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By Charles French, Chris O. Hunt, Reuben Grima, Rowan McLaughlin, Simon Stoddart & Caroline Malone

Volume 1 of Fragility and Sustainability – Studies on Early Malta, the ERC-funded *FRAGSUS Project*

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FRAGSUS

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On the cover: *View towards Nadur lighthouse and Għajnsielem church with the Gozo Channel to Malta beyond, from In-Nuffara (Caroline Malone).*

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Preface and dedication

Caroline Malone

The *FRAGSUS Project* emerged as the direct result of an invitation to undertake new archaeological fieldwork in Malta in 1985. Anthony Bonanno of the University of Malta organized a conference on 'The Mother Goddess of the Mediterranean' in which Colin Renfrew was a participant. The discussions that resulted prompted an invitation that made its way to David Trump (Tutor in Continuing Education, Cambridge University), Caroline Malone (then Curator of the Avebury Keiller Museum) and Simon Stoddart (then a post-graduate researcher in Cambridge). We eagerly took up the invitation to devise a new collaborative, scientifically based programme of research on prehistoric Malta.

What resulted was the original Cambridge Gozo Project (1987–94) and the excavations of the Xagħra Brochtorff Circle and the Għajnsielem Road Neolithic house. Both those sites had been found by local antiquarian, Joseph Attard-Tabone, a long-established figure in the island for his work on conservation and site identification.

As this and the two other volumes in this series report, the original Cambridge Gozo Project was the germ of a rich and fruitful academic collaboration that has had international impact, and has influenced successive generations of young archaeologists in Malta and beyond.

As the Principal Investigator of the *FRAGSUS Project*, on behalf of the very extensive *FRAGSUS* team I want to dedicate this the first volume of the series to the enlightened scholars who set up this now 35 year-long collaboration of prehistoric inquiry with our heartfelt thanks for their role in our studies.

We dedicate this volume to:

Joseph Attard Tabone
Professor Anthony Bonanno
Professor Lord Colin Renfrew

and offer our profound thanks for their continuing role in promoting the prehistory of Malta.

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For Chapter 6, Reuben Grima wrote the first draft of this contribution, receiving comments and additions from the other authors.

For Chapter 7, Simon Stoddart wrote the first draft of this contribution, receiving comments and additions from the other authors.

For Chapter 9, we thank Sharlo Camilleri for providing us with a copy of the GIS data produced by the MALSIS (MALtese Soil Information System) project. We are grateful to Prof. Saviour Formosa and Prof. Timmy Gambin, both of the University of Malta, who facilitated the donation of LiDAR data, together with computer facilities, as part of the European project ERDF156 *Developing National Environmental Monitoring Infrastructure and Capacity*, from the former Malta

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Firstly, the FRAGSUS Project is the result of a very generous research grant from the European Research Council (Advanced Grant no' 323727), without which this and its two partner volumes and the research undertaken could not have taken place. We heartily thank the ERC for its award and the many administrators in Brussels who monitored our use of the grant. The research team also wants to record our indebtedness to the administrators of the grant within our own institutions, since this work required detailed and dedicated attention. In particular we thank Rory Jordan in the Research Support Office, Stephen Hoper and Jim McDonald – CHRONO lab, and Martin Stroud (Queen's University Belfast), Laura Cousens (Cambridge University), Glen Farrugia and Cora Magri (University of Malta), the Curatorial, Finance and Designs & Exhibitions Departments in Heritage Malta and Stephen Borg at the Superintendence of Cultural Heritage. Finally, we thank Fr. Joe Inguanez (Emeritus Head of Department, Department of Sociology, University of Malta) for offering us the *leitmotif* of this volume while a visiting scholar in Magdalene College, Cambridge: '*Mingħajr art u ħamrija, m'hemmx sinjorija*' translating as 'without land and soil, there is no wealth'.

Foreword

Anthony Pace

Sustainability, as applied in archaeological research and heritage management, provides a useful perspective for understanding the past as well as the modern conditions of archaeological sites themselves. As often happens in archaeological thought, the idea of sustainability was borrowed from other areas of concern, particularly from the modern construct of development and its bearing on the environment and resource exploitation. The term sustainability entered common usage as a result of the unstoppable surge in resource exploitation, economic development, demographic growth and the human impacts on the environment that has gripped the World since 1500. Irrespective of scale and technology, most human activity of an economic nature has not spared resources from impacts, transformations or loss irrespective of historical and geographic contexts. Theories of sustainability may provide new narratives on the archaeology of Malta and Gozo, but they are equally important and of central relevance to contemporary issues of cultural heritage conservation and care. Though the archaeological resources of the Maltese islands can throw light on the past, one has to recognize that such resources are limited, finite and non-renewable. The sense of urgency with which these resources have to be identified, listed, studied, archived and valued is akin to that same urgency with which objects of value and all fragile forms of natural and cultural resources require constant stewardship and protection. The idea of sustainability therefore, follows a common thread across millennia.

It is all the more reason why cultural resource management requires particular attention through research, valorization and protection. The *FRAGSUS Project* (Fragility and sustainability in small island environments: adaptation, cultural change and collapse in prehistory) was intended to further explore and enhance existing knowledge on the prehistory of Malta and Gozo. The objective of the project as designed by the participating institutional partners and scholars, was to explore untapped field resources and archived archaeological material from a number of sites and their landscape to answer questions that could be approached with new techniques and methods. The results of the *FRAGSUS Project* will serve to advance our knowledge of certain areas of Maltese prehistory and to better contextualize the archipelago's importance as a model for understanding island archaeology in the central Mediterranean. The work that has been invested in *FRAGSUS* lays the foundation for future research.

Malta and Gozo are among the Mediterranean islands whose prehistoric archaeology has been intensely studied over a number of decades. This factor is important, yet more needs to be done in the field of Maltese archaeology and its valorization. Research is not the preserve of academic specialists. It serves to enhance not only what we know about the Maltese islands, but more importantly, why the archipelago's cultural landscape and its contents deserve care and protection especially at a time of extensive construction development. Strict rules and guidelines established by the Superintendence of Cultural Heritage have meant that during the last two decades more archaeological sites and deposits have been protected in situ or rescue-excavated through a statutory watching regime. This supervision has been applied successfully in a wide range of sites located in urban areas, rural locations and the landscape, as well as at the World Heritage Sites of Valletta, Ġgantija, Ħaġar Qim and Mnajdra and Tarxien. This activity has been instrumental in understanding ancient and historical land use, and the making of the Maltese historic centres and landscape.

Though the cumulative effect of archaeological research is being felt more strongly, new areas of interest still need to be addressed. Most pressing are those areas of landscape studies which often become peripheral to the attention that is garnered by prominent megalithic monuments. *FRAGSUS* has once again confirmed that there is a great deal of value in studying field systems, terraces and geological settings which, after all, were the material media in which modern Malta and Gozo ultimately developed. There is, therefore, an interplay in the use of the term sustainability, an interplay between what we can learn from the way ancient communities tested and used the very same island landscape which we occupy today, and the manner in which this landscape is treated in contested economic realities. If we are to seek factors of sustainability in the past, we must first protect its relics and study them using the best available methods in our times. On the other hand, the study of the past using the materiality of ancient peoples requires strong research agendas and thoughtful stewardship. The *FRAGSUS Project* has shown us how even small fragile deposits, nursed through protective legislation and guardianship, can yield significant information which the methods of pioneering scholars of Maltese archaeology would not have enabled access to. As already outlined by the Superintendence of Cultural Heritage, a national research agenda for cultural heritage and the humanities is a desideratum. Such a framework, reflected in the institutional partnership of the *FRAGSUS Project*, will bear valuable results that will only advance Malta's interests especially in today's world of instant e-knowledge that was not available on such a global scale a mere two decades ago.

FRAGSUS also underlines the relevance of studying the achievements and predicaments of past societies to understand certain, though not all, aspects of present environmental challenges. The twentieth century saw unprecedented environmental changes as a result of modern political-economic constructs. Admittedly, twentieth century developments cannot be equated with those of antiquity in terms of demography, technology, food production and consumption or the use of natural resources including the uptake of land. However, there are certain aspects, such as climate change, changing sea levels, significant environmental degradation, soil erosion, the exploitation and abandonment of land resources, the building and maintenance of field terraces, the rate and scale of human demographic growth, movement of peoples, access to scarce resources, which to a certain extent reflect impacts that seem to recur in time, irrespectively of scale and historic context.

Anthony Pace
Superintendent of Cultural Heritage (2003–18).

Chapter 9

Locating potential pastoral foraging routes in Malta through the use of a Geographic Information System

Gianmarco Alberti, Reuben Grima & Nicholas C. Vella

9.1. Introduction

The study presented in this chapter aims to complement the earlier GIS study of nineteenth century AD land-use of the islands of Gozo and Malta by Alberti *et al.* (2018) by adding another dimension to the reconstruction of the human exploitation of the landscape, and thus provide a better understanding of the agricultural potential and productivity of the Maltese landscape. It locates potential pastoral foraging routes across the landscape with the aid of a Geographic Information System. While the method and procedures used to accomplish this goal are detailed in the following section, the availability of a model of agricultural productivity of the land on the one hand, and a repertoire of evidence directly and indirectly related to pastoral movements across the island (such as the location of the garrigue areas, public spaces and farmhouses with animal pens) provided sufficient grounds to undertake this research. This approach was meant both to enrich the interpretation of evidence dating to earlier/pre-modern periods and to suggest a range of archaeological and anthropological questions as well as new avenues of inquiry driven by the results of analyses of a better documented (however recent) period.

Modelling of the agricultural quality in Malta on the basis of the data provided by mid-1800s cadastral maps (*cabrei*) showed that the Maltese landscape is a complex patchwork as far as its suitability for human economic exploitation is concerned (Alberti *et al*. 2018). The analysis made it evident that there is a wide variability in land quality, even over small distances, because of a complex interplay between different natural and cultural factors, resulting in a fragmented and variable landscape. The modelled agricultural suitability also showed that a considerably large part of Malta is unlikely to have been optimal for agriculture during the early modern period. This holds true for the thin-soiled and scrub-covered karstland (or garrigue areas; in Maltese: *moxa* and *xagħri*) which features as a relatively large part of the Maltese landscape, such as the flat-topped Upper Coralline Limestone plateaus in the west-central part of the island. It has been observed that farmhouses with animal pens, as well as public spaces or wasteland, are located at the very fringe of (and/or amongst) these uncultivated areas. It has also been stressed that this apparently unproductive landscape has been turned into an important part of the agrarian economy. Importantly, the uncultivated areas provided (and to an extent still provide) grazing grounds for sheep and goats, quarried stone for construction, brushwood for fuel, as well as herbs, greens, wild game and flowering plants for bee pasture (Blouet 1963; Forbes 1996; Lang 1961; Rolé 2007; Wettinger 1982).

9.2. Methods

9.2.1. Data sources

The research presented here is based on three strands of evidence which are each linked to pastoral activities and foraging excursion networks. These are the location of farmhouses with animal folds, and the garrigue and wasteland areas of the islands. In combination with archival, ethnographic and oral evidence, these traits provided the building blocks of the GIS used in this analysis of pastoral foraging routes.

The location of farmhouses in which the presence of animal-folds or 'stables' is documented has been derived from the sample of *Cabreo* maps used for the modelling of agricultural quality (Alberti *et al.* 2018). Within the sample, 29 stables were identified for inclusion in this analysis. No sites in the central-eastern part of Malta were included because the modification of the landscape, caused by the dense urbanization of this sector of the island, has made it impossible to locate any set of ground control points to be used in the process of geo-referencing the cadastral maps.

The location and extent of the garrigue areas have been recorded as a GIS shapefile layer consisting of 52 polygons. This data layer is part of a larger dataset about the Maltese natural and man-made landscape produced by the MALSIS (MALtese Soil Information System) project (Vella 2001), which was made available to us by the former Ministry of Sustainable Development, the Environment and Climate Change. In this dataset, garrigue zones have a minimum and maximum area of 2.18 and 530.2 hectares, respectively, with a median value of 18.74. Their average elevation (m asl) goes from nearly 0 to 242.4 m, with a median value of 87.65 m. The average slope goes from 0 to 64.72 degrees, with a median value of 13.17. They correspond to portions of the karstic Upper Coralline Limestone plateaus, which, as noted, are generally not suitable for agriculture due to a host of factors including the virtual absence of soil, the high exposure to the winds and the lack of water (Rolé 2007). Both literature and ethnographic sources indicate that these areas have been used for different activities, among which goats and sheep grazing (Lang 1961; Rolé 2007).

The third element useful to the aim of this research is the location and extent of areas that were recorded and described in the British period as 'public spaces' or waste land. These data were derived from early 1900s survey sheets (Alberti *et al.* 2018), and was subsequently fed into the GIS through manual digitization. A total of 217 polygons were employed. Public spaces feature a minimum and maximum area of 0.02 and 17.83 hectares respectively, with a median value of 0.32. Their average elevation goes from 0.33 to 248.22, with a median value of 98.77. Their average slope goes from 0.72 to 31.22, with a median value of 5.71.

These spaces proved to be variable in shape and location. They may open-up along the roads or tracks flanked by rubble walls, actually consisting of an enlargement in the area taken up by the road itself. These are zones that are often overgrown and ideal for roadside grazing. In some cases, the spaces are located at the junction between roads or tracks, probably providing flocks travelling in different directions with manoeuvring space in order not to get in the way of one another. Public spaces can be thought of as important nodes along the routes used for the movement of herds across the landscape. In the GIS dataset, more than half of the public spaces or 60 per cent (n=131) intersect a road, with the remainder placed at a certain distance from them. In comparatively fewer instances (86 cases), public spaces do not have an apparent connection with the road network; rather, they correspond to portions of the karstic Upper Coralline Limestone plateaux.

The distances between the public or waste land spaces and the 1895 road network were analysed using the survey map drawn and compiled by Captain E.M. Woodward, Leicestershire Regiment 28 D.A.A.G. A total of 69 per cent (150) of the public spaces were found to lie at a distance between 0 and 10 m from the nearest road, regardless of the road type. The remaining cases are spread over different distance classes (defined at 10 m intervals), each comprising a decreasing amount of cases. Only one public space lies between 310 and 320 m from the nearest road. If we take the road type into account, about half of the public spaces have a minor road in their close proximity (51 per cent, corresponding to 111 cases), while the remainder breaks down between secondary roads (24 per cent, 52), footpaths (13 per cent, 28), and main roads (12 per cent, 26). These figures do not take into account the actual distance to the nearest road type. The latter is admittedly difficult to summarize with a single representative value (e.g. mean or median) because of the very right-skewed distribution. However, if we consider the proportion of cases whose distance to the nearest road type is between 0 and 10 m, it turns out that public spaces tend to be comparatively closer to footpaths (75 per cent, 21 out of 28), minor roads (74 per cent, 82 out of 111) and secondary roads (69 per cent, 36 out of 52) than to main roads (42 per cent, 11 out of 26).

9.2.2. Foraging routes and least-cost paths calculation

The location of stables, garrigue areas and public spaces provides the foundation for attempting to locate potential foraging routes. To accomplish that, a GIS-based calculation of least-cost paths (LCPs) was used. This is a widely applied approach in the study of how human behaviour relates and engages with movement across the landscape (Conolly & Lake 2006; Herzog 2014; Van Leusen 2002; Wheatley & Gillings 2002). LCP analysis is generally adopted in the study of land accessibility and land-use patterns (Wheatley & Gillings 2002), when the relation between humans and the landscape, such as for instance, for the acquisition of raw materials (Tripcevich 2007) which must be grounded in an understanding of how human movement is differentially affected by the landscape (Conolly & Lake 2006, 214). Once the influence of external factors (either environmental or cultural, or both) on the movement of humans through the landscape is framed in terms of cost, then an analysis which can take into account the cost of movement, instead of simple straight-line distances between locations, may provide a more complex, more realistic and less misleading picture of human spatial behaviours and decisions (Gorenflo & Gale 1990, 243).

GIS-aided estimation of least-cost paths has been used in a variety of contexts and for a wide array of purposes including, but not limited to (and see also: Herzog 2014; Verhagen *et al.* 2011), the study of prehistoric travel corridors (Bell *et al.* 2002; Kantner 2004; Teeter 2012; Whitley & Hicks 2003), human movement and land accessibility (Contreras 2011; Murrieta-Flores 2012; Richards-Rissetto & Landau 2014), prediction of archaeological sites location (Rogers *et al.* 2014), maritime pathways (Alberti 2017; Indruszewski & Barton 2006; Newhard *et al.* 2014), Roman aqueducts (Orengo & Miró 2011) and roads (Verhagen & Jeneson 2012).

In this study, the cost of movement is conceptualized in terms of walking time. This was appropriate as both literature and ethnographic accounts frame foraging excursions in terms of time spent to move from the starting location to the target grazing areas (Arnon *et al.* 2011; Endre Nyerges 1980; Schlecht *et al.* 2006, 2009). Since livestock trails have turned out to follow least-effort routes trying to minimize the impedance provided by the terrain's slope (Arnon *et al.* 2011; Ganskopp *et al.* 2000; Stavi *et al.* 2008), and since slope is a significant factor, albeit not the only influential one (see also symbolic costs, type of terrain, energy expenditure, weather condition, clothing, loads carried, gender, age, fitness, body characteristics, headwinds, field of view (Aldenderfer 1998, 11; Kondo & Seino 2009; Pingel 2010; Wheatley & Gillings 2002, 141)), affecting the speed of movement in rugged terrains (Bell *et al.* 2002; Bicho *et al.* 2017; Kondo & Seino 2009; Murrieta-Flores 2014) (Fig. 9.1a), it was decided to implement a re-scaled version of the widely used (Herzog 2014, 2016) Tobler's hiking function (Tobler 1993), whose modification to fit animal walking speed is described shortly. This is a useful and more accessible tool for estimating the influence of terrain slope on the timing of movement (Aldenderfer 1998, 11; Kantner 2004; Richards-Rissetto & Landau 2014).

Grounded in empirical data, the function predicts the walking speed as dependent on slope according to the following formula: $v = 6*\exp[-3.5*\text{abs}(s+0.05)]$, where v is the walking speed in km/h and s is the slope measured as rise over run. The maximum predicted walking speed of about 6 km/h is reached on a gentle (-2.86 degrees) downhill slope (Conolly & Lake 2006, 218). Beyond that threshold, the walking speed exponentially decreases because during downhill walks the muscular energy of the legs is spent in braking. Remarkably, while the function has been devised on the basis of mid-1950s empirical data, recent GPS-aided studies have confirmed the function's broad validity (Kondo & Seino 2009; Zolt & Dombay 2012). Tobler's function cannot be directly used in its form (expressing km per hour), but has to be solved for time (Pingel 2010, 138); in other words, it is the reciprocal of the function (hours per km) that has to be implemented in GIS.

As noted above, Tobler's function has been re-scaled to fit an animal's walking speed during foraging excursions. The distribution of the latter, as empirical data show, turns out to be right-skewed and to vary along a continuum. It ranges from very low speed values (corresponding to grazing while walking) to comparatively higher values (up to about 4.0 km/h) corresponding to directional travel toward feeding stations (Arnon *et al.* 2011). In an attempt to find a balance between different figures (Arnon *et al.* 2011; Endre Nyerges 1980; Schlecht *et al.* 2009, 2006), it was decided (but see below) to consider 1.5 km/h as the average flock speed (Endre Nyerges 1980, 468). It roughly corresponds to the average speed recorded in other studies (Arnon *et al.* 2011; Schlecht *et al.* 2009). The above figure is considered the typical speed of flocks during excursions in which grazing takes place while walking (Fig. 9.1b), which in most situations can be

Figure 9.1. *a) Sheep being led to their fold in Pwales down a track; notice the quite steep slope which is bound to negatively affect the walking time; b) Sheep grazing along a track on the Bajda Ridge in Xemxija, Malta. The pasture is located in fallow fields in Miżieb ir-Riħ. Notice that sheep are grazing while walking (estimated average speed derived from literature: about 1.5 km/h) (N. Vella, 9 January 2005) (G. Alberti).*

considered a typical form of grazing (Arnon *et al.* 2011). Tobler's (1993) hiking function has been rescaled by a factor of 0.25 to represent the walking pace of a flock instead of humans. The mentioned factor corresponds to the ratio between the flock average speed (1.5) and the maximum human walking speed (about 6.0) on a favourable slope (-2.86 degrees).

Paths following least costly routes have been calculated using ArcGIS 10.1's Path Distance tool (ESRI 2017d), which locates the minimum cumulative travel cost when moving on a raster from a source location to destination locations. Remarkably, it allows anisotropic cost estimation (Conolly & Lake 2006, 215–21; Wheatley & Gillings 2002, 138ff) that includes the calculations of slope-dependent costs such as those based on Tobler's (1993) function. The reciprocal of the latter, expressed in metres (representing the time in hours to traverse 1 m), has been fed into the tool as a customized vertical factor table, following the procedure first used by Tripcevich (2007) in the context of archaeological research. The table stores the time (in hours) it takes to cross 1 m for each slope value, the latter ranging from -90 to +90 degrees. While a slope raster derived from a digital terrain model (DTM) and expressing the slope in absolute values (i.e. not distinguishing between down and up slopes) is fed into the tool as a cost surface. In this case, the tool internally calculates whether each slope value is either negative or positive when moving from one cell to another (ESRI 2017c), and associates each signed slope value with its corresponding time value (in the mentioned vertical factor table). Once the time it takes to traverse 1 m at each signed slope value is determined, it is finally multiplied by the actual surface distance (ESRI 2017c & d; Etherington 2016; Rogers *et al.* 2014, 263). Eventually, the tool calculates the accumulated time it takes when moving from the source raster cell to the next neighbouring cell, producing a cumulative cost-distance raster. The tool also returns a backlink raster, which indicates, for each cell, which neighbouring cell one has to move to in order to reach the source location along a least costly path (ESRI 2017d).

Two rasters were fed into the Path Distance tool. The first was a LiDAR-derived DTM with a cell size of 10 m. The resolution used has been deemed suitable for the research questions at hand given the spatial extent of the analysis. The relatively coarse cell size has been considered a good compromise in an attempt to find a balance between accuracy in the representation of the terrain's elevation and the need to reduce the distortions caused by the human-made structures retained in the DTM (e.g. Verhagen & Jeneson 2012). This is particularly evident in the southern sector of the island, where the runway of Malta international airport is located. Apart from that, the DTM provides a more generalized picture of the terrain, in which some characteristic features of the landscape, such as terrace walls, have been smoothed out to a certain extent.

The slope raster fed into the Path Distance tool as a cost surface was derived from the DTM referred to earlier. The slope raster has been preliminarily modified in order to gauge the influence of our model of agricultural suitability on the LCP calculation. Literature and ethnographic evidence indicate that during their grazing journeys shepherds tend to avoid cultivated fields (Bevan *et al*. 2013). On this informed assumption, it was decided to factor agricultural quality into the LCP analysis. This was achieved by applying weights (e.g. Rogers *et al.* 2014, 264; White 2015, 410) to the slope, deriving them from the raster representing the fitted probability of optimal agricultural quality (Alberti *et al.* 2018). A higher slope value has been assigned to those parts of the landscape for which the estimated probability for optimal agricultural quality is larger than 0.60, rendering those areas costlier to traverse.

We decided to calculate two series of LCPs. The first uses garrigue areas as both the source and the destination of movement, in order to estimate the path network between them. The rationale behind this rests on the fact that, as noted, these areas are indicated by literature and ethnographic sources as being preferentially used for grazing. Since the calculation of LCP needs both a source (i.e. the starting location) and destination locations (i.e. places where the movement actually ends), and since there is no substantive reason to prefer any given location over another as a destination within each garrigue area, it was decided to draw a set of random points within the garrigue polygons, with a minimum inter-point distance of 20 m. In total 139 points were eventually generated. Each point has been used as a destination in the LCP calculation from each garrigue area.

A second series of LCPs was calculated using the stables as source locations and the mentioned random points as targets. The aim of this second series of LCPs was to estimate the least costly paths along which foraging journeys may have taken place. Since both ethnographic data and literature indicate that time is an important constraining factor for foraging journeys, and since (in spite of a considerable variability across species and season) 10 hours can be considered an average duration of grazing day (Schlecht *et al.* 2006), the present calculation of LCPs has been first limited to five hours, and increased to six and eventually to seven for the reasons described later while reporting the results. The rationale for using a time limit is to locate which target location can be reached along a least costly path from each stable, while also leaving enough time for the return journey to the stables. Finally, it should also be noted that the calculation of these two LCP networks allows the relationship between public spaces and potential pastoral routes to be examined. This is useful to explore the hypothesis, informed by the existing literature and ethnographic evidence, that the public spaces may be nodes along foraging paths.

9.3. Results

9.3.1. Garrigue to garrigue least-cost paths

Figure 9.2a shows the network of LCPs connecting each garrigue area to each random point within them. Dashed lines have been used to represent the paths; when they show up as a continuous black line, it means that two or more paths are actually overlapping (see §9.3.2). Overall, the image represents the potential routes along which a foraging journey may take place. As expected, these paths (139 in total) minimize the traversed slope. The minimum and maximum average slope is 1.28 and 15.77 degrees, respectively. The median average value is 5.19 degrees, with 90 per cent of the cases having an average slope equal to or smaller than 9.76 degrees, and just the top 10 per cent of the cases exhibit an average slope between 9.76 and 15.78 degrees.

As a result of the described weighting scheme, the LCPs also tend to avoid areas with a high probability for optimal agricultural quality. The median average probability of the terrain they traverse is 0.05, with a minimum and maximum equal to 0 and 0.51, respectively. In 90 per cent of the cases it is equal to or smaller than 0.23. The effect of the adopted weighting scheme can be visually appreciated from Figure 9.2b. It is apparent how LCPs tend to avoid the bottom of valleys since these feature the highest probability for optimal agricultural quality. This holds particularly true for the central sector of the island, and for two 'pockets' in the north-central area, in the Mosta and Naxxar neighbourhood.

As touched upon earlier, the estimated LCPs show some degree of overlap, which can be better appreciated (e.g. Bevan & Conolly 2013) in Figure

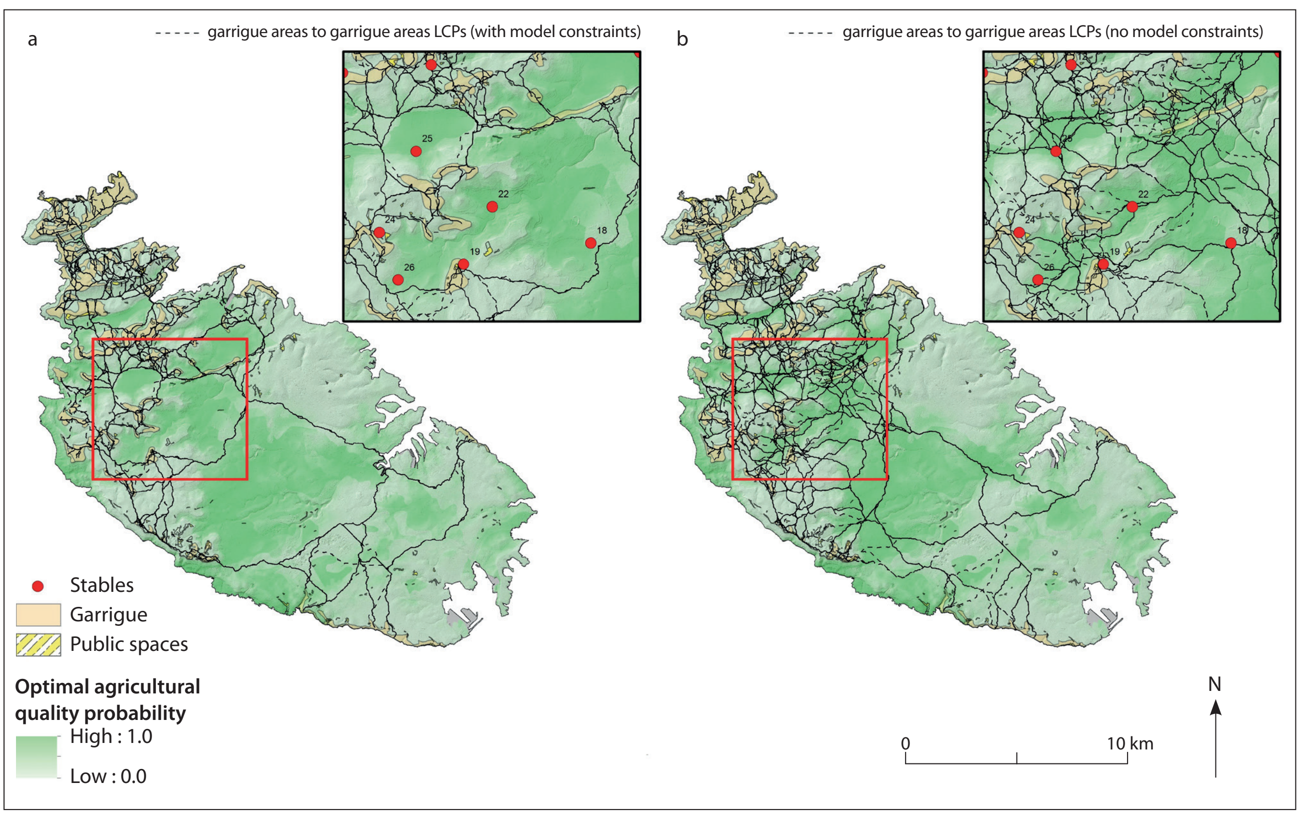

Figure 9.2. *Least-cost paths (LCPs), connecting garrigue areas, representing potential foraging routes across the Maltese landscape (the latter is given a colour that represents the probability of optimal agricultural quality, according to the* Cabreo *model): a) LCPs with the model used as a constraint (LCPs tend to avoid more fertile areas); b) no model constraint (see also Fig. 9.3) (G. Alberti).*

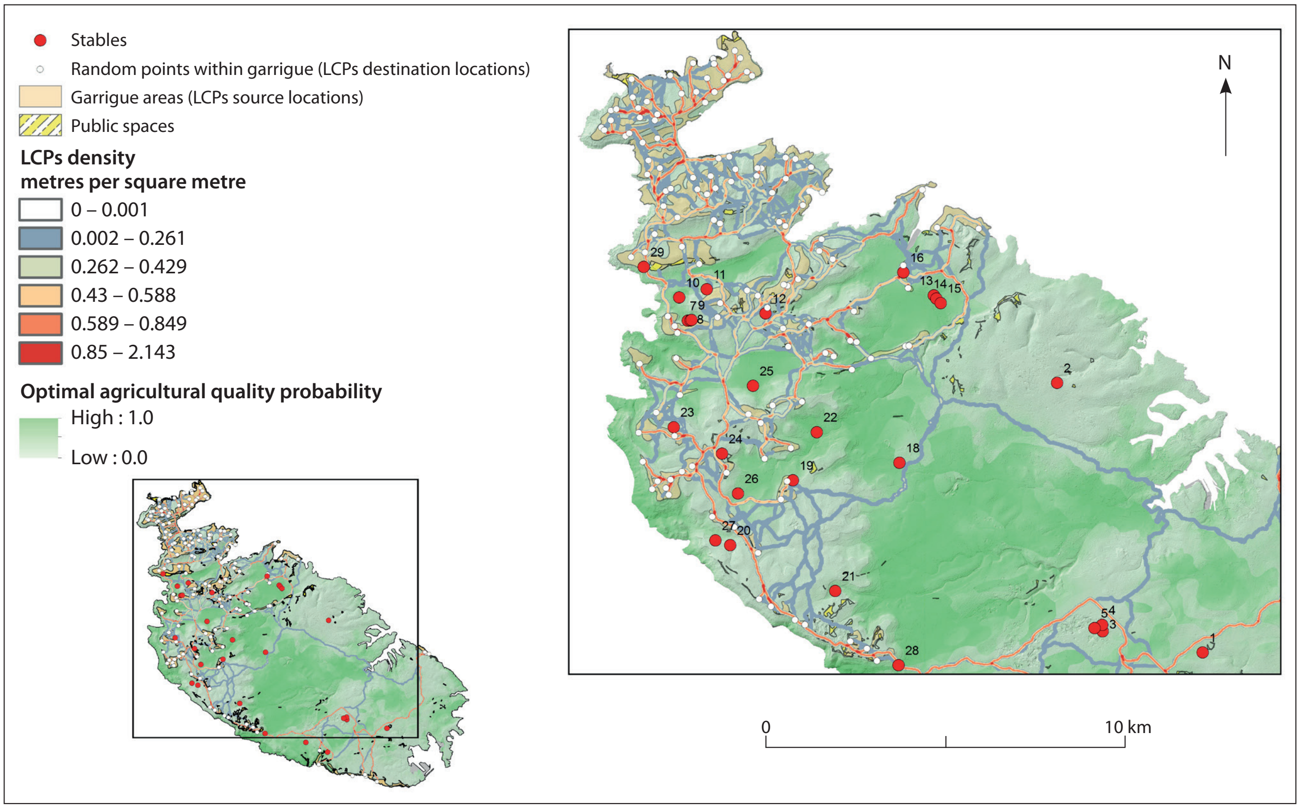

Figure 9.3. *Density of LCPs connecting garrigue areas to random points within the garrigue areas themselves. Density (metres per square metre) calculated as the sum of the length of each path's segment falling within a 50 m search radius centred on each raster cell, divided by the area enclosed by the search radius (G. Alberti).*

9.3. It represents the density of LCPs (in metres per square metre) calculated as the sum of the length of each path's segment falling within a given search radius centred on each raster cell, divided by the area enclosed by the search radius (ESRI 2017b). A search radius of 50 m has been used, and to break the density values down into five classes. Jenks' classification algorithm (Jenks 1967; Smith 1986) has been employed for its ability to maximize groupings inherent in the data (ESRI 2017a). This is apparent in the extent to which among all the areas traversed by the estimated LCPs, some are actually characterized by a comparatively higher density of paths. This holds true for the northernmost sector of the island, the north-central part, and the westernmost part along the western coast of Malta.

The analysis indicates that public spaces tend to lie close to the estimated LCPs. The median planar distance of public spaces to the nearest LCP turns out to be 89 m, which becomes 39 m if we consider a 50 m buffer around each side of the LCP. Remarkably, the first quartile of the distribution is equal to 0, meaning that one quarter of the cases (out of a total of 217) has a minimum distance equal to 0. In other words, the LCPs either cross the public spaces or touch their boundary. Overall, 53 per cent (116) of the public spaces lie between 0 and 100 m away from the nearest LCP, while just 20 per cent (43) lie between 100 and 300 m away. Cumulatively, 73 per cent (159) lie within a distance of 300 m. It is worth noting that only 27 (12 per cent) public spaces feature a distance equal to or larger than 1 km to the nearest LCP. Remarkably, these more distant public spaces are mainly located at the fringe of the densest urbanized area of the island (see Fig. 9.4, where the Jenks' method has been used). They could possibly have been related, spatially and functionally, to garrigue areas cancelled out by modern urbanization.

The tendency for public spaces to be close to the estimated LCPs can be statistically assessed by means of a randomized procedure (O'Sullivan & Unwin 2010; Wheatley & Gillings 2002) whereby the distance from each public space's centroid to the nearest LCP is first computed and averaged. The significance of the observed average minimum distance is assessed by comparing it against a distribution of

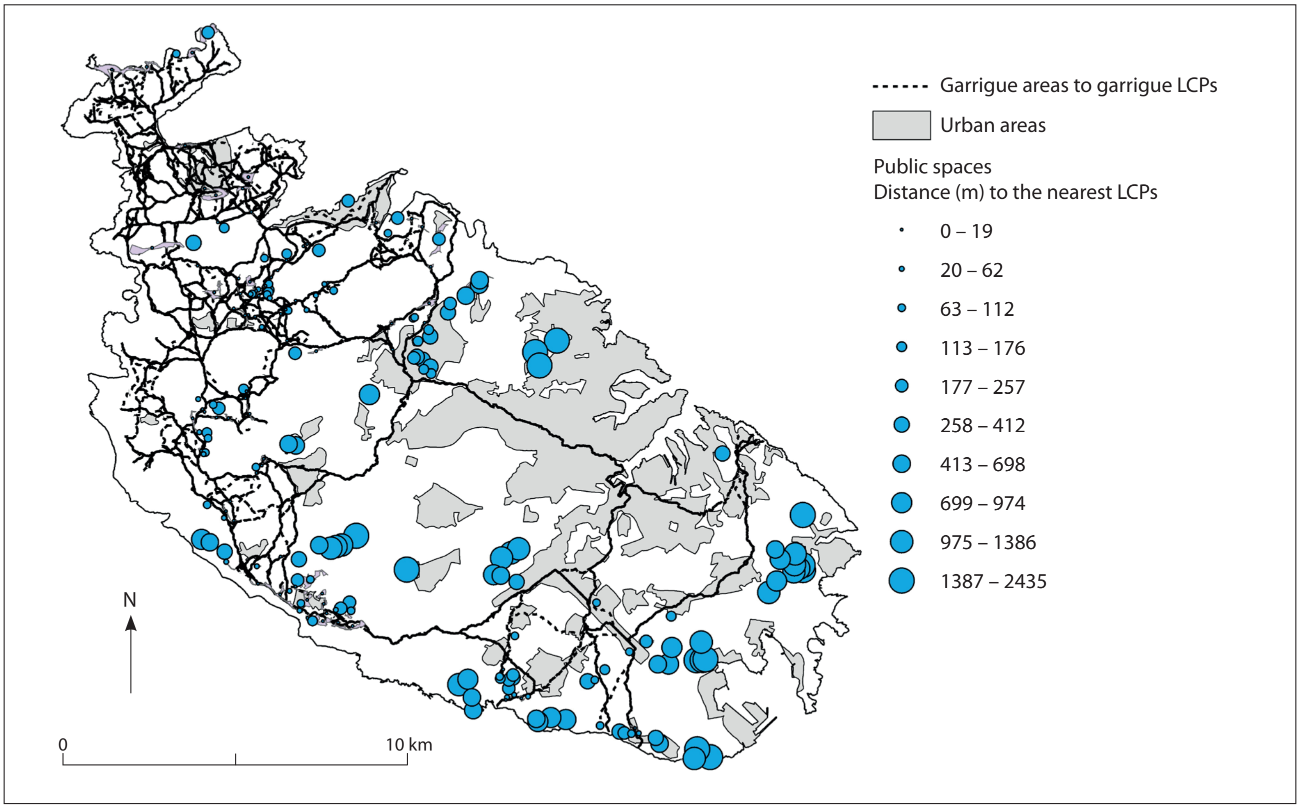

Figure 9.4. *Location of 'public spaces', with size proportional to the distance to the nearest garrigue-to-garrigue LCP. The classification of the distance value is based on Jenks' natural break method for its ability to maximize groupings inherent in the data. Extent of the modern urbanized area is also shown (G. Alberti).*

average minimum distances calculated across 199 sets of random points drawn within a study window (Rosenberg & Anderson 2011). A p-value can be empirically worked out; it reflects the proportion of cases in which simulated average distances proved equal or smaller than the observed average distance (Baddeley *et al.* 2016, 384–7). The study window is the extent of Malta excluding the urbanized areas and those zones that the LCPs are intentionally avoiding (modelled probability of optimal agricultural quality larger than 0.60; see §9.3.1). The analysis indicates that the observed average minimum distance is 380 m, while the average of the randomized minimum distances is 510 m. The tendency for public spaces to lie close to the estimated LCPs is significant (p: <0.05).

9.3.2. Stables to garrigues least-cost paths

Figures 9.5–9.7 show the LCPs connecting stables to the random points within the garrigue areas. Two symbologies refer to the two legs of the journey, one from the start location to the destination (outbound), the other in the opposite direction (inbound). As stated above, the LCP have been calculated with a time limit of five hours for the outbound journey, devised on the basis of literature. Additional calculations have been nonetheless performed increasing the limit to six and, eventually, seven hours. The reason for this was to maximize the number of target locations that could be reached. In fact, while just 35 per cent and 40 per cent (out of 139 cases) could be reached with time intervals of five and six hours respectively, 50 per cent (69) of the destinations can be reached once seven hours are considered. It must be noted that for ten stables (2, 6, 10, 13–15, 17, 22, 25, 27) the analysis resulted in no LCP being estimated. In one instance (2; see Fig. 9.6b), this was because the nearest target location is beyond the 7-hour limit. Nine stables (6, 10, 13–15, 17, 22, 25, 27) cannot be connected to any destination because they are surrounded by land featuring a probability for optimal agriculture above 0.6, resulting in an extremely limited area than can be traversed within seven hours.

Overall, the time spent in median to reach the destinations is 3.51 hours. One quarter of the destinations can be reached within 2.47 (1st quartile) hours, and three quarters within 5.39 (3rd quartile).

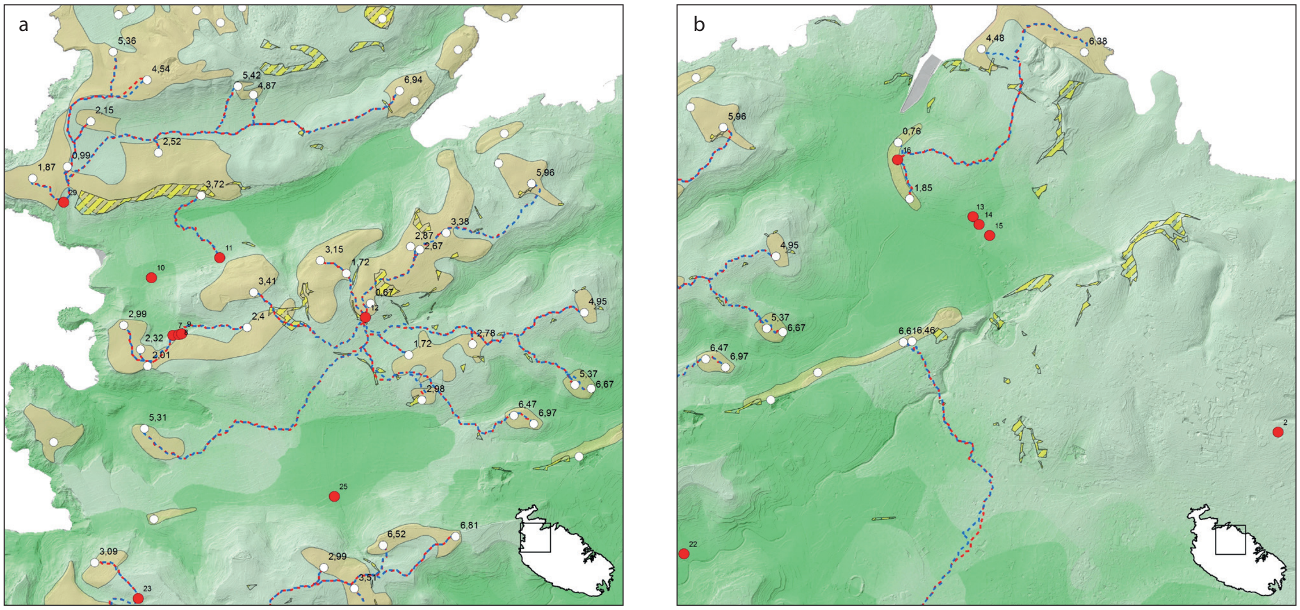

Figure 9.5. *LCPs connecting farmhouses hosting animal pens (hereafter 'stables') to randomly generated points within garrigue areas in northwestern (a) and northeastern (b) Malta. Dashed blue and red lines represent the outbound and inbound journey respectively (for legend and scale bar, see Fig. 9.7) (G. Alberti).*

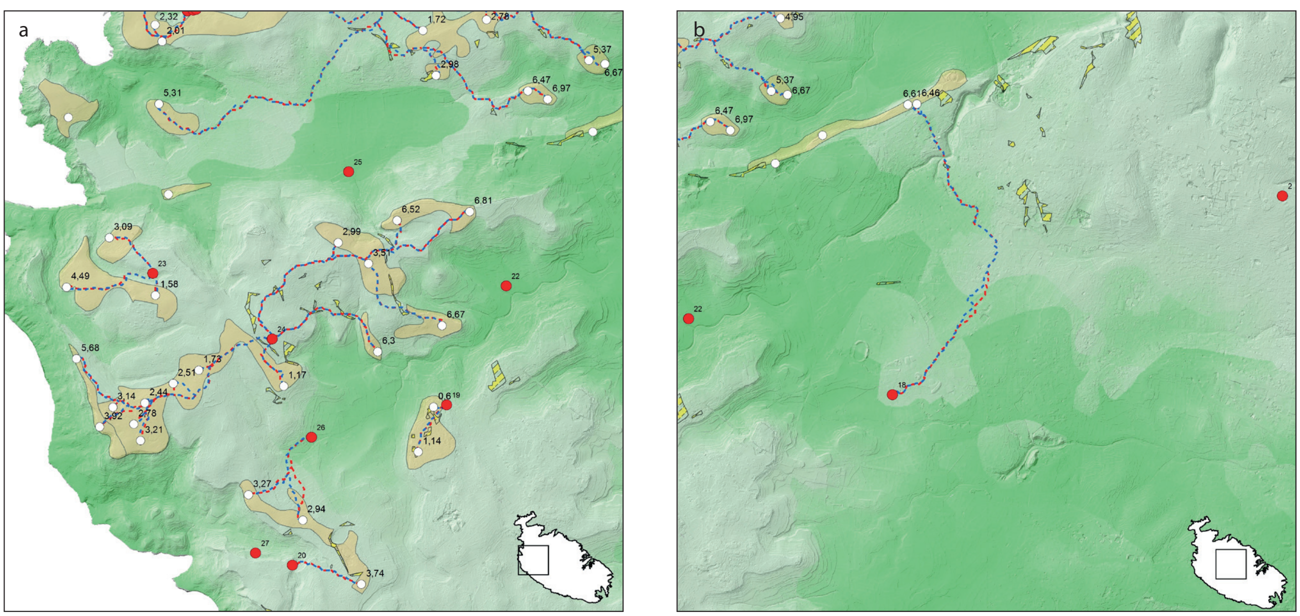

Figure 9.6. *As for Figure 9.5, but representing west-central and east-central Malta (for legend and scale bar, see Fig. 9.7) (G. Alberti).*

If we break down the data by a two-hour interval, 17 per cent (12) of the locations can be reached with a journey between zero and two hours, 39 per cent (27) between two and four hours, 25 per cent (17) between four and six hours, and 19 per cent (13) between six and seven hours. Cumulatively, 56 per cent of the location can be reached within a four-hour journey, 81 per cent within six hours, with the remaining 19 per cent reachable within seven hours. The outbound excursions reach a median planar distance of 996 m from the starting locations. In the middle 50 per cent of the cases, the distance is between 625.40 m (1st quartile) and 1708.83 m (3rd quartile). In only the top 10 per cent of cases is the distance covered between 2161.71 and 3761.52 m, with just two cases scoring a distance between 2500 and 3000 m, and just one case between 3500 and 4000 m.

As touched upon above while considering the overall LCPs, the weighting scheme used allows the addition of complexity to the estimated paths as well. Considering for instance stable number 11 in northern Malta (Fig. 9.5a), it is interesting to note that the LCP, while traversing quite a flat area featuring a relatively low probability for optimal agricultural quality, makes a westward detour to bypass a zone featuring a higher probability. The same holds true for the LCPs from stable number 18 (Fig. 9.6b), which follow an eastward-bent path that traverses a low-probability portion of the land.

The analysis shows that the time spent to return to the stables is in median 3.47 hours, with the 1st and 3rd quartile equal to 2.46 and 5.38, respectively. There is no remarkable difference in the duration of the outbound and inbound journeys, as their median difference of 0.013 hours indicates. The maximum absolute difference is equal to 0.153 hours, corresponding to the time differential between the LCPs connecting stable number 24 to a destination lying west of it and that can be reached in 5.68 hours (Fig. 9.6a). The journey in the opposite direction would last 5.84 hours. Considering the two legs of the estimated LCPs, the analysis indicates that a typical grazing journey would last 6.99 hours (median), with 50 per cent of the journeys competed between 4.94 (1st quartile) and 10.77 (3rd quartile) hours. The lower 10 per cent (7 cases) of the journeys can be performed within 3.18 hours, and the top 10 per cent can be completed in a time-span between 13.03 and 13.90 hours.

As for the distance between stables-to-garrigues LCPs and centroids of public spaces, the observed average minimum distance is of 908.90 m is considerably smaller the randomized average minimum distance of 1347 m (across 199 simulations; using the same analytical windows mentioned earlier), with an associated significant p-value (p: <0.05). About 15 per cent of the public spaces (32) lie at a distance between 1000 and 2500 m, and a small group (about 10 per cent, corresponding to 20 public spaces) lies between 3000 and 5000 m. If the location of all these cases is considered (Fig. 9.8), it can be noted that they tend to lie in the eastern part of the island, in the very sector which is opposite to the zone (namely, the northwestern and western) toward which the location data of the stables is 'structurally' skewed as mentioned earlier. If these cases are excluded, the remaining 165 instances indicate that public spaces are in median 188.27 m distant to the nearest LCP connecting each stable to the destination points within a 7-hour walk; 12 per cent (20) are at a distance of 0 m, meaning that LCPs actually cross the spaces or touches the public spaces' boundary. Some 25 per cent (41) are within 47 m distance, while 75 per cent (124)

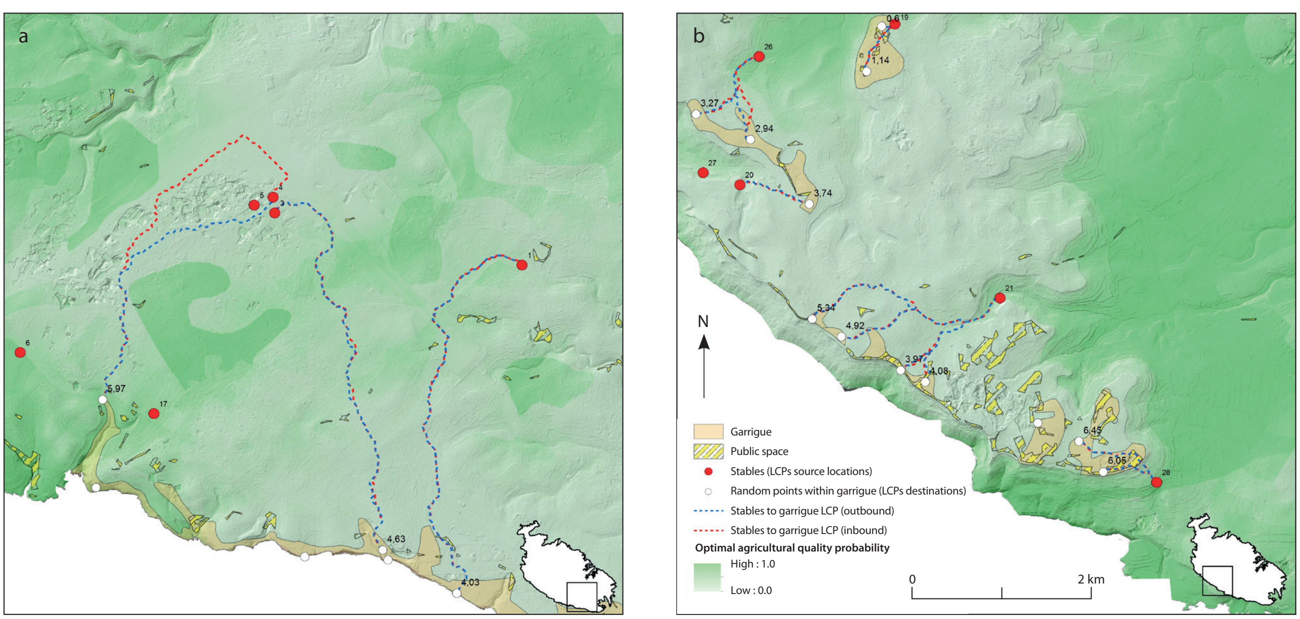

Figure 9.7. *As for Figure 9.5, but representing southern and southwestern Malta (G. Alberti).*

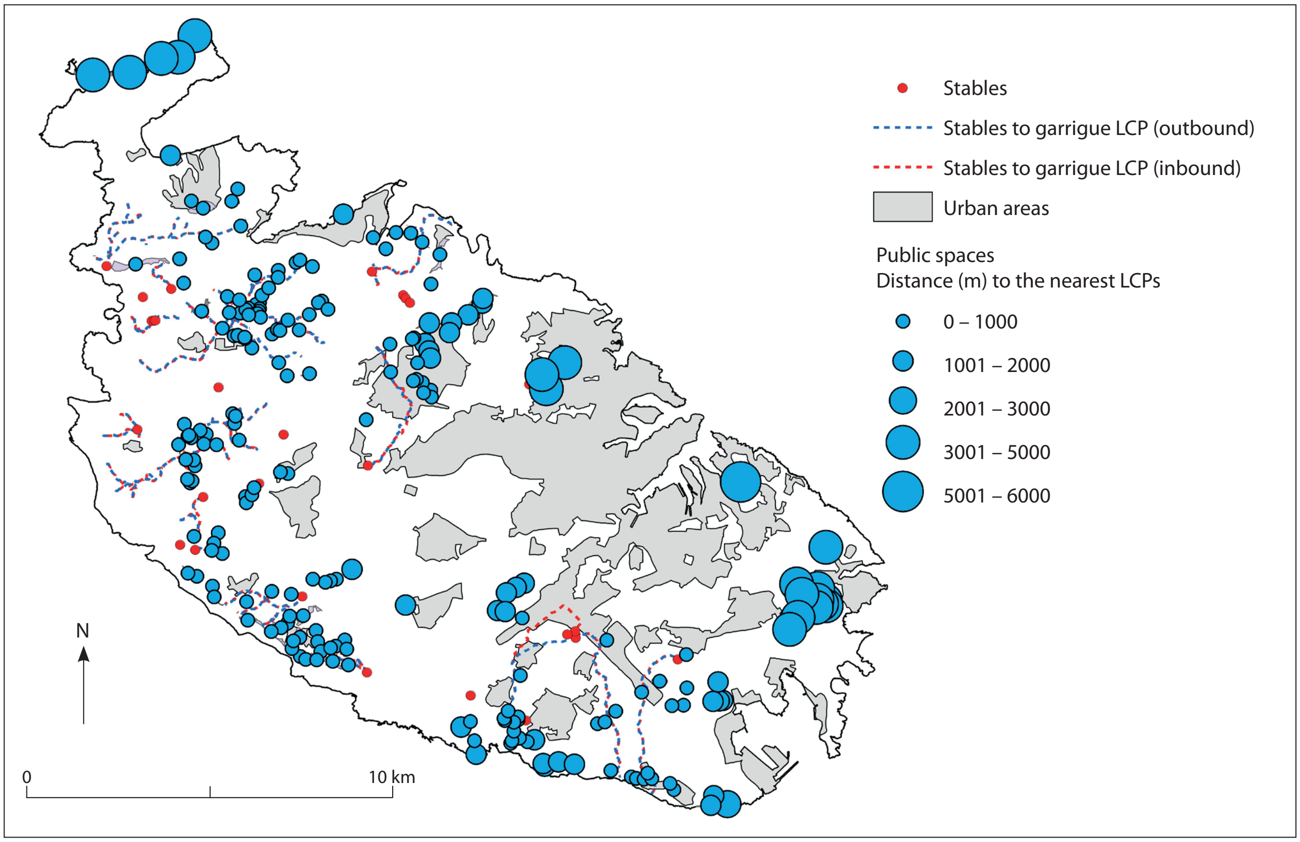

Figure 9.8. *Location of 'public spaces', with size proportional to the distance to the nearest outbound journey (stables to garrigue areas). Distance values classified using the Jenks' natural breaks method as in Figure 9.3. Inbound and outbound journeys, and the extent of modern urbanized area, are also shown (G. Alberti).*

lie within 447.44 m. Overall, these figures indicate that the estimated LCPs and public spaces tend to be close in space.

9.4. Discussion

The analysis reveals some interesting features of the Maltese rural landscape in relatively recent historical periods. These findings nicely dovetail with the previous study of the agricultural productivity in Malta in the mid-1800s (Alberti *et al.* 2018). While the latter has generally brought to the fore the interplay between good agricultural land and sectors of the landscape less suitable for agriculture but potentially exploitable for other economic activities, the research pursued in the present work allows the further characterization of the way in which the parts of the Maltese landscape less suited for agriculture have been exploited for complementary, yet equally important, purposes such as herding and grazing.

Employing as constraining factors the modelled agricultural quality and the documented tendency of grazing routes to avoid good agricultural areas, this study has proposed a model of likely grazing itineraries that features a complex network of paths connecting those garrigue areas used by shepherds as grazing areas. Informed by the parameters selected on the basis of the literature, the network minimizes the traversed slope and tries to avoid the bottom of valleys, the latter corresponding to areas of good agricultural quality. This network can be thought of as representing plausible routes connecting areas of foraging exploitation.

The analysis has also attempted to gauge how (if any) the so-called public spaces or wasteland areas relate to that network.[1] Interestingly, those areas were found to be spatially related to the foraging route network. Even though from an analytical standpoint, a complicating factor is represented by the different preservation of public spaces between the eastern and western sectors of study area, the fact that the majority of the public spaces lie within a 300 m distance from the estimated foraging paths is taken here as evidence hinting to a functional connection between the two.

It has been noted above that, in our GIS-based foraging routes estimation, some farmhouses could not be connected with any destination location within the garrigue areas since the farmhouses are surrounded by land featuring a very high agricultural quality. In this respect, it must be noted that the possibility to move flocks in areas of densely cultivated fields was assured by the existence of walled paths (droveways). Interesting examples still survive in a quite densely urbanized area between the modern towns of Mosta and Naxxar, in central-eastern Malta (Fig. 9.9). In the locality called Tal-Wei, for example, four walled paths converge in a public space (0.33 ha). From a functional point of view, the paths would have allowed flocks to move across the landscape without traversing cultivated fields, unless some sort of agreement had been previously established between shepherds and farmers to allow grazing on their fields following a harvest or in those, particularly in Gozo, where self-seeded *sulla* (*Hedysarum coronarium*) grows in abundance, as we know from the literature and local informants (Bowen-Jones *et al.* 1961, 199, 227).[2] The public space would have also provided manoeuvring space for flocks moving towards different destinations. It turns out that a segment of the GIS-based estimated foraging route connecting the garrigue areas is just 147 m away

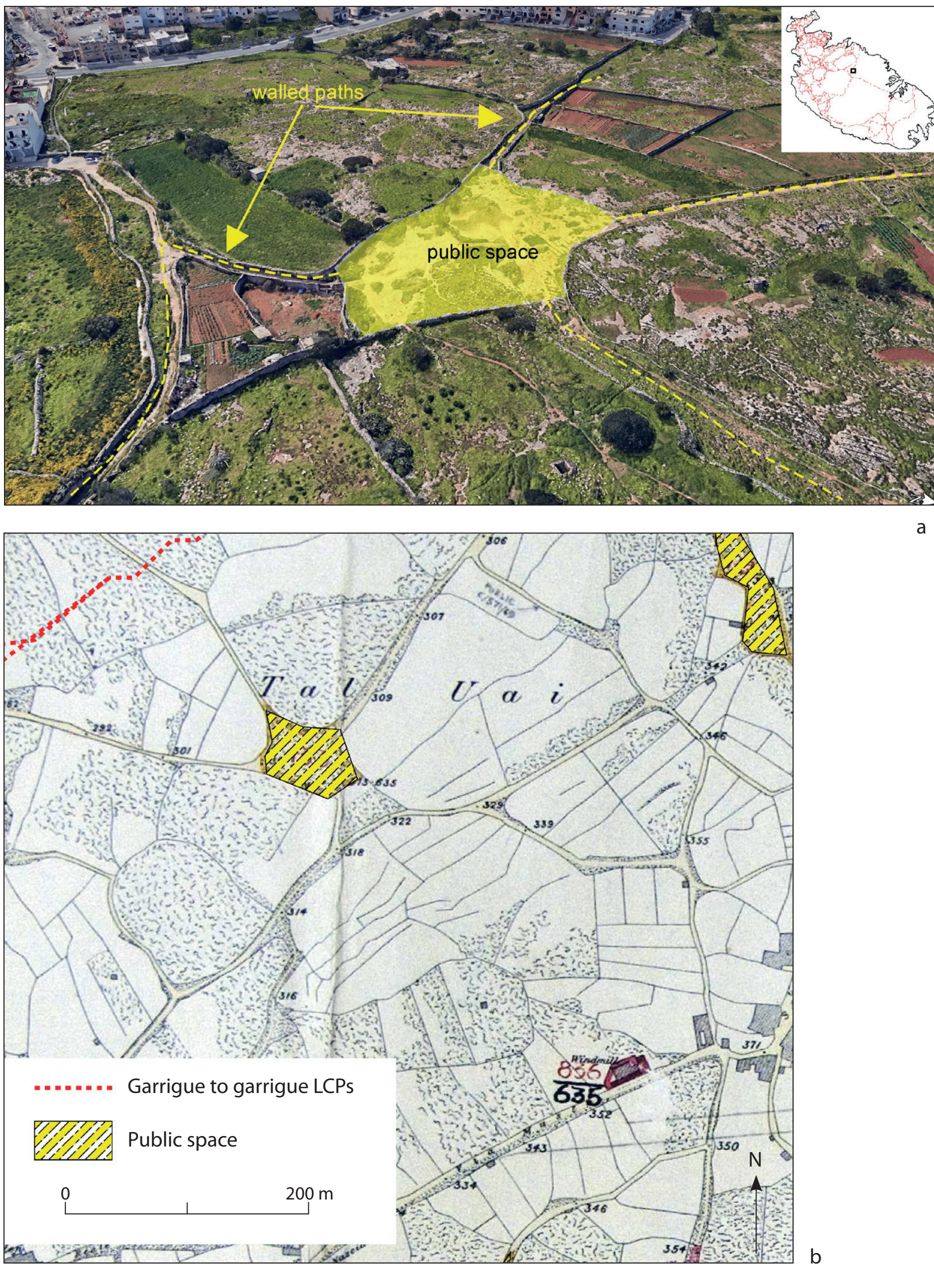

Figure 9.9. *a) Public space at Tal-Wei, between the modern town of Mosta and Naxxar; the extent of the public space and the layout of the walled paths leading to the space are highlighted; b) Tal-Wei public space as represented in 1940s survey sheets. The red line represents a segment of the GIS-estimated foraging route passing about 100 m away from the public space (G. Alberti).*

from the mentioned public space. Bearing in mind that in a highly dense urbanized zone, like the one under discussion, the estimation of the foraging route is likely to have been affected by the noise retained in the DTM purged from modern construction, the Tal-Wei case represents an interesting instance in which, from a postdictive standpoint (Armstrong *et al.* 2016; Patacchini & Nicatore 2016), GIS-based estimates show a reasonable degree of plausibility in relation to actual evidence on the ground.

If the estimated LCPs can be taken as representing potential corridors for movement of flocks across the landscape, another strand of evidence turns out to dovetail with the GIS-based estimations. The evidence relates to the location and spatial distribution of villages bearing the Maltese prefix *raħal* (often contracted to ħal), a number of which have been associated with minor settlements, hamlets or more generally 'villages' that disappeared during the Medieval period (Wettinger 1975). The Arabic meaning of the word *rahl*, which survives in Spain and Sicily, is that of a stopping place after a day's journey. It must be acknowledged that the etymology and the process of linguistic and semantic adaptation along the transmission from Arabic to local languages (such as Spanish, Sicilian and Maltese) is extremely intricate and not without uncertainties. It has been argued, however, that the prefix can be etymologically connected to traveller's way-stations or huts used by itinerant shepherds in southern Spain (Glick 1995) and in Sicily (Dalli 2016, 373) and by extension, to locales associated to livestock breeding or animal husbandry, such as farmsteads, animal folds or estates (Dalli 2016). The Maltese *merħla* (herd, normally of sheep and/or goats) and its plural *mrieħel* or *merħliet* share the common root *r-ħ-l* with *raħal* seemingly confirming the pastoral connotation (Fiorini 1993, 118).

Building on the available documentation of the distribution of those toponyms, this study has made a considerable effort to improve their positioning beyond the six-figure reference given by Wettinger (1975, 190, 205 & fig. 12) by looking at all minor localities associated with individual ħal toponyms (recorded in Wettinger 2000) and locating these on the series of six-inch to one mile maps of Malta produced in the early 1900s. Some uncertainties do remain as for the exact location and the original extent of these villages. In any case, the above procedure allowed the building of a database featuring 69 locations. These are shown in Figure 9.10, where they have been given a 500 m radius buffer representing the hypothetical, and admittedly subjective, extent of each village. The colour of the buffers reflects the division of the distance to the nearest garrigue-to-garrigue LCPs into four classes using the Jenks' (1967) natural breaks method cited earlier. In spite of positional uncertainties, it can be appreciated that the villages seem to lie not far from the network of LCPs. As a matter of fact, 58 per cent (40 out of 69) of the buffers are at a distance of zero metres from the LCPs, meaning that the latter are tangential to, or intersect, the buffer; 10 (*c*. 15 per cent) are at a distance between 41 and 295 m, with fewer and fewer instances falling within increasing distance classes. All in all, it seems that the location of the *raħal* toponyms tends to be close to the estimated pastoral foraging routes. Another characteristic that deserves further study is that several of these toponyms, such as Ħal Mann, Ħal Millieri, or Ħax-Xluq, coincide with nodes where several minor roads and tracks converge, linking them to the network of walled droveways.

Other evidence turns out to be interesting from a postdictive standpoint. East of Rabat, the estimated LCPs pass in the vicinity of the Tal-Merħliet road (minimum distance *c*. 120 m), whose name (meaning 'of the herds') is actually related to sheep and flocks (Fig. 9.10). West of Rabat, an area called Tal-Merħla turns out to be surrounded by the estimated LCPs, with the nearest estimated foraging route being about 100 m distant. Further west, another Tal-Merħla place-name and a Tal-Merħla road are close to the estimated LPCs, with the former 250 m distant from the nearest foraging route, and the latter actually intersecting part of the LCP. West of Qrendi, the LCPs pass near a church dedicated to San Nikola Tal-Merħliet (minimum distance *c*. 515 m) that, in turn, falls within the territory of the lost village of Raħal Niklusi (Wettinger 1975, 374). In the eastern sector of Malta, the estimated LCPs leading to the garrigue areas lying in the same zone cross an area named after St Rocco (distance to the nearest LCP: 51 m). The latter is traditionally considered to be protector of herds, especially against infectious diseases (Mandarini 1860, 338–9). Moving to the south, two place-names featuring a connection to the same saint lie at 243 m (Misraħ Santu Rokku) and 600 m (Ta' Santu Rokku) away from the nearest LCP. Finally, immediately east of Salina Bay (north-eastern Malta), the estimated LCPs cross an area named Il-Merħla.

Besides the general foraging route network connecting the grazing areas, the analysis sought to locate likely paths connecting individual farmhouses to garrigue areas within an animal walking-time limit of seven hours. The latter has been devised whilst taking into consideration both literature and analytical constrains. While the actual routes located by the analysis are interesting in their own right from a purely cartographic perspective, the estimated journey duration proves even more interesting once compared

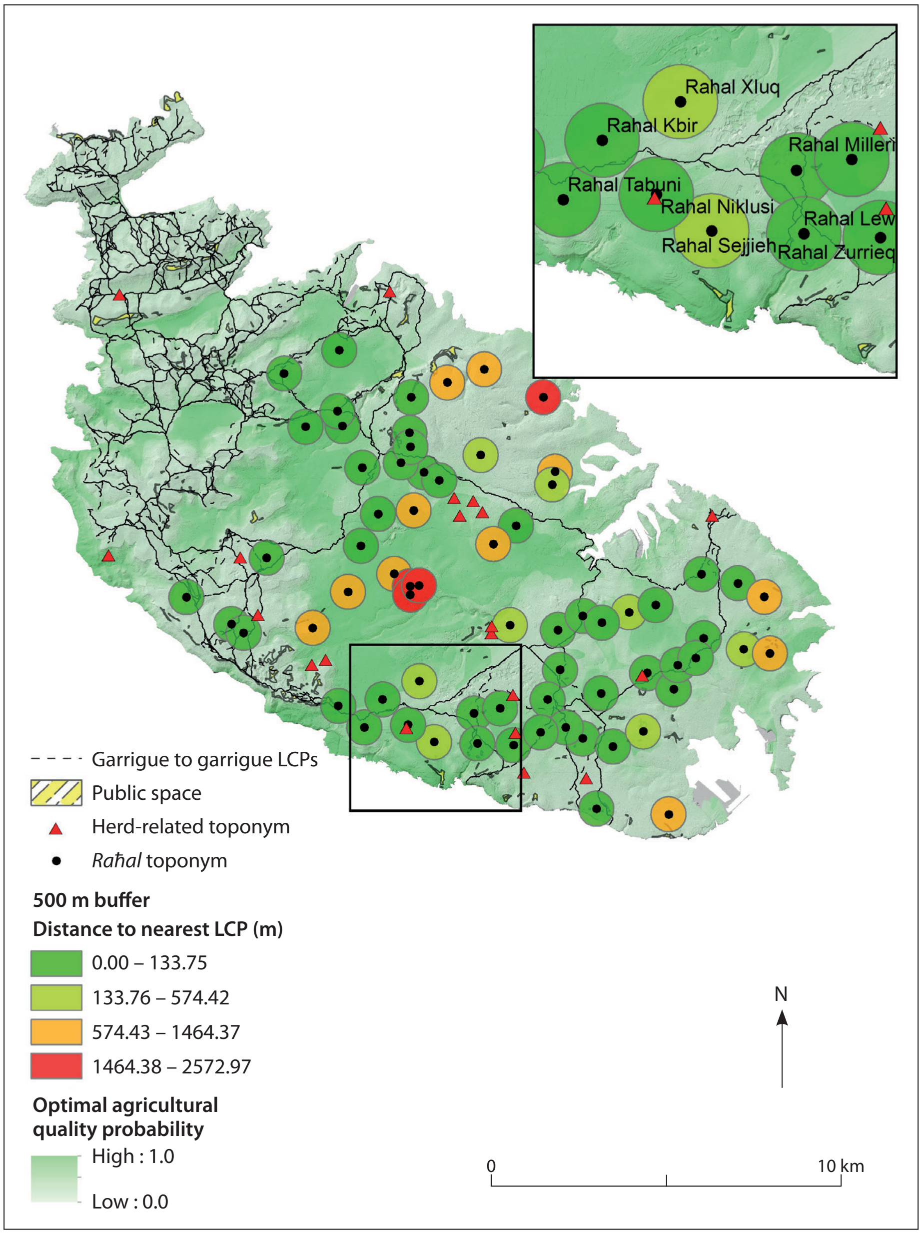

Figure 9.10. *Approximate location of the (mostly disappeared)* raħal *toponyms. Circles represent 500 m buffer to account for locational uncertainty. Buffers are given colours reflecting the distance to the nearest GIS-estimated foraging route. Red triangles represent the location of herd-related toponyms (G. Alberti).*

with empirical and ethnographical data. Considering that 50 per cent of the estimated foraging excursion (outbound plus inbound) in Malta fall between 4.94 and 10.77 hours (see §9.3.2), it turns out that these figures are comparable with empirical GPS-derived data gathered in other cultural and geographical contexts. In the Negev (Israel), for instance, the average journey has a duration of 5.5 hours, with a minimum of 4.3 recorded in May and a maximum of 7.7 recorded in March (Arnon *et al.* 2011, 137–8). In northern Oman, foraging excursions last about 9 hours on average (Schlecht *et al.* 2009, 358), while in western Niger it varies across seasons between 7.6 and 10.4 hours (Schlecht *et al.* 2006, 230).

The plausibility of the GIS-based estimates is strengthened by ethnographic data derived from interviews with local shepherds conducted by one of us (NCV) between 2016 and 2018. These relate to practices that go back to the period between the 1950s and 1970s when the informants were young and used to tend flocks with their father or other relatives. One of the informants was the owner of a farmhouse located in western Malta, in the Għar il-Kbir area (Fig. 9.11). The shepherd reported that the main grazing area for his flock consisted of the garrigue zones lying immediately southwest and northwest of the farmhouse, along the escarpment of the Dingli Cliffs and at Il-Bosk, respectively. He also provided information about the duration

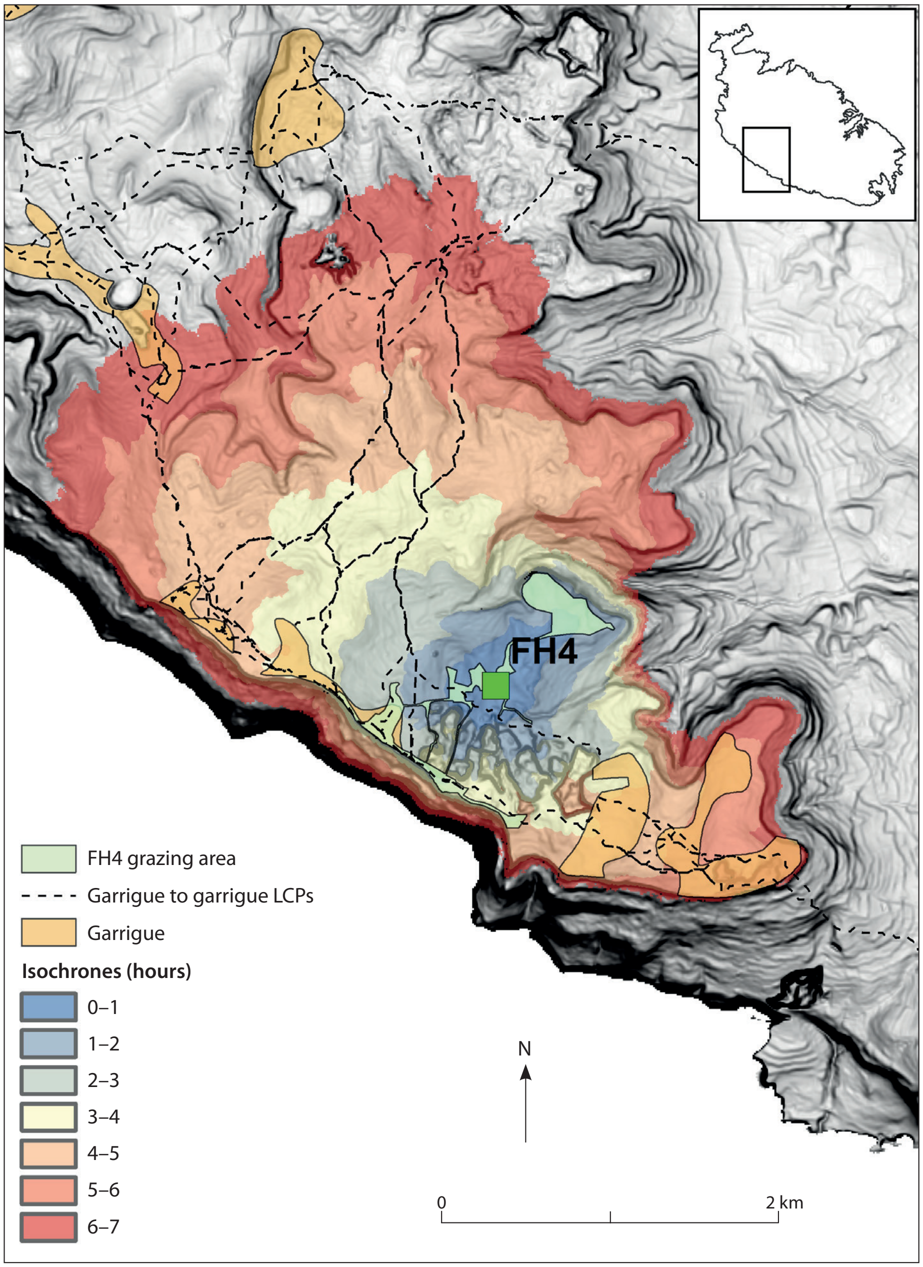

Figure 9.11. *Isochrones around farmhouse 4 representing the space that can be covered at 1-hour intervals considering animal walking speed (grazing while walking; averaging 1.5 km/h on a favourable slope) (G. Alberti).*

of the foraging excursions, which used to be done between 6:00 and 8:30 am in summer (June–October), and between 9 am and 2 pm in winter (November–May). Even though these figures feature seasonal variability, they prove consistent with the estimates deriving from our analysis. The shorter summer duration fits in lower 10 per cent of the estimated journeys, which, as seen, can be performed within 3.18 hours. The longer winter excursions fall between the 1st quartile (4.94) and the median (6.99) of the estimated durations.

The duration of the excursions reported by the informants turns out to be also consistent with the accumulated (animal) walking time surface calculated moving from the farmhouse outwards (Fig. 9.11). The grazing area immediately surrounding the farmhouse at Misraħ Għar il-Kbir lies well within the one-hour walking time buffer. The larger garrigue zones south-west of the farmhouse, lying between the Maddalena Chapel and Ta' Żuta, is reachable within four hours, while the foraging area lying to the northeast at Il-Bosk can be reached within a maximum walk of two hours. In these settings, it is possible to complete the whole journey (outbound and inbound) well within the limits of the time windows reported by the informant, especially during the most time-constrained summer excursions.

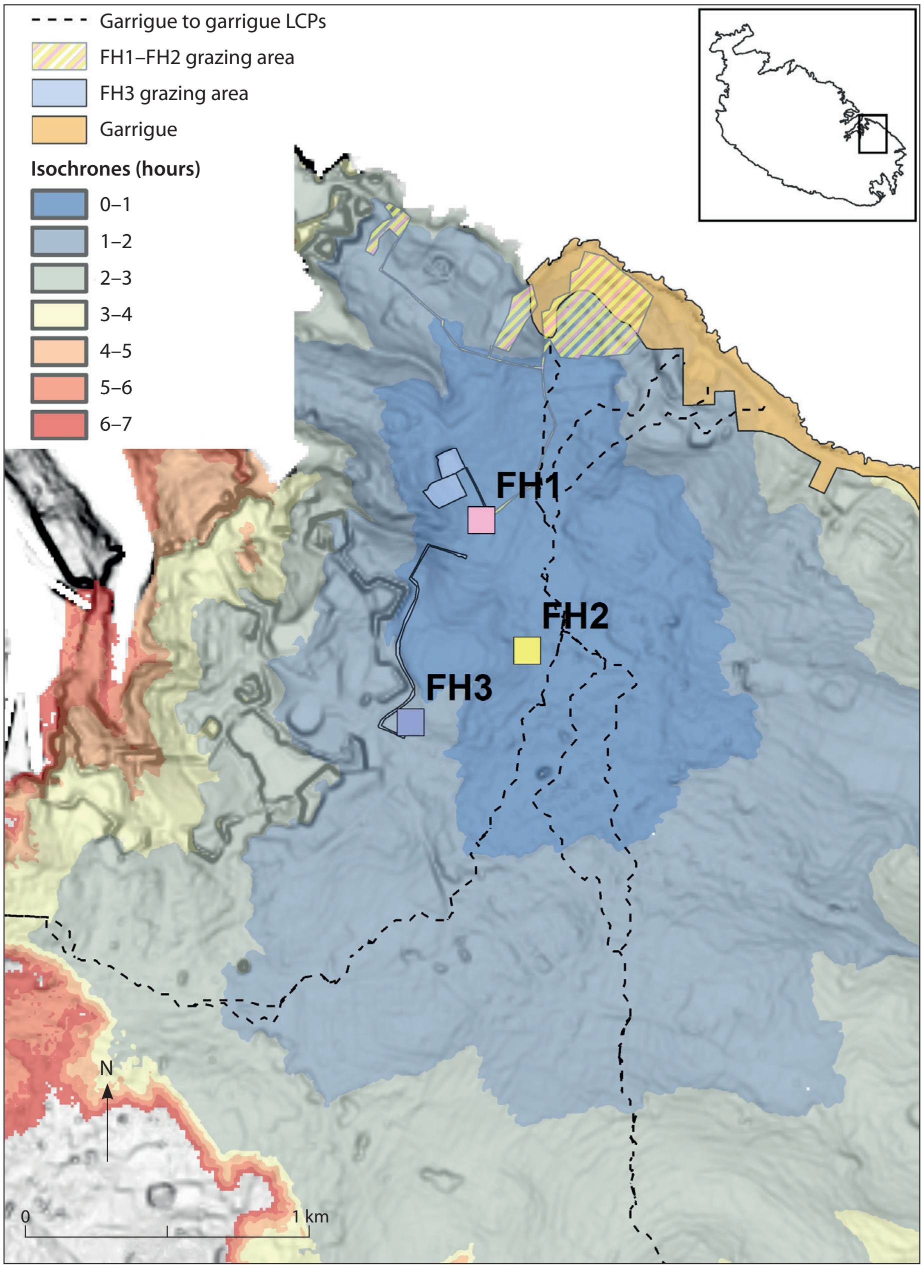

Figure 9.12. *Isochrones around farmhouse 2 representing the space that can be covered at 1-hour intervals considering animal walking speed (grazing while walking) (G. Alberti).*

A similar picture emerges from the ethnographic data relative to three farmhouses located in southeastern Malta, immediately east of Kalkara (Fig. 9.12). One person whose father was a shepherd who kept a flock of about 50 sheep/goats in farmhouse 1 at Il-Wileġ recalled how just like the shepherd from farmhouse 2 (located at the intersection of country roads near Santa Domenica) he used to take the herd to two garrigue areas lying to the north between Rinella and San Rokku, overlooking Il-Kalanka tal-Patrijiet. The farmer from farmhouse 3 (located at Tal-Fata) used to take a herd of cows to two smaller rocky areas, immediately northeast of farmhouse 1. Besides further confirming the use of garrigue areas as grazing land, and besides indicating that the choice of the grazing area is not always dictated by geographic proximity, these cases prove consistent with the GIS-based estimates. The grazing areas used by the herds kept in farmhouses 1 and 2 can be reached in a walking time between one and two hours from both locations, with just the northeasternmost fringe of the larger garrigue area lying outside the two-hour limit. The same holds true for farmhouse 3, whose grazing area lies in the middle of the two-hour walking time buffer. They prove therefore suitable, time-wise, for grazing excursions similar to those reported by the owner of the farmhouse in western Malta.

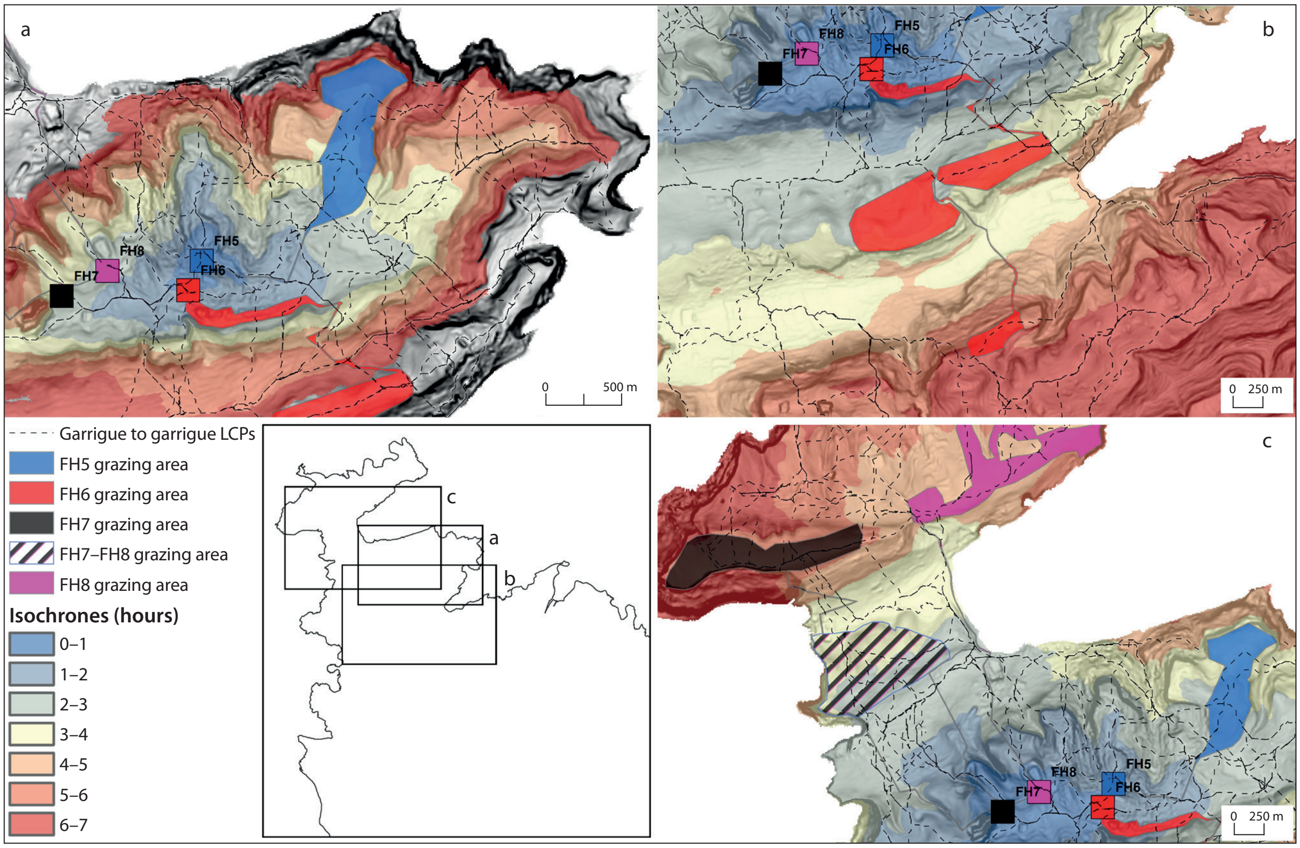

Figure 9.13. *a) Isochrones around farmhouse 5 representing the space that can be covered at 1-hour intervals considering animal walking speed (grazing while walking); b) Isochrones around farmhouse 6; unlike Figs. 9.11, 9.12, 9.13a, animal walking speed during directional travels is considered (averaging 3.6 km/h on a favourable slope); c) Isochrones (considering directional travel's speed) around farmhouse 7 (G. Alberti).*

Data derived from interviews of shepherds in northern Malta present a slightly different picture. One out of four informants (farmhouse 5) used to take flocks to a garrigue area that lies not too far (both time- and distance-wise) to the northwest (Fig. 9.13a). About half of the garrigue area can be reached within four hours, with only the northernmost sector requiring six hours to reach. Considering the animal average walking speed while grazing, the garrigue areas used by the other three informants lie at a larger time distance. Yet, if we keep in mind that both literature (Arnon *et al.* 2011; Schlecht *et al.* 2006, 2009) and ethnography indicate that shepherds may opt for faster directional long-distance travels (featuring an average speed of about 3.6 km/h) (Arnon *et al.* 2011, 140), the data regarding those three cases prove not too different from farmhouse 5 and, all in all, consistent with our GIS-based estimates. The large grazing area south of farmhouse 6 at Mellieħa (Fig. 9.13B), in the areas of Ix-Xagħra tal-Ħawlija and Ix-Xagħra tal-Għansar/Xagħra tad-Dar il-Bajda, can be reached within three and four hours of fast directional walk down walled droveways, while the smaller one further south at Il-Qala (near San Martin) can be reached within six hours, again along walled tracks. The owner of the sheep/goat fold (Maltese: ċikken) marked as farmhouse 7 reported the use of a grazing area lying to the north at Il-Biskra (Fig. 9.13c).[3] It can be reached within three and four hours along a track and a minor road, while the other one in use further north at Id-Dahar is reachable within six hours along minor roads. The shepherd from another sheep/goat fold (ċikken) marked as farmhouse 8 (Fig. 9.13c) reports the use of the grazing area at Il-Biskra common to the preceding farmhouse, which can be reached within a 4-hour walk. The same farmhouse uses another grazing area further north at L-Aħrax (Fig. 9.13c), whose southern half (namely, the one for which the evidence of its use as pasture is more certain) can be reached within five hours.

It is worth noting that the reported duration of the foraging excursions in this area turns out to be generally longer compared with the evidence from southern Malta, with a time inflation that is reasonably related to the larger distances to be covered between the farmhouses and the garrigue areas. The excursions span from about eight hours in winter (8 am to 4 pm) to about 13 hours overall during summer (4–9 am, 4–12 pm). In spite of larger distances to be covered, the very possibility to opt for a faster directional route, using a road network that is related to post-AD 1850s agricultural improvement in the area, enables the shepherds to meet the time limits imposed by the season during which the excursions take place.[4] In these settings, the estimated walking time buffers prove compatible with the reported durations. Garrigue areas reachable within three, four, five, or even six (in the most extreme case) hours of directional travel turn out to be suitable for excursions whose duration may last from a minimum of five to a maximum of eight hours. The reported durations are also compatible with the duration of the foraging excursions estimated from our sample of farmhouse locations. Foraging excursions lasting five and eight hours fall within the middle 50 per cent of the distribution of the estimated journeys, which ranges between 4.94 and 10.77 hours.

9.5. Conclusions

The present study has drawn together and presented archival, archaeological, ethnographic and oral evidence of traditional pastoral foraging routes and practices in a small Mediterranean island setting. Informed by ethnographic work elsewhere, and by earlier work on the highly variable affordances presented by the early modern landscape, least-cost path modelling and post-dictive evaluations have been developed to elucidate the spatial-temporal dynamics that dictated pastoral routes and practices in Malta. Using GIS-based weighted cost-surface analysis, the successive iterations of the argument have examined the relationship between farmsteads where herds were penned, the public open spaces where garrigue was available, and the network of droveways that connected them together, and which may trace their origins at least as far back as the late Medieval period. It has been demonstrated that their distribution and inter-relationships is consistent with strategies to optimize the exploitation, through pastoral foraging, of land that was less optimal for agriculture. The portrait that emerges is one of intensive exploitation of the landscape through a mixture of strategies, each adapted to the highly variable affordances presented by different environments. It has also been demonstrated that the relationship between these different strategies, most notably between crop cultivation and pastoralism, was very carefully managed and regulated. The network of droveways that controlled and facilitated the movement of flocks across the landscape was integral to the sustainable co-existence of these activities, and an essential component of subsistence strategies in a fragile and frugal small island environment.

Notes

1 A comprehensive diachronic study of Malta's 'public spaces' or commons has still to be undertaken. In the Late Middle Ages, public spaces often consisted of precious grazing grounds for sheep and goats, unhindered access to which was considered a right to be upheld (Wettinger 1982). In the early modern period this practice continued, as it most certainly did in the British period, but the granting of parcels of rocky ground (xagħri) for cultivation by reclamation from the late sixteenth century onwards (Blouet 1967; Chircop 1993, 30–2) must have reduced the area for rough grazing considerably and probably made the need of walled paths/tracks or droveways for safe passage of flocks from one grazing ground to another more acutely felt. The process of enclosure through the erection of rubble walls and fields connected by paths, tracks that can act as droveways recalls the situation in the limestone uplands of south-east Sicily, a process which got underway in the mid-nineteenth century (see Giorgianni 1990). The analogy warrants further study.

2 Grazing on stubble following the harvest or in fallow fields was confirmed by the informant of farmhouse 1 from Kalkara who recalled descending with his father into the terraced fields in the valley between Rinella battery and the area taken up by the industrial estate of Kalkara (now Smartcity). Informants from Qala (Gozo) confirmed the existence of the same practice. Unless the fields belonged to the shepherd, the rights to allow animals to graze was obtained from the owner, often against payment, a practice which has a deeper ancestry (see Catania 2015, 120–4).

3 A ċikken consisted of an open-air enclosure built in rubble where animals pertaining to small owners of sheep and goats were bred. The surface was rocky and slanting to ensure easy removal of animal liquid waste. Cane and reeds were used to roof certain areas of the enclosure to provide animals with shelter from the summer sun. No formal lodging quarters for the shepherd existed. The Mellieħa examples are here denoted farmhouses 5, 7 and 8.

4 The rectilinear pattern of roads and tracks is related to the project of agricultural improvement in this part of Malta undertaken in the British period and the local agricultural society in the second half of the nineteenth century (Società Economica Agraria) (see Hunt & Vella 2004/5, 63 & note 18).

Temple landscapes

The ERC-funded *FRAGSUS Project* (*Fragility and sustainability in small island environments: adaptation, cultural change and collapse in prehistory, 2013–18*), led by Caroline Malone (Queens University Belfast) has explored issues of environmental fragility and Neolithic social resilience and sustainability during the Holocene period in the Maltese Islands. This, the first volume of three, presents the palaeo-environmental story of early Maltese landscapes.

The project employed a programme of high-resolution chronological and stratigraphic investigations of the valley systems on Malta and Gozo. Buried deposits extracted through coring and geoarchaeological study yielded rich and chronologically controlled data that allow an important new understanding of environmental change in the islands. The study combined AMS radiocarbon and OSL chronologies with detailed palynological, molluscan and geoarchaeological analyses. These enable environmental reconstruction of prehistoric landscapes and the changing resources exploited by the islanders between the seventh and second millennia BC. The interdisciplinary studies combined with excavated economic and environmental materials from archaeological sites allows Temple landscapes to examine the dramatic and damaging impacts made by the first farming communities on the islands' soil and resources. The project reveals the remarkable resilience of the soil-vegetational system of the island landscapes, as well as the adaptations made by Neolithic communities to harness their productivity, in the face of climatic change and inexorable soil erosion. Neolithic people evidently understood how to maintain soil fertility and cope with the inherently unstable changing landscapes of Malta. In contrast, second millennium BC Bronze Age societies failed to adapt effectively to the long-term aridifying trend so clearly highlighted in the soil and vegetation record. This failure led to severe and irreversible erosion and very different and short-lived socio-economic systems across the Maltese islands.

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