Analyzing Patterns of Movement and of Settlement

in the East-Andean Mountains of Ecuador

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Abstract: The Quijos and Cosanga study area is located in the East Andean mountains in Ecuador. This area is probably the origin of the Cosanga pottery which has also been recorded in the late cultures of the Andes in northern Ecuador. The trade of pottery in prehispanic time is one of the reasons for studying this area in terms of movement patterns. Based on the assumption that the ancient movement patterns are preserved in old paths, least-cost path analysis is used to identify the main friction factors. Four old paths are considered, and it seems that slope and crossing streams are important friction factors, though the match of the known routes and the least-cost path reconstructions is not perfect in most cases. Based on the model describing the movement patterns, the routes between known ancient path segments are reconstructed. Moreover, least-cost site catchments are generated for seven Late Period settlements recorded in a survey project directed by Andrea Cuéllar in 2002. According to Cuéllar, three of these settlements are small, two are moderately nucleated and two are large nucleated. The catchment sizes and the settlement sizes do not correlate, suggesting that other aspects beyond subsistence played an important role for choosing a settlement location. Viewshed calculations show that two of the nucleated Late Period settlements could have exercised visual control over the old routes.

Keywords: Least-cost paths, site catchments, viewsheds, East Andean mountains

Introduction

The aim of this study is to analyze prehispanic patterns of movement and of settlement in the Quijos and Cosanga region covering 137.5 km² in the East Andean mountains in Ecuador (Fig. 1). This research is based on archaeological data provided by CUÉLLAR (2006, 2009), on ancient paths published by DELGADO (1999) and on topographic data from different sources. According to the ASTER altitude data, the elevation range in the study area is between 1,536 and 3,012 m asl. Most parcels of land are quite steep; the median slope is 29.3 percent. Cuéllar selected this area for a survey project and in her Ph.D. thesis she analyzes the finds and the botanical data (CUÉLLAR 2006, 2009). It is most welcome and should become standard practice for other projects that the archaeological and the digitized topographic data can be downloaded from the web (CUÉLLAR 2010) so that other archaeologists get the opportunity to test new methods with this data.

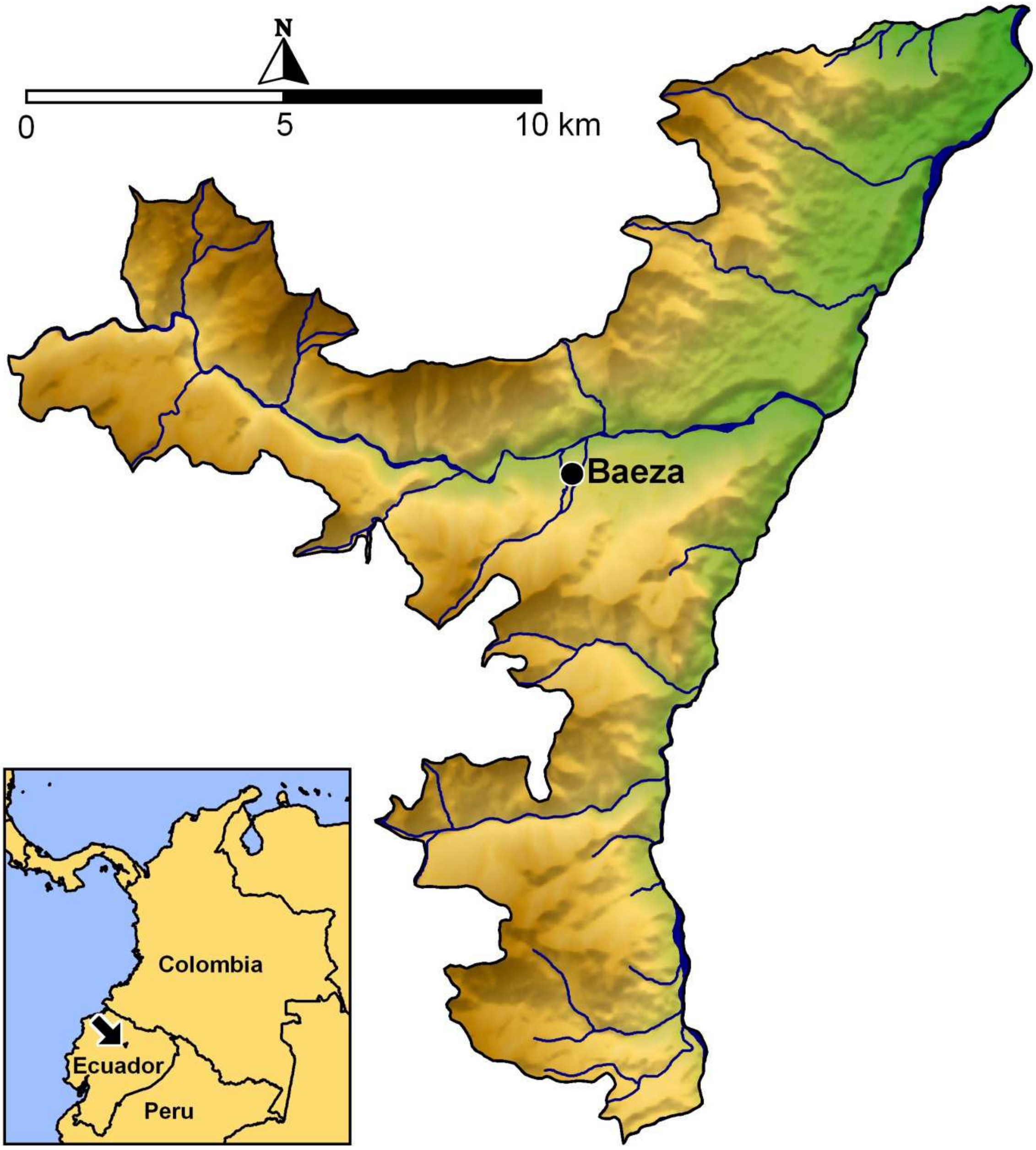

Fig. 1 – The Cosanga and Quijos study area. The digital elevation model shown is based on the ASTER GDEM, which is a product of METI and NASA. The Cosanga River forms the eastern border of the study area, and the other main river in this area is the Quijos which runs in east direction close to the town Baeza and joins the Cosanga.

The study area is most probably the origin of the Cosanga ceramic (Fig. 2; PORRAS 1975), and this is important in the context of a study on movement patterns, because the presence of this pottery type has also been recorded in late cultures of the Andes in northern Ecuador (ATHENS 1980; BRAVO 2005; BRAY 1991; ECHEVERRÍA & URIBE 1981; UGALDE 2004; UHLE 1926). In fact, Cosanga ceramic is well known in the archaeological literature of Ecuador, since JIJÓN Y CAAMAÑO (1920) introduced the term and Porras popularized it in the mid-1970s. The chronological frame of Cosanga ceramic varies between two temporal positions: one defends its affiliation with the Regional Developmental Period sites (300 B.C. to 800 A.D.), and the other one with the Integration Period sites (800–1,500 A.D.) in highland Ecuador. The ceramic material of the Quijos and Cosanga survey was made available to one of us, and the chronological analysis of the pottery sherds was the basis of the Ph.D. dissertation by Yépez (2008).

Fig. 2 – Early (left) and late (right) Cosanga pottery from the study area.

In this rugged terrain, the map distance does not seem appropriate to estimate the effort required to transport goods from one location to another. Instead, we try to identify the factors determining the friction of pedestrian movement in our study area based on historic accounts and the analysis of ancient routes in this region that preserve the patterns of movement of their construction period. These friction factors are found by least-cost path (LCP) calculations. Several friction factors can be combined in one cost function, and the choice of the cost function determines the outcome of the LCP calculation. The LCP results of several plausible cost functions are compared with the known ancient routes. The pattern of movement can be described in terms of the cost function producing the best reconstruction of the known routes.
Due to the steep gradients and soils of naturally low fertility (CUÉLLAR 2009:83-85), the prehispanic inhabitants of the study area faced quite bad conditions for agriculture and for transport or movement. Moreover, the amount and intensity of rain is high in the study area (CUÉLLAR 2009:66; annual precipitation in Baeza: 2,456 mm) induces overflow of rivers and flooding. Heavy rains increase the probability of landslides, especially if steep slopes were denuded of vegetation. Although the study area provided neither favorable conditions for transport nor for agriculture, Cuéllar recorded seven Late Period (ca. 500–1600 A.D.) settlements of different sizes (tab. 1). This study will present catchments for each of these sites applying the cost function derived from the LCP calculations. By analyzing catchment sizes, the main soil within each catchment and the size of the corresponding Late Period settlement, we come to the conclusion that agricultural needs were not the main factors determining the locations of most Late Period sites. Instead visual control of the trade routes seems to play an important role for some of these settlements.

Old Paths in the Quijos and Cosanga Region

Several historic accounts describe the prehispanic routes in the Quijos and Cosanga region. According to OBEREM (1962:49-51), the first Europeans entering the Quijos area were a military group led by Gonzalo Días de Pinera. The account of this military operation dating back to 1538 describes slippery and steep footpaths with boggy intervals. Prehispanic paths were in general very narrow (Gonzalo Díaz de Pinera [1538] in OBEREM 1962:53) and only used by humans. The use of pack animals seems to be a phenomenon starting in early colonial times (16th century). Due to diseases, the breeding of cattle within the study area might have been quite limited so that, contrary to the mountainous part of the old Nueva Granada in Colombia (LANGEBAEK 2002:31), only minor route changes are to be expected for improving cattle transport. The footpaths in the territory of the Quijos seem to have been in constant use from the 16th to the 19th century. In fact, the first sources, written by missionaries in the 17th century, refer only to indigenous carriers with respect to transport (OBEREM 1962:91-92) instead of horses. Even the travelers of the 19th century still employed indigenous porters (MURATORIO 1987:41-61). As recently as in the 20th century, the introduction of roads replaced the old footpaths, which then were abandoned. The archaeological evidence recorded by Delgado (1999:2·15) indicates that the broader tracks with pavements were built on or close to the prehispanic footpaths so that a long continuity of these routes is likely.

The reports available create the impression that in prehispanic times, rivers were crossed at fords, and bridges were constructed only after the advent of the Spanish. The use of small boats seems to have been an exception, a more regular use was probably introduced by the Spaniards or recent travelers in order to cross the Cosanga River at times of inundation.

We studied four old footpaths that were recorded in the Quijos and Cosanga region to analyze the prehispanic patterns of pedestrian movement. Two short routes (3.2 and 6.7 km) within the study area are described by DELGADO (1999: fig. 4.4; Fig. 3, (1) and (2)), he also published a map of a longer route (12.3 km) south of our area of investigation (1999: fig. 4.3; Fig. 3, (3)). The reconstruction of these old paths by Delgado is mainly based on archaeological evidence, only small portions were interpolated, except for the extension of the long route to the south, which was not included in our analysis. The accuracy of the maps by Delgado are in issue, for instance, we are not sure if path (3) really crosses a tributary to the Rio Urcusiqui twice within 150 m. Incorrect labeling of the coordinate grid and differences between the topographic maps used by us and by Delgado might have introduced additional inaccuracies.

DELGADO (1999:2·15) recorded a plastered colonial path close to the prehispanic footpath for the southern route. This route is roughly identical with paths mapped by Humboldt (Humboldt [1814], Carte de la Province de Quixos, in MORENO YÁNEZ 2005:130). Humboldt's maps of the region are based on earlier official material dating back to 1799 (OBEREM 1962:102).

Another old footpath known from oral tradition is still visible in the landscape (Fig. 3, (4); Fig. 4). This route section crosses the western border of our study area and agrees well with historical accounts from the 17th, the 18th, and the 19th century (OBEREM 1962:94-95; Hernández Bello, Miguel [1799] in GUTIÉRREZ 2002:104-105; MURATORIO 1987:51-56). One of us (Yépez) recorded tracked this footpath using a GPS receiver.

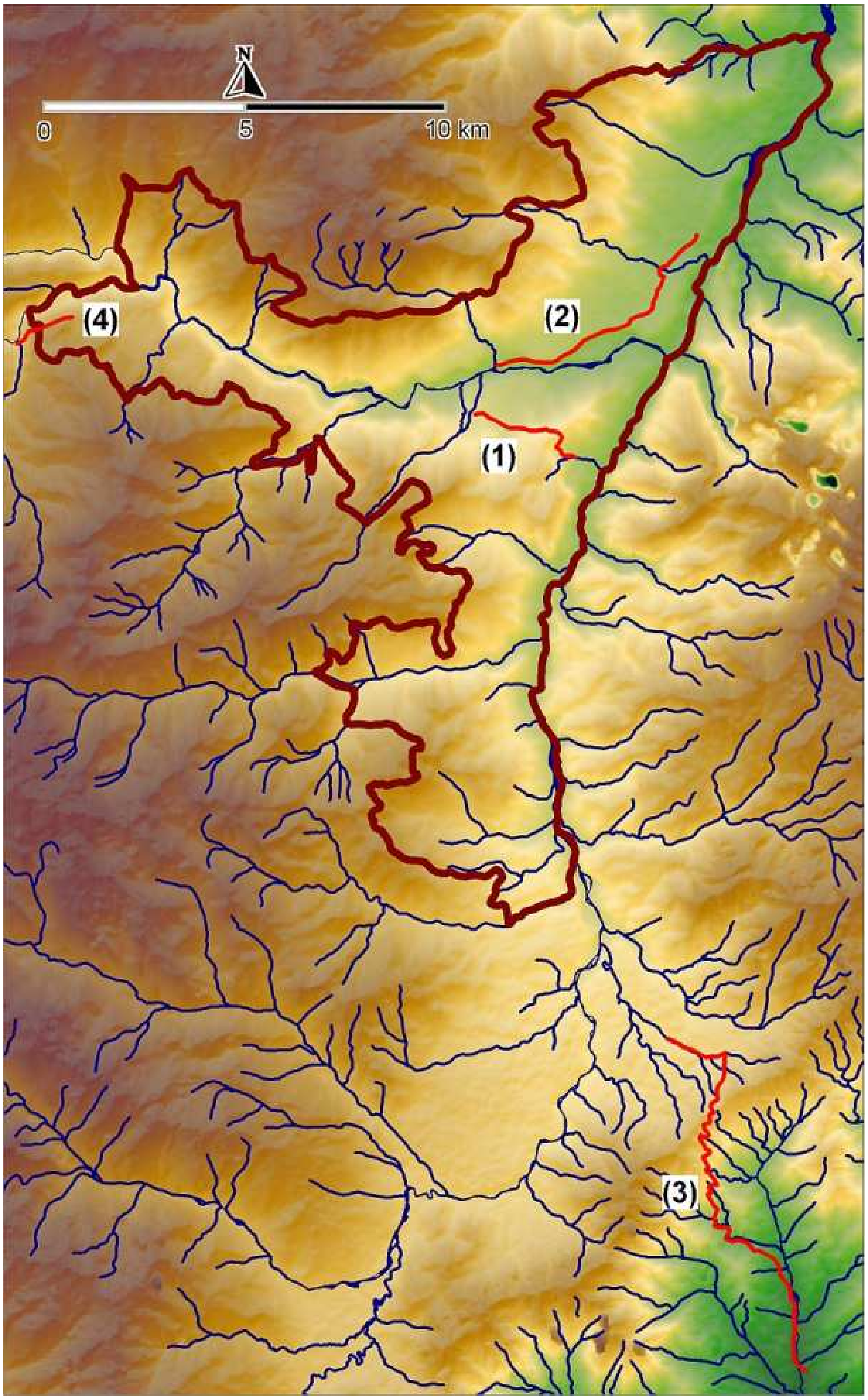

Fig. 3 – The three ancient paths mapped by Delgado (1)–(3) and another old path recorded by Yépez (4).

In steep terrain, for a path parallel or diagonal to elevation contour lines, some construction work is necessary. In rural parts of Germany, hardly any construction activities for long-distance connections were carried out in Medieval times, whereas the Romans were able to build contour line roads (NICKE 2001:13). It seems quite likely that the early inhabitants of the Quijos and Cosanga area were able to construct contour line paths because they created terraces. This is supported by Fig. 4 and the fact that path (2) coincides with the 1,800 m asl contour line for about 2 km.

Fig. 4 – Left: Contour line section of path (4) mapped in Fig. 3. Right: Another section of path (4), with some similarity to sunken roads that were formed in Medieval Europe.

Route Reconstruction

The objectives of this section are to find the factors determining the friction of pedestrian movement in our study area by applying LCP calculations to reconstruct the ancient routes described above. Quite a few archaeological studies already applied LCP calculations for these purposes in other regions of the world (e.g., BELL & LOCK 2000; CONOLLY & LAKE 2006:252-256; LLOBERA 2000; SCOTT & MADRY 1996; VAN LEUSEN 2002:6·4–6·9,16·12–16·15;WHEATLEY & GILLINGS 2002:157-158; WHITE & SURFACE-EVANS 2012).

Slope is the most popular geographic factor in archaeological LCP applications (e.g., case studies in WHITE & SURFACE-EVANS 2012). As mentioned above, in the study area steep slopes are nearly ubiquitous, and so slope most probably plays an important role for the movement patterns. Slope can be derived from a digital elevation model (DEM), and correct results depend on the accuracy of this data.

The ASTER Global Digital Elevation Model with a cell size of ca. 33 m was used for this study. The data set is provided by NASA and METI along with a detailed map displaying the quality of each elevation value. The quality depends on the number of ASTER DEM scenes available for that point. According to the ASTER DEM quality data, the elevation data within the study area is reliable, each elevation point is deduced from at least seven scenes. Unfortunately, this is not the case for the region south of the study area where the longest old route was recorded: except for the first two kilometers in the north, the number of scenes covering this area never exceeds three, often only one scene could be used and a considerable proportion of the elevation data was filled in from the lower resolution SRTM data.

Another source of inaccuracies are landscape modifications since the construction times of the old paths. Geological processes such as landslides and inundations continually change the mountainous terrain of Ecuador. Detailed observations of such processes can be found in the studies by BUSSMANN et al. (2008). The COMMITTEE ON NATURAL DISASTERS (1991) describes the impact of the earthquakes recorded in March 1987. Most of the substantial landscape changes due to geological processes are probably in the river valleys so that the location of some fords moved in the past. Man-made terraces, pits for pottery clay extraction, and other human impact also changed the landscape morphology. However, detailed landscape reconstruction is beyond the scope of this study.

The DEM resolution is another issue. Some deeply incised creeks and sudden fall-offs cannot be modeled adequately by a sampling grid with a cell size of 33 m. A sampling grid always introduces some smoothing, and features which are smaller than the sampling interval may escape detection. The DEM resolution and lack of data on the streams as well as landscape changes do not allow to reconstruct the prehispanic ford locations. The reconstruction of the movement patterns would benefit from a map of ancient ford locations as used by VAN LEUSEN (2002:16·13–16·15; see also HERZOG 2013a). The limitations of the DEM cannot be overcome easily, however, in other parts of the world the reconstruction of ancient paths based on DEM data with comparable resolution was successful (e.g., HERZOG 2013a).

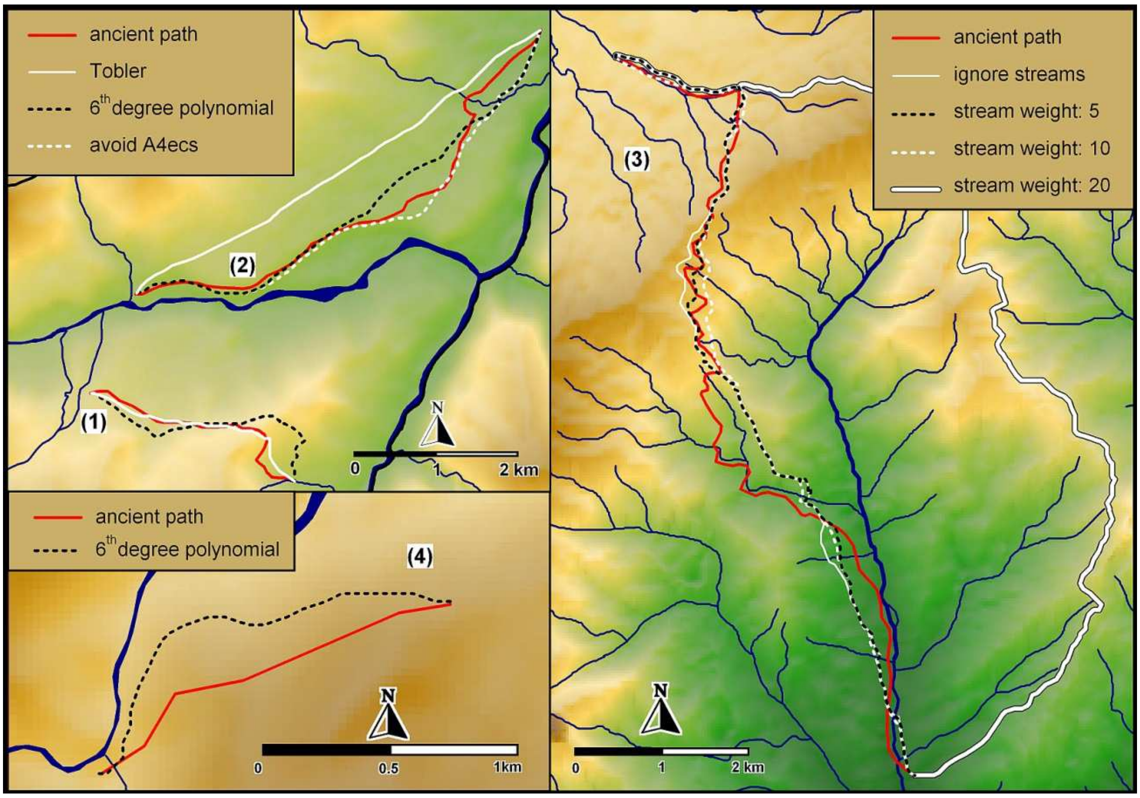

Fig. 5 – Reconstruction attempts for the four ancient paths depicted in Fig. 3.

Fig. 5 shows some route reconstruction attempts for the ancient paths depicted in Fig. 3. The PC program used for the calculations was developed by one of us because of the drawbacks of the procedures available in standard GIS software such as: limiting the path sections to eight directions; unintuitive results when dealing with slope friction; no support of the most important slope-dependent cost functions; no possibility to multiply slope friction with other friction factors (HERZOG 2013a, 2013b).

Path (1) does not cross any streams and different soil categories apparently do not influence the route so that slope is the only cost component included in the LCP calculation. Several slope-dependent cost functions have been proposed for archaeological path reconstruction (e.g., CONOLLY & LAKE 2006:219-221; VAN LEUSEN 2002:6·6–6·7). HERZOG (2013a) provides a detailed discussion of these cost functions and their properties, and only a short summary is given here: all paths require some effort and some time, therefore cost functions assigning zero or negative costs for some slopes are not appropriate. Moreover, a sudden cost increase for a very small change in slope is not intuitive. Probably the most popular cost function in archaeological path calculation is the Tobler hiking function (TOBLER 1993; applied for instance in PARSLOW 2009; POSLUSCHNY 2010; most case studies in WHITE & SURFACE-EVANS 2012) which does not suffer from any of the drawbacks mentioned above. But the Tobler function is not based on reliable experiments evaluated by statistical methods, it is a rule of thumb. For this reason, a sixth degree polynomial derived from physiological data of walkers published by MINETTI et al. (2002) seems more appropriate.

For path (1), the LCP based on the Tobler hiking function is closest to the ancient route, whereas the sixth degree polynomial produces a less convincing route reconstruction. With path (2), the Minetti et al. cost function performs better than the Tobler approach. A cost multiplier for crossing streams was introduced for the LCP calculations of path (2), however, none of the LCPs identifies the location of the ford correctly. This is also true for path (3), for which LCP calculations are problematic due to low quality DEM data. Path reconstruction can be improved for path (2) when a cost multiplier of 1.5 is introduced for areas that were designated by *A4ecs* on the modern map of agricultural potential. According to CUÉLLAR (2009:85-87), the *A4ecs* soils are ranked first in terms of their fertility for corn production. The ancient paths of this region might have kept away from fertile *A4ecs* soils because the local farmers tried to use as much as possible of the best soil. The evidence that *A4ecs* soils are avoided is fairly weak and cannot be tested with the other known ancient paths due to absence of such soils in their neighborhood.

When trying to reconstruct path (3) by an LCP, several multipliers for crossing streams were tested: multipliers 5 and 10 performed best. All reconstruction attempts for the GPS recorded path (4) led to similar results, but the ancient path is steeper and more direct.

The stability of the LCP results was tested by introducing some random variation in the DEM data: random values with a continuous uniform distribution in the range of -5 to +5 m were added to the initial elevation data. For both paths (1) and (2), the distance between the initial LCP and the LCP based on the modified DEM never exceeds 130 m. So, the impact of DEM inaccuracies on these two path reconstructions seems to be quite low. This applies to path (3) as well, though the maximum distance between the initial LCP and the path computed from the modified DEM is 280 m. In the southern part, west of the Río Urcusiqui, the latter path is closer to the old path recorded by Delgado. For the very short path (4), the LCP resulting from the modified DEM is also somewhat nearer to the true path, but the maximum distance between this LCP and the initial LCP is low – about 70 m.

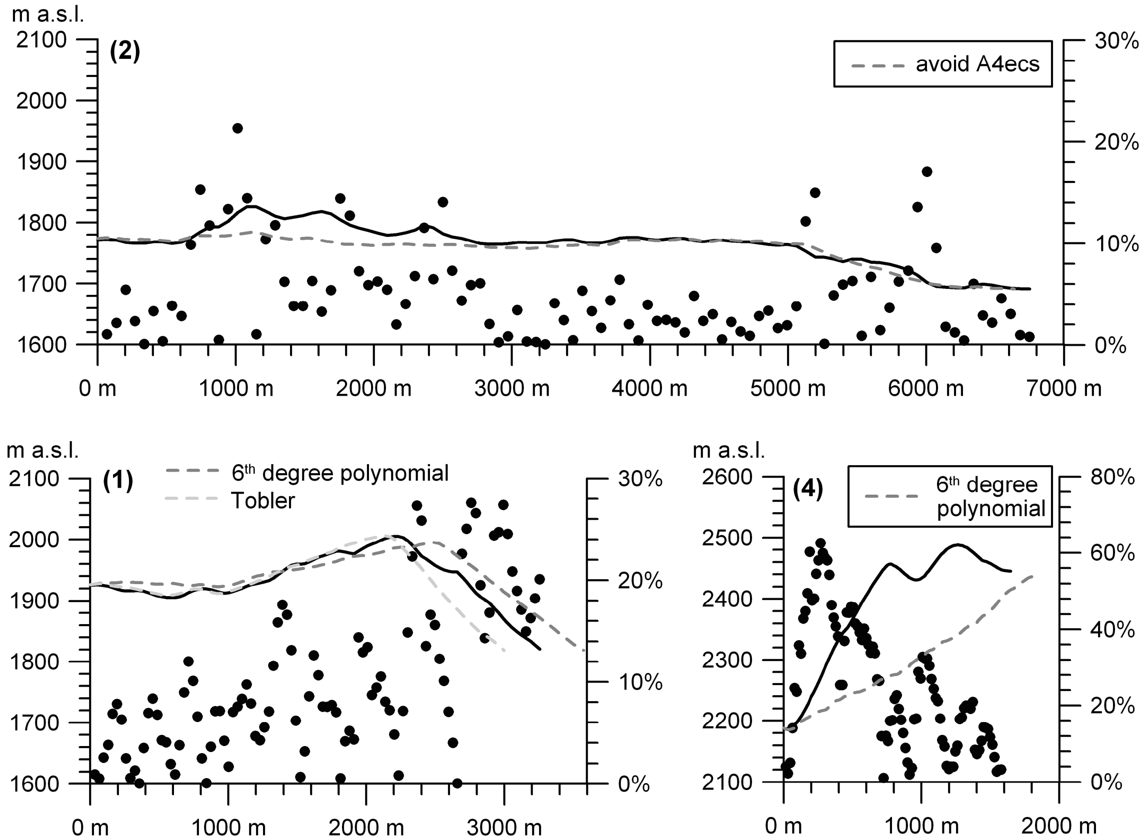

Fig. 6 – Cross sections in west-east direction for three ancient paths (black lines) and corresponding LCPs (dashed gray lines). The slope of ancient path subsections is depicted by black dots, the slope values can be read from the vertical axis on the right hand side of each diagram.

Fig. 6 shows cross sections of three ancient paths and of corresponding LCPs as well as scatter plots indicating the slope of the ancient path subsections (in percent). Path (3) was omitted due to the poor quality of the DEM in this area. In general, the LCP cross sections are smoother than the corresponding ancient paths, and on average, the slope is lower, due to the construction rules for these LCPs. The three paths analyzed show different patterns. Whereas the slopes of all subsections belonging to paths (1) and (2) are below 30 percent as expected from physiological investigations (MINETTI 1995), steep slopes of up to 63 percent are recorded on path (4), especially in the western section. Most striking is the difference between the cross section of path (4) and the corresponding LCP: whereas the LCP climbs the slope at a constant gradient, the western section of the ancient path is very steep, and later on a small valley is passed. Perhaps prehispanic walkers preferred steep direct ascents to contour line paths on very steep slopes. Currently, our software is not able to deal with this complex situation.

Another possible friction factor is visibility, this factor has received some attention in archaeological LCP studies (e.g., BELL & LOCK 2000). Often seeing landmarks is important, and large viewsheds increase the safety of the traveler. Path (2) follows a route of high visibility at the edge of the terrace high above the river Quijos, whereas the southern part of path (4) runs through the valley of Río Urcusiqui with low visibility. Therefore no visibility component was included in our model for LCP calculations. However, visibility issues probably played an important role for some Late Period sites in the Quijos and Cosanga study area (see

below). Furthermore, we found that aspect (i.e. the horizontal direction to which the slope faces) is not relevant for the four paths considered here, though some authors (e.g., NICKE 2001:18) note that south- or east-facing slopes are preferred by ancient routes.
In conclusion, the route reconstructions presented above are better than the straight line connections between start and end point, but still some of the LCPs are not as close to the ancient paths as we hoped for. We are well aware that other cost components like vegetation cover may play a role as well, and that topographic data of the phases considered are a desideratum; especially in a region with substantial geological processes as described above, modern data probably is an inadequate substitute. Tentatively we propose that the movement patterns of the indigenous population in the Quijos and Cosanga region are best described by modeling slope friction by the sixth degree polynomial function based on data published by MINETTI et al. (2002), and by applying a multiplier of 5 for crossing streams.

Site Catchments

After identifying the factors determining the friction of movement in our study area, realistic site catchments can be calculated (e.g., BANNING 2002:78-79, 158; CONOLLY & LAKE 2006:224-225; PARSLOW 2009:56-57; RENFREW & BAHN 1996:242-243; ZIMMERMANN et al. 2009). The site catchment area comprises all points that can be reached when expending time (or energy) up to a certain time (or energy) limit. These shapes replace circular areas of influence that have been used previously, but ignore the topography (cf. the concentric rings for the San José Mogote polity published by DRENNAN & PETERSON 2008; catchment radius data given in MCMAHON 2007). RENFREW & BAHN (1996:242-243) note that the more accurate term is site exploitation territory. Often the resources within the site catchment areas are analyzed to get some insight into the mode of subsistence or function of the site (e.g., POSLUSCHNY 2010; SURFACE-EVANS 2012).
The size of the catchment area depends on the cost limit (costs in terms of the model derived from the LCPs) beyond which the exploitation of the resources is no longer relevant for the site considered. The choice of the cost limit depends on the scale of the analysis. Most archaeological catchment studies dealing with agricultural societies apply a radius in the range of 750 m to 5 km, or the equivalent time or effort to reach this limit on level ground in the absence of impeding circumstances (ZIMMERMANN et al. 2009). In Fig. 7, the cost limit of the catchment areas was set to the effort equivalent to walking 1.5 km on level ground. This cost limit ensures that the catchments of the seven Late Period sites in our study area recorded by CUÉLLAR (2009:119-150) hardly overlap at all.

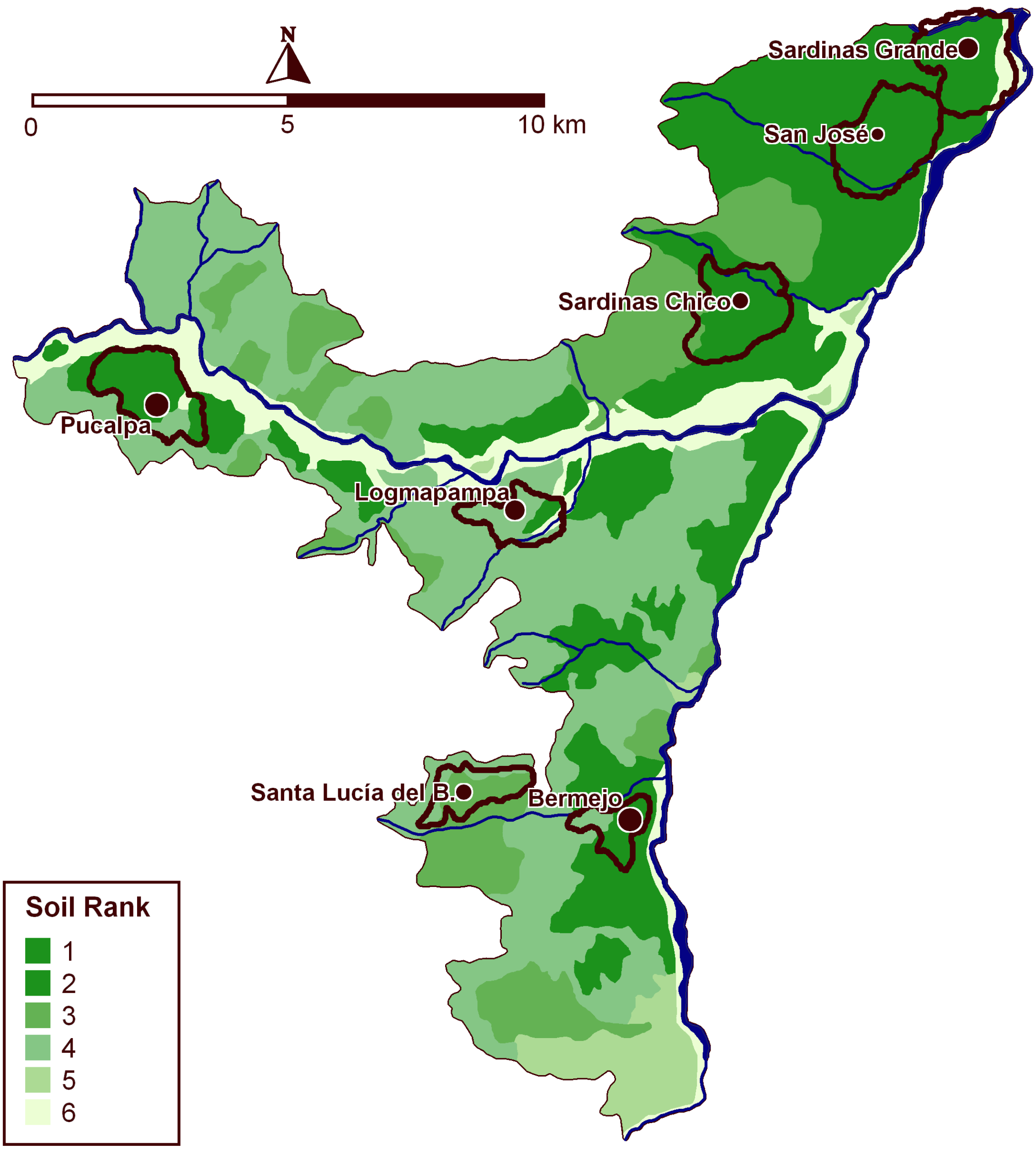

Fig. 7 – Site catchments for seven sites discussed by CUÉLLAR (2009). The settlement centers of these sites were derived from the test-pits dug for retrieving data on pollen, phytoliths, and macroremains. For both Logmapampa and Bermejo, the test pits were allocated to two clusters each, and the results for one of these cluster centers is shown. In the background, the soil rank map published online by CUÉLLAR (2010) is shown.

Tab. 1 lists for each site considered the catchment area size, the main soil rank within the catchment area, a condensed version of Cuéllar's description of the site, and the results concerning the botanical remains. The data in Table 1 indicate that there is no correlation between settlement size and the size of the corresponding site catchment area. The large nucleated settlement Pucalpa is the only site in Table 1 with a favorable location with respect to agriculture: the site catchment is somewhat larger than average and includes a high proportion of the best soil. But the only other large nucleated settlement in the study area, Bermejo, has a very small catchment area, and is located on second-best soil. The catchment area of the smallest settlement according to Cuéllar's list exceeds the size of all other catchment areas. The soil in this area is of the same quality as that of Bermejo. Mostly bad soils can be found in the fairly small catchment area of the nucleated settlement Logmapampa.

For a crop based subsistence economy, we would expect that people select settlement locations with good soils and large catchments, i.e. fields that can be reached easily. But the observations listed above suggest that factors beyond agrarian productivity played an important role for settlement location during the Late Period. Maybe producing and trading Cosanga pottery provided a more important contribution to sustaining the settlements than agricultural activities.

Location	Page	Classification by Cuéllar	Main Soil Rank	Altitude	Catchment Area	Description by Cuéllar
San José	131	very small settlement	2	1,710	331	very few terraces, a shallow canal; limited crop variety, no other plants of significant human use, no forest indicators
Sardinas Grande	135	moderately nucleated settlement	2	1,650	325	various terraces and canals; very few plant varieties, no direct evidence of crop production, but no indication of crop exchange with higher altitude locations, either
Sardinas Chico	145	small settlement	2	1,890	289	terraces; typical plants of this low altitude setting, reflecting use of both wild and domesticated resources
Pucalpa	121	large nucleated settlement	1	2,400	264	numerous terraces and canals; crops correspond to climatic conditions (high altitude), forest indicators
Logma-pampa	143	moderately nucleated settlement	4	2,040	151 (119)	terraces; weed remains indicate marshy environments, no direct evidence of crop production, but no evidence of external provisioning either
Santa Lucía del Bermejo	149	small settlement	3	2,250	146	some agricultural terraces; botanical assemblage recovered corresponds to local environmental characteristics
Bermejo	139	large nucleated settlement	2	2,010	109 (124)	abundant terracing; evidence of crop production is limited to corn

Tab. 1 – List of sites with botanical remains as classified and described by CUÉLLAR (2009) on the pages given in the page column. The soil rank relies on Cuéllar's soil classification. The table is sorted according to the catchment area given in hectare. For Bermejo and Logmapampa, the catchment area sizes for the alternative settlement centers are given in parentheses.

Relationships between Routes and Settlements

A close relationship between the ancient routes and the Late Period settlements is to be expected if trade was important during that period. However, within the study area, only short stretches of the ancient routes are known (Fig. 3). We tried to fill the gaps by reconstructing additional paths. First the LCP connecting the eastern end point of path (4) with the western end point of path (1) was calculated (Fig. 8: dotted dark violet line). The resulting LCP passes Pucalpa at a distance of about 400 m, but comes quite close to the site of Logmapampa (ca. 140 m). In fact, Cuéllar's test-pits of Logmapampa are located south of the reconstructed path whereas those of La Palma are north of the route. In La Palma no botanical remains were retrieved, and therefore, this site was not included in the site catchment analysis above. At the site of La Palma a few artificial terraces are preserved, and Cuéllar's team collected large samples of Cosanga ceramics from this area (CUÉLLAR 2006:216-218).

Moreover, we assumed that path (3) which was recorded south of the study area proceeds in north direction close to the Cosanga and enters the study area. Based on this assumption a point on the southern border of the study area was selected, where we expect the extension of path (3) to enter the area of investigation. The LCP connecting this point with the western end point of path (1) was calculated (Fig. 8: dotted dark violet line). In the north, the LCP runs parallel to path (1) but crosses a tributary of the Cosanga River at a different location. This again underlines the necessity to include ford locations in the calculation. The LCP runs through the river valley similar to stretches of path (3). In Fig. 8, another LCP connects the eastern end point of path (4) with Sardinas Grande, and was forced through the ford recorded for path (2) (Fig. 8: light pink path). The western part of this LCP agrees with the LCP discussed above. The LCPs based on the DEM with random modifications in the range of -5 to +5 m are in general quite close to the initial LCPs, indicating that the outcomes of the LCP calculations are fairly stable. But in some areas, these LCPs are closer to the known locations. For instance, in the eastern part, the center of Pucalpa is passed at a smaller distance of about 50 m.

The map distance between the reconstructed route heading south and Bermejo is about 570 m, but Bermejo is at an altitude of about 2010 m asl, whereas the elevation values in the river valley vary around 1810 m asl. So for walking directly from the river valley to Bermejo, an average slope of 35 percent has to be negotiated.

Viewshed analysis

The location of Bermejo reminded us of hillforts in Europe. For example, Celtic hillforts in the Burgundy region of France were studied by MADRY & RAKOS (1996), and a strong correlation of the known Celtic roads with the visibility from the hilltop defenses was found. The large nucleated settlement Bermejo with a very small site catchment area could have watched over the trade route along the Cosanga River. Moreover, the visual impact of Bermejo on a traveler on the route might have been significant, due to the fact that it is located above the viewer's line of sight (WHEATLEY & GILLINGS 2002:205-206).

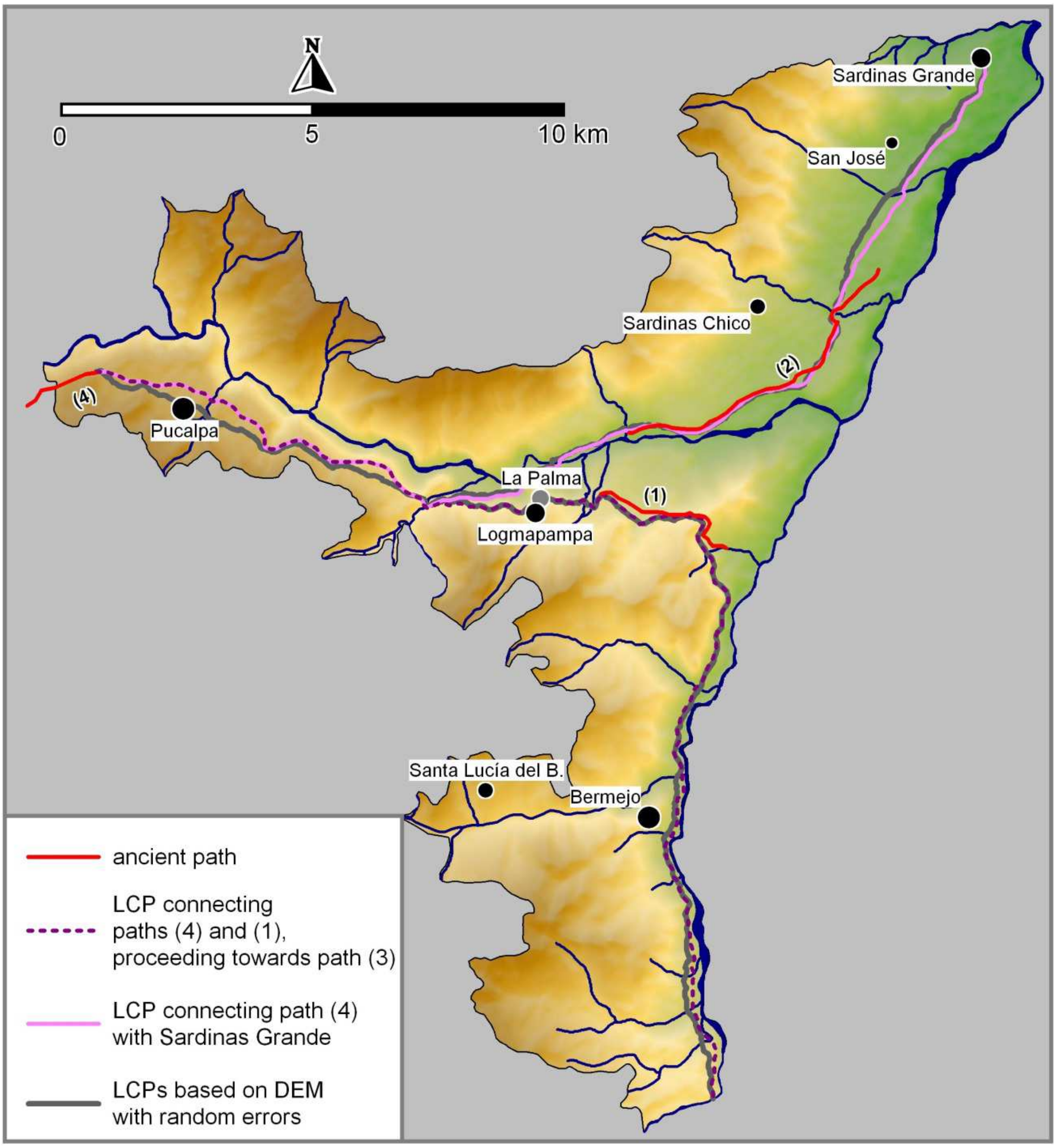

Fig. 8 – Least-cost paths connecting the end points of known ancient paths, Sardinas Grande and a point on the southern border of the study area.

For this reason, the visual relationship between the settlements discussed above and the reconstructed routes was investigated by calculating simple binary viewsheds (Fig. 9). The result of GIS-assisted viewshed generation depends on the accuracy and resolution of the DEM (discussed above), on palaeovegetation (tree factor), and the virtual viewer's exact position and height (CONOLLY & LAKE 2006:225-233; VAN LEUSEN 2002:6·9–6·14; WHEATLEY & GILLINGS 2000; WHEATLEY & GILLINGS 2002:201-216). An eye height of 2 m above the terrain was selected for the viewing position, assuming a small artificially elevated platform or the like. The botanical analysis of CUÉLLAR (2009:119-150) suggests that forest was by no means ubiquitous in the study area during the Late Period.

Fig. 9a shows the viewsheds with a radius of 5 km for Bermejo, Pucalpa, and Sardinas Chico. According to Fraser (referred to by WHEATLEY & GILLINGS 2002:203), a circle with a radius of 5 km includes the visibility class 'intermediate', whereas objects visible at a larger distance are in the 'distant' class. For each settlement, several viewer's positions were tested and the resulting viewsheds compared. The differences were quite small in most cases. For Bermejo, six stretches of the reconstructed route are within this viewshed area with a total length of about 3.7 km. The Pucalpa viewshed includes only about 680 m of the reconstructed route. The areas visible from Sardinas Grande are mainly in the north outside the study area (not shown). The viewshed of Sardinas Chico includes both a 1.2 km stretch of path (1) and 2.1 km of path (2). Some parts of path (2) can also be seen from San José (three stretches with a total length of nearly 1 km), and also about 2.1 km of the reconstructed route to Sardinas Grande (not shown). At a distance of about 8.5 km, 480 m of path (1) are visible from San José. The viewshed of Santa Lucía del Bermejo does not include any reconstructed ancient paths. No significant changes were observed between the viewsheds based on the initial and the modified DEM except for Bermejo: the visibility of one of the stretches is reduced by 570 m.

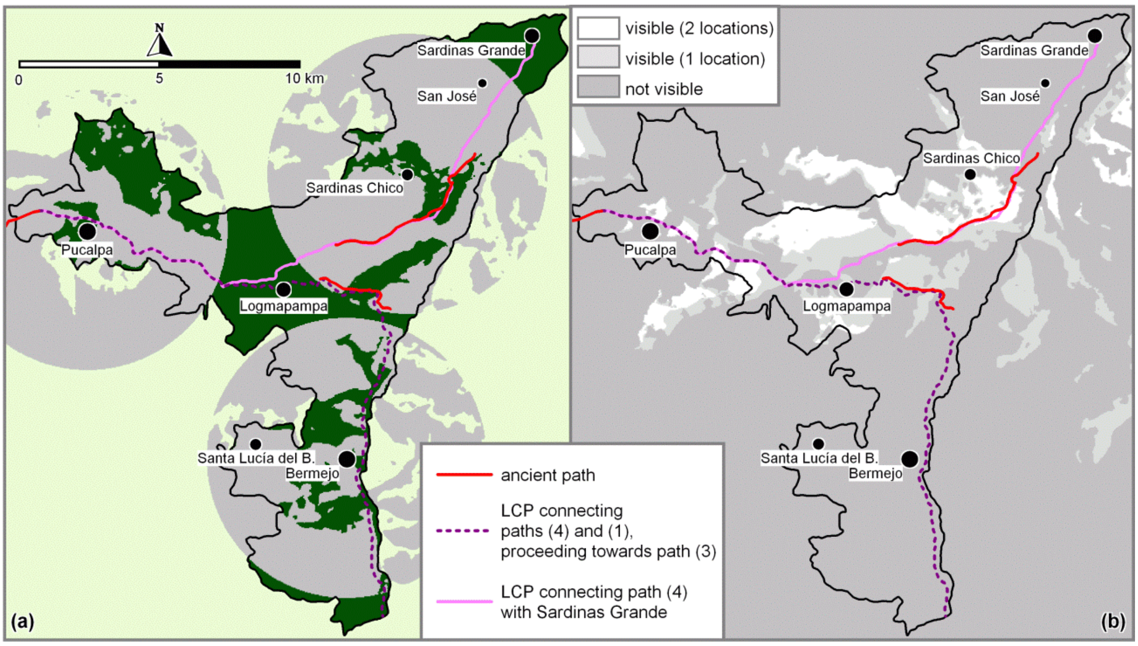

Fig. 9 – Viewsheds (a) for Pucalpa, Sardinas Chico, and Bermejo with a radius of 5 km (b) for Logmapampa with a radius of 15 km. In (a), green areas within the gray circles signify areas that are visible from the viewshed centers. For Bermejo the viewer position on top of the ridge was chosen. For Logmapampa, a cumulative viewshed map is shown, i.e. the viewsheds of two locations with a distance of about 400 m (altitudes: 2,044 m and 2,122 m asl) were combined; white zones are visible from both locations, light gray zones can be seen from one location only.

Fig. 9b combines the viewsheds of two different locations in Logmapampa. The path advancing from the west enters the viewshed of Logmapampa at a distance of 7.5 km. In the west, the viewshed includes a total of about 3.85 km of the LCP connecting the eastern end point of path (4) with the western end point of path (1). People arriving from the east can be detected at a distance of about 3.4 km. In addition, a stretch of more than 6.3 km of the LCP between the eastern end point of path (4) and the ford in path (2) are visible from Logmapampa. So both Bermejo and Logmapampa could have exercised visual control over the routes. The other settlements on the list of Cuéllar allow only a limited view on the reconstructed paths.

Discussion

In areas of high topographic variability spatial analysis of the archaeological data should rely on least-cost distance rather than map distance because the effort and time required for covering 1 km of map distance may vary significantly. For estimating least-cost distances adequately, the patterns of movement can be derived from paths constructed during the period considered. Ideal conditions for identifying the friction factors are hardly ever met. However, even a coarse approximation to the past movement patterns seems to be more appropriate than map distances in the Quijos and Cosanga study area with high topographic relief. On the basis of our attempts of reconstructing ancient paths we propose a least-cost distance that combines slope-dependent energy expenditure with a penalty for crossing streams.

The site catchment analysis applying this least-cost distance produces evidence that the social or economic organization of the Quijos during the Late Period did not correspond to that of a society mainly dependent on self-sufficiency farming. Two nucleated settlements in the study area, Bermejo and Logmapampa, have a very small catchment area, and Logmapampa is located on very bad soil. We propose that these two settlements had some relationship with the old routes which were tentatively reconstructed for the study area. People on the ridge of Bermejo are able to watch large sections of the reconstructed route in the Cosanga valley. Logmapampa is very close to a reconstructed route in east-west direction, and the combined viewshed of two locations in Logmapampa includes a fairly large portion of the reconstructed paths in both the east-west direction and towards the north. The reconstructed routes could have been used for transporting the Cosanga pottery to the late culture sites in northern Ecuador.

However, some additional research is necessary to prove our hypothesis. A more detailed chronological framework could provide insights about continuity and contemporaneity of the sites considered. The provenance of Cosanga pottery should be clarified: Archaeometry provides methods to analyze the chemical composition of ceramic sherds and to compare these with clay deposits in the study area. Moreover, substantial efforts are required to reconstruct the ancient routes to the north on a larger scale. These include recording the visible traces of these paths, interviewing indigenous people, LCP calculations, and comparing the results of these endeavors with historical maps and accounts.

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