value of looking at both tails: if the model fails, it can be informative when determining a new variable to test.

For the shortest route model, the above method for developing the optimal model was slightly modified, but the method for quantitatively assessing significance remained the same. By definition the shortest route between two points is a straight line. This also means that unlike the easiest or fastest models whose individual routes tend to converge in areas of the landscape with low cost values, the shortest model routes do not ever converge. Rather there are as many unique routes as there are combinations of sites and this quickly fills the entire study area (figure 4). Therefore, instead of drawing straight lines between each site and every other site, straight lines were drawn between each site and the nearest sites in every direction (figure 5). This model matched 11.4 percent of the hollow ways, and the corresponding sample population of models matched an average of 14.1 percent of the hollow ways with standard deviation of 1.4 percent. The two-tailed Z-Test indicated the probability of the optimal route model matching 11.4 percent of the hollow ways is 5.4 percent, which is not significant at the 95 percent level. Bootstrapping yielded a probability of 4.97 percent, which is not significant at the 95 percent level.

The Fourth Millennium

The hollow ways are a palimpsest of path and routes worn over millennia from the repeated traction of people and animals across the landscape. While it is known through excavation that they date at least as far back as the mid-third millennium based on pottery evidence that includes 3rd millennium B.C. 'characteristic 3rd-millennium B.C. fine stonewares' and less diagnostic chaff ware in the fill of excavated hollow ways around Tell Brak (Wilkinson et al. 2010: 755-766). The fill, of course, represents the periods after the hollow ways are out of use and, therefore a *terminus post quem* for the actual use of the hollow ways. It is uncertain how long it would take for these features to achieve their depths of 120-175cm. Jason Ur (2011) has used remote sensing to digitize these hollow ways, and a comparison between the fourth and third millennium sites of the North Jazira Survey taken from the database of the Durham-based Fragile Crescent Project (2013) in relation to Ur's digitized hollow ways supports the possibility that at least some of the hollow ways do extend back to the fourth millennium. All sites in the western portion of the North Jazira Survey Area that were inhabited during the fourth millennium were abandoned in the early third millennium (figure 6). Nonetheless, a few appear to be connected by hollow ways (figure 7). If this is the case, then routes have the potential to provide new data about society at the time. Unfortunately all but a couple of these sites were reoccupied in the first millennium B.C. (Fragile Crescent Database 2013) so it is also possible that the hollow ways in the western portion of the North Jazira Survey Area are younger. Only future fieldwork will resolve this with absolute certainty.

Having investigated the variables of ease, time, and distance for the third millennium, this section supposes the routes whose wear resulted in the formation of hollow ways by the third millennium *do* extend into the fourth millennium[5]. The same physical variables are examined in an exercise of 'what if…'

The easiest optimal route model overlapped 11.8 percent of the preserved hollow ways, while the generated sample population (n=120) of random models with the same parameters overlapped 12.2 percent of the hollow ways with standard deviation 0.7 percent. The two-tailed Z-Test reveals the probability of the model overlapping 11.8 percent of the hollow ways is 56 percent, so this overlap is not significantly different from random at the 95 percent level. Bootstrapping also indicated the model is not significant with a probability of 28.93 percent.

The fastest optimal route model matched 17.7 percent of the hollow ways. A sample population of 90 models matched an average of 20.5 percent of the hollow ways with a standard deviation of 0.9 percent. The two-tailed Z-Test indicates the model's overlap of 17.7 percent has a probability of 0.2 percent, which *is* significant at the 95 percent level. Bootstrapping yields a probability of 1.10 percent, which agrees with the Z-Test results that the results of the fastest optimal route model are significant – again, in the wrong direction.

Finally, the shortest optimal route model, generated using the same method as the shortest optimal route model for the third millennium, overlaps 10.6 percent of the preserved hollow ways. The sample population of 90 models overlapped an average of 12.0 percent of the hollow ways with 0.7 standard deviation. A two-tailed Z-Test indicates the optimal model's overlap of 10.6 percent has a probability of 4.6 percent which is significant at the 95 percent level. Likewise, bootstrapping indicates a probability of 3.30 percent, which is also significant at the 95 percent level; but may be overstated. Once again, the direction of the significance indicates that, like time, distance was also not important to fourth millennium travelers.

One More (Optional) Step

It is possible to have ArcMap display the specific locations where the model and the preserved routes overlap. This answers questions like: Are the points scattered, or do they form route segments? If they do form route segments, where? Are people avoiding or diverting to a specific place or feature? Taking this additional step can add depth particularly to any positive results, because it allows the researcher to easily determine if their route model aligns with any segments of preserved routes (figures 8 and 9). This process can also highlight if the model is only crossing the preserved routes perpendicularly many times (compare, for example, the overlap displayed in figure 10 between sites 143 and 150 versus the overlap between sites 143 and 148). In this case, while none of the variables as a whole seems to account for route choice in the third and fourth millennia B.C., there are segments which do appear to align to certain variables.

During the third millennium, the route between Al-Hawa (Site 1) and Site 23 appears to be explained by an optimization of ease and/or time, particularly once that route is more than two kilometers beyond Al-Hawa (figure 8a and b) despite a preserved segment located closer to Al-Hawa. Meanwhile, the routes between Al-Hawa and Site 9 and Al-Hawa and Site 29 appear to be accounted for by an optimization of distance (shortest route, figure 8c). This alignment between the shortest route model and the preserved routes occur at the nearest preserved sections to Al-Hawa at about a kilometer's distance from the site. These alignments of consecutive points lasting a kilometer or more seem significant, even if the variables are poor at accounting for the route system as a whole during the third millennium.

[5] The volume and frequency of repeated travel along a route necessary to create a hollow way in the Jazira (or elsewhere) remains unknown.

In the fourth millennium, the route between Al-Hawa and Site 23 again appears to be explained by optimization of ease and/or time, and there appears to be additional alignment with the easiest route model further southeast along this possible long distance route as it approaches Site 45 (see figures 9a and b). Meanwhile an optimization of distance may explain portions of the hollow way segment running past Site 23 (figure 9c). Further west, an optimization of distance aligns with the route between Site 174 and Site 145, especially along the preserved segment nearest Site 174 (figure 10). Optimization of distance also aligns with the entire preserved route between Site 148 and Site 143; as well as another route from Site 148 to Site 131, matching in particular to the entire preserved segment nearest Site 148 (figure 10).

Discussion

This paper set out, as a primary aim, to provide one solution to John Kantner's (1997, 2004, 2012) problem of statistical validation. *The method offered removes any assumptions about travel and allows the route data to become a line of evidence in itself.* Furthermore, while this paper focused on physical variables, this method is not limited to these.

Any variable can be modeled and tested, including cultural variables. It is known that the use of the hollow ways date back to at least the early/mid-third millennium, yet none of the key physical variables account for their location at this time. The only significant variable, time, is significantly worse at overlapping the preserved routes location compared to random models, suggesting the important variable(s) in route choice during the early third millennium worked against time. While I have not tested the physical variable "access to water", my hypothesis is that cultural variables provide the dominant factors behind route choice – not physical ones. The landscape in the North Jazira Survey region is very flat such that the physical cost difference of travelling one place instead of another is negligible. Additionally, centers are spaced only about 5 km apart – a distance that can be covered by an unburdened person in about an hour, negating the need to plan access to water along the way as a longer journey would.

Assuming the hollow ways date back to the fourth millennium B.C., the results are similar. The overlap rate of the easiest model was not significantly better or worse than that of a population of random models, while the significance of both the fastest and shortest models are indicate neither time nor distance were important considerations in route choice.

This does not mean physical variables never take precedence in route choice, but this study demonstrates that physical variables do not always take precedence. To provide a contrasting example to the present study: in mountainous regions where the physical difference in cost between travelling through valleys and passes rather than up and over steep slopes and peaks is enormous, physical variables – especially ease – are expected to take precedence[6].

Additionally, while physical variables fail to consistently overlap the preserved route models at least as often or greater than random models, the additional step of highlighting the locations of overlap (see in figures 8-10) allows for examination of the results on a more local scale. In figures 8-10, it can be seen that optimization of all three variables (easiest, fastest, shortest) *could* explain route choice in a few individual segments in the region of Al-Hawa and some of the route segments further west in the fourth millennium. This suggests different variables may take precedence along different segments of the routes, lending support to the notion that people may optimize according to multiple variables along their journeys.

That human travel in less restrictive topography, such as the flat plains of the North Jazira, is determined primarily by people's cultural landscape rather than their physical landscape fits well with anthropological studies which show that people learn and navigate their landscape by topographical gossip based either on the culture's economic or ideological landscapes.

[6] In a previous study, the physical variable ease accurately predicted the location of the historically known High Road, also a branch of the so-called "Silk Road", through the North Central Zagros Mountains (de Gruchy 2008).

This duality of physical and cultural landscapes has enormous implications for archaeologists interested in studying past routes. It means that we cannot simply assume the importance of physical variables like ease, time, and distance. Cultural variables need to be considered and this is where the methodology presented in this article has the potential to contribute the most for locations with preserved routes.

There is little doubt that, despite their lack of formal construction, the locations of the hollow ways of Northern Mesopotamia were not the result of aimless wandering, but purposeful travel whether this was to fields, pasture, or as is the case with those selected for this study: longer distance travel to other sites. Understanding the conscious decisions to travel one way and not another by assessing which variables account for different segments of these hollow ways has the potential to add a new line of evidence to our understanding of Northern Mesopotamian culture, especially once it is possible to establish firmly the formation dates of the many hollow ways.

The strength of this method is that so long as the variable can be modeled, it can be quantified against preserved routes, wherever they occur in the world, both generally across an entire preserved system and specifically along individual route segments. In this way, routes open up as a new source of evidence that inform about the route choices important to cultures in the past and highlight where the variables behind those choices were important.

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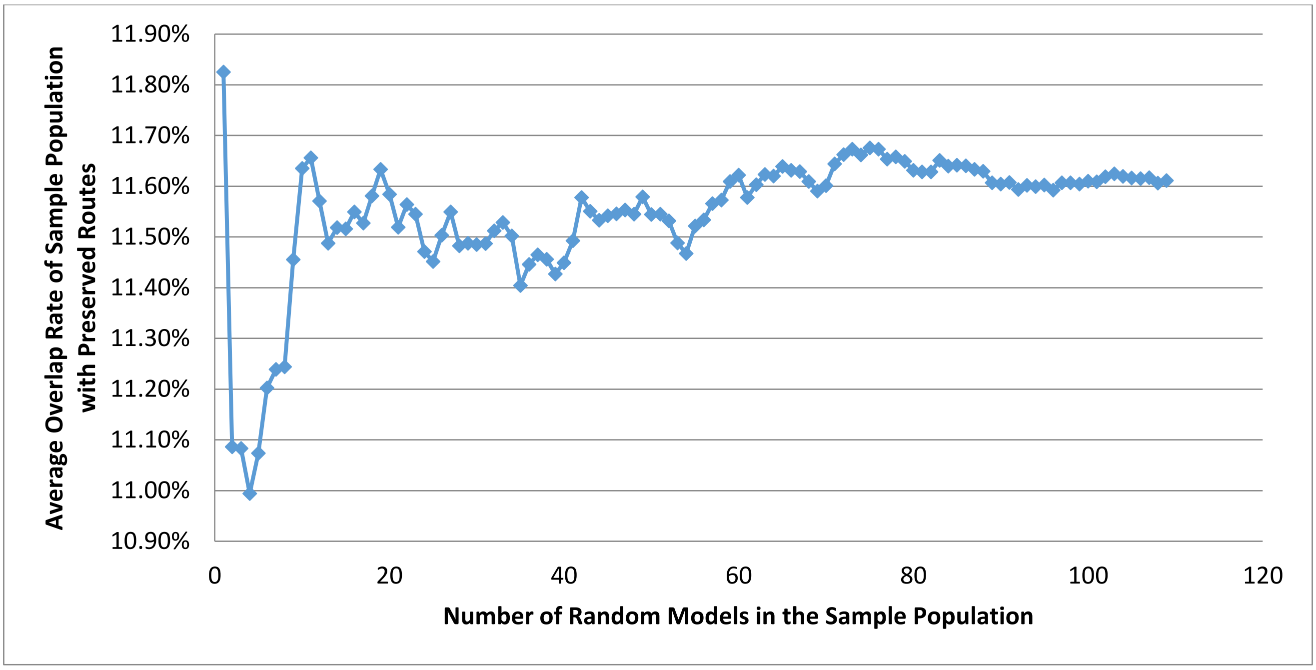

Figure 1 After generating 110 sample models with 3,846 points spaced a minimum of 82 meters apart in the third millennium study area and recording both the percentage each overlapped the preserved hollow ways and the cumulative average of these values, it was found that μ = 11.6% for the population of such models with a standard deviation of 1.2%. By comparison, the easiest route model, which also contains 3,846 points spaced at least 82 meters apart, overlapped 9.3% of the hollow ways.

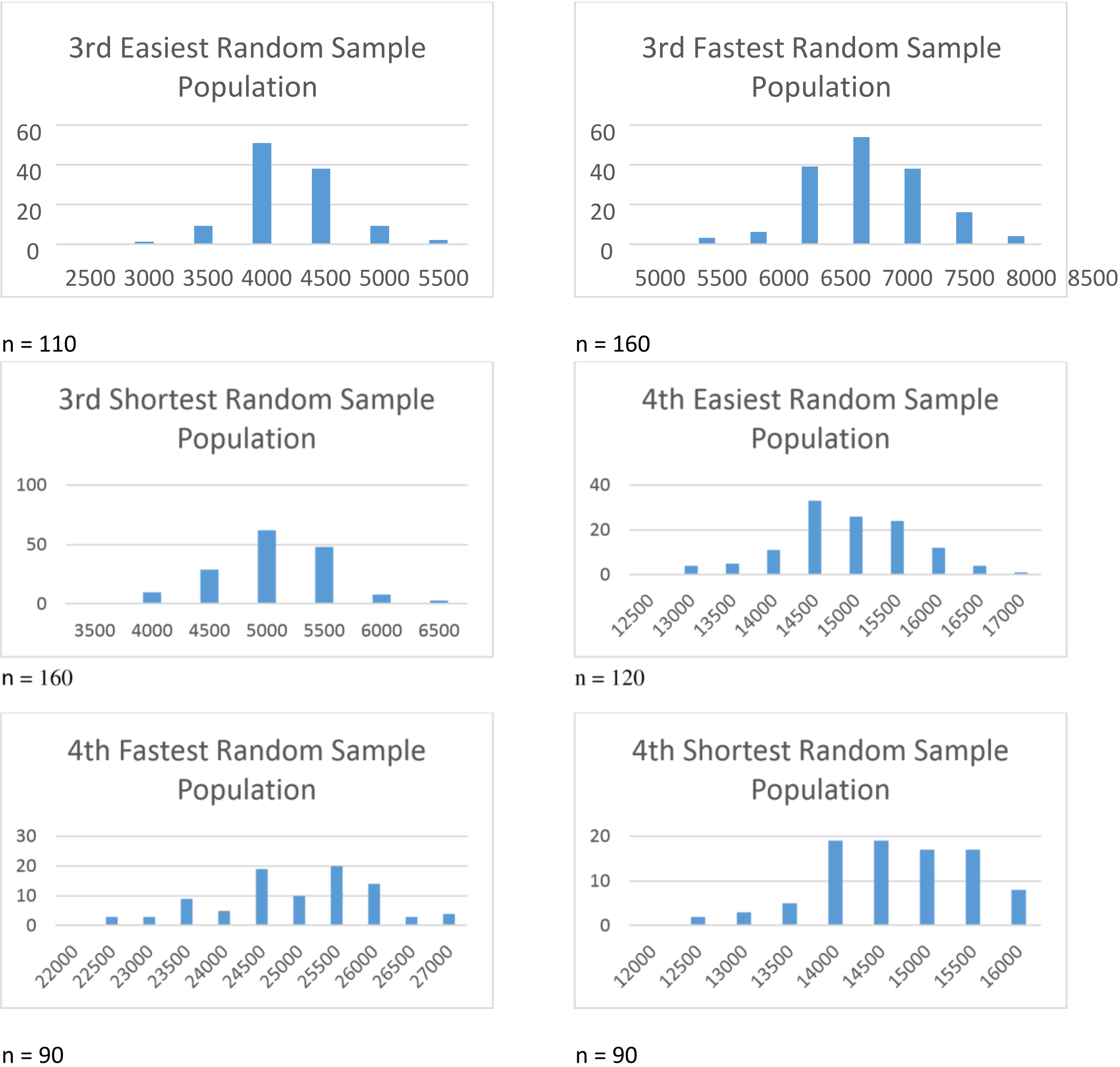

Figure 2 Histograms for each of the six random model sample populations for the easiest, fastest, and shortest route models of both the early 3rd and 4th millennia B.C. The number, n, represents the number of models in the sample population. The x-axis of each histogram records the number points in the random model point shapefiles that overlap preserved hollow ways. The y-axis of each histogram records the frequency. For example, in the fourth millennium, 20 random models with the same specifications as the fastest optimal route model have between 25,500 and 25,999 overlapping points with preserved routes. In all cases the distributions for the rate of overlap between random models and preserved routes are normal, though this is less apparent in the histograms with smaller n-values. With more samples, the normal shapes of these histograms would become more apparent.

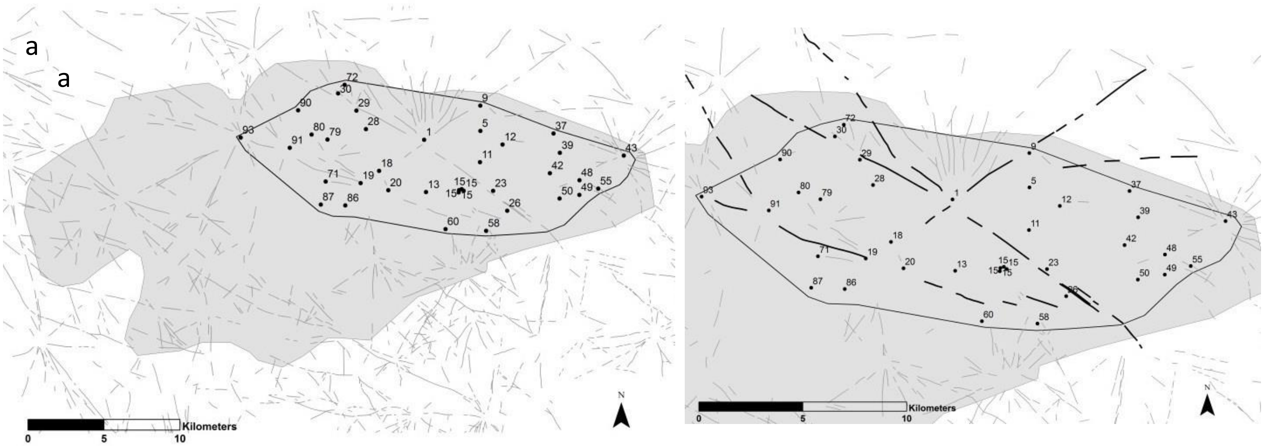

Figure 3a The grey polygon represents the survey area of the North Jazira project (from the Fragile Crescent Database 2013). All

37 sites identified as third millennium are concentrated in the northeastern portion of this survey area (ibid.). Site 1 is al-Hawa (ibid.). The study area defined for the third millennium portion of this paper is shown outlined in black. The hollow ways, displayed as grey lines, were digitized by Jason Ur using CORONA imagery (Ur 2011). **Figure 3b** Hollow ways identified as long distance route connecting sites are shown in black.

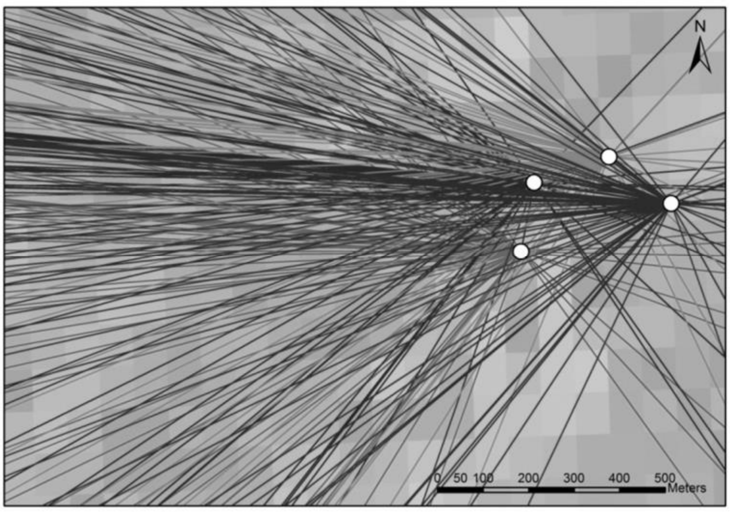

Figure 4 The shortest (straight-line) route between each site and every other site quickly identifies every cell of the underlying raster cost layer as a route location. This figure shows an area around the four sites of Site 15 after only about half of shortest routes between each of 74 site locations to every other had been drawn. The different shades of gray in the background are the individual cells of the underlying raster.

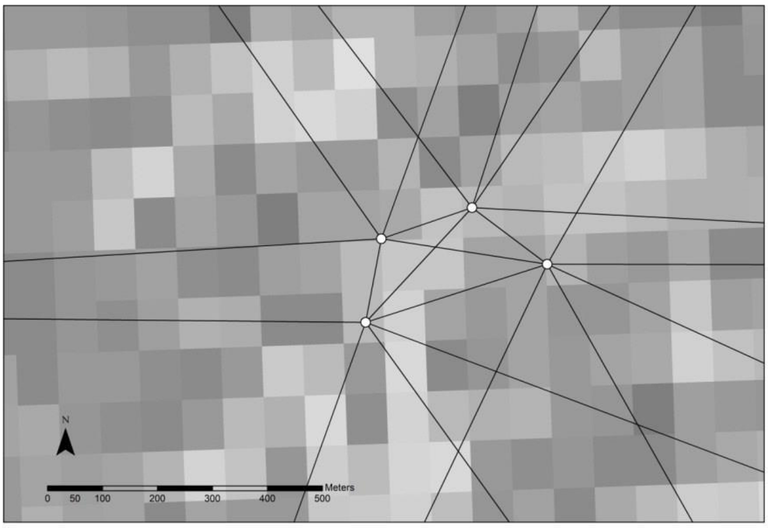

Figure 5 The same view as figure 3, showing the methodology applied. Instead of indiscriminately drawing straight line routes from each site location to every other, lines are only drawn to the nearest sites in each direction.

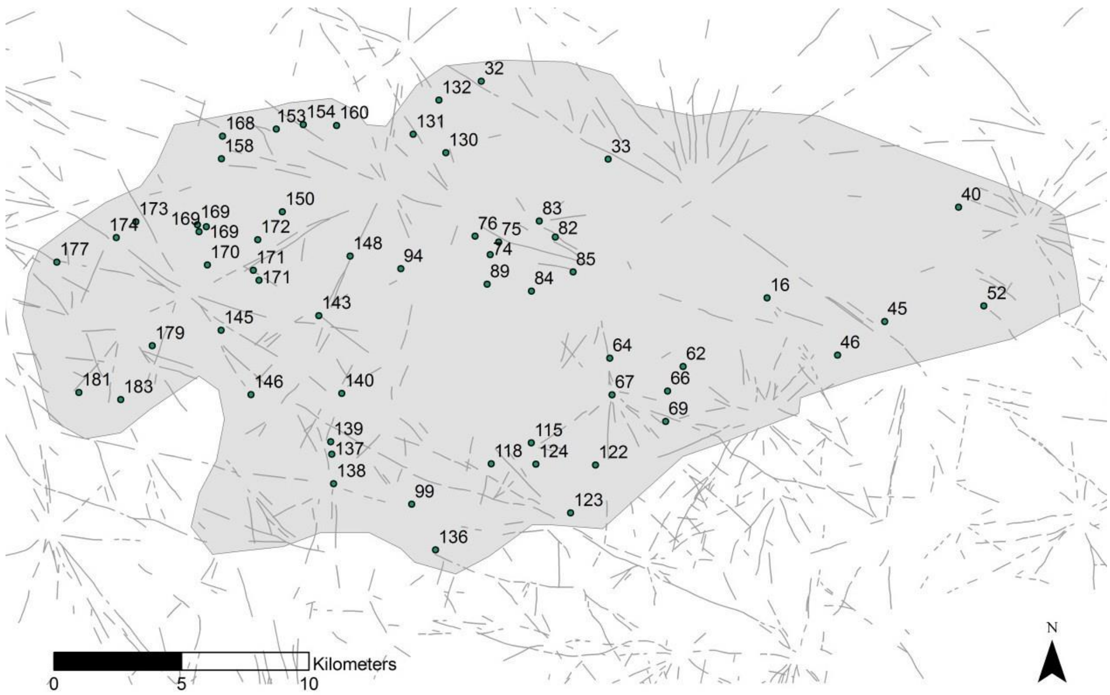

Figure 6 Sites identified in the North Jazira Survey that are inhabited during the fourth millennium, but not the third millennium. While the hollow ways seem to align to at least some of these sites, almost all are re-inhabited during the first millennium B.C. (Fragile Crescent Database 2013).

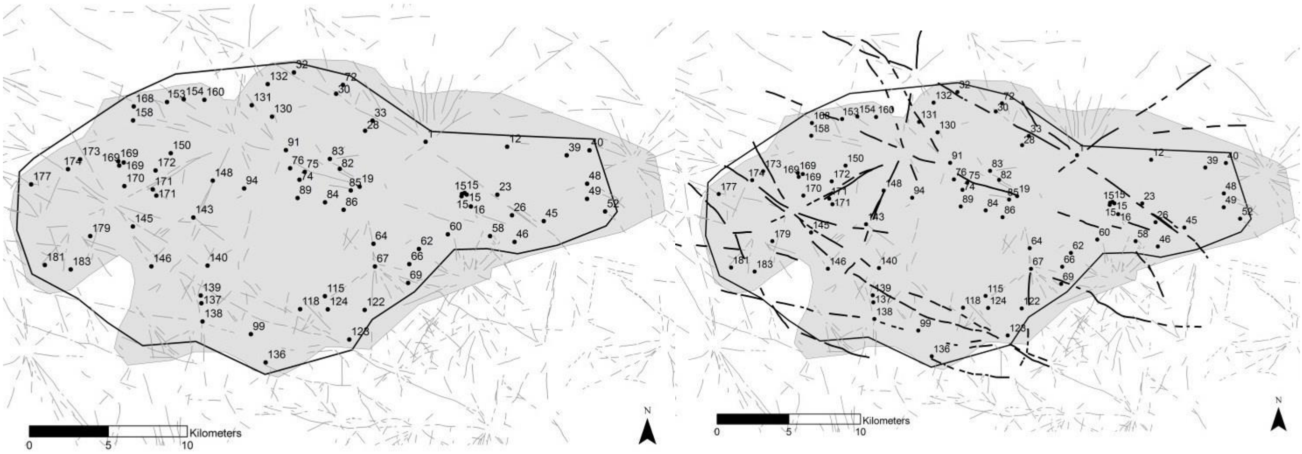

Figure 7a The grey polygon represents the survey area of the North Jazira project and all 77 sites identified as fourth millennium (from the Fragile Crescent Database 2013). Site 1 is al-Hawa (ibid.). The study area defined for the fourth millennium portion of this paper is shown outlined in black. The hollow ways, displayed as grey lines, were digitized by Jason Ur using CORONA imagery (Ur 2011). **Figure 7b** Hollow ways identified as long distance route connecting sites are shown in black.

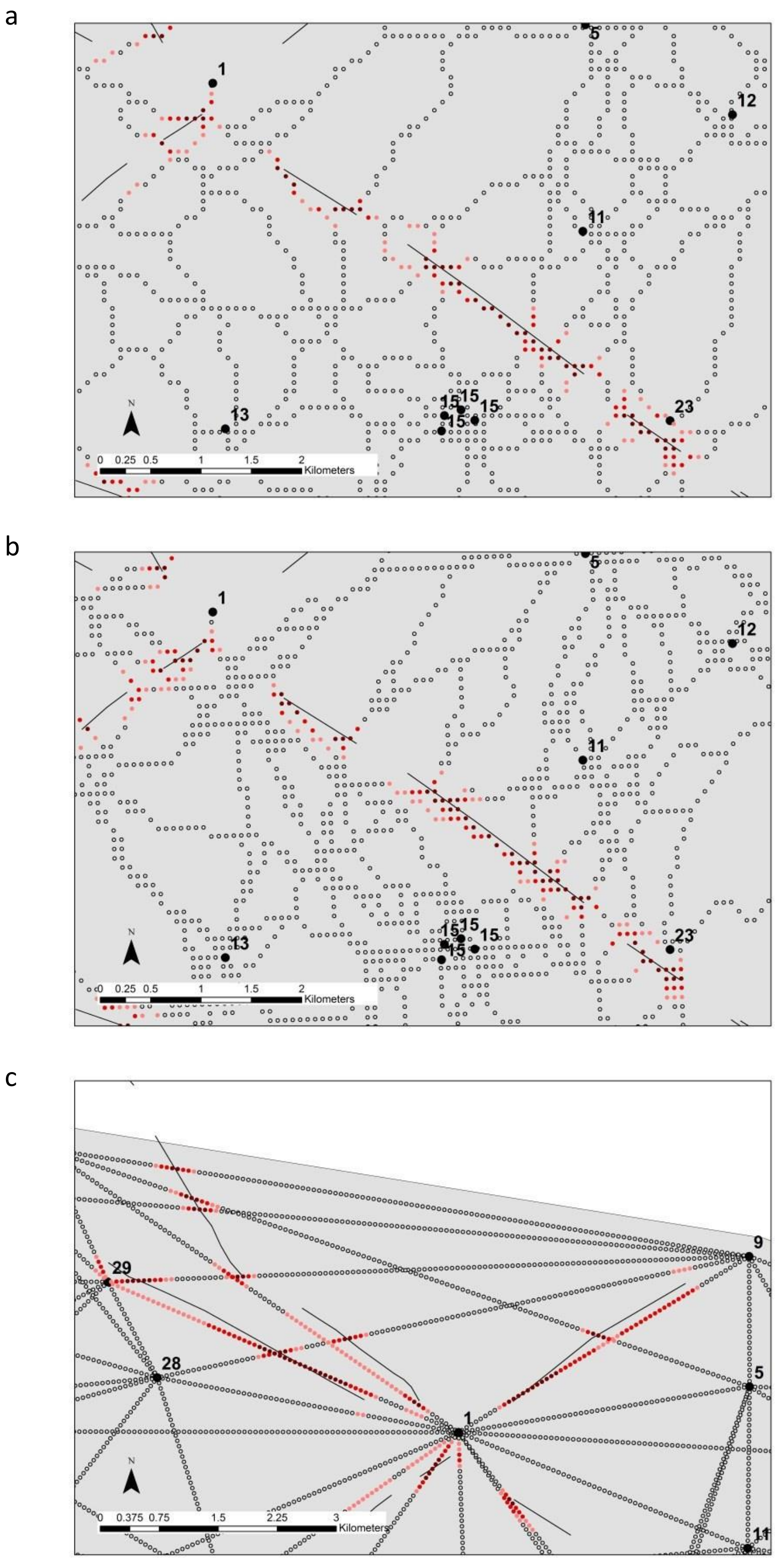

Figure 8 The alignment between the three third millennium optimal models (a – easiest, b – fastest, c – shortest) and the preserved long distance hollow ways. The dark red points overlap the preserved segments; the red points lie in adjacent pixels, and the pink pixels are 2 pixels from the hollow ways. The gray points are more than three pixels from the preserved hollow ways.

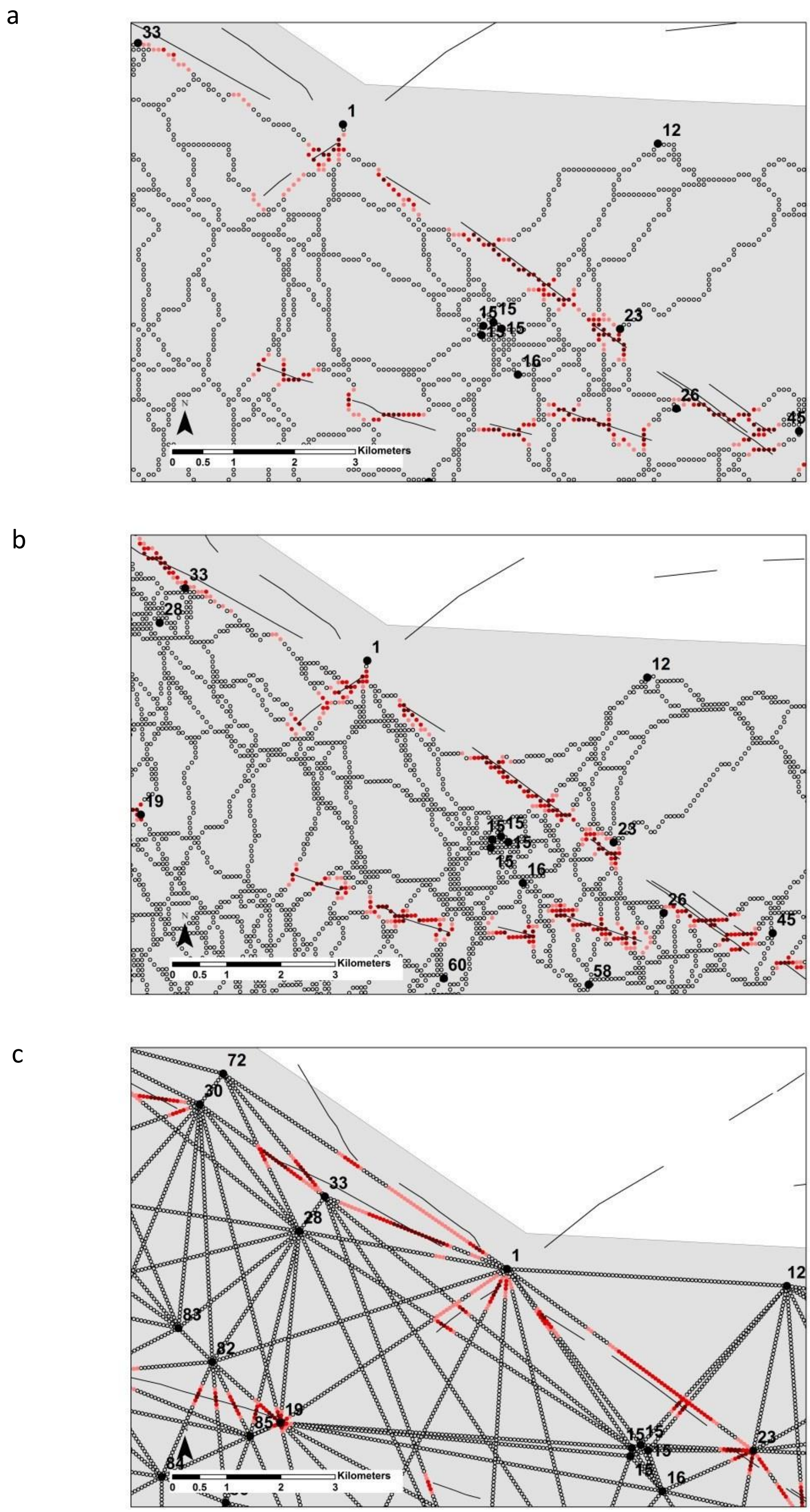

Figure 9 The alignments in the area of Al-Hawa (Site 1) between the three fourth millennium optimal models (a – easiest, b – fastest, c – shortest) and the preserved long distance hollow ways. The dark red points overlap the preserved segments; the red points lie in adjacent pixels, and the pink pixels are 2 pixels from the hollow ways. The gray points are more than three pixels from the preserved hollow ways.

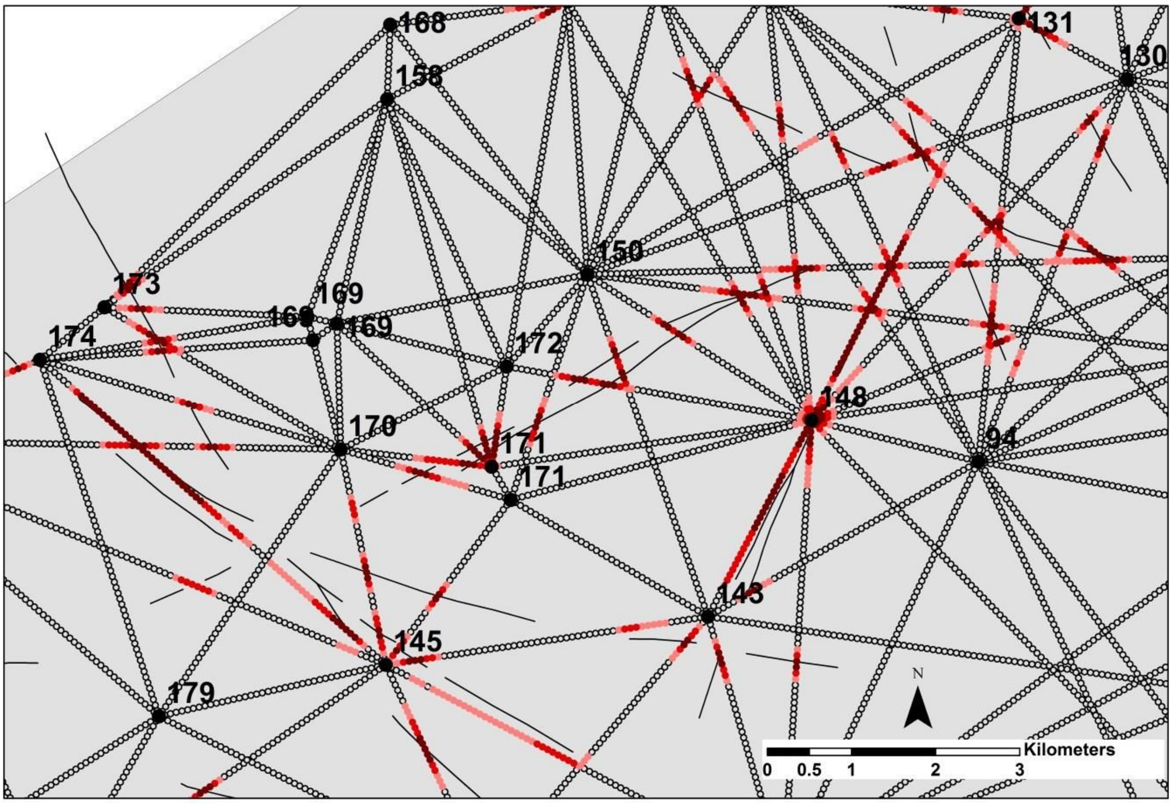

Figure 10 The multiple fourth millennium shortest route alignments with the preserved long distance hollow ways in the western portion of the North Jazira Survey area. The black points overlap the preserved routes, the increasingly lighter shades of gray indicate points which are two then three widths from the hollow way segments. The lightest points are more than three widths from a preserved segment.