



REFEREED PAPER



Combining Historical Maps, Travel Itineraries and Least-Cost Path Modelling to Reconstruct Pre-Modern Travel Routes and Locations in Northern Tigray (Ethiopia)

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ABSTRACT

Investigating long-distance travelling routes is crucial for understanding both historical decision-making processes as well as possible regional points of interest that may have been lost in the course of time. Located in the northern Ethiopian highlands, the city of Aksum was the starting and return point for both, Ethiopian, Arabian, and European travellers on the north-south passage to Cairo, Jerusalem or Europe, at least from the fifteenth century onwards. We extracted locations from travel itineraries from the fifteenth and sixteenth centuries and analysed historical maps from the fifteenth to the twentieth centuries. This data was used to calculate several least-cost paths (LCPs). Results suggest that route planning in historical times was in some cases very cost effective, while in others, visiting specific locations may have played a major role in path selection. Additionally, LCPs based on historical waypoints reveal several remarkable historical locations along their way.

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Introduction and rationale

Throughout the last three millennia, the northern Ethiopian Highlands present a unique example for the coexistence of strong local traditions along with close multi-regional contacts (Phillipson, 2007). During the first millennium BCE, cultural contacts to the Arabian Peninsula became apparent, known as the Ethio-Sabean material culture. This is evident by common styles and inscriptions found in several archaeological sites in Tigray, most dominantly the temple of Yeha (Japp *et al.*, 2011; Haburaj *et al.*, 2020). Early in the first-century CE, the Aksumite state has emerged. This regional empire had its centre c. 35 km east of Yeha, in the city of Aksum, where massive steles have become globally renowned (Phillipson, 2007; Fattovich, 2010). The Empire of Aksum was an influential African civilization, which had trade relations far beyond the African continent until c. 700 CE (Finneran, 2007; Harrower *et al.*, 2019). Following the rule of some local dynasties, during the thirteenth to the seventeenth centuries the power moved south of Aksum to form the Solomonic dynasty (Amhara) which governed much of the highlands (so-called ‘Solomonic’ and ‘Gondarine’ periods). In the eighteenth to the nineteenth centuries this entity has weakened and Tigray again came to self-governance as most of the country was now divided up amongst several noble families (the so-called ‘Zemene Mesafint’). The Ethiopian highlands were reunited under Menelik II in 1889 (Zewde, 1991; Crummey, 2000; Fattovich, 2010). During much of this later period, Northern Tigray has been controlled or influenced by several local and foreign groups (e.g. Muslim invasion in the sixteenth century (Ethiopian-Adal War; Ross, 1922; Gilkes, 2002), European missionaries (Caraman, 1985).

Although many multi-national visitors have arrived in northern Tigray, the local population maintained much of its Aksumite material culture and the region has not been fully colonized except for a short Italian occupation in the twentieth century (Finneran, 2007; Fattovich, 2010; Trento, 2013). Whereas both the Ethio-Sabeans and Aksumites had supra-regional contacts, little is known about the precise course of past long-distance pathways, although some attempts were made to suggest possible route courses (Harrower and D’Andrea, 2014). From the fifteenth century onwards, a number of European travel itineraries provide information on possible route locations, as they document resting places (villages, cities, monasteries) and landmarks (mountains, rivers, depressions). Also from that time onwards, historical maps provide hints on places of interest, which were significant for the route

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planning for these travellers. The number of published maps increased drastically in the nineteenth century beforehand and during the ‘Scramble for Africa’ (Griffiths, 1986; Michalopoulos and Papaioannou, 2016).

Northern Tigray is topographically diverse, with plateau regions, hills, ambas, and deeply incised valleys that would limit the possibilities of long-distance routes. Additionally, some urban centres such as the city of Aksum, have remained dominant for two millennia. Therefore, reconstructing route networks from the fifteenth century onwards, may also give insights in routes that were used in the Aksumite Period or earlier. As with many long-term historical routes, one of the main prisms used for understanding their course, is through the most stable cost of travel, i.e. topography. The steepness of the slope affects both the time of travel as well as the energy required to get from one point to the other (Herzog, 2013). Therefore, topographically convenient path connections may be continuously used over centuries or millennia (Ökse, 2007). The modelling of topographic least-cost paths is a common method to compute the most cost-effective connection between two or more points on basis of a digital elevation model (Seifried and Gardner, 2019; Nir *et al.*, 2021). In a regional study in the Northern Ethiopian Highlands, Nyssen *et al.* (2020) show that modelled least-cost paths at least partly predict present and long-time used pathways.

In this study we want to learn about historical route settings in northern Tigray in historical times. The area under investigation is centred around the ancient places of Aksum and Yeha and was analysed using historical travel itineraries and historical maps. These text and map sources include information on villages, monasteries and other possible resting places, as well as their relative positioning and possible descriptions of routes between them. With help of present-day topographic maps, we geocoded the places mentioned in these historical documents, a process impeded by name changes places underwent over time, inaccurately described locations as well as abandonment of some of the places. Based on this data, we calculated least-cost paths connecting historical places in the study area with farther away locations on the north–south passage between Cairo and Aksum, such as Debarwa and Toagitha (Uogherti) in Eritrea. The major question was, whether cost-effectiveness was the main driver for the selection of routes, or whether other variables influenced the course of long-distance pathways, such as religious-cultural practices or environmental effects (e.g. climatic conditions, water access, river crossings, and so on). Furthermore, we explored whether the reconstruction of a possible historical long-distance pathway network in northern Tigray can help to recognize historically important places in the region, which have vanished over time.

Study area

The study area (Figure 1) is located in the northern Tigray region and covers parts of the northern Ethiopian highlands. The Mareb River cuts through the locally plateau-like landscape in an E–W direction and forms a natural border. To its north, on the Eritrean side, the highland landscape continues via Adi Kwala across the Kohaito plateau. The tropical highland climate in the region is characterized by a significant seasonality of rainfall with a minor rainy season (belg) between March and May and the major rainy season (kiremt) between July and October (Berhane *et al.*, 2020). This seasonality seems to prevail already since the middle Holocene (Nyssen *et al.*, 2004). Accordingly, most of the smaller rivers are periodic and only major rivers are perennial (such as the Mareb River or the Tekeze River).

The most important modern towns in the core study region are Aksum and Adwa, which are both located in the plateau area. In the northern-central part of the study area, a presumably structural N–S striking depression structure occurs (here called Rama depression; Busch *et al.*, 2021; Nir *et al.*, 2022), which is about 10 km long and up to 4 km wide (E–W).

The present-day road network consists of a paved road that connects the towns between Adigrat and Shire in a more or less E–W-direction. It is part of the national road B30 that connects Adigrat with Gondar and primarily runs across the plateau area (Figure 1). One northward route goes via Adigrat, another one, which affects the core study region, connects Adwa via Daro Tekle through the Rama depression with Gondet/Aila and Adi Kwala (Eritrea).

Methods and data

Historical references

A squared area of about 80 by 80 km centred around the cities Aksum and Yeha (core study region) was the focus area of data collection. In this core study region, we collected and structured all available toponyms found in maps and itineraries (Supplementary Material C).

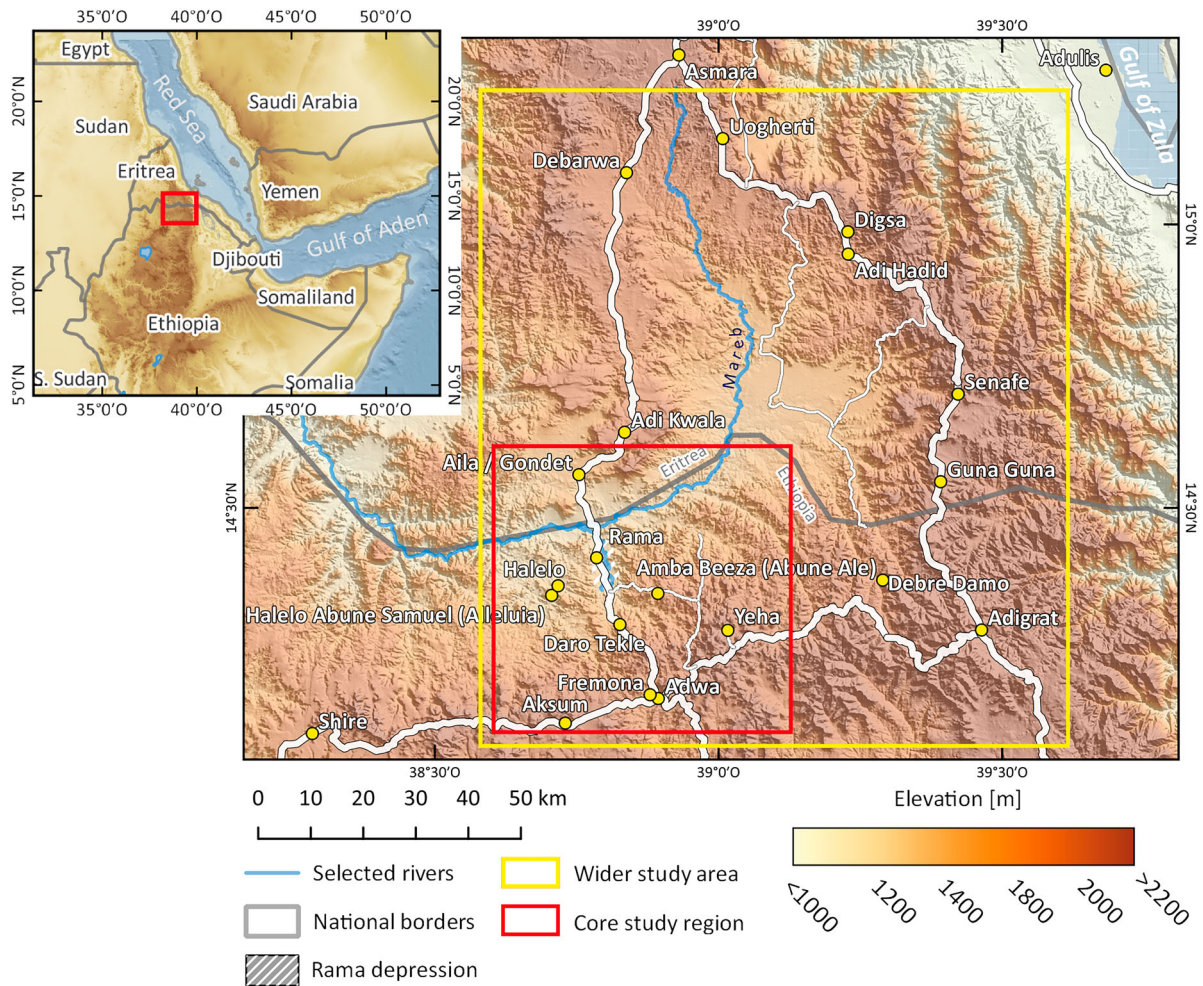


Figure 1. Overview map showing the wider study area (orange frame) and the core study region (red frame). Inset map shows context in the Horn of Africa. Thick white lines depict modern major roads, thin white lines depict minor roads. Hillshade map based on AW3D30 digital elevation model (JAXA, 2005).

The oldest available sources which relate to the core study region are the four itineraries written down by the Venetian Alessandro Zorzi, which cover the time span from 1400 to 1524 (Table 1). Zorzi listed the itineraries, which he collected from Ethiopian pilgrims and European adventurers travelling to or from Ethiopia, around the year 1524 in Venice without ever having travelled to Ethiopia by himself (George, 1959; Ayenachew, 2016). These itineraries were translated into English and interpreted by Crawford (1958). Another resource covering this era is the report of Father Francisco Alvarez (‘The Prester John of the Indies’), who joined a Portuguese mission to Ethiopia from 1520 to 1526, translated from Portuguese into English and interpreted by Beckingham and Huntingford (1961). Complementary to the written sources, the oldest available map is the ‘Egyptus Novelo’, dating to c. 1454 (Van Duzer, 2019: 141). An interpreted and redrawn version of it is depicted in Crawford (1958: 14 f.).

Table 1. Itineraries referred to in this study.

Year	Name	LCP name	Route	Mentioned waypoints used in this study ^a	Reference
c. 1400	Zorzi’s Iter F	LCP-2-1400	Jerusalem to Aksum	Aksum, Adwa, Toagitha (Uogharti), Asmara	Crawford (1958: 28 f.)
Before 1517	Zorzi’s Iter I	LCP-2-1400+	Aksum to Cairo	Aksum, Torat (Adwa), Gulti, Alleluia, Aila, Debarwa, Asmara	Crawford (1958: 55 ff.)
Before 1518	Zorzi’s Iter III	LCP-1-1518	Barara to Cairo	Fremona, Aksum, Lelia (Alleluia), Debarwa	Crawford (1958: 71 ff.)
Before 1523	Zorzi’s Iter IV	LCP-1-1518	Ugie to Jerusalem	Aksum, Lelia (Alleluia), Debarwa, Massawa	Crawford (1958: 78 ff.)
1520	Journey of Father Alvarez	LCP-1-1520	Massawa to Shoa	Aksum, Adwa, Yeha, Debarwa, Massawa	Beckingham and Huntingford (1961)

^amentioned are only places that could be localized in this study.

All the above-mentioned sources pre-date the invasion led by Grañ ('the left-handed'), responsible for destroying some of the places mentioned in these early sources (George, 1959). The invasion started in Adal at the Red Sea in 1528 and was defeated by the troops of Christovão da Gama in 1543 (Caraman, 1985: 9).

As place names frequently are subject to change in the course of centuries (Chauke, 2015), also different translations can result in different names for the same place (Moller, 2019). Places may not have existed centuries or decades ago, and other places may have vanished over time. Thus, geographical references, landmarks, and rivers were useful in finding the area of interest in historical maps. While sometimes the data from the maps is rather easy to interpret because known places are mentioned at their more or less correct geographical position, in other cases a precise localization of places mentioned on historical maps is impossible. Many of the historical maps are publicly available via <http://www.afriterra.org> or <https://ethiomap.huma-num.fr> and the respective weblinks can be found in Supplementary Material A.

The alignment of places on the analysed pre-eighteenth-century maps, where no routes are denoted, may only serve as a rough indication of the historical path network. Maps from the nineteenth century reflect the routes individual expeditions have travelled on (e.g. Lefebvre, 1847), while some maps also compile routes of several expeditions (e.g. Salt, 1814). These nineteenth-century expeditions used to follow the existing path network, making their descriptions valuable for the reconstructions of pre-modern path networks, as the eighteenth- and nineteenth-century maps present a route network prior to construction of the modern roads by the Italians in the twentieth century. Thus, the latter are more likely to indicate older routes than the twentieth-century maps (Crawford, 1958: 56).

Least-cost path modelling

Least-cost path (LCP) analysis is a well-established tool to compute a preferred movement route between two points and is mostly based on topographic features (e.g. Alberti, 2019; Gowen and de Smet, 2020; Nir *et al.*, 2021). LCPs between different locations in the Ethiopian and Eritrean highlands were calculated based on topographic data generated from a Digital Surface Model (DSM, AW3D30; JAXA, 2005) with a horizontal resolution of 30 m. Due to calculation limitation resulting from the long distances between the points of origins and destinations, the DSM was aggregated into a 60 m resolution raster in the R statistical software environment (R-Core-Team, 2020). Elevation values were then transformed into a conductivity transition layer using the package 'gdistance' (van Etten, 2017), based on Tobler's hiking cost calculation (Equation (1)) (Tobler, 1993):

$$6 * \exp(-3.5 * \text{abs}(x[\text{adj}] + 0.05)) \quad (1)$$

where $x[\text{adj}]$ stands for slope angle as rise or descend for adjacent cells (Rees, 2004; Herzog, 2013; Alberti, 2019). An adjutancy of 8 (queen) was used, meaning the 8 neighbouring pixels were tested by the algorithm as moving directions for each pixel along a constructed way. The pixel with the least topographic difference to the one already along the way is chosen as the next pixel. Based on the resulting transition layer, LCPs were calculated using the 'create_lcp' function in R (package 'leastcostpath'; Lewis, 2020). The desired paths used for calculating long-distance LCPs are the direct LCPs from Aksum to Debarwa (LCP-1-D) and from Aksum to Toagitha (LCP-2-D). These locations were chosen according to their repeated appearance in the earliest itineraries (Table 1). A second set of LCPs (LCP-1-1517, LCP-1-1518, LCP-1-1520, LCP-2-1400, LCP-2-1400+) was an attempt to follow a similar long-distance origin and goal but additionally incorporate transit points (Seifried and Gardner, 2019) described in the analysed itineraries within and outside the core study region (Table 1). For the transit points, a LCP is calculated from each point to the next according to the historic sources and following the way from Aksum to Debarwa (LCP-1-D) or to Toagitha (LCP-2-D). These LCPs were then bonded together using the 'rbind.SpatialLines' command in R (package 'sp'; Bivand *et al.*, 2013). A comparison of both sets of LCPs was conducted to evaluate the possible effect of the local transit points on the path chosen by the travellers. The differences between the LCPs were calculated using the 'PDI_validation' function (package 'leastcostpath'; Lewis, 2020) in R. The R code and the input parameters are available in the supplementary material.

Results and discussion

Source criticism

Cartographers create maps with a specific purpose in mind. The purpose is not necessarily the most precise planar representation of a specific area, as empty spaces on a map may have been filled by the cartographer with fictional

mountain ranges or rivers for aesthetic purposes. A paradigm shift occurred from the eighteenth century when it became established that places with no data can remain blank for the benefit of higher precision (Bassett, 1994). Beyond, some of the historical maps were not drawn to scale, and their spatial representation can contain variable and unknown distortions.

We are aware that this study is based on maps and accounts drawn or noted by Europeans. As Nyssen *et al.* (2019) report, indigenous historical spatial information from the study area is often contained in form of lists and found in church manuscripts in the ancient Ethiopian Ge'ez language; the analysis of these sources was beyond the scope of this study. Furthermore, there exist indigenous maps from the core study region, such as the circle maps from the eighteenth and nineteenth centuries, which are centred around the ancient capital of Aksum. These maps consist of concentric circles divided into different sectors. The sectors represent specific places or areas and point into the appropriate direction (Bassett, 1998; Nyssen *et al.*, 2019). Nyssen *et al.* (2020) have shown on basis of least-cost path modelling that the circle maps are useful for route planning. However, the circle maps made accessible by Nyssen *et al.* (2020) do not include waypoints, e.g. between Aksum and Hamasien/Debarwa. For this reason, the circle maps were not implemented into our dataset. Earlier indigenous maps from the region are not known (Voigt *et al.*, 2003).

Historical documents

Fifteenth and sixteenth centuries

The map *Egyptus Novelo* (c. 1454) depicts several places in northern Tigray (Figure 2(A)). A river named *Saraue* most likely represents the Mareb River: it is not tributary to any other river or lake and vanishes inland. Likewise, the Mareb River ends at an inland delta (Gash delta) in eastern Sudan near Kassala. To the south and west of this river, several places in the study area are mentioned, which also appear on later maps or reports of this region: Philemona, Alleluia, Gult, and Damo.

Philemona likely refers to Fremona (Crawford, 1958), which became one of the two most important Jesuit monasteries in Ethiopia (Martinez, 2005). Fremona lies on a hill close to the modern town of Adwa. Other names for this location are E. Nebersc, Firemona, or Maigoga (gazetteer of Lindahl; Martinez, 2005). The Jesuit mission settled at Philemona around 1560, along with people from the expedition of Christovão da Gama (Martinez, 2005). In the course of time, Fremona became fortified (Bent, 1893b: 110) and served as an important link between the Red Sea coast and the central and southern Ethiopian highlands. However, after the restoration of the Orthodox faith, Fremona was abandoned until around 1650. An earlier church on the same hill dates to the early fifteenth century, indicating that the place was already of importance before the Jesuit mission arrived and that the name already existed, too. This theory is supported by ancient inscriptions mentioning a similar name in Aksum (Martinez, 2005) and by its denotation on the *Egyptus Novelo* map from 1454.

On the *Egyptus Novelo* map, a place named *Alleluia* is mentioned close to Philemona (Figure 2(A)). On subsequent historical maps, Alleluia reappears in different spelling variants (e.g. Lelia, Alello, Dabra Halole, see Supplementary Material C) as well as in three travel itineraries (Table 1). According to the three travel reports from 1517 to 1523, Alleluia was located along 'the western route' travelling from Asmara towards Aksum (Crawford, 1958: 34). This route

is well attested by Zorzi's Iters I, II and IV. It may also safely be inferred from some of the places marked on *Egyptus Novelo*, which [...] are found to be strung out along it. These are, from south to north: Gult, Alleluia, the districts of Saraue and Maragus [...]. (Crawford, 1958: 34)

Although information is sparse, Beckingham and Huntingford (1961: 164) mention that Alleluia was a monastery that had been burnt during the invasion led by Grañ in 1535. Caraman (1985: 47) states that '[t]he destruction of Hallelujah was a setback for the Catholic mission, for it represented a source of monasticism common with the West'.

The name *Gult* (also Gulti, Guelte) is mentioned on *Egyptus Novelo* and in Zorzi's Iter I (Table 1), but this place cannot be precisely located. Crawford (1958, 58) notes '[i]t must have been somewhere near Fremona' and that it is '[...] a name which has not survived'. The term *gult* may however also relate to a specific type of land tenure (Crewett *et al.*, 2008) and thus does not necessarily have to refer to a single place.

According to Crawford (1958: 34), *Damo* is most likely the monastery of Debre Damo, which still exists today and is located about 20 km north-west of Adigrat (Figure 1). It is the oldest church of Ethiopia, dating back to the sixth-century CE (Phillipson, 2007). It is occasionally affiliated with one of the Nine Saints, Za Mikael Aregawi, who introduced monasticism to Aksum and the region in the sixth-century CE (Munro-Hay, 2012).



Figure 2. Excerpts from fifteenth- and seventeenth-century maps. The toponyms of the core study area are underlined in red. Maps are not to scale. (A) Egyptus Novelo (c. 1454; image courtesy Bibliothèque nationale de France). (B) Map of Eschinardi (1684). (C) Map of Ludolf (1683). (D) Map of Coronelli (1690). B, C and D courtesy of afriterrra.org. See details for all maps in Supplementary Material A.

Although Aksum is not mentioned on Egyptus Novelo, all studied travel reports include Aksum as a waypoint. Zorzi's Iter F from 1400, Zorzi's Iter I from 1517 as well as the travel report of Father Alvarez from 1520 also mention Adwa as a waypoint. Additionally, as the only source from this time period, the travel report of Alvarez mentions Yeha as a waypoint (Table 1).

Seventeenth and eighteenth centuries

More than 200 years after Egyptus Novelo, the map of Ludolf (1683), Figure 2(C) denotes several places in the core study region: Guelt (Gult), Alallaya (Alleluia), and Mai gagoa (Fremona). Hiob Ludolf, a German scholar, incorporated indigenous knowledge into the map as he consulted an Ethiopian monk in Europe in the mid-seventeenth century (Nyssen *et al.*, 2019). Adawa (Adwa) and Aksum are among the new places on the map that were not depicted on the Egyptus Novelo map. Although Alleluia was destroyed in 1535, it is

still mentioned more than 100 years after destruction on this map. However, on the Ludolf map (1683) it is depicted with a much smaller symbol than Fremona and Aksum. Likewise, Fremona was abandoned by the Jesuits around 1650. Either the map displays a time when Fremona was still a Jesuit monastery, or the place kept some of its significance after its abandonment. The interpretation of an ongoing importance of the location Alleluia even after its destruction corresponds to the continuous appearance of Fremona on later maps. The map of Coronelli (1690), Figure 2(D) includes similar locations as Ludolf's and also has a small symbol for Alleluia while it does not mention Gult.

Different from both aforementioned maps, the map of Eschinardi (1684; Figure 2(B)) displays Accum (Aksum), Fremona, and Alello (Alleluia). The Eschinardi map does not mention Adwa but a place or region termed *Gama* south of the Mareb between Fremona and Alello. Among the studied sources, this is the only mention of a place or region with a spelling similar to the modern city of *Rama*. From its position on the map in-between mountains, its location might coincide with the area of the modern city of Rama. Although speculative, this notion is supported by some variations within the alphabets of Semitic languages such as Arabic. The latter has one letter that includes what would sound like both R and G (Ghayn غ). As Tigrinya is considered 'Ethio-Semitic' and Arabic itself was introduced in Tigray during the post Aksumite period, these possible changes in spelling should be considered analysing locations on historical maps (Ferguson, 1970). The drawing of a church on a hill next to *Alello* fits to its characteristic of having been situated 'on a high and big mountain', according to the travel report of Alvarez from 1520 (Beckingham and Huntingford, 1961: 164). *Guele*, situated north of the Mareb near Gama and Fremona might refer to the place Gult mentioned in some earlier itineraries and on Ludolf's map (Guelt), where it is placed south of the Mareb (Figure 2(C)).

The map of De L'Isle (1707) dates to the early eighteenth century (Figure 3(A)). In the core study region, only Axum (Aksum), Adowa (Adwa), and the ruins of Fremone (Fremona) are mentioned. A route is drawn connecting Massawa at the Red Sea, Dubarua (Debarwa) and Fremona from where it continues south-west to the at that time capital Gondar. A route connection between Aksum and Debarwa is also implied by a historical circle map analysed by Nyssen *et al.* (2020).

Nineteenth century

On the map of Mollo (1811; Figure 3(B)) the towns of Axum (Aksum) and Adowa (Adwa), as well as Fremona are denoted. Adwa and Aksum are connected by a route. From Adwa, a route extends to the east and then towards north in the direction of Massawa, indicating the eastern route towards north. From Aksum the route extends to the west via Sire (Shire).

The map of Bruce (1813), Figure 3(C) offers comparably more detail than the maps of De L'Isle (1707) and Mollo (1811). Bruce (1813) records for the core study region Axum (Aksum), Adowa (Adwa) and Fremona, and additionally for the first time a location called *Hiha*, which may refer to modern Yeha. Other places like *Ribierainy* or *Maybinni* mapped in the core study area could not be localized or related to modern locations. On the Bruce map (1813) Fremona is displayed far north of Adwa (like in the Mollo map, 1811) and has a route connection only to Aksum, although in fact it is located in a distance of about 10 km to Adwa. However, there is an east-west connection similar to the one mapped by Mollo (1811). From Aksum there are two connections to the south. One goes straight to the south and then to the east, the other one runs south-west and leads to Gondar. The northern route from Aksum connects with Fremona, where continuing northward the route forks off in a western route connecting with Baira and in an eastern route connecting with Dobarwa (Debarwa), where also both routes merge again. Thus, the map displays two options for the western route towards north. Although not shown in the excerpt of Figure 3(C), an eastern route towards the north is also depicted on the original map.

On the map published by Salt (1814; Figure 3(D)), Axum (Aksum), Adowa (Adwa), Fremona and Yeehah (Yeha) are recorded. Several place names are hard to decipher in the available version. From Adwa, a route leads north and forks off with the western branch leading to Yeehah (Yeha) and from there continuing northward, while the eastern branch does not evidently connect with known historical places. The north-westward heading route from Adwa connects with Fremona and then runs along the footslopes of a mountain ridge following the left side of a major river course, before it crosses the Mareb River, connects with *Aderbahti* and continues running into *A Wild District*. This passage, with the river running in between mountain ridges to the east most likely corresponds to the northward striking topographic depression around the modern town of Rama. In case this allocation is correct, the depicted mountain ridge to the north of Fremona corresponds to the ridge of Amba Beesa and Sjemro Kiristos (Amba Christos), and the mountain ridge to the north-west of Axum corresponds to the ridge where Alleluia is located (see Figure 5). Thus, this northward route starting from Adwa as recorded in the Salt map (1814) corresponds to the western route



Figure 3. Excerpts from eighteenth- and nineteenth-century maps. The toponyms of the core study area are underlined in red. Maps are not to scale. (A) Map of De L'Isle (1707). (B) Map of Mollo (1811). (C) Map of Bruce (1813). (D) Map of Salt (1814). (E) Map of Lefebvre (1847). (F) Map of Bent (1893). (A)–(F) courtesy of afriterrra.org. See details for all maps in Supplementary Material A.

towards north as documented Zorzi's Iters I, III and IV (Table 1). Beyond, several options for an eastern route towards north are also depicted on the full map published by Salt (1814).

The map published by Lefebvre (1847; Figure 3(E)) is highly detailed, as it displays a wealth of place names, routes, and topographical details. Axoum (Aksum), Adoua (Adwa) and Yeha are denoted, while Fremona is missing on the map. From Adwa, one route leads to Yeha, and from there continues north-east. From the route connecting Adwa with Yeha about half-way a branch forks off heading north via Beeza, Amba Christos, then crosses the Mareb River and continues on to Gondet (Gundet) and Addikoala (Adi Kwala). Beeza also appears on the modern map as Amba Beesa – a plateau with two distinct hills marking its eastern and western margins (Figure 5). Even these two small hills appear to be displayed on the Lefebvre map. The name Amba Christos may refer to the Sjemro Kiristos, which is documented in the Soviet military map (1977) but not on the current Ethiopian topographical map (1997). An additional

route starts from Adwa leading north-west to Darotecli (Daro Takle), then using a hard to localize course until Gondet (Gundet). This route possibly passes through the Rama depression where it stays to the right of a river ('Maye Korgra'). As shown in Figure 1, Daro Takle is a common waypoint at the southern 'entrance' of the Rama depression. Thus, the map gives two options for the western route towards north, in addition to an eastern route.

Lefebvre himself, while travelling from Adwa to Massawa in January of 1840, made a stop at Beeza (Amba Beesa) before he went on through hilly terrain towards the Mareb River (Cooke, 1867: 205). He calls this the *Seraé road*. The name is similar to the *Saraue* mentioned already on Egyptus Novelo (c. 1454). On the Lefebvre map, Seraé is the region north of Addikoala (Adi Kwala). Thus, he might refer to a western route towards north instead of the eastern route, which, goes north via Yeha without crossing the Mareb River.

Compared to Lefebvre (1847), the map published by Bent (1893a) offers less details in the core study region (Figure 3(F)). The intention of the Bent map was to provide an overview of trade routes across Ethiopia on a single book page. In consequence, this small scaled map is much coarser than the aforementioned maps. The Bent map outlines the towns of Axum (Aksum), Adowa (Adwa) and Gondet (Gundet), as well as Fremona and Ava/Yeha. It displays direct connecting routes between Aksum, Adwa and Yeha. From Yeha the outlined north-east bounding route continues via the Kohaito plateau in Eritrea to Adulis and Massawa. Starting from Adwa there is a northbound route to Gundet outlined, which continues to Asmara and Massawa (the 'western route'). However, due to the small scale the Bent map does not allow to distinguish whether the northbound route passes along Amba Beesa or Alleluia.

Twentieth century

The map by the Italian Istituto Geografico Militare (1934; Figure 4) dates from the early twentieth century. It shows a widely ramified route network. Reappearing places from the aforementioned historical maps are Axum (Aksum), Adwa, Fremona, Jeha (Yeha), Daro Takle, Amba Beesa, Amba Cristos, Gual Aila (Gundet). Along the so-called Rama depression area runs a river called *T. Mequam*; along the river course several springs are mentioned (Mai Lala, Mai Bairai). Close to the present-day town of Rama the map shows a fortification on a hill termed 'For. ^{no}Mequam (Roviae)'.

Two major roads pass Adwa: An east-west bound route connecting Gondar with Adulis and Massawa goes from Adwa via Adigrat and Senafe; unlike shown in the Bent map (1893), the town of Yeha does not lie along this route. Another major road starting from Adwa heads north to Daro Tacle (Daro Takle), where it forks away. One branch heads north-east to Amba Beesa from where it turns north and heads to Adi Kwala. The other branch descends down into the Rama depression (indicated by the winding road close to 'Mai Bairai') where the route runs north-west parallel to the *T. Mequam* River and turns north after it has passed 'For. ^{no}Mequam (Roviae)'. After crossing the Mareb River it heads northward to Gundet (Gual Aila), from where it continues to Adi Quala (Adi Kwala).

The Soviet military (1977) map (excluded here because an excerpt could not be properly reproduced at the necessary scale) shows a widespread route network densely intertwined over the whole study region. The only larger (unpaved) roads are the east-west connection between Adigrat and Shire, to which also Axum (Aksum) and Adwa are connected. The northbound route goes from Adwa via Daro Takle through the Rama depression. For the first time, the town of *Rama* appears on a map.

Route reconstructions and least-cost path analyses

The first set of least-cost paths, direct connections from Aksum to Debarwa (LCP-1-D) and from Aksum to Toagitha (LCP-2-D), result in total lengths of about 117 (LCP-1-D) and 130 km (LCP-2-D) (Table 2, Figure 5). Starting from Aksum, both paths run northward. Shortly after crossing the Mareb River, the way to Debarwa continues north while that to Toagitha turns north-east (Figure 5).

The second set of LCPs processed includes transit locations mentioned in the itineraries (Table 1). The length of the different LCPs was converted into travel time per day for three different scenarios (16 km; 20 km; 24 km). According to Crawford (1958: 55), the travel speed of a caravan averaged 10 miles per day (about 16 km) in rugged terrain and up to 15 miles per day (about 24 km) in flat terrain. Thus, the value of 12.5 miles per day (about 20 km) serves as an average pace, as the terrain in the study area is heterogeneous. Considering the average pace, both direct LCPs from Aksum to Debarwa (LCP-1-D) or Toagitha (LCP-2-D), although slightly different in length, most likely required six days of travelling. Compared to these routes calculated only from considering the topography, the LCPs following historical locations are always slightly longer. The LCPs from Aksum to Debarwa following Zorzi's Iter III and IV (LCP-1-1518) is only one km longer than the 'ideal' LCP-1-D, resulting also in a most likely travel time of six days. The LCP-1-1517 from Aksum to

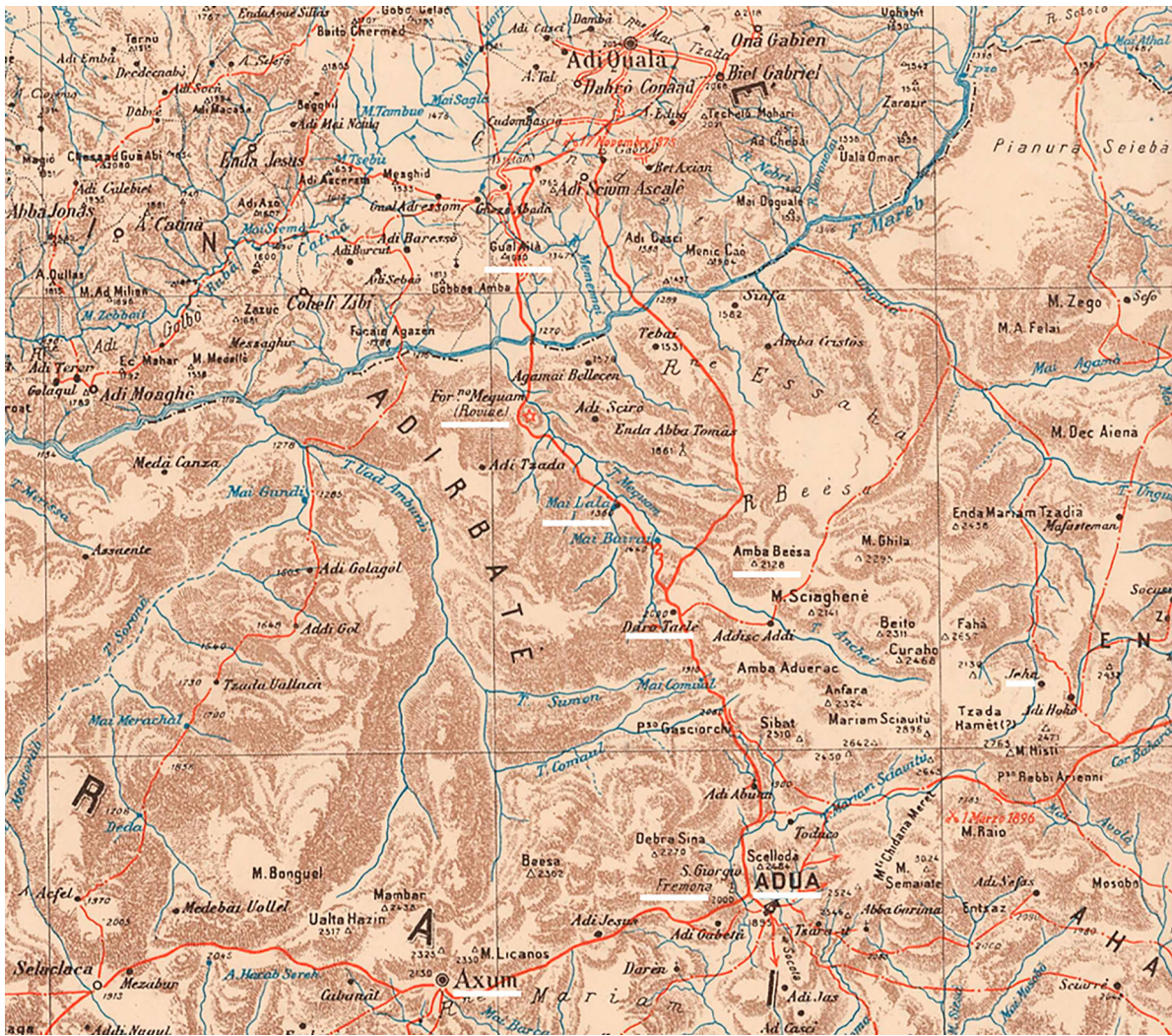


Figure 4. Excerpt from an Italian military map of 1:400,000 (1934). The toponyms of the core study area are underlined in white.

Debarwa related to Zorzi's Iter I requires seven days travelling time, as it includes a detour via Adwa. The LCP-1-1520 from Debarwa to Aksum following the journey of Alvarez runs via Yeha and also requires seven days (Table 2).

The calculated LCP-2-1400 of the eastern route connecting Aksum and Toagitha, as described in Zorzi's Iter F (1400), needs to be carefully pondered. Unfortunately, two place names mentioned in Zorzi's Iter F, which were located between Toagitha and Aksum, have vanished and could not be localized. These missing locations are Ligaxo(n) and Antisiment. Crawford (1958: 28 ff.) suggests that Ligaxo(n), although 'unidentifiable', existed somewhere between Adwa and Entichio (which is located 30 km north-east of Adwa) and that Antisiment could be Abba Tsehma, which was a '2 day's journey east of Adua' (Crawford, 1958: 38). Furthermore, he suggests that the route of Bruce (1769–1770) coincides with the track of Iter F. From Asmara south towards Aksum, the route of Bruce stayed on the plateau to the east of the Mareb, thus completely avoiding a river crossing. As we could only locate a very little number of places mentioned in Iter F, and as the interpretation of Crawford (1958) remains speculative, we calculated two different scenarios for this

Table 2. Least-cost path lengths and calculated travel times, based on three scenarios.

LCP name	km	Travel time [days]			
		16 km (10 miles)	20 km (12.5 miles)	24 km (15 miles)	
Direct LCP Aksum – Debarwa	LCP-1-D	117	7	6	5
Direct LCP Aksum – Toagitha	LCP-2-D	130	8	6	5
LCP Iter I (before 1517)	LCP-1-1517	141	9	7	6
LCP Iter III and IV (before 1518)	LCP-1-1518	118	7	6	5
LCP Alvarez (1520)	LCP-1-1520	141	9	7	6
LCP Iter F (ca. 1400)	LCP-2-1400	138	9	7	6
LCP Iter F modified	LCP-2-1400+	192	12	10	8

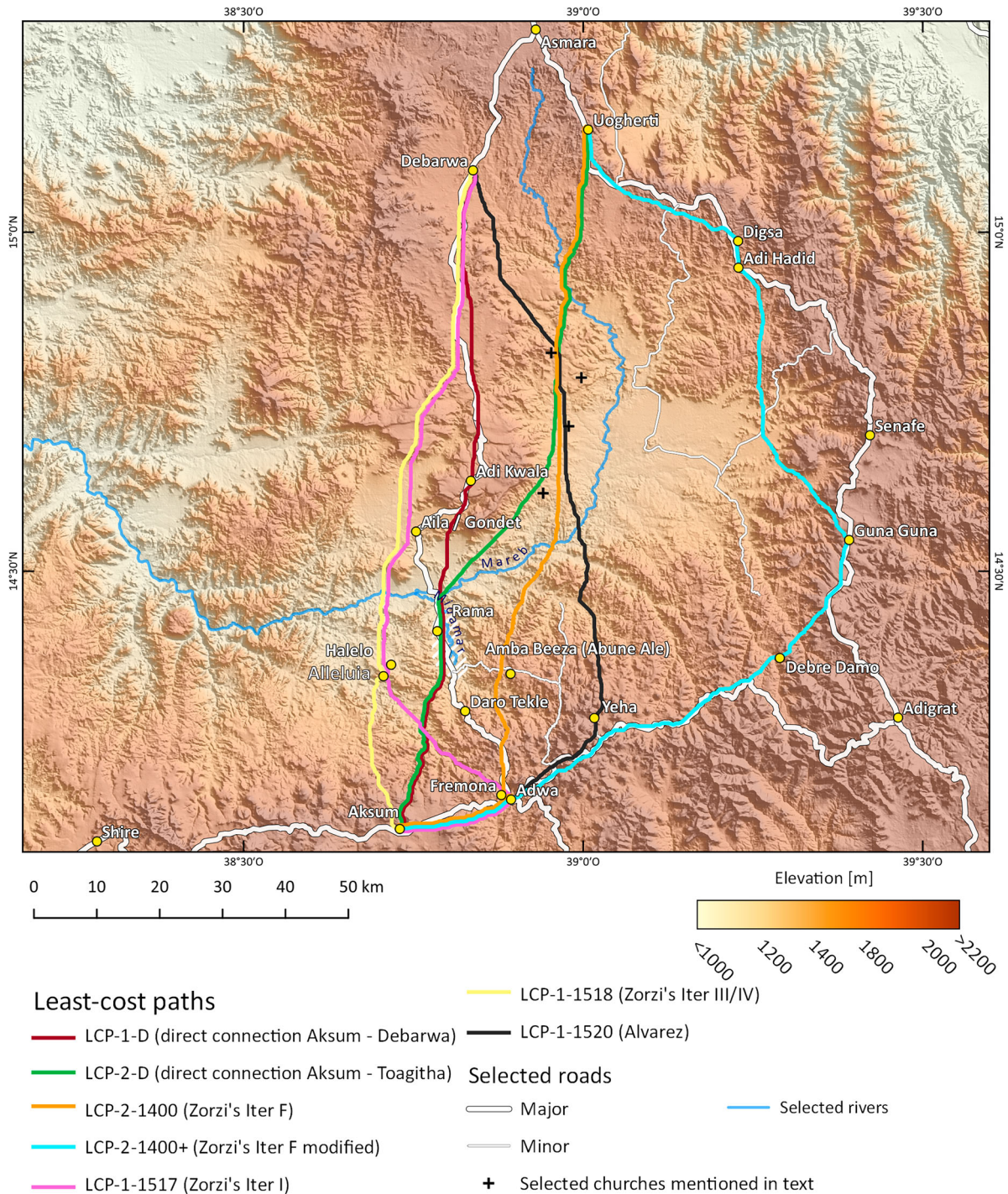


Figure 5. Calculated least-cost paths in the study area. Hillshade map based on AW3D30 digital elevation model (JAXA, 2005).

eastern route. One is the LCP-2-1400 based on the sparse (but safe) information available in Zorzi's Iter F and a second one (LCP-2-1400+), which contains some additional places found on Egyptus Novelo and parts of the track described by Bruce, following Crawford's (1958: 37) suggestion (Figure 5). Starting in Aksum, LCP-2-1400 crosses the Mareb River twice on the way to Toagitha and measures 138 km. The LCP-2-1400+ goes via Debre Damo and avoids crossing the Mareb River, resulting in the longest of all connections, measuring 192 km.

In average, the LCPs including waypoints mentioned in the itineraries (Table 1) are about 0.5–17% longer than the direct LCPs (Figure 5, Supplementary Material B). LCP-1-1517 from Aksum to Debarwa passing by Adwa, Alleluia and Gondet/Aila would result in a length increase of c. 17% compared to the direct LCP-1-D (117 km). While LCP-1-1518, which is only passing by Alleluia and Aila would extend the travel distance only by 0.8% (total 118 km) compared to LCP-1-D. The route from Aksum to Debarwa passing by Yeha (LCP-1-1520), as described by Alvarez (1520), would extend travel distance and travel time compared to LCP-1-D by c. 17%.

On the eastern route from Aksum towards Toagitha passing by Adwa (LCP-2-1400) would increase the direct travel distance (LCP-2-D) by 6.2%. When considering the additional stops, some LCPs change their course distinctly, while others may deviate shortly but then remain closely parallel to the course of the direct LCP. In the case of Zorzi's Iters I, III and IV (represented by LCP-1-1517 and LCP-1-1518) a slight deviation of the routes' courses (4.5–5.6%) is evident. Although most of the LCPs do not follow the same course, they remain close to each other (Figure 5). In contrast, LCP-1-1520 deviates from all other LCPs by 16.9–19.9% (Figure 5, Supplementary Material B).

Comparing the calculated LCPs, two general observations can be made. Firstly, the direct LCPs from Aksum to Debarwa (LCP-1-D) and from Aksum to Toagitha (LCP-2-D) both follow the Rama depression. Considering waypoints based on the historical sources, would result in the omission of the Rama depression. The second observation is related to the location of Alleluia. It is evident that the LCPs calculated while considering Alleluia as a waypoint (LCP-1-1517, LCP-1-1518), would ultimately reach very close (about 750 m) to Aila (Figure 5), in opposite to the direct LCPs. Thus, Aila appears to be a feasible waypoint on the historical route.

Localizing Alleluia

Although mentioned in the earliest analysed documents as an important monastery and repeatedly noted as a waypoint in the region, Alleluia disappeared from the records from the eighteenth century onwards. In the scope of reconstructing past routes, it is of interest to precisely localize this historical waypoint. While some merely mention Alleluia on 'a high mountain' (Alvarez, 1520 in Beckingham and Huntingford, 1961: 164), several hints give evidence for a likely location of the historical Alleluia. Manoel Barradas (1634 in Pankhurst, 1996: 132) mentions in his notes about Alleluia:

From Fremona it lies one day to the North. [...] But often when coming and going to Debaroa I passed within sight of it, as it is built on the top of a range of mountains, and although it is in the middle of a dense copse it can be clearly seen, even from very far away.

Zorzi's Iters I and II describe the monastery being a two days travel away from Adwa or Aksum accordingly, mentioning another day of travelling to cross the river Mareb on the way to Aila (Crawford, 1958: 125 and 145, and supplementary data). In agreement with these descriptions, Alello (Alleluia) is depicted by a church building on a solitary hill on the map of Eschinardi (1684, Figure 2(B)). Caraman (1985) mentions that Alleluia was founded by the influential *Abbot Samuel*, who lived in the fourteenth century according to Pankhurst (1996: 132), and that it is 'situated on a mountain above the river Mareb, twenty miles north-west of Aksum', without giving exact coordinates (Caraman, 1985: 47).

From the placement on Egyptus Novelo (1454), the studied maps from the seventeenth century, and the aforementioned itineraries, Alleluia must have existed on a hill in the wider surroundings north of Adwa and Aksum (about one to two days' travel time) and south of the Mareb (Figure 5). According to the topographic map of Ethiopia (ETH 50k 4 1438 D1), there is a modern village named Halelo and a church compound named Halelo Abune Samuel located about 25 km north of Aksum and about 14 km south of the Mareb. Thus, it is reachable within one to two days of travel time from Aksum. The church compound lies on an isolated hill, which rises to 400 m from its surroundings. The good visibility of this location and the topography as well as the distance from Aksum, Adwa, and the Mareb River, fit well with the historic descriptions. The name of the modern church *Abune Samuel* is another indicator, as it refers to the ancient founder of the monastery of Alleluia (Caraman, 1985: 47).

Finneran (2012), however, states that Debre Halle Luya (Alleluia) goes back to *Abune Alef*, who, in the traditional accounts, was one of the *Nine Saints*. Furthermore, Finneran (2012: 258) states that

'Alef settled furthest north at Bi'isa on the Mareb River' and that this location is 'identified tentatively with a monastery known as Abune Gebre Nazrawi approximately half way between Adigrat and Nebelet but this is not clear'.

The toponym *Bi'isa* may be congruent with the place *Beesa* found on some of the analysed maps. At Amba Beesa, a plateau already mentioned by Lefebvre (1847) located about 20 km north of Adwa, a church on a hill named 'Abune Ale' is denoted on the modern Ethiopian map. This might in fact be the location that Finneran (2012) and Munro-Hay (2012) referred to as one of the places corresponding to the *Nine Saints*. Thus, Alleluia (Debre Halle Luya) and Abune Alef (at Amba Beesa) are two individual places, and not one, contrary to Finneran (2012) suggestion. They are located on isolated hills, separated by the Rama depression, and are located about 15 km apart from each other (Figure 5).

The number of monks living in Alleluia prior to destruction range from 500 (Crawford, 1958: 123 and 125) to 5,000 monks (Crawford, 1958: 145). Although these numbers might be exaggerated, they underline the

importance the monastery had in the past. Albeit Alleluia was reportedly destroyed in 1535 (Beckingham and Huntingford, 1961), it is still shown on maps dating to the seventeenth century (Figure 2(B–D)). This corresponds to the observation of Barradas (Pankhurst, 1996: 132), who noted in 1634 that it ‘was a very large and celebrated place with many friars’, but in the beginning of the seventeenth century only few monks were living there. Accordingly, on Ludolf’s map from 1683 Alleluia is still depicted, but with a relatively small symbol. This may indicate that, despite its loss of importance, the place was still in use more than hundred years after its destruction. Even Bent (1893b: 97) writes in his itineraries from the late nineteenth century about Alleluia that ‘[t]his spot is the usual halting-place for caravans, and is called Lah-lah-ah, and soon after our arrival peasants came from a village on the hills [...]’.

Changes over time

The toponyms in the core study area found on the studied maps are listed in Supplementary Material C. It is evident that the oldest reported places in the fifteenth century were Alleluia, Fremona and Gult. While Fremona appeared on all studied maps throughout the centuries, except for the more recent Soviet map, Gult disappeared from the maps from the late seventeenth century onwards and could not be localized. Alleluia was also mentioned until the late seventeenth century and likely reappeared as *Halelo Abune Samuel* on the modern Ethiopian topographic map. Mai Lala, as mentioned on the Italian and Russian maps from the twentieth century refers to a creek or spring in the Rama depression, some 10 km to the east of Halelo Abune Samuel. It does not seem to be directly related to Alleluia, albeit the name suggests it. However, it is common that specific locations give names to an entire micro region (Meyer, 1944). Later the name may be readopted by another specific location in the area, not necessarily within the same spot.

Adwa and Aksum are missing on the map of Egyptus Novelo but are mentioned, except for few cases, starting with Ludolf’s map from 1683. Yeha is mentioned only from the nineteenth century onwards. Due to its position within the undulating terrain of the Adwa mountains (Machado, 2015), it was probably not a suitable resting place for travellers on the western north–south route, which is corroborated by the outcomes of the LCP analyses (Table 2, Figure 5). Also the modern settlement of Yeha as well as the archaeological site of Yeha are located 1.5 km apart from the main road. In contrast, the main traffic axis is directly running through Aksum and Adwa. Other places such as Amba Beesa, Daro Takle or Gondet/Aila appear from the mid-nineteenth century on when the area was mapped in more detail.

Comparing reconstructed historical route networks with least-cost paths

As already pointed out by Crawford (1958), two different main routes for travellers on the north–south passage from Massawa towards Aksum and continuing into neighbouring regions in the south were established at least from the fifteenth century onwards. Our core study region covers the southern section of the western route, which, according to Crawford (1958) was most likely the more frequently used ‘beaten track’. This route is already described in Zorzi’s Iters I, III, and IV (Table 1). LCPs analyses including waypoints as mentioned in the itineraries indicate a clear western trajectory both with and without using the location of Gondet/Aila as transit location. This route went north from Adwa or Aksum via Alleluia, crossed the Mareb River about 8.5 km south-west of Gondet/Aila, continued on the Kohaito plateau towards Debarwa and then to Asmara or Massawa (Figure 5). The LCP analyses also revealed that this western route is considerably shorter than the eastern route running from Aksum to Toagitha via Debre Damo, which is represented by LCP-2-1400+.

During the processing of the LCPs, the Mareb River was not considered as an obstacle, as an *a priori* determination of the location of a bridge would be highly speculative. It is assumed that the Mareb River was not difficult to cross through the wide alluvial plains using pack animals. In the studied itineraries there is a lack of descriptions indicating bridges or passages to cross the Mareb River as well as allusions to any problems crossing the Mareb. However, seasonality of rainfall and runoff has to be kept in mind, thus passing the Mareb River during rainy seasons with increased runoff might have been impossible. In general, the route selection might have depended on seasonal and climatic conditions, which could turn the Mareb River into an obstacle. Low discharge during the dry season most likely favoured the western tracks from Alleluia to Massawa via Gondet/Aila. This in turn may have even resulted in the establishment of Gondet/Aila as a resting place before or after the river crossing. A decision to choose a different route, excluding Gondet/Aila or Alleluia may be the result of the use of a bridge or passage across the Mareb River during phases of increased runoff. Currently there is one bridge located at Adis Alem, directly north-west of Rama, while pathways on both sides of the River indicate a possible passage downstream of this bridge at Adi Berah. Both

locations are about 6 km apart from the crossing points suggested by the LCPs processed exclusively including topography. The eastern route, as calculated by LCP-2-1400+ and as indicated in several maps from the nineteenth century, completely avoids crossing the Mareb but involves up to three extra days of travel. It is possible that this route was used preferably during the rainy season when the runoff of the Mareb River was increased.

According to the LCPs processed exclusively considering topography (LCP-1-D, LCP-2-D) travelling along the flat Rama depression is easier and faster than traversing the hilly areas connecting Alleluia and Gondet/Aila or Amba Beesa. However, our analyses of historical documents reveal that the Rama depression became relevant for long-distance transport only from the twentieth century onwards, when modern roads were constructed. The older maps and itineraries both indicate that the western northbound route from Aksum went either along the hilly landscape via Alleluia to Gundet or through hilly terrain via Amba Beesa to Gondet. It seems that the Rama depression was avoided by travellers. This may be due to its hot climate, which differs from the more moderate conditions of the neighbouring highland regions. Additionally, we emphasized that the once-famous monastery of Alleluia was already a waypoint on the western northbound route by the early sixteenth century. On the eastern branch of the western northbound route, the church of Abune Ale at Amba Beesa may have attracted travellers or pilgrims for a stop. The LCP-1-1518 between Aksum and Debarwa calculated after Zorzi's *Iter III/IV*, which includes Alleluia, is only one kilometre longer than the direct LCP-1-D which runs through the Rama depression. As such, travellers did not even have to commit to a detour prolonging their journey when they took the route along the monastery of Alleluia.

Considering Yeha as a waypoint rather than Alleluia and Gondet/Aila travelling from Aksum to Debarwa, as in the descriptions made by Alvarez (LCP-1-1520, [Table 1](#), [Figure 5](#); Beckingham and Huntingford, 1961), completely changes the course compared to the direct LCP-1-D. After LCP-1-1520 goes into Eritrea, it comes across a church as well as a modern unpaved road after 6 km that remains closely parallel to the LCP-1-1520 for at least 30 km. Two more churches are located about 800 m from this LCP while two additional churches are located 2–3 km away from the path on adjoining hills (see [Figure 5](#)). The alignment of these present-day structures may indicate that the route suggested by LCP-1-1520 follows a commonly frequented area with a possible historical background.

Conclusions

The combined analysis of historical travel descriptions and historical maps from the past 500 years and least-cost path modelling have provided insights in the effectiveness of historical route planning and the existence of former waypoints and resting places. Compared to a 'perfect' least-cost path connecting Aksum and Debarwa calculated exclusively considering topography, a LCP considering historically documented waypoints is only about 1% longer.

Together with the historical sources, the least-cost path analysis helped to validate the positions of the locations Alleluia and Amba Beesa. Alleluia was an important monastery and waypoint in the fifteenth century which we localized on a hill to the north of Aksum. The waypoint Amba Beesa, a hill with a church on top may be related to a monastery foundation by Abune Alef, one of the Nine Saints. Amba Beesa was previously tentatively assumed to lie somewhere between Adigrat and Nebelet; based on the analysis of travel itineraries and historical maps we localized this place about 20 km to the north of Adwa.

Beyond, it can be underlined that two different routes from Aksum towards Debarwa were historically in use. The shorter and probably more often used western route goes from Aksum either via Alleluia to Gondet/Aila, or from Aksum via Amba Beesa towards north. The eastern route via Adwa and Debre Damo, as calculated on basis of combined travel reports, is significantly longer than the western route but avoids the crossing of the Mareb River, which may have been necessary during rainy seasons. The Rama depression, which is suggested by hypothetical 'perfect' LCPs and is used by the modern road, did not seem to play a role in pre-modern times in terms of long-distance travel. Incorporating texts with relatively inaccurate historical maps and least-cost path analyses has proven to be a useful approach in reconstructing previously unknown travellers' waypoints and routes.

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