

Cultivated mountain slopes in the north of Madeira Island, Portugal

DISSERTATION

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Summary

The age of European maritime discoveries was the beginning of intense anthropogenic influence on many formerly uninhabited islands. The establishment of a permanent resident population marked the starting point of profound alterations in the landscape. In this thesis the spatiotemporal dynamics of human-landscape interaction in the central northern parish of Ponta Delgada, Madeira Island, Portugal have been analyzed. This area has a uniquely well-adapted and highly resilient agricultural landscape, consisting of numerous interconnected bench terrace systems.

The agricultural terraces in Ponta Delgada parish have been intensively used for centuries, but remain fertile until today. Moreover, they have proven to be particularly resilient against erosive forces, a trait that gains importance with ongoing climatic changes. What structural subtleties have led to the exceptional stability of the terraces and to which degree has local adaptation been made on every single site? What was the role of traditional agriculture in maintaining soil fertility at a high level and which external resource inputs took place on the terraces? How has the spatiotemporal development of the terrace systems occurred and what were the underlying motivations in former times and more recently?

In order to answer these questions extensive geomorphological, geoarchaeological and pedological analysis of the terrace systems and terrace soil have been executed. These methods were supplemented by interviews with local farmers.

The analysis of the terraces has shown that meticulous adaptation of the structure of the dry-stone walls, the extent and shape of integrated drainage systems and the layering of the terrace filling has taken place. Along with the stability of the terraces, good soil quality was essential for successful farming. Therefore, during the construction period, soil layers covering the area of the future agricultural terrace were removed layer by layer. These were deposited alongside the terrace construction site and if necessary, even freed from stones. After preparing the basis of the dry-stone wall, the soil was filled into the future terrace body while keeping the natural sequence of the layers. The chronological sequence of terrace construction supports the idea that in the early phase of extension of terraces into the mountains, farmers did not build these close to the settlement, but rather in the areas that offered the best solar exposition in the valley and had a watercourse nearby to feed an irrigation system.

Traditional agricultural practices applied over centuries had relatively closed nutrient cycles. The sectors of animal keeping, plant production and housekeeping were closely interconnected. A strictly followed procedure of crop rotation and frequent polyculture contributed to keeping soil fertility and organic carbon levels high.

Shifting land use intensities were always a common phenomenon on the island, in most cases driven by changing demands and prices of agricultural commodities on the world market. Since the mid-20th century massive emigration took place and consequentially land use has diminished dramatically. Most of the terrace systems at higher altitudes and of more time-consuming access have fallen into disuse. Presently, the trend of land abandonment is ongoing and dating up to 2019, approximately 47 % of the terraced land has been abandoned within the research area.

Zusammenfassung

Auf vielen ehemals unbewohnten Inseln begann der starke anthropogene Einfluss im Zeitalter der europäischen Seefahrerentdeckungen. Der Beginn der Besiedlung der Inseln markierte den Ausgangspunkt für tiefgreifende Veränderungen der Landschaft. In dieser Arbeit wird die zeitlich-räumliche Dynamik der Mensch-Landschafts-Interaktionen in der zentralen nördlichen Gemeinde von Ponta Delgada auf der Insel Madeira, Portugal, analysiert. Dieses Gebiet verfügt über eine einzigartig gut angepasste und äußerst widerstandsfähige Agrarlandschaft, die aus zahlreichen miteinander verbundenen Ackerterrassen-Systemen besteht.

Die Terrassen in der Gemeinde Ponta Delgada werden seit Jahrhunderten intensiv landwirtschaftlich genutzt. Sie sind dennoch bis heute fruchtbar geblieben. Außerdem haben sie sich als besonders erosionsresistent erwiesen, eine Eigenschaft, die mit den anhaltenden klimatischen Veränderungen an Bedeutung gewinnt. Welche strukturellen Feinheiten haben zu dieser außergewöhnlichen Stabilität der Terrassen geführt und wie wurden die Terrassen an die Spezifik der Standorte angepasst? Welche Rolle spielte die traditionelle Landwirtschaft bei der Aufrechterhaltung der sehr guten Bodenfruchtbarkeit und welcher Ressourceninput fand von außerhalb der Terrassen statt? Wie hat sich die räumlich-zeitliche Entwicklung der Terrassensysteme vollzogen und was waren die zugrundeliegenden Motivationen für Veränderungen in der Vergangenheit und aktuell?

Um diese Fragen zu beantworten, wurden umfangreiche geomorphologische, geoarchäologische und pedologische Analysen der Terrassensysteme und der Terrassenböden durchgeführt. Diese Methoden wurden durch Interviews mit lokalen Landwirten unterstützt. Die Analyse des Terrassenaufbaus zeigt, dass eine sorgfältige Standortanpassung der Struktur der Trockenmauern, der Ausdehnung und Form der integrierten Entwässerungssysteme und der Schichten der Terrassenauffüllung stattgefunden hat. Neben der Stabilität der Terrassen war eine gute Bodenqualität für eine erfolgreiche Bewirtschaftung grundlegend. Deshalb wurden in der Bauzeit die natürlichen Bodenhorizonte, die die Fläche der zukünftigen landwirtschaftlichen Terrasse bedecken sollten, Horizont für Horizont abgetragen. Das Substrat wurde seitlich der Terrassenkonstruktion abgelagert und ggf. von Steinen befreit. Nach der Vorbereitung der Basis der Trockenmauer und, wenn nötig, des Drainagesystems, wurde das Substrat unter Einhaltung der natürlichen Horizontfolge in den zukünftigen Terrassenkörper verfüllt. Die zeitliche Abfolge des Terrassenbaus macht deutlich, dass in der frühen Bauphase in den Bergen die Terrassen nicht in der Nähe der Siedlung erbaut wurden, sondern an Standorten mit der besten Sonnenexposition im Tal und einem Wasserlauf in der Nähe, der ein Bewässerungssystem speisen konnte.

Traditionelle, über Jahrhunderte angewandte landwirtschaftliche Praktiken ermöglichten nahezu geschlossene Nährstoffkreisläufe. Die Bereiche Tierhaltung, Pflanzenproduktion und Hauswirtschaft waren gut miteinander verknüpft. Eine strikt eingehaltene Fruchtfolge und Polykulturen trugen dazu bei, die Bodenfruchtbarkeit und den Gehalt an organischem Kohlenstoff im Boden zu halten.

Wechselnde Landnutzungsintensitäten waren seit jeher ein häufiges Phänomen auf der Insel, in den meisten Fällen angetrieben durch die sich ändernde Nachfrage und Preislage für landwirtschaftliche Rohstoffe auf dem Weltmarkt. Seit Mitte des 20. Jahrhunderts fand eine massive Abwanderung der Bevölkerung statt. Infolgedessen hat sich die Landnutzungsintensität dramatisch verringert. Die meisten Terrassensysteme in höheren Lagen und mit aufwändigerem Zugang sind aus der Nutzung gefallen. Bis 2019 waren es bereits etwa 47 % der Terrassenflächen im Untersuchungsgebiet. Der Trend der Nutzungsaufgabe setzt sich weiter fort.

Resumo

Em muitas ilhas anteriormente desabitadas, a forte influência antropogénica começou na era dos descobrimentos. O início da colonização das ilhas marcou o ponto de partida para mudanças profundas na paisagem. Neste trabalho, foi analisada a dinâmica temporal-espacial da interacção homem-paisagem no município de Ponta Delgada localizada no centro-norte da Ilha da Madeira, Portugal. Esta área tem uma paisagem agrícola única, bem adaptada e altamente resiliente, constituída por numerosos sistemas de socalcos aráveis interligados.

Os socalcos no município de Ponta Delgada foram intensamente utilizados durante séculos, mas têm permanecido férteis até aos nossos dias. Também demonstraram ser particularmente resistentes às forças erosivas, uma característica que se está a tornar mais importante com as mudanças climáticas em curso. Que subtilezas estruturais levaram a estabilidade excepcional destes socalcos e em que medida é que cada socalco individual foi adaptado à sua localização específica? Que papel desempenhou a agricultura tradicional na manutenção da muito boa fertilidade do solo e que recursos externos foram introduzidos na zona arável? Como se processou o desenvolvimento espaço-temporal dos sistemas de socalco e quais foram as motivações subjacentes às mudanças no passado e no presente?

Para responder a estas questões, foram realizadas extensas análises geomorfológicas, geoarqueológicas e pedológicas dos socalcos e do solo das mesmas. Estes métodos foram apoiados por entrevistas com agricultores locais. A análise da estrutura dos socalcos mostrou que tinha havido uma cuidadosa adaptação local em termos da estrutura das paredes de pedra seca, da extensão e forma dos sistemas integrados de drenagem e das camadas de enchimento do socalco. Para além da estabilidade dos socalcos, a boa qualidade do solo era fundamental para o cultivo bem sucedido. Por conseguinte, durante a construção, as camadas de solo que cobriam a área do futuro socalco eram removidas camada por camada. Estas foram depositadas ao lado da construção e até mesmo limpas de pedras, se necessário. Após a preparação da base do muro de pedra seca e se necessário, do sistema de drenagem, o solo foi reenchido na futura estrutura do socalco, respeitando a sequência natural de camadas. A sequência cronológica da construção de socalcos torna claro que na fase inicial da sua construção nas montanhas, os socalcos não foram necessariamente construídos perto do povoado, mas nas áreas que ofereciam a melhor exposição solar no vale e tinham um curso de água nas proximidades que podia alimentar um sistema de irrigação.

As práticas agrícolas tradicionais utilizadas durante séculos tiveram ciclos de nutrientes relativamente fechados. A criação de animais, a produção de culturas e a economia doméstica estavam bem ligadas. A rotação de culturas e as policulturas rigorosamente seguidas ajudaram a manter a fertilidade e o teor de carbono orgânico do solo.

A alteração das intensidades de uso da terra sempre foi um fenómeno comum na ilha. Na maioria dos casos era motivado pela alteração da procura e da situação dos preços de produtos agrícolas no mercado mundial. Desde meados do século XX, tem havido uma migração maciça da população, e por conseguinte, a intensidade do uso da terra diminuiu drasticamente. A maioria dos socalcos em altitudes mais elevadas e de acesso mais elaborado, caíram em desuso. Em 2019, cerca de 47 % das áreas de cultivo na zona de estudo já tinham sido abandonadas, e actualmente a tendência de abandono de terras continua.

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1 Motivation

Why of all places study human-landscape interaction on Madeira island?

In the period 2002 to 2003, I have taken a yearlong professional course in ecotourism and mountain guiding at the Hotel and Tourism School of Madeira. During this time, I learned about many aspects regarding the islands' history, fauna, flora, geography, hydrology and gained practical experience in mountain guiding. Regular excursions into the various types of landscapes of Madeira were part of the course. The outstanding agricultural landscape with innumerable terrace systems reaching from sea level high into the mountains, always interwoven with water channels for irrigation, was fascinating but, I took them for granted. Only years later, during my studies of environmental science in agricultural landscapes did I realized how unique and sustainable Madeiran agricultural landscapes are.

This triggered curiosity to know more about this singular agricultural landscape and the people having created it. Literature research on the topic resulted only in sparse information. Previous research had focused on the situation of agriculture at the time and on past economic cycles of agricultural products. Authors like Orlando Ribeiro (1985) in his book "A segunda metade do sec. XX na Madeira", Perreira (1989) in his famous book "Ilhas de Zarco", Leça (2011) in his publication "Agricultando" and Ribeiro (1997, 2005) in his publication series "Subsídios para a História do Concelho" have researched the agricultural production on the island. This included research on types of crops and varieties cultivated, on amounts produced and sold, on crop distribution over varying altitudes and solar exposition, on the general market situation and on changes in production over time. Other scholars have investigated the historical outlook of the island based on historical reports from seafarers and explorers. They concluded that upon discovery, the island was almost entirely covered with dense laurisilva woodland.

Recent publications regarding the islands history do mention the outstanding agricultural terrace systems and the effort necessary to build them. Travel reports of visitors to the island describe the extraordinary agricultural terrace land and marvel at the beauty of the landscape, like T. Edward Bowdich (1825) in "Excursions in Madeira and Porto Santo during the autumn of 1823" or Paulo Perestrelo da Camara (1841) in "Breve Notícia sobre a Ilha da Madeira". Portuguese poets like Fernandes and Gouveia included the cultural landscape in their literary works, underlining the importance and the cultural value of the traditional Madeiran landscape.

Nevertheless, a detailed scientific investigation of this remarkable system of interwoven agricultural terraces, footpaths and staircases combined with dense systems of irrigation channels has never been done before. This apparent lack of knowledge on the history of this cultural landscape, its formation, its spatial dynamics over time and the intervention of the local inhabitants having transformed the landscape into its present state, gave origin to this research project.

To unravel landscape history, proxies need to be found that guard information on past and recent processes of change in the landscape. Landscapes are highly complex mosaics of a variety of elements. Each one of them containing its very own piece of history. Thus, reading landscapes and their dynamics requires a multi-proxy approach in order to capture all available information, which has been preserved within various landscape elements. In this project the spatio-temporal dynamics of the landscape, the local best farming practices and land use traditions have been addressed using two different approaches. One is a detailed approach of the most prominent landscape element: the agricultural terraces. A number of terraces within a set of terrace systems have been analyzed. This includes a study of the terrace structure with the filling body, the soil characteristics of the different layers and the dry-stone wall supporting the terrace. The second approach is of more general character, addressing wider spaces of the cultural landscape, including methods like vegetation analysis, spatial analysis of land use, studies of local micro-toponymy, interviews with farmers and a survey of artefacts indicating former use of the landscape such as dry-stone walls and steel cables for the transportation of goods. Land use changes have been accessed by interviews held amongst the local farming community, decision makers and historians. Very recent changes could be accessed by comparing aerial photos from 2010 to the present state in the landscape, which in turn was accessed by numerous reconnaissance walks, often in the company of local farmers and mountaineers.

This multidisciplinary and detailed assessment of landscape elements of both natural and anthropogenic origin provides detailed information on landscape dynamics and the mutual adaptation of human inhabitants and their surrounding landscape. It answers questions on the shifting degree and the spatial dimension of interaction between the local population and the surrounding landscape over time. Furthermore, it is the aim of the project to contribute to the preservation of traditional knowledge on the local agricultural terrace systems. Sadly,

the century long practice of passing theoretical and practical skills from one generation to the next is currently in great decline.

2 Geographical Outline

2.1 Location

The Portuguese Island of Madeira is situated in the Eastern subtropical area of the North Atlantic Ocean between 32°38` and 32°52`N and 16°39`and 17°16`W and is part of the Madeira Region, which is composed by four Island groups.

The three northern island groups are named Madeira Archipelago and include the main island Madeira (739 km²) and its islets (Ilhéu da Cevada, Ilhéu do Farol, Ilhéu do Guincho, Ilhéu da Rocha do Navio, Ilhéu da Rocha das Vinhas, Ilhéu das Ceroulas, Ilhéu Mole), the neighbouring island Porto Santo (42 km²) and its offshore islets (Ilhéu da Cal, Ilhéu de Ferro, Ilhéu da Fonte da Areia, Ilhéu de Fora, Ilhéu das Cenouras and Ilhéu de Cima) and the sub-archipelago of the Desertas Islands (12,6 km²) composed by Deserta Grande, Ilhéu Chão and Búgio. The fourth group of islands belonging to the Madeira Region is the small and rocky southern island group of Selvagens. These are located approximately 290 km further south and consist of Selvagem Grande, Selvagem Pequena and Ilhéu de Fora, amounting to a total surface area of 3,6 km² (Boieiro, Aguiar, & Rego, 2015).

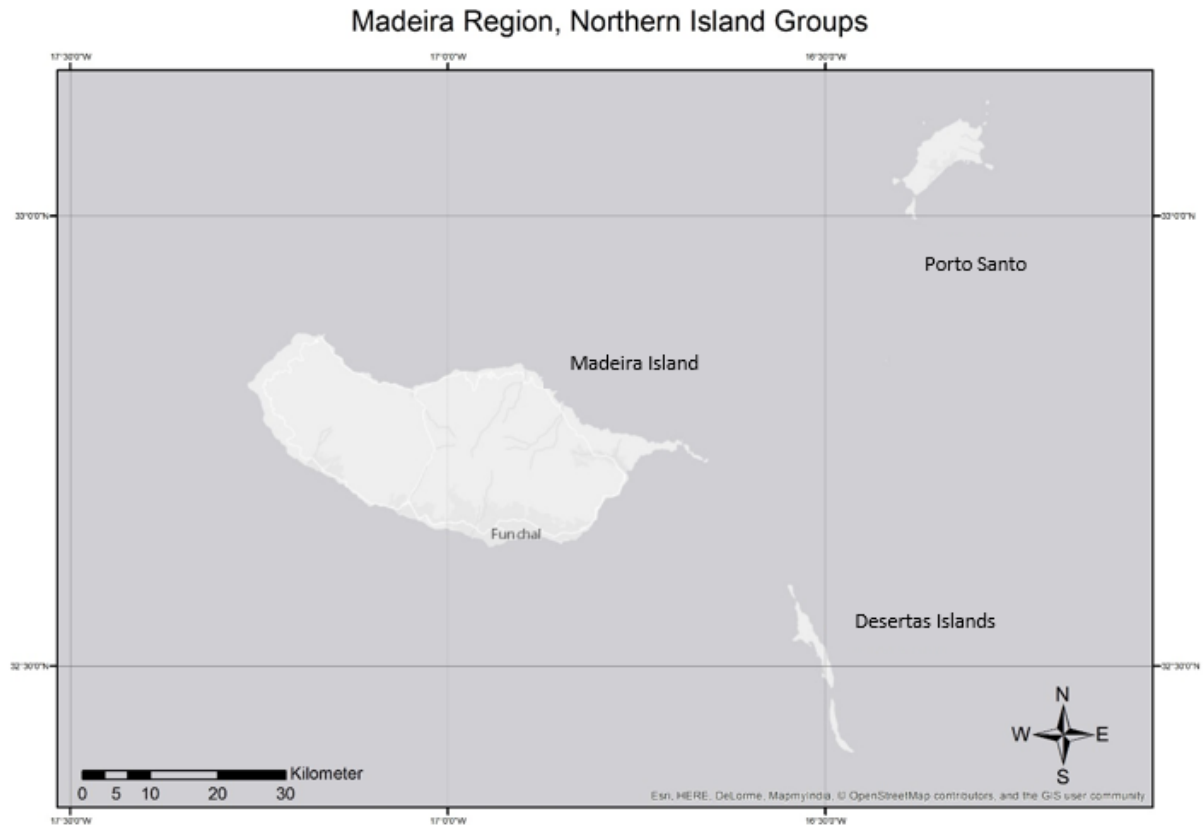


Figure 1: Localization of Madeira Island groups

The island's position is relatively isolated in the Atlantic Ocean; the nearest continental coast is the Moroccan coast near the seaside town of Essaouira, some 550 km to the east-southeast. The Portuguese mainland is located approximately 1000 km to the northeast and the capital city of Lisbon lies approximately 1300 km distant.

The Madeira archipelago is a typical example of an oceanic island group of volcanic origin, with a relatively small subaerial part based on a much larger volcanic edifice. According to Ribeiro (1985) the volcanic edifice of Madeira Island rises approximately 5000 m from the ocean floor, but just the upper 1862 m are subaerial, amounting to only 4,2 % of the total volcanic edifice. Nevertheless, very steep slopes characterize this volcanic edifice both above and below sea level. The part that emerged beyond sea level has many near vertical sea cliffs, both on the northern and the southern coast reaching, in case of Cabo Girão¹, an altitude of 580 vertical meters. The high mountain area of Madeira Island presents deep, ravine-like valleys and gorges. Extremely steep rock walls rise up to the highest peaks in the eastern section of the Island. Approximately 35 % of the surface area is situated above 1000 m a.s.l.

¹ Famous sea cliff west of the metropolitan area of Funchal

and approximately 90 % is located above 500 m a.s.l. (Mata et al., 2013; O. Ribeiro, 1985). Below sea level huge abyssms can be observed: between Madeira and Porto Santo, located only 43 km northeast of Madeira, an underwater gorge reaching approximately 2500 m of depth separates the islands (Mata et al., 2013). Within distances of 25 to 35 km from Madeira’s shoreline water depth is around 3000 m. At the outermost sections of the volcanic edifice, the ocean floor lies approximately 5000 m below sea level, within the great fraction zone known as Mid-Atlantic-Rift. The islands of the Madeira Archipelago are located on the submerged part of the African plate approximately 600 km east of the Abyssal Plain of Madeira (Mata et al., 2013; Ramalho & Ribeiro, 2010).

2.2 Morphology of Madeira Island

The Island of Madeira has an elongated shape formed by a central mountain range extending from East to West. The maximal length from Pico do Furado (Ponta de São Lourenço) in the east to Ponta do Pargo in the west measures 57 km (purple line) and the widest part of the island is located between Ponta da Cruz (Funchal) in the south and Ponta de São Jorge in the north with 23 km distance (red line).



Figure 2: North-south axis and longitudinal extension

The island is clearly structured by a central mountain range dividing it into a southern and a northern part (blue line), which present distinct conditions as regards to climate, orography,

soils, vegetation and land use including settlement area and infrastructure. According to Orlando Ribeiro (1985) Madeira can be divided into three main areas (cf. figure 3):

a) The easternmost part with its slightly ascending slopes and numerous small flattish areas at various altitude levels.

b) The rugged central mountain massif with its deeply carved valleys and vertically ascending rock walls. The highest point of the island, Pico Ruivo (1862 m a.s.l.) is part of this central mountain massif. Located approximately 32 km west of Pico do Furado lies the narrowest and lowest section of the central mountain range, the Encumeada pass (1007 m a.s.l.). At Encumeada two important rivers (Ribeira de São Vicente and Ribeira Brava) have their headwaters that carved deep valleys into the northern and southern slopes. The wide valley of São Vicente extends 6.6 km to the sea and in a southerly direction the Ribeira Brava river formed the 10.5 km long Ribeira Brava valley. These valleys form a north-south axis, separating the eastern part of the island from the west.

c) The western part of the island is characterized by the high plateau of Paúl da Serra, slightly inclining to the northwest. Towards the north, this plateau falls away sharply to the coastline. The southern slopes are gently descending seawards, where they fall as vertical cliffs on the final 200 to 300 m.

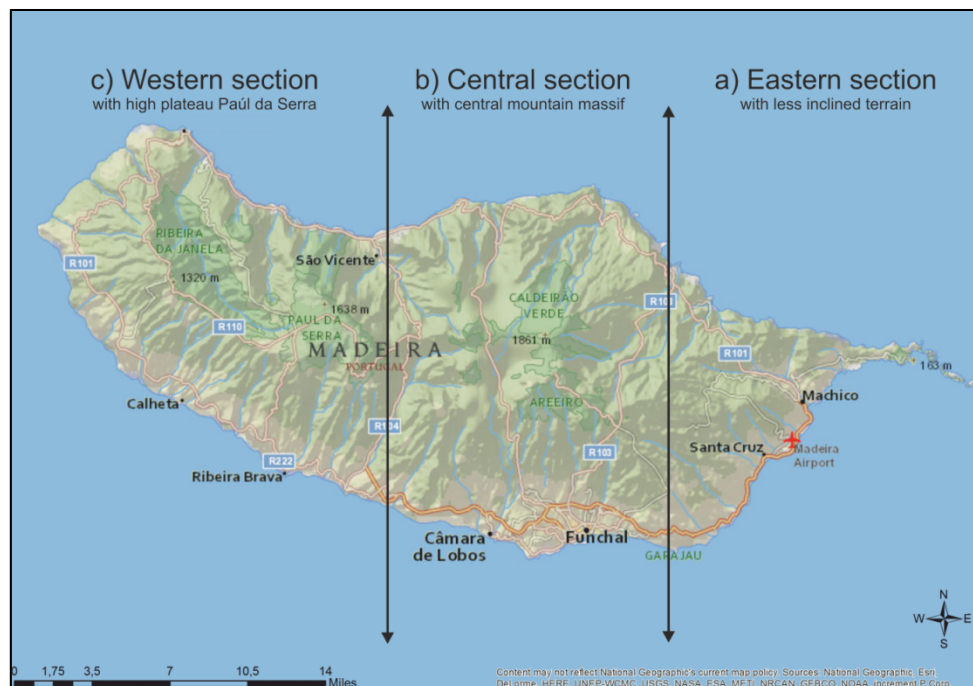


Figure 3: Spatial division into sections of similar morphological character

The eastern section of the island is characterized by gently ascending slopes from sea level to approximately 1000 m a.s.l. While the southeastern part, between Garajau and Machico, presents only a few sea cliffs of small extension, the northeastern part is marked by a continuous line of sea cliffs of considerable height, reaching 738 m a.s.l. at Pico da Coroa and many other points along the clifftops with nearly 600 m a.s.l. This line of sea cliffs is interrupted only at two locations: Faial and Porto da Cruz. In general terms the northern part of the eastern section has less smooth terrain and more steeply ascending slopes, the roughness of the terrain increases with greater proximity to the central mountains. Nevertheless, this section of the island has been intensely used and modified by agricultural activities. The easternmost part of the island, the peninsula of São Lourenço is the lowest and driest area on Madeira. Furthermore it is the only place on the island where dunes have formed, the sand supposedly originating from the Würmian cold period, when the sea level was more than one hundred meters below its present day level (M. L. Ribeiro & Ramalho, 2007).

The central section of the island is dominated by considerably high and very rugged mountains of volcanic origin, including the highest peak of the island: Pico Ruivo de Santana² with an altitude of 1862 m a.s.l. This central mountain massif marked by a continuous ridge of mountains clearly divides the area into a northern part, with the town of Santana and a southern part with the capital city of Funchal and Câmara de Lobos. The central mountain massif is linking most of the highest peaks. It extends from Encumeada to Pico Ruivo; passing the peaks of Pico do Jorge (1691 m a.s.l.), Pico Casado (1725 m a.s.l.) and Pico Coelho (1790 m a.s.l.). From Pico Ruivo the range extends towards the southeast, passing the second highest peak, Pico das Torres (1851 m a.s.l.), Pico do Gato (1712 m a.s.l.) and Pico do Cidrão (1798 m a.s.l.), it links to the third highest mountain: Pico do Arieiro (1818 m a.s.l.). The peaks of this central mountain area have very steep rock walls and abrupt, often dissected valleys of several hundred meters of depth. The vertical distance from Pico Ruivo to the bottom of the Curral das Freiras valley to the settlement of Fajã dos Cardos is approximately 1000 m within only 600 m of horizontal distance.

² The correct name of this peak is Pico Ruivo de Santana, but most authors refer to it only with the abbreviated name of Pico Ruivo.



Figure 4: Central mountains with Pico das Torres and Pico Cidrão

These vigorously shaped mountains have evolved due to very peculiar lithologies of the volcanic material. There are strong differences in weathering intensity and erosion resistance between the various rock types. Two groups of rocks are predominant: pyroclastic and effusive. The pyroclastic materials such as tuffs, ashes, breccias are very heterogeneous and not particularly resistant to erosive forces, while the effusive rocks, like basalt, are very hard and resist over much longer periods of time. As a result, exposed basaltic dykes are a common feature in the central mountains. The pyroclastic material that once surrounded them, has been removed by the weathering agents and the basaltic material has remained in the shape of thin vertical walls. Many of them have altitudes of several dozen meters and only a few meters of width, giving origin to an even more remarkable roughness of the terrain. Pico das Torres area, as the name indicates (mountain of towers), is famous for its numerous basaltic dykes.



Figure 5: Basaltic dykes at Pico das Torres, Vivaldo Nunes 2017

In Ribeiro & Ramalho (2007) the dense network of basaltic dykes has been described as the “inner skeleton” of the central massif, since its low erodibility protects the pyroclastic materials and thus effectively reduces their erosion.

From the high mountain area in the central massif, the slopes extend on both the northern and southern side with only a few flattish interruptions down towards the coast. The slopes are deeply cut by a number of valleys, mostly oriented in north-south direction, with varying extensions in length, width, depth in relation to the nearby ridgelines, and water carrying capacity. The lateral sizes range from a few meters between the rock walls (Ribeira da Metade, Ribeira de São Jorge) to widths of almost one kilometer like Ribeira dos Socorridos and Ribeira de Machico.

The western section of the island is dominated by the high plateau of Paúl da Serra forming its center. With a size of 25 km² and an extension of 17 km x 6 km, it is the largest flat area on the island. The average altitude is approximately 1400 m a.s.l. with its highest point at Pico Ruivo do Paúl (1640 m a.s.l.) in the northeastern part. From there the plateau has a gentle declination in a northwesterly direction with the lower areas being Fanal (1100 m a.s.l.) and Alto da Ponta do Pargo (998 m a.s.l.).

The types of rock material having formed Paúl da Serra high plateau are dominated by pyroclastic materials. These are renowned for a high water permeability and thus turn the

western plateau into the most important area for groundwater recharge on Madeira Island (Mata et al., 2013; Prada, n.d.). This is not only due to very limited terrain inclination and respectively low surface runoff, but also due to a high annual precipitation averaging ca. 2700 mm. In addition, there is an equally high amount of interception. On the northeastern facing slopes of Paúl da Serra, in the area of Bica da Cana, Prada et al. (2000) have measured annual amounts of interception of 2771 mm. Accordingly it can be stated that the heather forest at these altitudes is an important contribution to groundwater recharge on the island.

To the east and the north of the Paúl da Serra, steep to vertical descents characterize the landscape. The southern and western facing slopes have a gentler gradient.

In the north, the origin of many narrow gorges like Ribeira do Inferno and Ribeira da Hortelã and some trenched valleys like Ribeira de João Delgado and Ribeira Funda can be found. Most of these streams have a length of less than 10 km and often the headwaters of streams flowing southwards and the headwaters of streams flowing northwards are in very close proximity, sometimes only 200 m distant from one another. The plateau itself is deeply cut by the longest stream of the Island, the Ribeira da Janela with approximately 22 km of extension. This stream has an east to northwest orientation and drains into the Atlantic Ocean between the settlements of Porto Moniz and Ribeira da Janela. Along the southern side of the Paúl da Serra numerous small valleys have formed, often ending as a vertical cliff, like Ribeira dos Câmbios, Ribeira dos Marinheiros and Ribeira Seca ou do Paúl.



Figure 6: Vertical drop of Ribeira dos Câmbios, approximately 400 m down the cliffline onto the beach

The biggest valley south of the Paúl da Serra is Ribeira da Ponta do Sol, starting at an elevation of 1400 m a.s.l. at the so-called Cascalho, a vertical, amphitheater shaped drop-off of basaltic rock. A huge waterfall exists here, which is augmented by water from springs in the lower parts of this rock wall and numerous other springs in the vicinity of Cascalho amphitheater.

2.3 Climate

The climate of Madeira Island is strongly influenced by (a) its geographical position defining general climatic characteristics and (b) by its distinct mountainous morphology giving origin to local climatic effects. Madeira Island is located in the subtropical zone of the northern hemisphere and accordingly its climate is influenced by a number of factors such as the Azorean Subtropical Anticyclone, protecting the island from the depressions of the North Atlantic, the continental anticyclone centers of North Africa and the northeasterly trade winds. In general terms the climate can be described as Mediterranean, with a relatively long dry period during the summer months of June, July and August (Ferreira Sepúlveda, 2011; Quintal, 1999). Nevertheless, the seasonally caused oscillations of typically Mediterranean climatic conditions are heavily moderated by the oceanic position of the island, being strongly influenced by the Gulf Stream and by the cool Canary Current. The resulting moderate climate with very little seasonal variation has been intensively studied. Already in 1889, Mourão Pita (in: Perreira, 1989) described the mean annual temperature in Funchal to be of 19.8° C. The

mean temperature in Funchal in the winter (December to February) is given with 17.9° C and for the summer months (June to August) 22° C were recorded. The obtained mean annual variation of merely 4.1° C between summer and winter that has been obtained with the limited technical possibilities at the time is fairly accurate, when comparing it with recent data. In the period of 1961 to 1990 the average annual temperature for Funchal weather station (located at 58 m a.s.l.) has been 18.7° C. In the winter period, the average temperature was 16.3° C and in the summer period 20.9° C, resulting in a variation of 4.6° C between mean summer and mean winter temperature (Instituto de Meteorologia, 2005).

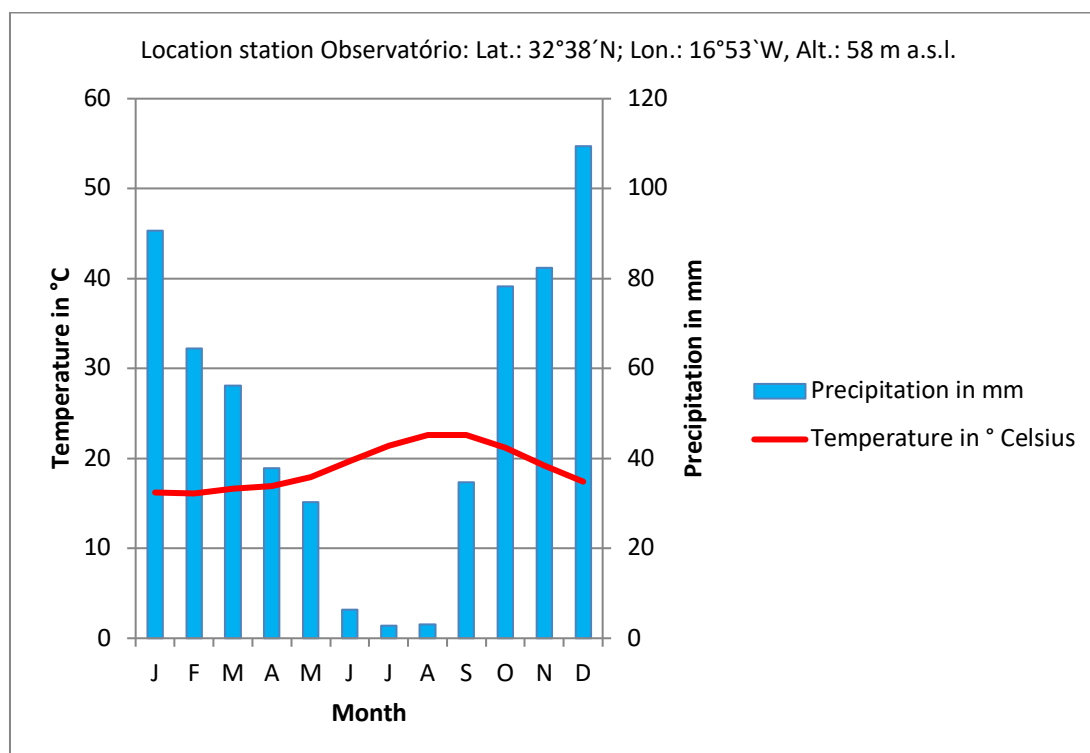


Figure 7: Climate normal (1971-2000), Funchal meteorological station Observatório, data from IPMA 2017

Contrary to this comparatively small variation between the seasons, there are pronounced differences between the south side and north side of the island and in relation to altitude. The north side of the island is colder, windier and more humid than the south side. Aside from the simple fact of having less solar exposition an important factor determining the climate in the north of Madeira Island are the predominant northeast trade winds. The air masses moving towards the island are often cool and rich in humidity. As they hit the natural obstacle of Madeiras' central mountain range they are forced to rise along the slopes. In the process, the air cools down further and has a lower capacity to hold water. This often leads to cloud formation in the afternoon and frequently to orographic precipitation.



Figure 8: Characteristic cloud formation over the northern slopes in late afternoon, photo taken at approximately 900 m a.s.l.

The northern meteorological station at Ponta Delgada (136 m a.s.l.) recorded a mean annual temperature of 17.9° C in the period from 1961 to 1990, being 0.8° C cooler than Funchal. More remarkable is the difference in precipitation between these two stations. In Funchal the average value between 1961 and 1990 is 641.2 mm annual, at Ponta Delgada the average annual value is approximately twice as high: it is recorded with 1136.1 mm. The huge difference between precipitation regimes becomes even more pronounced at higher altitude. The highest meteorological station of the island at Chão do Arieiro (1610 m a.s.l.) recorded a mean annual precipitation of 2928.6 mm in the period of 1961 to 1990. The temperature at this elevated place is comparatively low with a mean annual value of 9.1° C. In general terms the climate of Funchal, being representative for a seaside settlement on the south side of Madeira, can be described as temperate, oceanic, dry and moderately rainy³. The climatic situation at Ponta Delgada, being representative for a seaside settlement on the north side of

³ Temperate (mean annual temperature between 10° C and 20° C), oceanic (difference between the mean monthly temperature of the hottest and the coldest month is less than 10° C), dry (mean annual air humidity value between 55-75 %), moderately rainy (mean annual precipitation between 500 and 1000 mm)

Madeira, would be described as temperate, oceanic, humid and rainy⁴. On the Arieiro station, being representative for the central mountain area, the general climate resulting from the annual mean values, would be described as cold, oceanic, humid and excessively rainy⁵. These three described meteorological stations are located closely to each other, from Funchal to the Arieiro station the distance measures 8.2 km heading further on to Ponta Delgada the distance measures another 13.5 km. These short distances show how strong local factors affect the islands general climate and the numerous microclimates. Within 8.2 km of distance a temperate, dry and moderately rainy climate is recorded and a second station is identified as cold, humid and excessively rainy. This illustrates quite well how strongly expressed microclimates are on Madeira Island.

Aside from these northeast trade winds, strongly affecting the local precipitation regime, there is another very influential wind: the so-called “Leste”. It blows from an east-southeasterly direction and is a hot and dry wind originating in the southern Sahara region. This wind brings a sudden rise in temperature and often transports small particles of yellowish dust from the Sahara, which it deposits literally all over the island. In 1956 the temperature in Funchal rose within a few hours to 38° C, a value never reached without “Leste” wind conditions (Pereira, 1989).

Another prominent weather phenomenon within the Madeira region is the occurrence of heavy rain sometimes causing dangerous flash flood events (Baioni, 2011; Couto, Salgado, & Costa, 2012; Fragoso et al., 2012; Pereira, 1989; Quintal, 1999; Ribeiro, 1985).

The average annual amounts of rainfall in the southern coastal areas, like Funchal (641.2 mm)⁶, Lugar de Baixo (572.3 mm)⁷ or Ponta do Pargo (769.0 mm⁸) are comparable with the amounts of average annual precipitation recorded in Lisbon (725.8 mm)⁹, but the distribution of rainfall over the year is much more concentrated in the Madeira region. The months of October and November are often characterized by very concentrated rainfall. From the beginning of the 19th century until 1999 a total of 30 flash floods, locally designated as *aluviões*, have been mentioned by Quintal (1999), out of which 13 took place in October and

⁴ Humid (mean annual air humidity is between 75 and 90 %), rainy is defined as mean annual precipitation between 1000 to 2000 mm

⁵ Cold (mean annual temperature between 0 and 10°C), excessively rainy (mean annual precipitation between 1000 and 2000 mm)

⁶ Data from Instituto de Meteorologia de Portugal

⁷ Data from Ribeiro, O.; 1985

⁸ Data from Ribeiro, O.; 1985

⁹ Data from IPMA (Instituto Português do Mar e da Atmosfera), climate normals 1971-2000

November. The most severe flash flood was recorded in 1803, on 9 October. The municipalities of Machico and Funchal were most affected and approximately 1000 people perished (Quintal, 1999; Vieira, 2003). Shortly thereafter, on 24 October 1842 another flash-flood event was registered, where the northern municipalities were more severely affected, besides the material losses such as devastated settlements, cropland and infrastructure, approximately 400 humans lost their lives (Câmara Municipal de Machico, 2003). More recently on 29 October 1993 the capital city of Funchal was struck by a disastrous flash-flood, resulting in 9 fatalities and approximately 400 displaced inhabitants (Quintal, 1999).

Another month that for several times in history is linked to flash floods on Madeira is February. The last severe flash flood, which caused 43 confirmed deaths, 8 missing persons presumed to be dead, 250 casualties and almost 600 displaced inhabitants, devastated the city of Funchal and neighboring municipalities on 20 February 2010. On this day at the Arieiro meteorological station, located at 1610 m a.s.l. and about 1 km from the periphery of the city of Funchal, 387.1 mm of rainfall have been recorded within 24 h (Couto et al., 2012; Fragoso et al., 2012). This station is situated close to the headwaters of Ribeira de João Gomes and Ribeira de Santa Luzia, two streams emptying into the Atlantic Ocean in the bay of Funchal.



Figure 9: Ribeira de João Gomes having flooded Rua da Ribeira de João Gomes from: “Aluvião na ilha da Madeira em 2010” (https://pt.wikipedia.org/wiki/Aluvi%C3%A3o_na_ilha_da_Madeira_em_2010) by Alexander Gehret is licenced under CC BY 2.0 (<https://creativecommons.org/licenses/by/2.0/>)

This was certainly an extreme event, but daily precipitation values between 60 to 100 mm are not uncommon within the winter period (IPMA, 2016). The steep mountainous character of the islands' surface provides very little water retention in the landscape and nearly no infiltration into the soil, resulting in short runoff and lag times and high peak discharge values.

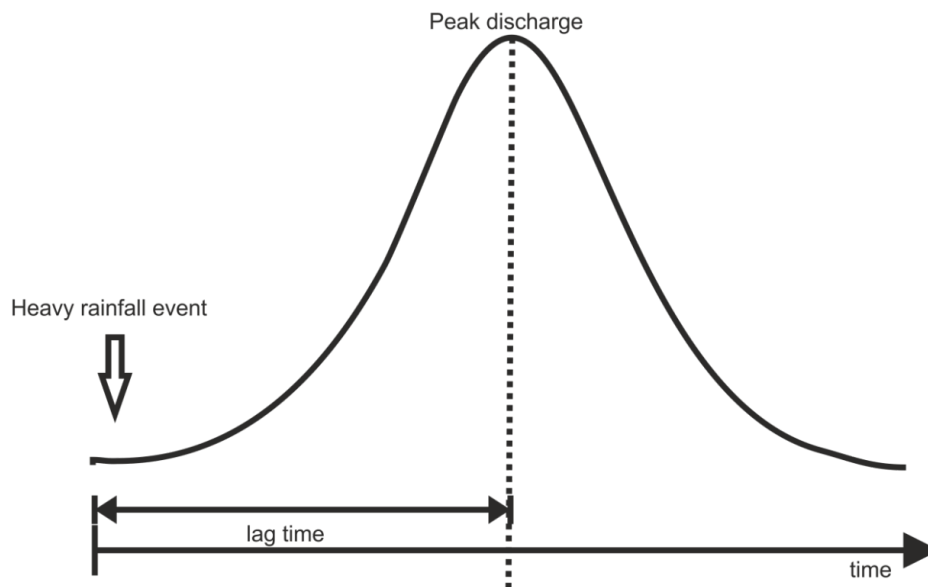


Figure 10: Typical discharge situation in a steep mountain environment, adapted from Quintal, 2005

The typical discharge situation in Madeiran streams is displayed in the figure above. After the onset of heavy rain there is only a short time period before water levels in the waterlines begin rising rapidly. The steeply rising curve shows that peak discharge is reached relatively quickly reached and does not leave much room for flood disaster prevention measures like placement of sand bags or evacuation of people from endangered locations.

2.4 Vegetation

In 1419, the discoverers of Madeira, João Gonçalves Zarco and Tristão Vaz Teixeira, encountered an island covered by dense, emerald green woodland. This natural woodland inspired the name of the island "Ilha da Madeira", which signifies island of wood¹⁰. Towards

¹⁰ See Luís de Camões, *Os Lusíadas*, Canto IV: Passámos a grande Ilha da Madeira, Que do muito arvoredo assi se chama; Das que nós povoámos a primeira,...

[We passed the big island of Madeira, which is named after its dense woodlands, the one (island) that we (referring to the Portuguese nation) settled first, ...)

the end of the 16th century the Azorean chronicler Gaspar Frutuoso wrote: “The island of Madeira was thus named, because of its well-expressed and huge woodlands and for the infinity of wood resources”.

The natural distribution of Madeiran flora is directly linked to the varying climatic conditions, most importantly temperature and humidity, at different altitudes. Accordingly four main altitudinal belts of distinct vegetation types have been identified (Aguin-Pombo & Pinheiro de Carvalho, 2009; Pereira, 1989; Quintal, 2005). These have been further differentiated by Capelo et al. (2004). The cooler and wetter climatic conditions on the north side are reflected in the expression of cooler vegetation belts at lower altitudes than on the south side of Madeira:

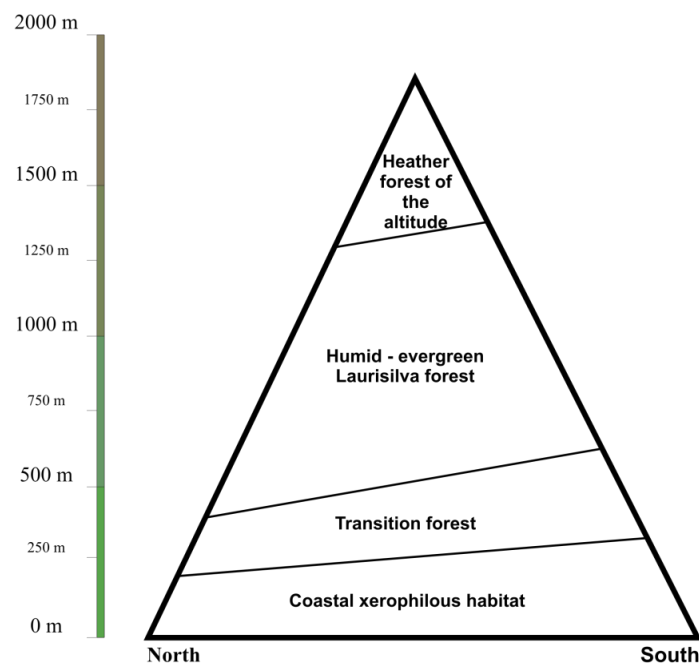


Figure 11: Natural altitudinal belts of vegetation communities on Madeira Island, adapted from Quintal, 2006

The coastal xerophilous habitat with the hottest and driest conditions on Madeira has naturally been dominated by Dragon Trees (*Dracena draco ssp. Draco*) and Wild Olive Trees (*Olea madeirensis*), main shrub species were Fish-stunning Spurge (*Euphorbia piscatoria*), Globe Flower (*Globularia salicina*) and Pride of Madeira (*Echium nervosum*). On herbal level the following species are common: Andryala (*Andryala glandulosa ssp. glandulosa*), Madeira Sea-Stock (*Matthiola maderensis*), Lotus (*Lotus glaucus*), Viscid Houseleek (*Aeonium glutinosum*), Hawkweed (*Tolpis succulenta*), Narrow-leaved Mustard (*Sinapidendron angustifolium*) and Carline Thistle (*Carlina salicifolia*).

The second bioclimatic altitudinal vegetation belt is transition woodland, some species of the coastal zone and few species of the Laurisilva zone can be found next to a number of species only growing within this habitat. In many national Portuguese publications this altitudinal belt is referred to as Laurisilva of the Canary Laurel (*Apollonias barbujana*), since this is the dominant specie within this woodland association (Capelo et al., 2004; Neves et al., 1996; Quintal, 2005). Other very common species are: Canary Holly (*Ilex canariensis*), Wax Myrtle (*Myrica faia*), Canary Willow (*Salix canariensis*), Ironwood (*Sideroxylon marmulano*) and Besom Heath (*Erica platycodon ssp. maderinicola*).

The Laurisilva bioclimatic belt is the most diversified one, with a high number of endemisms and many rare endemic species in tree, shrub and herb layers. Some of the most characteristic tree species are: Madeira Laurel (*Ocotea foetens*), Bay Tree (*Laurus novocanariensis*), Madeira Mahogany (*Persea indica*), Lily-of-the-valley-tree (*Clethra arborea*), Picconia (*Picconia excelsa*), Beefwood (*Heberdenia excelsa*) and the Madeira Holly (*Ilex perado ssp. perado*).

In the shrub layer there are a number of wide spread indigenous species. Besides many others the following are very common: Bastard Hares's Ear (*Phyllis nobla*), Madeira Blueberry (*Vaccinium padifolium*), Besom Heath (*Erica platycodon ssp. maderinicola*), Shrubby Sow Thistle (*Sonchus fruticosus*), Shrub Trefoil (*Teline madeirensis*), Wax myrtle (*Myrica faia*), Meliferous Spurge (*Euphorbia mellifera*), Soft broom (*Genista tenera*), Madeira Mountain Stock (*Erysimum bicolor*) and Crysanthemum (*Argyranthemum pinnatifidum ssp. pinnatifidum*).

The Laurisilva has a distinct herb and moss layer due to the amount of different microclimatic conditions ranging from humid valleys to dry conditions on basaltic dykes reaching above the treetops. Consequently, the Laurisilva is outstandingly rich in terms of biodiversity and is habitat of many endemic species. Some of the most common species are: Festuca (*Festuca donax*), Madeira Moneywort (*Sibthorpia peregrina*), Selaginella (*Selaginella denticulata*), Pteris (*Pteris incompleta*), Big Leaved Thistle (*Cirsium latifolium*), Large-Leaved Saint John's Wort (*Hypericum grandifolium*), Anemone-Leaved Storck's bill (*Geranium palmatum*), Madeira storck's bill (*Geranium madeirense*) and many types of mosses. In Madeira there are references for 540 taxa of briophytes, of which 70% correspond to mosses and 30% to liverworts and hornworts (Fontinha, Sim Sim, & Lobo, 2006).

The highest altitudinal vegetation belt is named heather woodland of the altitude [*Urzal de altitude* (Quintal & Vieira 1986, Quintal 2005)], covering all high mountain areas of the island.

Main species are: Tree heather (*Erica arborea*), Besom Heath (*Erica platycodon ssp. maderinicola*), Madeira Blueberry (*Vaccinium padifolium*), Crysanthemum (*Argyranthemum pinnatifidum ssp. montanum*), Pride of Madeira (*Echium candicans*), Soft broom (*Genista tenera*), Madeira Mountain Stock (*Erysimum bicolor*), Madeira Heather (*Erica maderensis*) and Thyme (*Thymus micans*).



Figure 12: The four main vegetational belts with characteristic plant species. a) Ponta de São Lourenço with Carline Thistle (*Carlina salicifolia*) on the left and Madeira sea-stock (*Mathiola madeirensis*) on the right b) Lower parts of Montado dos Pessegueiros with Globe Flower (*Globularia salicina*) and Ironwood (*Sideroxylon marmulano*) c) Valley of Ribeira de São Jorge with Bay Tree (*Laurus novocanariensis*) in the foreground d) Upper parts of Montado dos Pessegueiros with Lilly-of-the-valley-tree (*Clethra arborea*) on the left, Besom Heath (*Erica platycodon ssp. maderinicola*) on the right and Tree heather (*Erica arborea*) in the center

At present, the above-described belts of natural vegetation only remained expressed in limited areas on the island. The more intense human interaction with the landscape has been, the more expressed were the changes to the formerly natural vegetation cover. Therefore, in the coastal xerophilous zone and in the transition zone other types of land use, like agriculture, forestry and urban areas, have displaced most of the indigenous vegetation. The native vegetation has additionally been diminished by forest fires and by the expansion of some introduced species with invasive character.

The vegetation belts of the Laurisilva and the heather woodland of the altitude have also been modified by human activities, like logging, creation of pasture areas, firewood collection and many other purposes (Kiesow & Dierssen, 2017; Pereira, 1989; Ribeiro, 2006). Nevertheless, these belts are still well expressed on huge parts of the islands surface. There are approximately 15.000 ha of well conserved laurel forest mainly along the northern slopes of the central mountain range, which have been classified as World Natural Heritage by UNESCO in 1999 (Freitas et al., 2011). There are some near inaccessible patches located within the steepest northern slopes of the central mountain massif and the Paúl da Serra, which some authors consider as almost untouched woodland. These parts are integrated into the Nature Park of Madeira as areas of special interest¹¹. Access to these areas is only permitted for scientific research activities. Such areas are: Caldeirão do Inferno, Pico Casado, Ribeira Seca da Fajã da Nogueira, Lombo Barbinhas and Montado dos Pessegueiros (Madeira, 1982).

2.5 Agriculture and land use

In 1989, Eduardo Pereira mentions that “the arable terrain covers an area of about 30.000 hectares of which just 20.000 ha are in use”. The land abandonment observed by Pereira has intensified during past decades: In 2013 only a small part of the arable terrain, namely 5262 hectares of terraced land was under cultivation (INERAM, 2014). From the active population of 108.805 people only 13.525 people were working full time in the agricultural sector during 2013, representing 12.4 % of the active population. In 1989, Perreira reports that 75 % of the population is working in the agricultural sector. These numbers indicate a strong and ongoing process of abandonment of this activity. The agricultural sector together with fishery only contributes with 2.4 % to the GDP of Madeira Region. In comparison, tourism and transport contributed with 32.2 % in 2013. The tourism industry on the island has provided alternatives for many young people from farming households not willing and in monetary terms no longer able to continue farming on their family’s land.

Due to the above-described orographic conditions, agricultural production exclusively takes place on terraced slopes with accentuated inclinations. The terraced area extends from sea level up to maximum altitudes of 700-800 m a.s.l. Single terraces are generally of small size, getting smaller and smaller with rising inclination of the mountain slope they sit on. When

¹¹ These areas are classified as Reserva Natural Integral, see Decreto Lei 14/82/M, Art. 3.º

terraces were constructed on sheer rock and the arable soil had been transported to the location, they are reported to have had little more than a dozen square meters of surface area (Ribeiro, 1985). Pereira (1989) states that “these fields sometimes have less than 50 m² of surface area”. Even the terraces constructed on ridges that had been covered by soil layers several meters thick usually provided only small arable surfaces of less than one hundred square meters. This system does not leave room for modernization or mechanization of work processes. Cultivation of this terraced land has to be performed in the traditional way of best practices created by generations of small-scale farmers using hard manual labor.

Since accessibility of terraces is usually limited to steep and narrow staircases integrated into the structure of the supporting terrace walls themselves, transport of even light machinery is often impossible. Consequently, preparation of the soil for planting has to be done manually by a long-pointed hoe, locally named Enchada. Planting of crops, maintenance measures like irrigation, manuring, mechanical and chemical phytosanitary measures and harvesting require manual work. Depending on the location of the respective farmed land the transport of harvested crops towards the nearest kind of road infrastructure can be a further challenge for the farmer since every gram of product has to be carried off the mountains on foot. Under these circumstances, only healthy and strong farmers can carry out farming activity with its exhausting tasks on a daily basis.

The economic efficiency of such a production system on the conventional market is considerably low. Farmers cannot compete with the prices producers in modernized cropping systems can offer, turning family agriculture on Madeira into an economically difficult business.

Nevertheless, the created terraced landscape, covering almost every mountain slope within the zone permitting agricultural production, is a unique testimony to the centuries long interaction between humans and nature. It is a symbol of the capacity of humankind to change and modify hostile landscapes into agricultural landscapes. Over centuries travelers, visitors and scholars from mainland Portugal and abroad, have marveled at the outstandingly beautiful cultural landscape and the hardship farmers were facing when growing crops under the given environmental conditions. The geographer Orlando Ribeiro remarked, “The different types of land use, despite the relief the island presents, show that it is a place of profoundly shaped landscape. One fourth of the island has to feed an abundant population, deliver quality

products for export and allow intensive animal husbandry. The agricultural system that is capable of meeting these necessities is based on three factors: The construction of terraces, the irrigation and the abundance of organic fertilizer. The cultivated surface is a product of human intervention, a victory over the slopes, the dry seasons and the poor quality of the soil” (Ribeiro, 1985). The agronomist J. Vieira Natividade (1954) adds that, “within a few hundred years the Madeiran farmer has built one of the most extraordinary agricultural systems in the world...”and the traveler R. Ackermann (1825) describes, “The uneven surface that prevails throughout the island produces an obvious difficulty in its cultivation”.

On the southern, sun exposed side of the island every mountain slope has been terraced. The established agricultural terrace systems are designed for a perfect fit to the slopes on which they have been constructed. This results in a very high number of different complexities regarding (a) the elaboration, height and width of the supporting dry-stone walls, (b) the material used for the wall structure, (c) the spatial extent of such a system along a ridge and (d) the integration of natural landscape features such as basaltic dikes, rock fissures or other rocky outcrops into the terrace structure. Furthermore, the traditional irrigation method of open water channels, locally designated as Levadas¹² implied a higher level of complexity and linkage of terrace body and dry-stone wall structures than non-irrigated terrace fields. Most traditional terrace systems would consist of 6-12 terraces with dry stone walls of varying height, thickness and size and type of material used for the dry-stone wall. Most of the presently cultivated terraces would be linked to an irrigation system. The lateral extension of Madeiran terrace systems would often be limited by natural landscape elements such as vertical or near vertical rock sections or steep drops into valleys or ravines carved by waterlines. There are dry stone walls literally built on the edges above deep ravines.

In accordance with different altitudinal positions, exposition of mountain slopes, accessibility in terms of footpath infrastructure and proximity to waterlines or springs, there were different forms of economically feasible land use and respectively practiced by local farming communities.

¹² The Levadas of Madeira Island are a dense network of open water channel systems constructed to ensure the availability of water in most areas on the island. Some transport water over relatively short distances of a few kilometers from the mountains towards the valleys, while others transport water over longer distances from the rainy north to the much drier southern part. Levada dos Tornos is the longest Levada on the island, with its tributary channels it reaches approximately 150 km of length (Tribunal de Contas, 2008).

Just as the natural vegetation adapted to the climatic conditions prevailing at the different altitudinal areas, so did the agricultural production. The south side of the island with its good climatic conditions and more favorable orography is almost entirely terraced from sea level up to 600-700 m a.s.l. The rougher north side of the island is discontinuously terraced with frequent interruptions by vertical rock walls, deep ravines and areas of very steep terrain. The southern part of the island is characterized by a clear stratigraphy of tropical, subtropical and temperate crops. In the zone between 0-350 m a.s.l. lies the main area for banana production presently spanning the region from Funchal to Arco da Calheta. Banana production provides the most important fresh fruit for export. Furthermore, this area serves for sugar cane (*Saccharum officinarum*) and fruit production like mango (*Mangifera indica*), papaya (*Carica papaya*), passion fruit (*Passiflora edulis*), custard apple (*Annona cherimola*), avocado (*Persea americana*) and guava (*Psidium guajava*). Above this altitude until roughly 500 m a.s.l. the vineyards for the world-famous Madeira wine are to be found. During winter months, when the vines are leafless the soil underneath the vinestocks is often used for intercropping with potatoes. Outside the vineyards local farmers cultivate a number of subsistence crops such as potatoes (*Solanum tuberosum*), sweet potatoes (*Ipomoea batatas*), beans (*Phaseolus spec.*), cabbage (*Brassica*), lentils (*Pisum sativum*), carrots (*Daucus carota subsp. sativus*), onions (*Allium cepa*) and lettuce (*Lactuca sativa*). Moreover, fruit trees like apples (*Malus domestica*), pears (*Pyrus communis*), cherries (*Prunus avium*), plums (*Prunus domestica*), peaches (*Prunus persica*), avocado (*Persea americana*), lemon (*Citrus limon*) and orange (*Citrus sinensis*) are common. On higher altitudes the main crops are walnut (*Juglans regia*) and sweet chestnut (*Castanea sativa*).

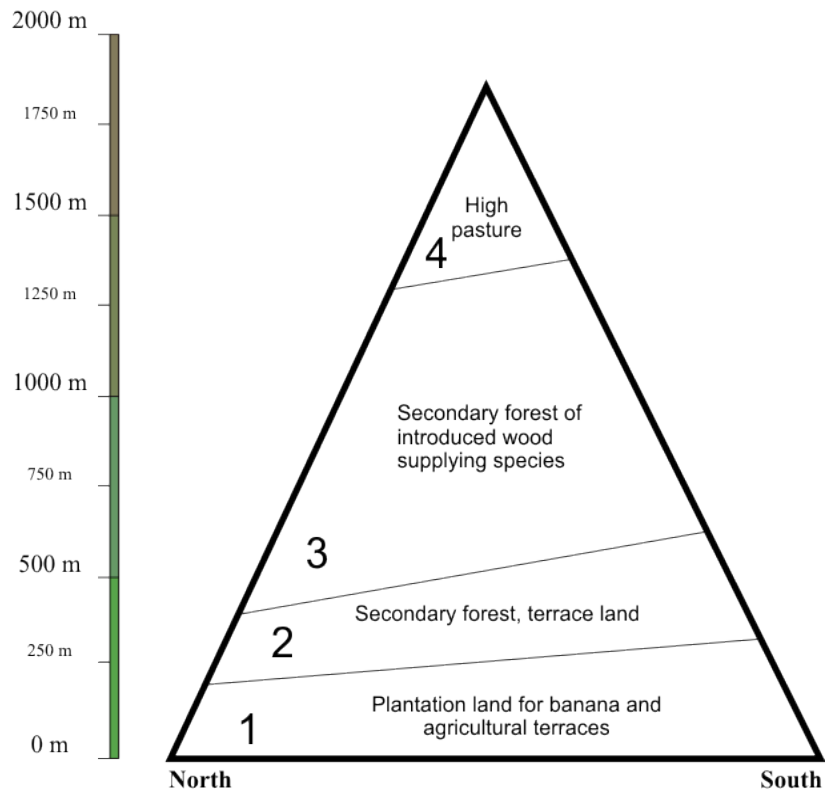


Figure 13: Typical landuse at different elevations, data from Ribeiro (1985) and DREM (2011-2019)

The regional statistical institution of Madeira Island DREM (Direcção Regional de Estatística da Madeira) has classified these forms of traditional land use on agricultural terraces into four main categories:

- a) Arable land
- b) Permanent pasture
- c) Permanent cultures and
- d) Family vegetable gardens

The first category includes all terraces used for annual crops such as cereals, maize (*Zea mays*), beans (*Phaseolus vulgaris*), potatoes (*Solanum tuberosum*), peas (*Pisum sativum*), carrots (*Daucus carota* subsp. *Sativus*), sweet potatoes (*Ipomoea batatas*) and beetroot (*Beta vulgaris*). The areas designated as permanent pasture do not only include terraces where animals such as cattle, sheep or goats graze, but also the terraces used for the acquisition of fresh fodder. Permanent cultures include fruit orchards, nut trees, banana plantations and sugar cane fields for commercial use.

The category of family vegetable gardens includes small holdings, often little more than 100 m², which are not the main source of income of the respective owner.

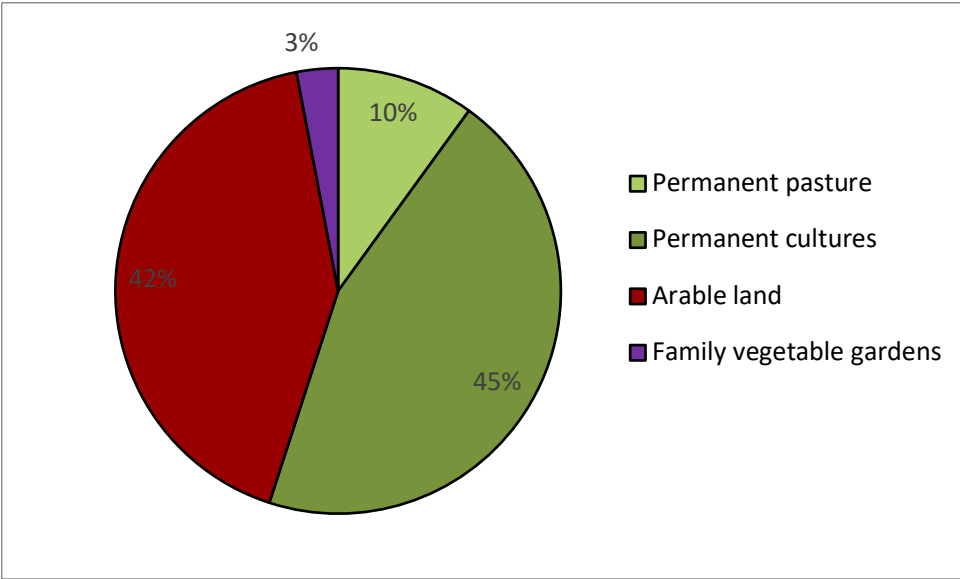


Figure 14: Distribution of land use categories, data from DREM, 2014

2.6 Population demographics and administrative units

The autonomous region of Madeira has 261,313 inhabitants, out of which the majority lives on Madeira Island (256,014) and only 5299 live on Porto Santo (Direção Regional de Estatística da Madeira, 2014). The density of population is one of the highest in Portugal. The country's average is approximately 300 inhabitants per square kilometer, while the average on Madeira is 326 inhabitants per square kilometer. In the capital city of Funchal population density reaches 1419 inhabitants per square kilometer and in the neighboring municipality of Câmara de Lobos 667 inhabitants per square kilometer. The municipality of Santa Cruz, bordering to the east of Funchal is also densely populated with 537 inhabitants per square kilometer. These numbers clearly reflect that the distribution of the population on the island is centered in and around Funchal; approximately 73 % of the total population resides here¹³. Furthermore, it has to be considered that the mountain areas are not suitable for living and the population mainly settled below 700 m a.s.l., thus having a further concentration of the population, than what is suggested by the regional annual statistical report.

¹³ All statistical data on population indicators refer to the year 2013, extracted from the report of the Direção Regional de Estatística da Madeira

Between 1991 and 2011, the number of inhabitants within the autonomous region of Madeira has fluctuated mainly due to emigration and immigration flows. Economic crisis or growth within the tourism sector are important push and pull factors. The annual resolution after the economic crisis in Portugal in 2010 shows a continuing decrease in resident population.

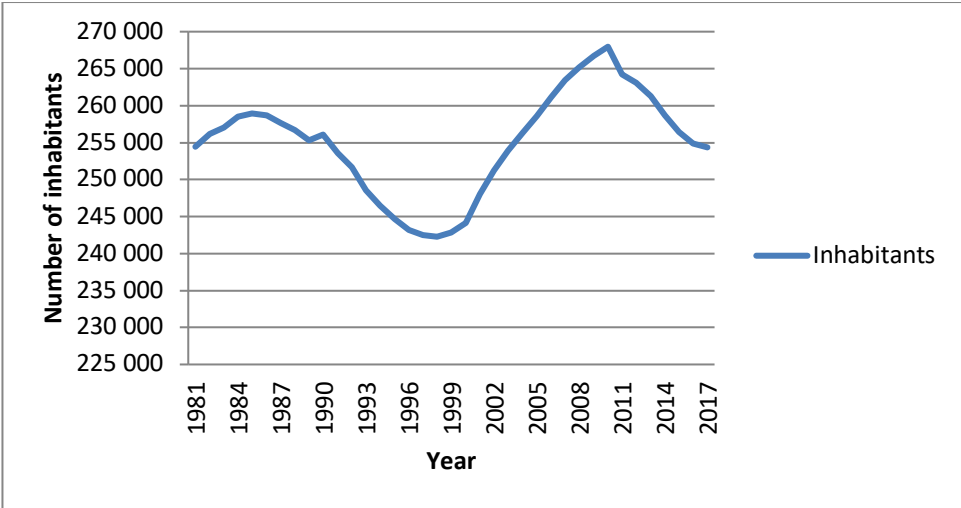


Figure 15: Resident population dynamics for Madeira region, in R.A.M. from 1981 to 2017, data from Direcção Regional de Estatística da R.A.M.

Madeira Island is administratively divided in 10 municipalities; the 11th municipality is Porto Santo. The border between northern and southern municipalities follows the natural dividing line of the central mountain ridge (cf. figure 3). There are four municipalities on the north side, the easternmost municipality of Machico has both a northern and a southern part and five municipalities are on the south side of Madeira.

Since 1976, Madeira has the status of an autonomous region within Portugal. Both island groups Madeira and Azores received this status within the decentralization efforts made by the new government after the carnation revolution that had ended the dictatorial regime in Portugal. Respectively Madeira obtained political-administrative autonomy, possessing its own regional parliament and a high degree of self-governance, which is most expressed in education and tax system (Vieira, 2001).

2.7 The research area of Lombadas da Ponta Delgada

In the central north of Madeira Island lies the municipality of São Vicente. It comprises an area of 78.9 km², consisting of the three parishes of São Vicente, Ponta Delgada and Boaventura (Direcção Regional de Estatística da Madeira, 2013). To the east it borders with the municipality

of Santana, to the south with the municipalities of Câmara de Lobos, Ribeira Brava, Ponta do Sol and Calheta, while to the west it borders with the municipality of Porto Moniz. In northern direction, the Atlantic Ocean is the natural border of the municipality of São Vicente. The research area is situated in the west-southwestern part of the parish of Ponta Delgada, in the area of the Lombadas da Ponta Delgada.

The research area of Lombadas da Ponta Delgada

Legend

— Border of research area

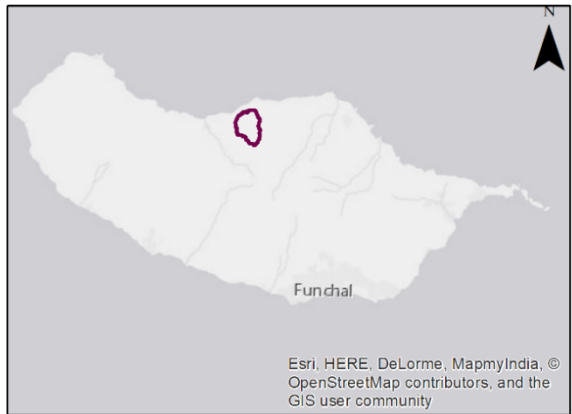


Figure 16: The research area Lombadas da Ponta Delgada, own figure with topographical base map from: Portugal, Serviço Cartográfico do Exército, Lisboa 1975

2.7.1 Morphology

The Lombadas of Ponta Delgada are tree ridges with a gentle gradient towards the north, situated at approximately 300 to 400 m a.s.l. The ridges from east to west are named Primeira Lombada, Segunda Lombada and Terceira Lombada. The main settlement is Primeira Lombada, where until present days a chapel dedicated to “Imaculado Coração de Maria” unites the inhabitants of the villages regularly. The second most important settlement is located on the westernmost ridge: Terceira Lombada. The smallest settlements are the hamlets of Segunda Lombada and Lombinho. While the main settlement Ponta Delgada and Lombinho are located at altitudes ranging from sea level to approximately 120 m a. s. l., the Lombadas¹⁴ are situated on an elevated plateau ranging from 280 m to 350 m a. s. l.



Figure 17: Settlements of Ponta Delgada (on the left by the sea), Primeira Lombada (on the elevated plateau) and Fajã da Areia (on the right by the sea)

The Lombadas are circumscribed by mountains rising steeply to a maximum elevation of 1468 m a.s.l. at Topo das Queimadas in the south and by two main mountain ridges descending in northwestern and north northeastern direction from Topo das Queimadas towards the north coast. Both ridges keep a relatively high altitude (1193 m a.s.l. at Topo da Lombada das Vacas on the western ridge and 1094 m a.s.l. at Estreitinho on the eastern ridge) for approximately the first 2.5 km from Topo das Queimadas and have a sharp drop of over 1000 m of altitude on the last 1.5 km before meeting the coast. The two mountain ridges are divided by one large valley formed by the streams of Ribeira da Camisa, Ribeiro do Velho and Ribeira da Granja. Ribeira da Camisa is by far the most important watercourse, having the biggest catchment

¹⁴ Locally the three hamlets of Primeira Lombada, Segunda Lombada and Terceira Lombada are referred to as the “Lombadas” when speaking of the tree together. In this thesis I will conform to this local convention.

area of the three streams and thus the highest flow rate¹⁵. It divides Primeira Lombada and Lombada do Meio from Segunda Lombada and Lombinho, which for their part are separated from Terceira Lombada by the stream Ribeiro do Velho. On the western side, Terceira Lombada borders at the stream Ribeira da Granja. These main streams have many small tributaries, which have given origin to a gashed landscape with deeply carved in gorges and abrupt rock faces. The source region of Ribeira da Camisa is characterized by innumerable tiny gorges, most of them close to Laje Negra.

2.7.2 Local climate

The microclimate in the research area is strongly influenced by the local topography. The high mountains with their vigorously steep slopes frequently give rise to orographic rainfall. In addition, the geographic position of Ponta Delgada exposes it to the prevailing northeast wind, thereby contributing to the formation of orographic rain. The average amount of rainfall in Ponta Delgada is 1136 mm. This amount has been measured by the official weather station located at 136 m a.s.l., the higher parts of the research area receive higher annual rainfall. The average annual precipitation in the mountains of Ponta Delgada is between 1600 and 2000 mm (Quintal, 2005). The combination of extremely steep topography and high intensity rainfall events makes the research area very susceptible to flash floods. These have provoked mayor damage in the past. Mimoso Loureiro (2011) reports on several flood events in the municipality of São Vicente and in Ponta Delgada:

Table 1: Heavy rainfall and flash flood events recorded in Ponta Delgada

2 nd and 3 rd October 1895	25 th and 26 th February 1920	6 th March 1928	7 th January 1979	6 th March 2001
landslides, floodings, infrastructures damaged	landslides, small floodings, storm damage	landslides, 32 casualties, 10 palheiros ¹⁶ destroyed	landslides, infrastructures damaged	landslides

¹⁵ Locally the valley is often referred to as “Vale da Ribeira da Camisa” (Ribeira da Camisa valley). In this thesis, I will conform to this local convention.

¹⁶ A palheiro is a small house, with one room only, which serves as cowshed. Size of the interior of these sheds varies between 3 x 3 m to approximately 4 x 4 m. The height of the room was approximately 2 m, above an attic existed directly below the roof, which was used for storage of hay and bedding material for the animals. Traditionally the sheds had a thatched peaked roof. The material used for thatching was wheat straw, requiring total renewal every 5 to 7 years. Presently most palheiros, which are still in use, have been modernized and covered by a metal roof.

The average annual temperature between 1961 and 1990 is 17.9°C varying between 15.2°C (January and February) and 21.4°C in August. In the upper parts of the parish both values are lower due to the effect of altitude. Generally, the climate of Ponta Delgada is described as temperate, oceanic, humid and rainy¹⁷ (cf. figure 18).

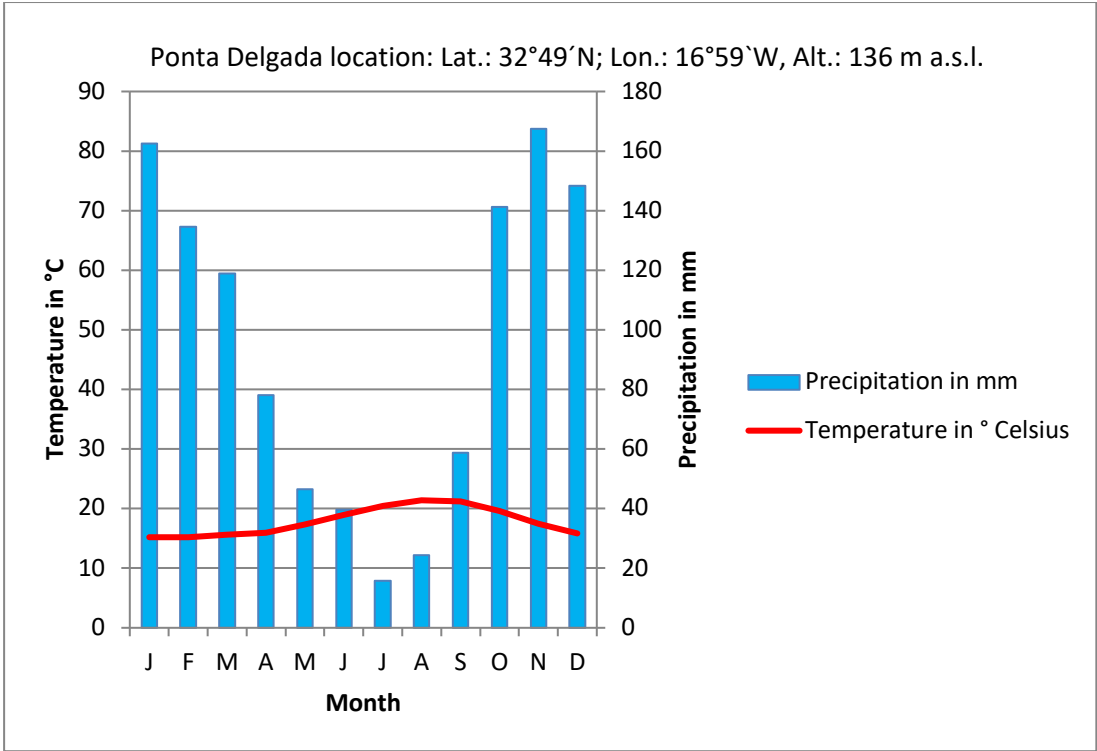


Figure 18: Climate normals (1961-1990) for Ponta Delgada, data from Instituto Português do Mar e da Atmosfera

2.7.3 Vegetation

The present vegetation in the research area has been strongly influenced by agricultural land use and forestry. Within the research area, it is indispensable to differentiate between two main types of land use: a) area of present or former agricultural land use and b) area of present or former use of forest resources.

All easily accessible ridges with slight inclination close to the villages have been thoroughly used for subsistence agriculture and the native vegetation has been greatly replaced by crop plants. These areas under cultivation were extended into the mountains by large scale terracing even of steeply inclined slopes at the Lombadas. From an altitude of approximately 600 m a.s.l. onwards agricultural production was not feasible resulting in a significantly lower

¹⁷ Cf. footnote 4

human modification of the landscape structure and the native vegetation. In the transition zone between the agricultural terraces and the woodland many land owners reforested the terraces, which dropped out of cultivation, with pine trees (*Pinus pinaster*) as a source of wood (Kiesow & Dierssen, 2017). This resulted in a belt of pine trees along the border with the natural woodland vegetation in the Lombadas and in almost every other settlement on Madeira (Portugal, R.A.M., Direção de Serviços de Informação Geográfica e Cadastro, 2007¹⁸). The research area represents the typical vegetation pattern found in the north of Madeira Island, the belt of Pine trees above the area under cultivation is followed by the indigenous Laurisilva forest up to an altitude of approximately 1300 m a.s.l., where the heather woodland of the altitude adjoins. Both vegetation communities have suffered alterations by human activities, but next to heavily modified sections, there are also sections showing hardly any signs of human intervention. In the basically inaccessible area near Laje Negra the Laurisilva forest is well preserved and rich in rare endemic species (Kiesow & Dierssen, 2017; Neves et al., 1996). The heather forest bordering these inaccessible areas only shows few signs of human interaction, whereas the heather forest community on the accessible ridges has partly been removed for the creation of high pasture and often profoundly altered as a source of fire wood.

2.7.4 Agriculture and land use

The parish of Ponta Delgada is intimately linked to agricultural production since it has been founded. Even fishery never played a major role in this coastal village. In terms of produce there are two important categories, for one thing the cash crops, for another thing the subsistence crops and fodder. Over time there were several cash crop cycles (cf. chapter 3), which either replaced parts of the subsistence crop production or gave origin to the extension of the area under cultivation (Ribeiro, 2005). According to the respective habitat requirements, cash crop cycles were differently expressed in the various altitudinal belts. The sugar cane cycle affected mostly the lower parts of the parish since its cultivation on the northern side of Madeira Island was not lucrative above 300 m a.s.l. (Pereira, 1989). In the two periods of prosperity of sugar cane, the lower parts of the area under cultivation were

¹⁸ The land use map COS2007 from the regional Direção de Serviços de Informação Geográfica e Cadastro provides the most recent data on land use on Madeira Island. On this map the existing pine forests are differentiated into three types: a) Open pine forest with deciduous trees, b) Pine forest c) Pine forest with deciduous trees

predominantly cultivated with this crop, while the area under cultivation above approximately 300 m a.s.l. remained for production of subsistence produce. The economic cycle of wine was expressed in the lower and higher parts of the agricultural area alike, thus limiting the available land for subsistence crop or fodder production in the parish. During the prosperity of these crops, they were cultivated in systems with very little or no rotation, certainly leaving negative effects on soil fertility. The loss of soil fertility is reported in Ilhas de Zargo (Perreira, 1989), História rural da Madeira (Sousa, 1994) and in Agricultando (Leça, 2011).

The cultivation of subsistence produce and fodder took place during all periods, since a high degree of self-sufficiency was indispensable. The range of crops reached from grains, over vegetables and fruits to nuts. Important grains were wheat (*Triticum aestivum*), rye (*Secale cereale*) and to a smaller degree barley (*Hordeum vulgare*). Strongly influenced by the discovery voyages of the Portuguese to Brazil, Africa and Asia, many subtropical and tropical fruits became part of the local agriculture. Potatoes (*Solanum tuberosum*), sweet potatoes (*Ipomoea batatas*), corn (*Zea mays*), chayote (*Sechium edule*) and taro (*Colocasia esculenta*) quickly gained importance and still make part of the spectrum of cultivated crops. Vegetables like bean (*Phaseolus vulgaris*), carrot (*Daucus carota subsp. Sativus*), beetroot (*Beta vulgaris*) and onion (*Allium cepa*) were planted frequently.

Amongst the fruits, fruit trees were most popular. Until present days, the cultivation of apple (*Malus spec.*), pear (*Pyrus ssp.*), peach (*Prunus persica*), fig (*Ficus carica*), lemon (*Citrus ssp.*), orange (*Citrus ssp.*), cherry (*Prunus avium*), custard apple (*Annona cherimola*), tomato tree (*Cyphomandra betacea*), guava (*Psidium guajava*) and strawberry guava (*Psidium guineense*) is common (Natividade, 1947). The only nut, which is presently grown, is the walnut (*Juglans regia*). Next to agriculture, the most important source of income in the past was forestry. The dense native woodlands provided many types of wood of high quality, which were very sought after for construction. The deciduous tree species picconia (*Picconia excelsa*), the beefwood (*Heberdenia excelsa*), madeira mahogany (*Persea indica*) and madeira stinklaurel (*Ocotea foetens*) were often used for the construction of vine presses, houses and in ship construction. For many purposes the trunks of wood had to be transformed into planks, thus creating the necessity of sawmills in the municipality (Vieira, 1997). Furthermore, the woodland provided firewood for domestic purposes and also served as feedstock for charcoal production (Pereira, 1989; Vieira 1997).

2.7.5 Population demographics

There are only few written sources on the development of the population in the municipality of São Vicente and hardly any separating the parish of Ponta Delgada from the other parishes constituting the municipality. Vieira (1997) presents some demographic data on São Vicente. Unfortunately, there are no continuous data sets available. The authorities collected most demographic data regarding São Vicente in order to know the number of men available for military service (Vieira, 1997). Figure 19 illustrates the population growth recorded in the municipality of São Vicente from 1864 to 1960.

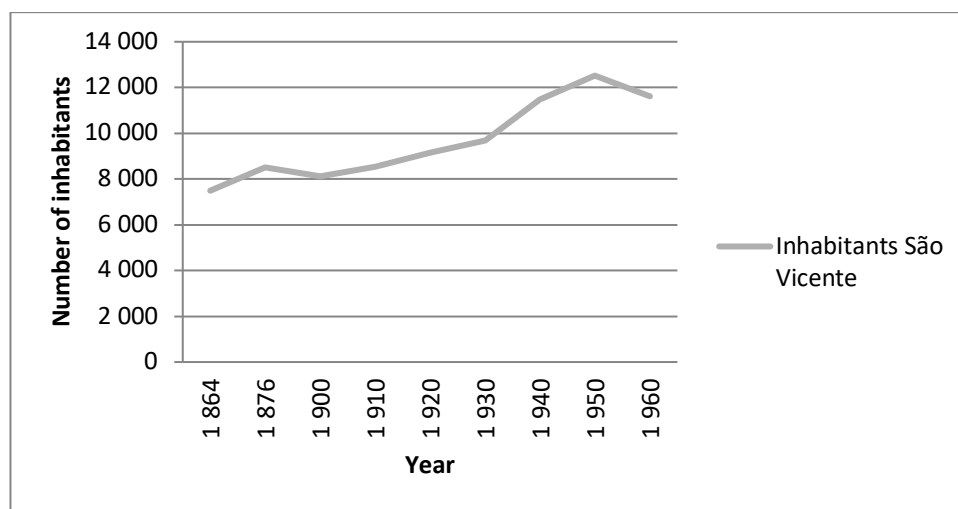


Figure 19: Resident population development in the municipality of São Vicente from 1864 to 1960. Data from Vieira, 1997

In this period, the general trend is an increase in population. The number of local residents rose from 7490 to 11603. Nevertheless, there are two periods of population decrease, one starting in the 1870s and a second one beginning in the 1950s. Both periods follow economically unfavorable times. In 1872, the phylloxera disease hit the vineyards in the Madeira region. Almost all vineyards were destroyed and old varieties could only be saved by grafting them onto rootstocks of American wine varieties, which were resistant to phylloxera. The loss of several years of export revenue caused a very difficult economic situation on Madeira Island. Therefore, many farmers, who could barely survive under these conditions, opted for emigration. The second phase of massive emigration followed the Second World War, Portugal fell into a strong recession and on Madeira Island rural populations suffered hunger. At the same time in Brazil, South Africa, Venezuela and Australia talented, hard working people were desperately needed in the agricultural sector. Consequently, many

families living in precarious situations on Madeira left for those countries. Generally, from the 1950s onwards, the population development trend turned around. The population decreased from 12521 local residents in 1950 to only 5151 local residents in 2017 (Direcção Regional de Estatística da Madeira, 2018).

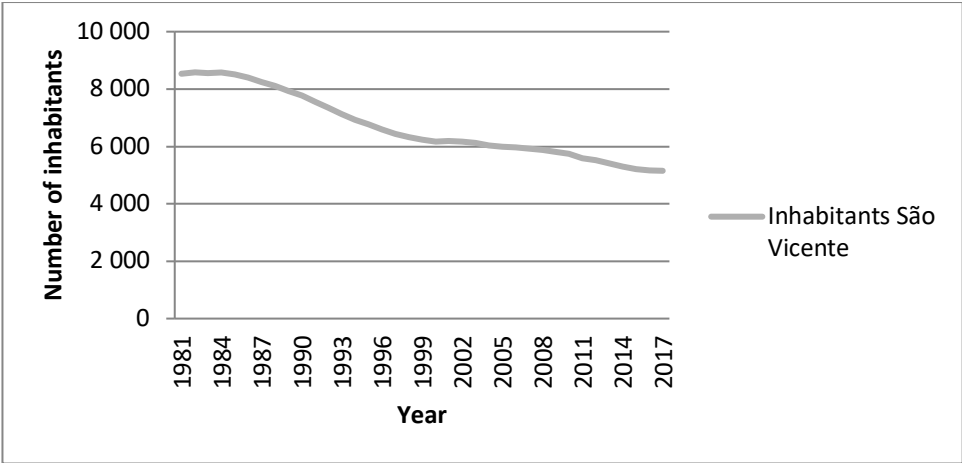


Figure 20: Resident population development in the municipality of São Vicente from 1981 to 2017, data from Direcção Regional de Estatística da Madeira, 2018

Lately, the northern municipalities have suffered a more pronounced population decrease than the southern municipalities due to limited access to the labor market largely based on tourism in the south of the island. Ponta Delgada remains a parish dominated by agriculture, which does not offer attractive perspectives for young people to start or take over a family farm. The decreasing trend in population development thus is likely to continue.

3 Literature review of land use history

This chapter focusses on the historical development of the interaction between humans and the landscape since the early days of settlement in the first quarter of the fifteenth century until present days. Madeira was an uninhabited island until the arrival of the first Portuguese settlers shortly after the discovery of the island in 1419. Consequently, the first settlers found a largely pristine landscape and began to modify the natural state of the landscape. Over time, many scholars from different disciplines, mainly historians, have studied various parts of the social, economic and agrarian history of the island. This research contributes to an overview of the numerous factors, which influenced the intensity and the type of interaction that occurred between villagers and their surrounding landscape.

Land use is generally influenced by three main types of factors: a) physical factors, b) economic factors and c) human factors. Amongst the physical factors climate, soil type and topography are of mayor importance in the Madeiran context. These factors have already been presented in the previous chapter. The remaining factors b) and c) are addressed in this chapter. Over centuries, the most important economic activities on the island have been agriculture and forestry. The economic trends on global cash crop markets have largely determined crop production and the financial situation of the island, which in turn allowed or forbade investments to develop the landscape.

Economic interests were a main driver for either intensification or discontinuation of certain crops and cropping measures. Madeira Island was characterized by several successive economic cycles, a term that was used by historians like Vieira (2002, 2004), Nepomuceno (1994) and others. It defines a period of time in which a certain product was the economically most important cash crop. Within an economic cycle the respective crop was the dominant land use type considering the altitudinal belt that best suited the climatic demands of the crop. Other agricultural products had to be grown in less favorable altitudinal zones or were not grown at all, but imported.

The various economic cycles had a strong impact on land use type, variety of land uses, extend of land use into the mountains and onto the cultural life on the island in terms of what is presently regarded as traditional or typical Madeiran food or produce. The agricultural crops influenced the composition of Madeiran people, for example the sugar cane production

required a number of slaves to be brought to the island. In later periods of flowering vine trade many British merchants came to the island.

Next to these economic factors, the individual or societal influence on land use should not be underestimated. The established administrative system of captaincies and the respective way of land allocation to noble families and settlers contributed decisively to the way land was used. Thus, the system of land allocation and administration is a fundamental part in understanding the mosaic of the environmental history of Madeira Island.

Both topics, the economic development with the various cycles of cash crops and the invention of the administrative system of captaincies have been in the focus of studies of a number of scholars. Most of these works are available in national and regional libraries and archives. For a compilation of the available information on the environmental history of Madeira Island documents and other written sources, such as books, reports, letters and journal articles have been consulted in the following libraries and archives sorted by their location:

a) Germany:

Central Library of Kiel University, Section Geography, Kiel

Library of the Romance Linguistics Seminar of Kiel University, Kiel

b) Continental Portugal:

Biblioteca Nacional Torre do Tombo, Lisbon

Biblioteca do Instituto de Investigação Científica Tropical, Belém, Lisbon

c) Madeira Region:

Biblioteca Pública Regional (Fundo Regional), Funchal

Arquivo Histórico da Região Autónoma da Madeira, Funchal

Museu Municipal do Funchal, Funchal

Furthermore, several antiquarian bookshops and specialized booksellers were searched for publications regarding Madeiran environmental history.

The most important antiquarian bookshop is without doubt Livraria Esperança in Funchal, where an entire room is dedicated exclusively to publications regarding Madeiran History. Other important sources of regional publications are Livraria Académica in Porto, Livraria Olisipo and Livraria Antiga do Carmo in Lisbon, which have provided several older studies and reports.

The aim of this chapter is to give an overview on the agricultural and environmental history of Madeira Island, shining a light onto the mayor factors that influenced the shaping and the modification of the mountainous landscape. This description encompasses the whole of Madeira and is of general nature, not differentiating in detail between the different locations. At the end of this chapter a detailed description on the agricultural and environmental history within the research area Lombadas da Ponta Delgada is given. This description is embedded in the formerly discussed temporal frame of human-landscape interaction.

3.1 Discovery and settlement

Madeira Island is first mentioned on a map in the Atlas Medíceo dating back to the year 1351. At the location of Madeira an island with the name Isla de Lognome is mapped. In 1375, this mysterious island is also depicted in a Catalan map (Carta Catalã) and in 1384 in the Carta de Walckenaer, which also depicts the island group of Madeira (Perreira, 1989). All of these maps do not illustrate the shape of the islands of the Madeira region correctly. Presumably, the cartographers did not have precise information on the shape of the islands, but knew about their location. In 1419, under the governance of the Portuguese King Dom João I, the two captains João Gonçalves Zarco and Tristão Vaz Teixeira, in service of the Infante Dom Henrique¹⁹, were assigned to take possession of the Islands for Portugal. When they left Restelo (Lisbon) with this royal order, their voyage was no discovery in the sense of detection of an unknown part of the globe, but more taking possession of a new land and executing topographical reconnaissance work (Ribeiro, 1985).

Arriving on the Island of Madeira João Gonçalves Zarco and Tristão Vaz encountered an uninhabited volcanic island, which was covered by dense woodland from low altitude up to the highest visible mountaintop. Most probably the name Ilha da Madeira (Island of wood) originated from these extended woodlands. Several chroniclers described the rich woodlands found on the arrival of the Portuguese. “The sailors found wild and new land, neither ploughed nor known since the beginning of the world until today” (Jeronimo Dias Leite, mid 15th

¹⁹ The Infante Dom Henrique is internationally better known under the title of Prince Henry the Navigator. He was the third oldest son of King Dom João I of Portugal and focused his work on the maritime expansion of the Portuguese kingdom. He founded the famous school of navigators in Sagres, Algarve. Some of the most well-known specialists of navigation, of cartography, of maritime currents and of naval construction shared their knowledge in this institution. In this work, I will refer to him with the Portuguese designation of Infante Dom Henrique instead of some of the often used English translations such as Prince Henry or Henry the Navigator.

century). Gaspar Frutuoso (15th century) describes the situation in the following words: “...gave the name of Madeira due to the well expressed and enormous woodlands that covered the island and the infinity of wood resources.” In the most famous literary account of Portuguese discoveries, *Os Lusíadas*, written by Luis Vaz Camões²⁰ in the late 16th century, the passage of Madeira Island is characterized this way:

“We passed the huge island of Madeira,
which is named after the enormous forests covering it,
the one [island] we settled first,
more famous for its name than for its conditions.”

João Gonçalves Zarco, Tristão Vaz Teixeira and a third captain, Bartolomeu Perestrelo, who accompanied them on their second voyage to the islands of Madeira and Porto Santo were assigned the task of colonizing these recently acquired uninhabited islands. Infante Dom Henrique, responsible for the maritime expansion of Portugal under King Dom João I, invented a new system of colonization and administration, which became known under the term of *Capitanías*, often translated into English as captaincies. In the period of maritime expansion of Portugal captains of ships used to receive a part of the land, or in case of Madeira region all the land, they had discovered as a captaincy and were entitled Donatary Captains. This was similar to becoming governor of the land. A Donatary Captain had strong power in administrative, economical and juridical terms, many privileges and special rights over his jurisdiction. This included the right to give land to settlers and thus structure the settlement process. In economic terms the exclusive right to own mills for cereals and other crops like sugar cane, to have ovens for bread backing and to possess the right to sell salt (Santos, 2008) had great implications and influence to these new lands. The Portuguese king had the right to overpower the Donatary Captains and maintained the exclusive right to inflict penalty of death (Nepomuceno, 2006; Serrão, 1992; Vieira, 1989; da Silva & Azevedo de Menezes, 1978a). The administrative system of the captaincy became the model for all future colonization processes that created the Portuguese overseas dominions, like Cape Verde Islands, São Tomé and Príncipe Islands, Guinea-Bissau, Angola, Mozambique, Goa, Macau, Timor-Leste and Brazil.

²⁰ Luis Vaz Camões is often considered Portugal’s greatest poet. He wrote lyrical poetry and drama, but is best known for his epic work on the Portuguese seafaring discoveries, named “*Os Lusíadas*”.

The captains João Gonçalves Zarco, Tristão Vaz Teixeira and Bartolomeu Perestrelo who discovered the Madeira Island group, became donatary-captains of the land. In this case the land was divided under the three captains. The task of colonizing the small island of Porto Santo was given to Bartolomeu Perestrelo, while Madeira Island was divided in two parts and each of the remaining captains was assigned to colonize one part. The division of the island was done along an imaginary line from Ponta do Tristão in the northwest towards Ponta da Oliveira in the southeast. This unusual division ensured that both captaincies would include southern and northern exposed slopes and that both would have at least one sheltered bay as future harbor.

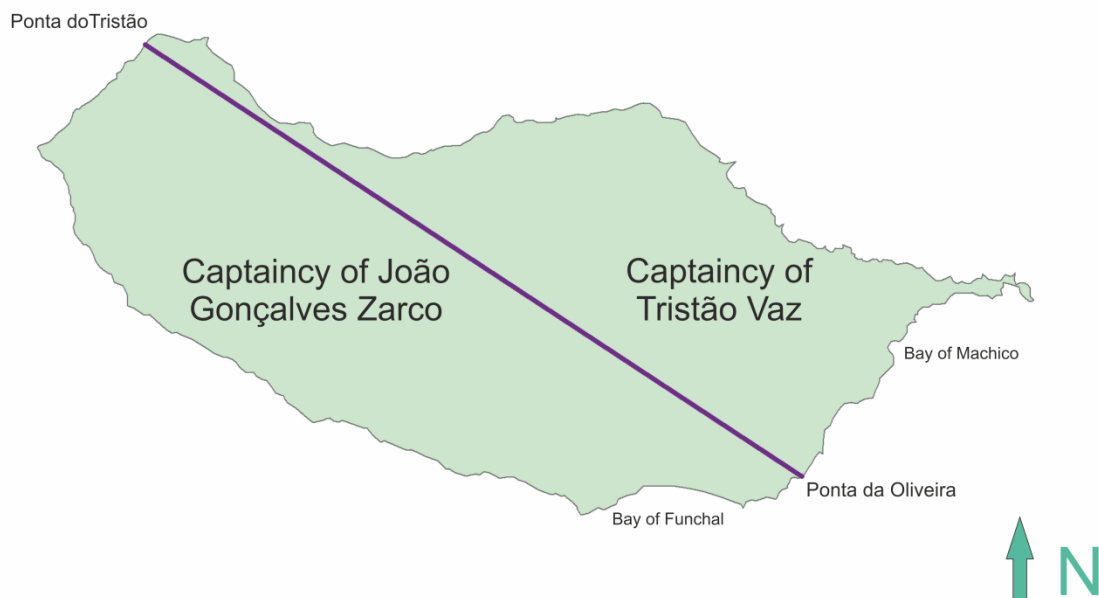


Figure 21: Division of captaincies on Madeira Island

Most probably the settlement of Madeira began already in 1420 (Damião Peres, 1960), but gained momentum in 1425 (Pita Ferreira, 1956), when larger parcels of land were given to noble families for colonization. This marked the point where humans started to modify the island from natural into cultural landscapes. The first places to be settled on Madeira Island were (a) Machico valley in the extreme southeast, a part of the captaincy of Tristão Vaz Teixeira, and (b) the large area around the bay of Funchal in the southeast, part of the captaincy of João Gonçalves Zarco (see figure 21).

3.2 Early agro-economic cycles

One of the main objectives of the donatary captains was to establish a permanent population and to produce agricultural crops for (a) subsistence of the population and (b) to take profit from the colony by cash crop production, namely cereals such as wheat. Mainland Portugal was suffering a constant shortage of wheat, which Dom João I was hoping to minimize by establishing a flowering cereal production on the recently acquired islands (Serrão, 1950; 1992). Thus, wheat is considered to be the oldest agricultural cash crop on the island (Ferraz Freitas, 1971; dos Santos, Freitas, Nunes, & Pinheiro de Carvalho, 2007).

The first variety of wheat introduced on the island by Infante Dom Henrique was “*trigo anafil*” also known as “*trigo português*”²¹ (Pereira, 1989, p. 621; da Silva & Azevedo de Menezes, 1978b, p. 661). The pristine and fertile volcanic soils of the island allowed very rich harvests in the first years of cultivation. Cadamosto reports from his first trip to Madeira in 1445 that “being as mountainous as Sicily, it is still [a] very fertile [island], harvesting every year thirty thousand “*estares venezianos*” of wheat [...] In the beginning its soils used to produce 60 for one and now produce 30 to 40 for one.” Da Silva (1978) confirms the outstanding fertility of Madeiran soils: “Everything grew well, to the point that from one “*alqueire*” of wheat [ca. 14 l] that was sown, at least 60 “*alqueires*” were harvested [...] everything grew in abundance.” The production of wheat constituted the first economic cycle on Madeira, but lasted only a few decades. Ribeiro (1989) reports that already “in 1433 the rents covered by the master of Madeira were of considerable value”. In the description of Cadamosto, who visited the island for a second time in 1455, a variety of export products is described: wheat (trinta mil “*alqueires venezianos*”), meat, cedar wood planks and yew, sugar and wine (Crone, 2016; Serrão, 1992).

Shortly after, the valorization of agriculture had risen to unexpected heights. It is said to have been Infante Dom Henrique who ordered the introduction of offshoots of sugar cane plants (*saccharum officinarum*) from Sicily (Italy) and experiment with planting these on the island (Greenfield, n.d.; Leça, 2011; Pereira, 1989; Serrão, 1992; Vieira, n.d.). This was done at a place known as “*Campo do Duque*”, which was property of Infante Dom Henrique²². This area was located in the presently urban area of Funchal, at the location of the cathedral of Funchal

²¹ „Trigo português“ means portuguese wheat

²² Infante Dom Henrique was Duque of Viseu, presumably the name “*Campo do Duque*” (engl.: Field of the Duke) originates from this ownership

(Pereira, 1989; Vieira, 2003). The successful cultivation at Campo do Duque set the beginning of the most important economic cycle on the island. A cycle that did not only change the landscape, the financial situation of the island and the labor market, but profoundly influenced the composition of the people, the social hierarchy and the commercial connections over Europe and subsequently over the globe.

Serrão (1992) mentions that Dom Henrique “ordered the introduction of many sugar cane plants to this island [Madeira], which proved to grow very well”. It is reported that in 1452 a contract was signed between Diogo de Teive and Infante Dom Henrique, which allowed the first to build a factory with a hydraulic press for sugar cane (Ribeiro, 1985; Serrão, 1992). From this time onwards, the expansion of the sugar cane cultivation on the island and the internal European sugar trade rose immensely. In 1456 a shipload of sugar from Madeira was exported to Bristol and surely there was earlier export of sugar to the capital city of Lisbon (Serrão, 1992). Madeiran sugar quickly became famous for its high quality (Serrão, 1992; Vieira & Clode, 1996) and was regarded as “white gold” (Vieira & Clode, 1996). In the period from 1460 until 1470 sugar cane production and the respective sugar trade experienced an impressive rise and without doubt sugar became the motor of the economy. In 1466 the time of wheat export from Madeira had finally passed, instead it became a necessary import commodity. From 1485 onwards Madeira imported wheat mainly from the middle and western coastal regions of Mediterranean Africa²³ and from the early 16th century onwards, the Azores provided most of the necessary wheat (Serrão, 1992).

The sugar cane plantations²⁴ were mostly extended on the warmer southern side of the island. The best conditions for its profitable cultivation were found from sea level to 400 m a.s.l. (Vieira & Clode, 1996). This information illustrates well how important and financially rewarding sugar cane cultivation had become. In recent publications the area considered best for cultivation of cane along the south side of the island is up to 300 m a.s.l. and on the north side just up to an altitude of 150 to at the most 200 m a.s.l. (Leça, 2011). With less favorable climatic conditions at higher altitudes the sugar content decreases considerably: the sugar content of the squashed sap from plants grown above 300 m a.s.l. is approximately 6 %, while

²³ This part of North Africa was called Barbary coast, in Portuguese *Berbéria*, see Serrão, 1992

²⁴ On Madeira, the term plantation has to be seen in the context of a small and very rugged island space available for cultivation of crops. The spatial dimensions of a plantation, like the ones established in later periods in South and Central America were never reached on Madeira Island.

the sugar content of the squashed sap from plants grown up to maximally 300 m a.s.l. reached an average of 12,5 to 13 % (Pereira, 1989)

The quick extension of sugar cane cultivation on Madeira Island was facilitated by the established system of land distribution to new colonists. With the system of *sesmarias* the donatary captain of the respective captaincy was allowed to give parts of the land of his captaincy to people willing to move to the island and establish a settlement with agricultural production for export. Generally these were people of mayor trust from his inner circle, often originating from noble families of Minho area (Serrão, 1992). These often-brought settlers from their homeland and with them agricultural knowledge and traditions. When the sugar from Madeira had gained an excellent reputation amongst European aristocracy and prices were so high that sugar was called the white gold more and more people came to the island. Next to settlers from the Portuguese mainland foreigners from various countries were attracted by the possible revenue in sugar cultivation and trade. In the early days of sugar trade several Italian merchants, of Genoese and Florentine origin, who had connections to European commodity markets came to Madeira (Vieira, 2003).

One famous example of an early sugar cane plantation with the technical advance of an irrigation system was in Lombadas da Ponta do Sol, where João Esmeraldo, a settler from Flanders, established one of the biggest sugar cane plantations on the island in the year 1473. Thus Ponta do Sol became the most important center of sugar cane production and processing on Madeira (da Silva, 1933). In 1494 João Esmeraldo's plantation produced approximately 1370 arrobas²⁵ (equals 20 tons) of sugar (Vieira, 2004) and in 1498 he already had a production of 3370 arrobas (equals 49.5 metric tons) of sugar and in 1525 he still produced 3277,5 arrobas (Vieira, 2004) on an area of 22,5 hectares. Next to the sugar cane production subsistence crops like cereals, vine and meat were cultivated on his land (Abreu de Sousa, 1994). Being a more important period in the colonization of the island João Esmeraldo quickly attracted "many tenth of colons and slaves for the vast terrains of Ponta do Sol" (da Silva, 1933). While the majority of colons originated from Minho province and some from the Algarve, most of the slaves were brought from Guinea (Abreu de Sousa, 1994).

The example of the plantation of João Esmeraldo in Lombada da Ponta do Sol, also named Lombada dos Esmeraldos, is only an example for the development of many sugar cane

²⁵ A Portuguese Arroba used to weigh 14,688 kg.

plantations on the island. Although it is certainly one of the biggest and best managed plantations in the early phase of sugar cane cultivation, many other landlords established similar plantations in other parts of the island. Figure 22 shows the rise of sugar production on Madeira Island from the mid 15th to the early 16th century and the decline until the late 16th century:

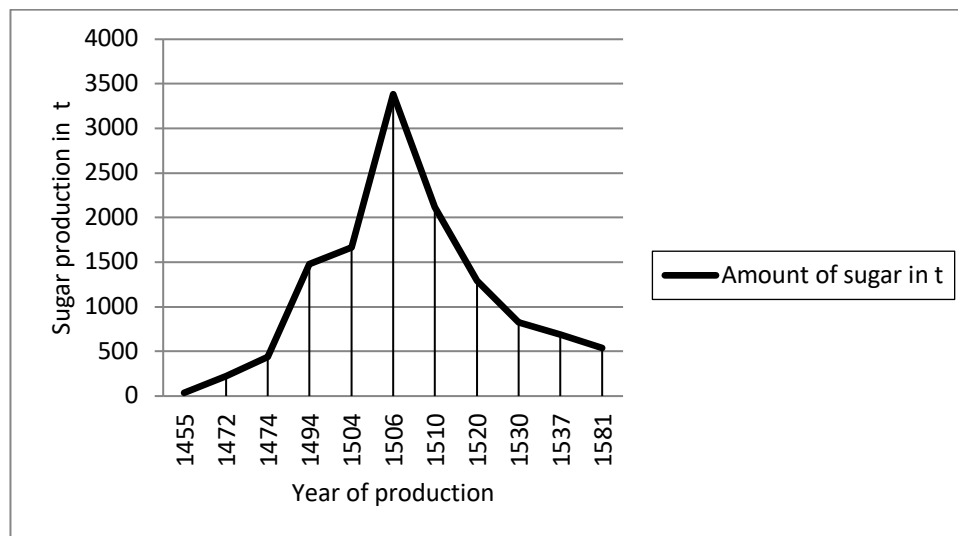


Figure 22: Sugar cane production on Madeira in t, data from Vieira, 2004b

3.3 Implications of sugar cane production to landscape and society

To produce these huge quantities of sugar under the orographic conditions on Madeira a lot of input in terms of workforce and landscape modification had to take place. Most of the sugar cane (*Saccharum officinarum*) had to be grown on bench terraces. The steeper slopes resulted in very narrow terraces with ingeniously constructed dry stone walls. To create a few hectares of plantation ground in numerous terraces had to be constructed. “The first extensive exploration gave way to the intensive use of the soil based on the numerous “poios²⁶” formed by the owners and landowners” (Vieira, 1996). This has led to entirely artificial land surfaces in basically every valley suitable for cane cultivation.

The terraces alone would not have permitted a fruitful sugar production since cane plants need huge amounts of water to grow well. This habitat requirement was satisfied by the construction of extended Levada systems for irrigation. Basically, every terrace had to be

²⁶ The term “poio” is a regional Madeiran term, signifying a man-made agricultural terrace used for crop cultivation.

connected to a Levada to assure optimal water supply for the plants. This gives an idea of the dimension of landscape modifications that took place while the sugar trade grew. Next to the direct implications of cultivation successive indirect implications for land use and landscape development took place. The areas covered by cane plantations could not be used for growing of subsistence produce. Respectively, the alimentation of the growing population had to be secured on less productive terraced fields at higher altitude. The woodlands that covered these higher zones and often steeper slopes were removed to gain additional space for agricultural terraces. Even with these measures Madeira Island did not achieve food self-sufficiency, particularly in terms of cereals like wheat (Nepomuceno, 1994).

Another important factor of landscape modification that came along with the sugar production was the rising consumption of wood for the processing of the raw product in the sugar factories. To extract 1 kg of sugar from sugar cane (*Saccharum officinarum*) approximately 15 kg of fire wood were necessary (Vieira, 2004). To satisfy this rising need of energy the natural wood resources were quickly overused and former woodlands disappeared at large scale. As Vieira (2004) describes: “Madeira got it’s name due to the large woodlands that covered the island upon arrival of the first Europeans. One hundred years later the situation on the south side is very different [...] Within a short time the hillsides above Funchal were bleak“. The same happened in all areas where larger plantations of sugar cane and the sugar factories were established. A near total deforestation of the south side was the biggest environmental change, since the colonization of the Island. In figure 23 the estimated consumption of firewood in the listed years is shown. The shape of the curve is equal to the shape of the production curve of sugar. The maximum value is reached in 1506, when 50,762 t of firewood were consumed by the sugar industry.

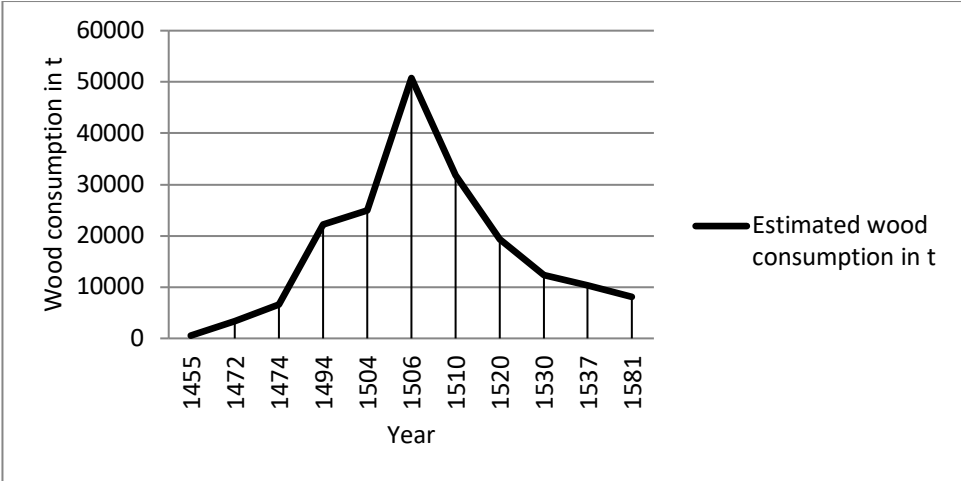


Figure 23: Estimated wood consumption in t, data from Vieira, 2004b

The economic dependency on wood resources resulted in the introduction of fast growing non-native species like pine (*Pinus pinaster*), which contributed further to a modification of the original landscape.

In the first decades of colonization the resident population increased only on a slow rate, but with the beginning and economic growth of the sugar industry this changed dramatically. Wealthy people were attracted as new colonists and, on the plantations, many recently arrived farmers from mainland Portugal received land for cultivation under the terms of sesmaria. Others came as free man to work on the plantations and in the sugar mills of landlords. The labor intense, but very remunerative sugar production made the employment of slave work on the plantations and in the households economically feasible. Nevertheless, most slave-owners had less than five slaves (Vieira, 1996). All these economic, political (offering good conditions to attract people) and social factors contributed to a fast population development. In table two a few exemplary years and the respective resident population are listed.

Table 2: Population development on Madeira Island from 1455 to 1841

Year	1455	1510	1572	1580	1584	1806	1820	1841
Number of residents	800	16000	19000	21800	25000	88000	97000	116000
Source reference	Cadamosto, 1455	Vieira et al., 2001	Silva & Menezes, 1965	Silva & Menezes, 1965	Vieira et al., 2001	Serrão, 1973	Serrão, 1973	Serrão, 1973

The increasing population from the mid-15th to the early 16th century suggests that most parts of the island were colonized in this period. The advantageous locations along the south side and with a preference on proximity to the ocean for short transport distances over the mountainous land were settled in the beginning of the colonization period. The less attractive places, high up on the south side, distant from the important ports and the few more flattish areas in the north of the island have been settled later. Probably the scarcity of subsistence crops required this extension of settlements to these locations of merely marginal production. In the graphic below the most important parishes are listed with the respective century when

they were founded. The first settlers have surely lived and worked there before, but only the dates when the settlement became a parish have been recorded.

Table 3: Foundation of parishes on Madeira Island, data from Brito Martins, 2017

15th century	16th century	17th century	18th century	19th century	20th century
Machico	Funchal Parishes	Paúl do Mar	Curral das Freiras	São Roque do Faial	Jardim da Serra
Funchal	Estreito da Calheta	Serra de Água		Santo António da Serra	Jardim do Mar
Santa Cruz	Água de Pena	São Pedro		Quinta Grande	Ilha
Câmara de Lobos	Estreito de Câmara de Lobos	Camacha		Achadas da Cruz	Santa Luzia
Ribeira Brava	Porto da Cruz				
Ponta do Sol	São Jorge				
Calheta	Arco de São Jorge				
Canico	Seixal				
São Vicente	Porto Moniz				
	Ponta do Pargo				
	Fajã da Ovelha				
	Arco da Calheta				
	Gaula				
	Canical				
	Ponta Delgada				

The rough orographic structure of the island made some preferential places for settlement a logical consequence. Often the small flattish areas by the sea, many times referred to as Fajãs, and the more gentle top sections of the ridges were selected. This is presently still visible in the toponymy of the villages. The various Portuguese designations for ridge, small ridge, small, relatively even area and so on²⁷ have been frequently given to small hamlets. Examples of this are found all over the island. In the following table some exemplary names of such hamlets are listed. In each district there are a number of “Lombos”, some “Achadas” and few “Fajãs” to be found; only one example for each toponym is listed in table 4.

Table 4: Toponyms indicating settlement patterns

District	Lombo	Achada	Fajã
Funchal	L. da Quinta	A. Grande (Monte)	Fajã de Santo António
Santa Cruz	L. dos Morenos	A. de Gaula	Fajã das Vacas
Calheta	L. do Doutor	A. de Santo Antão	Fajã da Ovelha
Ponta do Sol	L. do São João	A. Carramanchão	Fajã e Eiras (Canhas)
Santana	L. do Cedro Gordo	A. do Marques	Fajã da Murta
Machico	L. das Faias	A. (Porto da Cruz)	Fajã dos Rolos
Porto Moniz	L. da Igreja	A. da Arruda	Fajã das Contreiras

²⁷ A ridge in Portuguese language is called “Lombo”, a small ridge is called “Lombinho”, a flattish area in the mountains is called “Achada” and a small, flattish area in the mountains is called “Achadinha”.

São Vicente	L. do Urzal	A. dos Judeus	Fajã da Areia
Ribeira Brava	L. da Apresentação	A. do Boieiro	Fajã das Águas
Camara de Lobos	L. Chão (Curral das Freiras)	Achada (Curral)	Fajã Escura (Curral)

Next to the founding of new settlements the recorded quick population growth from mere 800 inhabitants in 1455 to 16000 inhabitants in 1510 clearly reflects the expansion of the economy, mainly marked by the exponential growth of sugar production, but also by the necessity of increasing the amount of agricultural produce to secure the alimentation of the recently established population. About 70 years later, in 1580 the resident population did not exceed 21800 inhabitants, it had reached a first population maximum. At the time the island offered economic opportunities for a wide range of people from different societal status. Skilled farmers were needed, strong workers for the mills and for construction of agricultural infrastructures and houses, experienced merchants to connect the production to the European export markets and many more. However, in 1580 the resident population is only 1,36 times higher than in 1510, compared to the former population development of 20 times more inhabitants from 1455 to 1510 this suggests that something has changed upon the island's economic situation.

3.4 Decline of early sugar cane market

As shown in figure 22 from 1506 onwards the sugar production on Madeira declined. This decline happened rapidly “within four years the production reached a value that was lower than at the beginning of the century. This situation worsened in the following two decades, when in the captaincy of Funchal, the sugar production declined by 60 %” (Vieira, 1993). The reasons for this remarkable and very sudden decline of sugar production are most probably a combination of internal and external factors. Externally the sugar market had gained new production areas and the price of sugar in the European marketplaces fell drastically. Amongst these new producers of sugar were first the Canary Islands and shortly thereafter São Tomé. The orography of São Tomé Island was much smoother and thus favored a rapid expansion of sugar cane fields. The tropical climate and the abundance of water granted rich harvests and implied much lower input and maintenance costs to producers. Another advantage was the proximity to the African coast and to the Portuguese colony of Angola, which began delivering cheap slave labour to the cane plantations. Production amounts of up to 12,000 t of sugar per annum became a reality.

Only a few years later another great producer became an important force on the sugar market: Brasil. This definitely marked the end of profitable sugar production under Madeiran conditions with regard to available space, orographic situation and the time-consuming irrigation process.

Internal difficulties on the island conditioned the sugar production further. The terrace soils that were planted over several decades in a monoculture cane system had largely lost the high fertility that used to characterize them in the initial phase of cane cultivation (Vieira, 2004). A shortage of fertilizer made a fast recovery of the impoverished soils impossible, only longer fallow periods could help improve this situation. The period of lucrative sugar production on Madeiran terraces was drawing to a close.

3.5 Late agro-economic cycles

As a result from the modified economic situation on the sugar market, the local land use pattern of monoculture plantation agriculture had to be changed, too. In the 1530s the cultivation of sugar cane was abandoned at large scale and the crop was more and more replaced by vines (*Vitis vinifera*), often by Malvasia grapes (Vieira, 2003). Until this period Madeira wine had not reached a high level of supra-regional recognition, even though it had already been introduced in the early phase of colonization, still under the protection of Infante Dom Henrique (Pereira, 1989). The extension of vineyards into the climatically mildest areas along the south side of the island combined with the introduction of a greater variety of grape wines were the decisive steps towards a new economic cycle. Giulio Landi remarks in his report, “that around 1530 wine was exported from Madeira Island”. In the mid-16th century the export of agricultural produce was clearly dominated by wine (Pereira, 1989). In the decade of the 1640s many English families came to Madeira and became involved in the cultivation and the trade of Madeira wine (da Silva & Azevedo de Menezes, 1978a). The most appreciated variety of grape was the legendary Malvasia, giving origin to the sweet Madeira wine. Beside Malvasia there were Sercial, Bual, Verdelho and Tinta grapes being cultivated. The major impulse to extend this culture farther was given in 1660 after the historical alliance between Portugal and England²⁸ had been fortified by the marriage of D. Catarina de Bragança with King Charles II of England (Pereira, 1989). During the following century Madeira wine was

²⁸ The treaty of Windsor, founding the Anglo-Portuguese Alliance, dates back to the year 1386 and is regarded as the oldest alliance in the world still in force. For detailed information on this treaty see Prestage, E. (1934) “The Anglo-Portugese Alliance”

mainly exported by British merchants and the commerce proved to be relatively stable in terms of quantity. Over this period of time the land use situation on Madeira was characterized by vineyards, mainly destined for export and by various subsistence crops such as “herbs, roots and fruits and potatoes and a few legumes” (Passos Vieira, 1991). There is no reference on the production of cereals. Wheat was generally traded for the economically more profitable wine. About 100 years later this would prove disastrous for the Madeiran population. In 1757 the governor Manuel Saldanha de Albuquerque reported on bitter famine of the rural population. In 1776 the port of Madeira was closed to all American shipping, due to the conflict between England and the American colonies. Generally, the activities in the port had slowed down drastically and there was a huge lack of wheat imports that the island needed urgently that never arrived. Furthermore, British merchants in Funchal placed very high prices on the small quantities of wheat that did arrive and lowered the value of Madeira wine by making it a cheap product. In 1779 the governor proclaimed that the island needed more subsistence production, “otherwise will be eternally dependent on the goodwill of its allies” (Passos Vieira, 1991).

There is still reference that “at the end of the XVIIIth Century many vines were planted on the island of Madeira” (da Silva & Azevedo de Menezes, 1978b). The cultivation and trade of Madeira wine prospered until 1851. In 1852 the vineyards were attacked by powdery mildew (*Oidium tuckeri*), that is supposed to have arrived from France. The major part of the Madeiran vineyards was severely affected and the harvest almost did not take place. In 1853 the production was a mere 2187 hectoliters and in 1854 dropped farther to a production of 620 hectoliters. The low yields continued and in 1855 the lowest annual production of 150 hectoliters was recorded. The applied treatment of the vines with sulfur in 1856 brought about a slight improvement and 264 hectoliters were produced. In 1857 the production of Madeira wine rose to 423 hl and continued to recover in the following year to a production of 770 hl. The process of recovery of the mildew disease proved to be slow and in terms of land use huge areas of vineyards were converted into subsistence cropping areas. The high investment costs of treating the vines combined with the low prices on the world market, made food importation a costly economic activity, forcing local farmers to pull out their vines and plant tubers and cereals instead. According to Pereira (1989) even the plantation of sugar cane returned to occupy former vine terraces. Nevertheless, wine production was never fully abandoned and with the introduction of the sulfur treatment and new varieties of mildew

resistant vines the production started to rise again (Rodrigues, 2015). While the introduction of these new vine varieties helped to diminish the danger of mildew caused crop losses, it brought with it a new disease: the phylloxera (*Phylloxera vitifolii*). Phylloxera devastated the vineyards in 1872 in much the same way the mildew had done before. Farmers started to doubt the worthwhileness of reestablishing vine plantations and in many areas they opted for different crops or even for emigration.

One of the main crops that benefitted from this situation of insecure wine production and frequently returning diseases was the banana. On Madeira the banana had a long history of cultivation, in mid 16th century there was banana cultivation on the island, but only in 1842 with the introduction of the locally named “bananeira anã” from China did the production grow (Pereira, 1989). In 1928, a company for fruit export was founded in Funchal, namely “The Ocean Islands Fruit Company”. This promoted the extension of banana cultivation in the lower southern areas of the island, making the banana the predominant cultivated fruit between the towns of Câmara de Lobos and Calheta. In 1952, the banana was cultivated on approximately 750 ha of the most suitable climate, having expelled subsistence crops from this area. This situation has not changed until present day, where the banana remains one of the most important export commodities on Madeira Island. In 2019 Banana was cultivated on 758 ha and a total of 17,597 t of banana were produced (INE, 2019).

3.6 Colónia-contract ownership system and its impact on land use

Besides the above described factors controlling the local market and thus directly modifying the land use situation another very influential factor has not been considered yet: The terms of land ownership. After the initial phase of settlement, where land ownership and land use were regulated by the *Sesmaria* system, in the 16th century (da Silva & Azevedo de Menezes, 1978b) or in the 17th and 18th centuries (Vieira, 2017), when most of the land was privately owned by former *Sesmeiros*, a new system directing the land use was introduced (Vieira, 2017). It was called *Contrato de Colonia* and brought with it very peculiar characteristics regarding the interrelationship between the landowner, called *senhorio*, and the farmer²⁹, cultivating the land.

²⁹ The farmer under the terms of the *colonia* contract would subsequently be called *colono* or, *caseiro*, in case he built a house on the land of the *senhorio*. If the farmer lived on his own piece of land he then was called *mieiro* (Vieira, 2017).

The *colonia* contract appeared, when owners of larger areas of land lost their interest in rural life and were financially able to move to more luxurious locations such as Funchal, Santa Cruz, Calheta, Ponta do Sol, Machico and Ribeira Brava (Pereira, 1989). Valuable crops like sugar cane permitted the leasing of land to farmers who would cultivate it and thus make a living from the payments. By establishing the *colonia* contract farmers and their *senhorios* struck up a complicated economic alliance. The land itself belonged eternally to the *senhorio* and was never sold to the farmers (Vieira, 2017). A farmer when taking over a part of the land, could build a primitive house, a stable and often would need to build dry-stone walls for agricultural terraces. Generally, the infrastructure for reaching the agricultural terraces had to be built by the farmer, too. Paved footpaths and on the steeper slopes, staircases of hewn basalt stone were a prerequisite for cultivation. Every object the farmer had built on the land of the *senhorio* was the farmers' personal possession. This included, next to material improvements, living objects like fruit trees or vineyards (Pereira, 1989; Vieira, 2017; da Silva & Azevedo de Menezes, 1978a). All values the farmer created on the land were called *benfeitorias*.

This complicated alliance between farmer and *senhorio*, with its created mutual dependency generally lasted for the lifetimes of both parties and did not terminate with the death of a contract partner, but was passed on to the next generation (Pereira, 1989). Both contract partners would not have been able to keep up the same standard of living without the other. Although, the farmers' living conditions under the terms of a *colonia contract* were miserable, without land to cultivate crops the survival of the family of the farmer would be improbable. Thus, farmers had no choice other than to stay with their *senhorio*, on whom they were completely depend. This situation only changed from the 19th century onwards, when emigration to the Americas became an option for farmers seeking to improve their living and working conditions.

Without the farmer, the *senhorio* on the other hand would not receive any agricultural produce that he could possibly commercialize or use for private consumption. The farmers' agricultural production guaranteed that the *senhorio* would obtain profit from his land without having to cultivate it. He received half (!) the production of the farmer (Pereira, 1989; Vieira, 2017). Frequently, this has led to very difficult, even reaching life threatening situations for the farming families. A single failed harvest of the main subsistence crops could have caused such an extreme situation (Gouveia, 1932). Furthermore, it was the *senhorio*, who determined which crops would be grown on which part of his land (Vieira, 2017). Often these

crops were cash-crops intended to maximize the income of the *senhorio* without considering the necessity of the farmers' family alimentation. A farmer was not allowed to harvest main crops without prior permission of the *senhorio* or an authorized person³⁰ acting in his name. Furthermore the *senhorio* received from his dependent farmers other necessary goods for daily life like firewood for heating and cooking (Gouveia, 1979; Pereira, 1989).

In case the *senhorio* wished to dismiss a farmer, he would have to pay for the *benfeitorias* the farmer had constructed. It is reported by Pereira (1989, p.502-503) that farmers were only allowed to build valuable constructions on the land with prior approval of the *senhorio*. When a farmers' family had fallen into disgrace, any improvement of their personal living space was obviously denied by the *senhorio*.

This interdependent system of the *colonia* contract with the far-reaching decisive power of the *senhorio*, brought with it a land use system that was often more oriented towards immediate profit, rather than towards sustainability with a wide spectrum of crops and the maintenance of soil quality. It also caused the expressed stratification of crop distribution observed on the island. Whenever a profitable cash-crop grew well within a specific altitudinal belt, it quickly became a monoculture. In most cases farmers were allowed to plant subsistence crops on higher slopes where cash crops would not develop in a profitable way. The farmers took care that these parts of land would be as productive as possible and undertook great efforts to secure soil fertility. The monetary interests of the *senhorios* were the main driver for the selection of crops and as such for the land use in general.

The system of *colonia* contract persisted into the 20th century; it was abolished only after the Carnation Revolution, which took place in Portugal on the 25th of April 1974. In the process of turning the Madeira Region into an autonomous region within Portugal the *colonia* tenancy contract was abolished in the year 1977 with the approval of law n.º 13/77/M on the 18th of October (Vieira, 2017).

3.7 Land use history of Ponta Delgada

The settlement of Ponta Delgada area took place after Manuel Afonso da Sanha, a settler from the city of Braga, arrived. He and his family received land for colonization in 1466 or 1469

³⁰ When a *senhorio* owned huge parcels of land he generally employed a land overseer (locally called *feitor*) to assure that the land was worked in the way he had ordered (Gouveia, 1979).

under the terms of sesmaria³¹. According to the law of sesmaria dating from 1375, modified in 1436 under king Dom Duarte I, he was obliged to turn the woodland allotted to him into arable land within ten years (Vieira et al., 2003). To be able to take the vast woodland into cultivation, farming families from mainland Portugal were encouraged to move to Ponta Delgada and cultivate the land in his name. Manuel Afonso da Sanha became the founder of the parish of Ponta Delgada (Mendes, 2008). The construction of the first chapel dedicated to Senhor Bom Jesus was completed during his lifetime (Vieira, 1997; Ribeiro, 2005). The initial processes of clearing land and initiating agricultural production was started and coordinated by Manuel Afonso da Sanha. Thus it can be stated that the human modification of the natural environment of Ponta Delgada area began around 1470. With its relatively even surface the headland of the present village of Ponta Delgada was perfectly suitable for agricultural use and was quickly cultivated. Slowly, the cultivation of new land proceeded towards the higher and less favorable parts of the parish.

3.7.1 Plant production

In the early decades after colonization, the main goal was to establish a local resident population and to reach a high degree of food self-sufficiency for the island population. Therefore, the production of staple foods was a necessity. The most important crops were cereals, particularly wheat. Quickly, the production was sufficient to satisfy the needs of the resident population and an even larger part of the production was available for export to mainland Portugal (Leça, 2011; Nepomuceno, 1994; Verissimo, 2014).

Ponta Delgada and the Lombadas da Ponta Delgada closely followed the economic cycles, which determined the islands general agro-economy. During the 16th and early 17th centuries, sugar cane cultivation was an important part of the local economy. Since the climatic conditions in the north of the island are not as favorable as in the southern parts of Madeira Island, cane fields could not be established profitably at altitudes above 250 m a.s.l. This confined production to the places of Ponta Delgada itself, Lombinho and the lower parts of

³¹ The distribution of land from the Portuguese crown to settlers was originally introduced in 1375 to promote the cultivation of land not used for agricultural purposes. A settler receiving land under the terms of sesmaria had to take it into cultivation within a timespan of ten years; he did not have to pay any kind of rent to the king. Cf. *História e autonomia da Madeira*, Vieira, Alberto in cooperation with Abel Soares Fernandes, Emanuel Janes and Gabriel Pita, 2003. The kingdom benefited from this method of land allocation by imposing a tax on the products from the land (Abreu de Sousa, 1994). The system of sesmaria was a fair system of land allocation, since the payment was imposed on the product and not on the land. Possible crop failure would affect both parties equally. Cf. *História Rural da Madeira A Colónia*, João José Abreu de Sousa, 1994

Primeira, Segunda and Terceira Lombada. Mainly the headland of Ponta Delgada and the plateau of Primeira Lombada were used for the cultivation of cane. This allowed farmers to produce great amounts of subsistence crops such as wheat and rye in the upper parts of the parish, securing local food supply and excess production for the local market. In the southeastern and central southern parts of the island food production was reduced to a minimum in order to have the highest possible production of cane. The northern areas like Ponta Delgada became known as “supplying zones of wheat of the land”³² (Abreu de Sousa, 1994). By the end of the 16th century and at the beginning of the 17th century, the Madeiran sugar market suffered massively from the rising foreign business competition from African markets, such as São Tomé and Fernando Pó, and the American markets such as Brazil and the Caribbean Islands. The declining profits derived from sugar cane production forced land owners to invest in a different market crop. Vines had been grown successfully on the island since the early years of settlement and have gained fame abroad, mainly in Britain and France (Vieira et al., 2003). Thus, many cane fields in Ponta Delgada were converted into vineyards and most Senhorios³³ built grape presses, the *largares*. In the 17th century Madeira wine became famous in the colonial parts of the Americas, in São Tome, on Cape Verde Islands and in the Orient (Vieira et al., 2003).

In Ponta Delgada the dual use of the land persisted, in the good locations at lower altitude vineyards replaced the sugar cane and in the upper parts of the parish basically subsistence crops were planted. The vineyards allowed planting other crops with short vegetation periods in between the vines after leaf shedding until leafbudding (Abreu de Sousa, 1994). This system of multiple cropping improved the food supply situation of the local resident population. Nevertheless, Madeira island including the northern parishes, suffered several times under periods of famine.

In 1757 the governor of Madeira, Manuel Saldanha de Albuquerque reports, that “in various parts of the island peasants live on roots of herbs and fruits and drink tea of prickly goarse flower” (Aires dos Passos Vieira, 1991). One of the main causes for the pronounced dependency of Madeira Island on wheat importation was that the most productive soils were dedicated to cash crops and only the marginally productive areas were destined for food

³² In Portuguese it is common to refer to a local product as a product of the land.

³³ A Senhorio was a land owner, who rented land to tenants and in turn received a certain percentage of the production. Generally, the Senhorios decided which crop the tenant farmers had to plant on which part of the land.

production. As long as the wine trade flowered, wheat was basically imported from Great Britain in exchange for wine. When, for economic reasons fewer merchant ships came to Madeira, the supply of staple foods was endangered (Aires dos Passos Vieira, 1991). In 1777, another period of famine devastated the island. The senate of Funchal declared on 14th July 1777 that no merchant would be allowed to export any wheat, rye, corn or flour. In Ponta Delgada and in the Lombadas the famine was not as bad as in Funchal, since the rural population had more possibilities to plant food crops in difficult times. Nevertheless, in 1779 catastrophic circumstances which led to people dying from famine were reported all over the island (Aires dos Passos Vieira, 1991)³⁴. The economy slowly stabilized until the first crisis in Madeira wine production arrived in 1852 and farmers again changed cash crops and reintroduced sugar cane by the end of the 19th century (Vieira, 1997; Pereira, 1989). In 1858 the first modern sugar cane mill opened in Ponta Delgada and in 1861 a second mill was installed (Gouveia, 2008; Vieira, 1997).

In 1907 approximately 1095 t of sugar cane were pressed in the municipality of São Vicente, which represented 2.4 % of the islands production. In 1911, the mills in Ponta Delgada were expropriated by the government and the production began to decline, until in 1943 mere 14.5 t of cane were harvested. Two decades later the government launched a cane support program, which increased cane production to 6492 t in 1966.

Besides sugar cane another product of the land gained more and more importance in the second half of the 19th century: the basket willow (*Salix viminalis*). After cutting the long and limber sprouts off, these are placed in boiling water to be able to easily strip the bark off. In most cases the treated raw material was used for wicker work in the private households but, small quantities were also exported. The art of wicker work was a valuable alternative to agricultural production since its products, like baskets, chairs and tables could be sold at the markets and to tourists, which raised the meager income of the rural families. Additionally, the basket willow grows well in humid spots and does not have high habitat requirements regarding soil quality. Consequently, it was often planted next to small brooks and on margins of terraces, in such a way as not to occupy valuable space on the agricultural terraces.

³⁴ Since Madeira and Great Britain were allies, on July 5th 1776 Funchal port was officially closed to ships with origin in the United States. The conflict between Great Britain and the American colonies caused a severe loss in economic relations and trade between Portugal and both Great Britain and the American colonies. Cf.: *Elementos para a história da vida quotidiana da Madeira na governação de João Gonçalves da Câmara Coutinho*, Aires dos Passos Vieira, 1991



Figure 24: Basket willow that has been used regularly

Next to cash crop production the agricultural area of Ponta Delgada has been characterized by subsistence agriculture. Over time the crop variety that was cultivated has shifted with the introduction of new crops. In the early years of settlement the predominant crops were wheat and rye (Nepomuceno, 1994). Additionally, various legumes and fruits were cultivated (Abreu de Sousa, 1994). The profoundest change took place when new crops, so far unknown on the European continent, were introduced from South America. The introduction of potatoes, sweet potatoes and taro substantially improved the survival of families. These crops adapted well to the mild Madeiran climate and provided rich harvests. Furthermore, the space occupied for their cultivation extended the agricultural area used up until then, since taro grows best in humid locations and was planted next to water lines on soils that were too humid for the already known and cultivated crops. In the 20th century a huge variety of mainly subsistence crops was produced in the Lombadas da Ponta Delgada. Vieira (1997), Ribeiro (2002) and Ribeiro (1985) reported on the cultivation of the following cereal crops: wheat (*Triticum sativum*), rye (*Secale cereale*), oats (*avena sativa*) and barley (*Hordeum vulgare*). Amongst the legumes, beans (*Vicia faba*), lentils (*Pisum sativum*), carrots (*Daucus carota subsp. sativus*), onions (*Allium cepa*), corn (*Zea mais*) potatoes (*Solanum tuberosum*), sweet potatoes (*Ipomoea batatas*), taro (*Colocasia esculenta*), beet (*Brassica napá*), fodder cabbage (*Brassica oleracea*), cauliflower (*Brassica oleracea var. botrytis*) and red beet (*Beta vulgaris*) were common. Cultivation of various types of fruits extended the food production (Serrão, 1992 and Natividade, 1947).

3.7.2 Animal production

The second most important sector of agrarian production was animal husbandry. It was common practice in the Madeira region to breed livestock in the higher parts of the agriculturally used areas, where there would not be competing with other types of land use (Ribeiro, 1985). Animal production included cattle, pig, goat and sheep. While in most Mediterranean countries the production of small livestock widely outnumbered the production of cattle, Madeira Island was known as a strong cattle-producing area. In 1940, there were 27.000 registered head of cattle. In 1942, this number was corrected to 36.000 head of cattle (Ribeiro, 1985). The parish of Ponta Delgada was a good example for the common practice of separating plant from animal production. On the highly productive and easily accessible terraces of Ponta Delgada headland animal production was limited to a minimum, while the higher parts of the parish were characterized by cattle farming. In the Lombadas da Ponta Delgada and Feteiras 634 heads of cattle were registered in 1893 (Vieira, 1997). Unfortunately, recent statistical information is presented on a less detailed scale: the villages of Boaventura, Ponta Delgada and São Vicente are condensed to the unit of the municipality of São Vicente. In 1955, the municipal register gives the number of 2209 head of cattle. In 1986, there were still three registered cream centrifuge places, one in Primeira Lombada, a second one in Terceira Lombada and another one in Ponta Delgada, serving approximately 200 cows (Ribeiro, 1985). Cattle was described by Ribeiro (1995) as an “essential part of the rural life on Madeira”. The production of milk allowed the farming families to have a modest income on a regular basis by selling the surplus production to the local dairy farm, where mainly butter was produced. A by-product of butter production was whey, which returned to farmers, who used it to feed their pigs. A valuable by-product derived from cattle was manure, the predominant fertilizer for agricultural terraces.

Other important livestock kept in the parish of Ponta Delgada were pigs, often kept near the houses and fed with potatoes, whey, sweet chestnuts, food leftovers and remains of terrace products such as sweet potatoe leaves or fruits peels. Ribeiro (1985) and Vieira (1997) mention that the basic supply of fats for the local resident population was secured by their pork production. It was very common amongst the rural population to keep chicken, too. They provided eggs, feathers and meat to the families. In rare occasions, people also kept sheep and goats close to the homesteads, but mainly they were kept on high pastures in the mountains. This practice allowed for the most efficient use possible of the sparse resources in

these locations. Apart from using deforested hillslopes or ridgelines as pasture areas, the remaining forest was an exceptionally important factor in the local economy.

3.7.3 Forestry

Until present days, the parish of Ponta Delgada has huge woodlands covering mountains, steep ravines and gorges. These rich wood resources were used since the beginning of settlement. Next to agriculture, forestry was one of the main sources of income and played a substantial role in daily life. The export of wood from the parishes in the north has already been reported in the 16th century (Pereira, 1989). During economically difficult times, the population had to rely on the resources of the mountain woodlands.



Figure 25: Mountain woodland around Ribeira da Camisa valley

The Laurisilva provided a huge variety of indigenous woods of outstanding quality. The indigenous Madeira Mahogany (*Persea indica*) with its warm reddish, brown wood was highly appreciated for furniture building (Da Silva & Azevedo de Menezes, 1978a) and even more famous for naval construction (Frutuoso, 1590). The timber of the Stinklaurel (*Occotea foetens*) was used from an early period on. Gaspar Frutuoso (1590) referred to its qualities for planks, as roof timbers and for the construction of sugar crates. Furthermore, he described it as most commonly used fuel in the sugar cane mills. The Madeira Beefwood (*Heberdenia excelsa*) is renowned for its hard wood and found application in vine presses, honey extractors and as treenails in construction. The Canary Holly (*Ilex canariensis*) with its hard wood also

served as treenails and was used in the construction of pieces that would be subjected to strong forces (Pereira, 1989).

Many species were used for domestic life, too. Wood was the main source of fuel for families and found application in cooking and heating. Usually small branches that could be more easily transported, were preferred. The wood from Tree heath (*Erica arborea*) and Besom heath (*Erica platycodon*) met this requirement and had very good burning characteristics. The local population cut this type of wood in the highest vegetation belt (cf. chapter 2) and left it to dry in sheltered places, such as under overhanging rock walls or in small caves, before it was carried down the steep trails into the valley. The residents of the Lombadas da Ponta Delgada interacted strongly with the surrounding Laurisilva and Heather woodlands.

4 Micro-toponymy in the mountain region of Lombadas da Ponta Delgada

4.1 Toponymy studies and function of toponyms

The study of toponymy has been defined in the Encyclopedia Britannica as “the taxonomic study of place-names, based on etymological, historical, and geographical information”. To the authors “a place-name is a word or words used to indicate, denote, or identify a geographical locality such as a town, river or mountain” (Britannica, 2015). There are two broad categories of place-names: habitation names and feature names. Habitation names denote a locality such as a homestead, village or town, while landscape feature names can be subdivided into hydronyms (water features), oronyms (relief features) and places of natural vegetation growth (Britannica, 2015) .

Traditionally the study of toponymy has been a tool used by scholars of humanities, especially in the field of linguistics. As stated by Tichelaar (2002) “to linguists specializing either in the historical or genealogical aspects of specific languages, or in the taxonomy of languages in general, toponyms contain a treasure of ancient language elements which allow them to underbuild their theories or test their hypotheses.” Another important application in the field of linguistics is the analysis of status, frequency of use and function of toponyms. This often leads to the field of history and politics. A popular example of intentional change of local names occurred in most colonized areas of the globe: introduced names in the language of the colonizing country have replaced Indigenous ones. Well documented examples of this change in status and frequency of use are found in Anglophone, Francophone and Lusophone Africa (Jacob, 2011).

Politically intended renaming of places has been a frequently occurring phenomenon. Radical political changes often resulted in renaming of places that had a memorial function within former governments. On the island of Madeira, several buildings and infrastructures used to honor the “Estado Novo”³⁵ system and its leader António de Oliveira Salazar, were renamed

³⁵ The Estado Novo regime in Portugal began in 1932, when António Oliveira Salazar was named Prime Minister. In 1933, a new constitution was introduced and turned the regime into an anti-parlamentarian, authoritarian regime. Salazar continued to be Prime Minister for 36 years, until he left the government due to health reasons. In Portugal, this period is also called “Salazarismo”. Salazar’s successor Marcello Caetano continued with the established political system until the canation revolution on 25th April 1974. Cf. Monteiro, Nuno Gonçalo; Ramos, Rui and Vasconcelos e Sousa, Bernardo (2012): “História de Portugal”.

after the Carnation revolution in 1974, which brought an end to the “Estado Novo” system. In the village of Serra de Água, a hydroelectric power station was named “Central Salazar” in honor of the regime under which it was built. After the end of the regime its name was modified to “Central da Serra de Água” thus changing from an ideologically influenced name to a mere geographical reference. In times of war, this phenomenon is even more expressed, in a study on critical place names by Rose-Redwood *et al.* (2009) US Army Majors list familiarity with the place, better navigation and communication as the main reasons for renaming places. Intentional changes in the landscape of names are a common feature over all times and places. It seems that names have a strong impact on people and their unconscious feeling of familiarity and safety. By giving a name to a place it turns into something known, and something an individual can refer to when communicating with other individuals. Hausner (2008) explains that “names have a community building function in society”. Since members of small groups of people use place names on local level, the names are a shared identity of this group. In political context it is also a way of establishing a kind of property right onto a place. The toponym is used as a signal of possession and ownership.

Lately the study of toponymy has been extended from the traditional applications to an even wider field of research. Place names contain a huge amount of historical geographical information. It is not only a designation for a certain feature or a certain area, but often has descriptive character. When people created a name they often relied on existing landscape elements and thus created a descriptive portrayal of the landscape during the time of naming and using landscape resources. When landscapes and the use of natural resources change, names remain for a certain period of time. They reflect a landscape that has undergone severe changes since then, not only by expansion of the interaction between humans and landscape or inversely by the abandonment of formerly performed activities but, also by transformations provoked by natural hazards like floods, landslides, forest fires or storms.

Toponyms perform an archive function, guarding past landscape structures, features and functions. For environmental historians this permits an additional way to access information on landscape development over time thus allowing a more detailed understanding of landscape dynamics and shifting intensities in human-landscape interaction and perception. In 2013, Lopes Leiva used toponymical studies for geobotanical and biogeographical research. He used place names as an “indicator able to support the reconstruction of progression and regression trends in plant covers”. In natural habitats, the formerly attributed names often

describe a type of vegetation that used to be present at the places and that might have been changed by human activities. Comparing the actual vegetation cover with the information on past vegetation types, opens an access to the changes that occurred since the initial naming of the features. In landscapes that experienced strong impacts due to territorial expansion of urban areas and infrastructure, the old names are a record of the vanished landscape.

4.2 Toponymy and micro-toponymy in Lombadas da Ponta Delgada

The island of Madeira is a very special place for investigation of toponymy and the information transmitted through the place and feature names. Since the island has been uninhabited prior to Portuguese settlement in the early 15th century, the first place names on the island were given by the discoverers and during the period of settlement by landlords and settlers. The toponyms have been passed on from generation to generation. The successive extension of the terraced agricultural area and the rising demand for woodland resources caused the number of toponyms to grow steadily. The origin of the attributed toponyms has been recorded partly in written sources and mainly by oral transmission from one generation to the next. According to Ross's definition (in Nash 2012) toponymy is called pristine, when "we are cognizant of the actual act of its creation". Many Madeiran toponyms used in official sources like maps fulfill this requirement. Local toponyms used and known exclusively within small communities are known as micro-toponyms. Usually the ancestors of the actual inhabitants have created them. The stories that gave birth to some of the place names have been transmitted as oral history, many times over several generations, and are almost always present in the memory of the inhabitants. Nash (2012) extends pristine toponymy as "knowledge (that) is retrievable through oral history in the locations where the place names exist", the large majority of toponyms on Madeira Island can be regarded as pristine toponyms. The density of information on the past landscape situation is therefore very high and remarkably detailed.

The farming communities of Ponta Delgada and Lombadas da Ponta Delgada have created a rich heritage of local toponyms. In the mountain territory used for economic activities such as logging, animal pasture or crop production toponyms were attributed to numerous landscape elements. They served as geo reference points of the local rural population. Within the mostly forested mountain territory, characterized by very rugged and abrupt surface structures, the

naming of landscape features was of utmost importance so as to clearly communicate positions amongst the farmers.

Furthermore, the outstandingly high diversity of natural structures connecting or dividing different mountain zones required a huge number of place and feature names to clearly refer to specific landscape elements, such as natural springs, watercourses, tiny passages within rock walls, trees of interest or boundaries of properties. Peasants successively extended the local micro-toponymy into the entire mountain area of Ponta Delgada and the Lombadas da Ponta Delgada. The farmers and shepherds attributing the new toponyms knew the mountain areas precisely, every single feature of the landscape was known to them. Many times, not only descriptive toponyms were attributed, but also observations, property possession and past events entered the landscape of place names.

Studying this formerly used network of geographical names reveals otherwise inaccessible information on former land use and exploitation of natural resources. Assuming that people attributed names to places that they visited not only once, but several times or even on a daily basis suggests that named areas used to have been significantly influenced by human activities. Some areas might have been just places of passage that needed to be communicated, while others were used more intensely like for logging or even for agricultural purposes. Consequently, the density of toponyms in a mountain landscape reflects the level of human interaction with the respective landscape.

4.3 Methods

The first step approaching local toponymy of a region is by researching for existing topographical maps displaying the names. Generally large-scale maps are more appropriate since their resolution is higher, but sometimes certain toponyms are shown on one map and do not appear on another one. This is not always linked to the scale, but to factors like the thematic focus of the map, the accuracy of field work, the experience and the disposition of the cartographer to research for common, local place names. Due to various reasons, these names might have changed over time, giving origin to various toponyms for one and the same place in the landscape. Therefore, studying historical maps of different periods can uncover such changes in toponymy.

To address local toponymy in Lombadas da Ponta Delgada and surrounding mountains studies of historical maps in the Arquivo Histórico Regional da Madeira (regional, historical archive of Madeira) have been carried out. Furthermore, literature study of traditional songs, poems, travel reports and guidebooks from the 19th and 20th centuries have been taken into account. The historic-romance “*A Cangá*” by Horácio Bento Gouveia, an author who grew up in Ponta Delgada and who critically described the social situation of peasants in the Lombadas, has provided detailed information on locations within the Lombadas da Ponta Delgada.

An additional source of information was the official military map of Madeira Island. The most recent topographical map edited by the Instituto Geográfico do Exército (2003) has a scale of 1:25,000 displaying the most important designations for landscape features like mountains, ridges, rivers and settlements. The preceding military map edition for Madeira dates back to 1974, also displaying the island at a scale of 1:25,000. These two maps have been compared to identify changes within this period, which in Portugal brought many modifications in toponymy due to the political shift from dictatorship to democracy.

In 2008 the former schoolteacher Duarte Mendes from São Vicente, who gave lessons in Ponta Delgada during decades, felt the necessity to study the toponymy of Ponta Delgada. At that time even roads, driveways to private houses and public squares had no signposts indicating their respective designations. Mendes (2008) points out that “the near inexistence of designations, [...] creates much confusion even amongst the resident population.” In this work he focused mainly on the assessment of mainly the settled area with its multiple features like roads, levadas, public buildings, and water storage basins, but does also mention and partly explain mountain toponymy in the area. The assessment has been executed with the utmost care and dedication. Nevertheless, the mountain toponyms only permit rough localization within the landscape since there are no maps or GPS-coordinates available. Even for the experienced non-resident hiker it continues to be a challenge to find the exact geographical position of the toponyms. Only with the help of a local, who knows the place names and their location it is possible to detect the exact position of the named features in the landscape. The knowledge of the exact location of the toponyms is crucial for the maintenance of local micro-toponymy and the information on landscape history that it contains. Therefore, the assessment of the geographical localization of the toponyms described by Mendes (2008) was a basic task for the understanding of the spatial extension of human-landscape interactions.

The studies of the above-mentioned sources only revealed a fragment of the rich micro-toponymy existing in the mountains of Ponta Delgada and the attached Lombadas region. Since most of the information has never been written down, but passed on from generation to generation in the form of oral history the only way of assessing this high-resolution proxy of landscape and forest history is by interviews with local residents of the area. Berleant-Schiller (1991) emphasized the special contribution given by native informants: "Far from being misinformed, local residents are the only sources of local speech, oral tradition and place names that are not on maps or that differ from those maps." To collect this local micro-toponymy, only retained and known by older local residents who still remember the times when mountain resources had to be exploited for family survival, approximately 40 personal interviews were conducted with local residents from the Lombadas area, Ponta Delgada and São Vicente.

For the interviews, informants of different age groups and gender have been chosen to uncover a maximum of knowledge on place names. Members of the older generation have a remarkably detailed local knowledge on place names. Amongst people of younger age this knowledge has diminished noticeably. Over the last decades, abandonment of marginal terraces at the foot of the steep slopes of the ridges facing towards Topo has been observed in all Lombadas villages and in the southern parts of Ponta Delgada. This abandonment combined with natural succession processes taking place affects the indigenous knowledge on toponymy: The new generation does not use the land anymore, therefore losing the need to exchange information with others on land related topics regarding this geographical area. When this refined network of names becomes superfluous for daily communication, it is no longer passed on to the next generation. Another factor playing a key role on how familiar people were with this local network of place names were the professions they executed. A few decades ago, hiking was not a typical pastime in northern Madeira Island and mobility was less than it is in modern days. People who knew best about the land in the mountains and its designations were the ones who went there for professional reasons like shepherds or lumberjacks, who had to cover long distances on their typical work days. To capture as much of the common local toponymy as possible especially these professional groups were interviewed. They are the only available source to retrieve the motivations that drove people to use the resources of the land in a specific way and often were able to explain how with which tools people used it. Many times, they could add the reason why a toponym was

attributed to a place and explain the origin of the names. Most of the other informants were farmers, many of them still owning land in marginal areas on mountain slopes. They could provide even more detailed information on former land use and its influence on place names in the Lombadas area.

The duration of the interviews varied from several minutes to several of hours. For the interviewer it is very important to evaluate a possible candidate in a short period of time. Since the focus of the interviews covered two areas, subsistence agriculture and micro-toponymy of the region, nearly every inhabitant could add valuable information, nevertheless the knowledge on place names was very different from one informant to another. In case a person did not know about the topics or had other reasons for not sharing knowledge, interviews were kept short. Farmers working on their fields had limited time available to answer questions, thus only permitting short interviews, too.

To uncover the historical and actual place names and their significance the interviews are a good approach, but to record their precise GPS-location and to understand, which network of trails formerly existed in the mountains the theoretical approach had to be based on practical field excursions. Four informants³⁶ agreed to go to the mountains to show the exact location of the places they described. In the field they also indicated other trails that we could not cover together, be it due to time reasons or to terrain conditions, which were not suitable for elderly people to pass, these have been personally covered in later occasions.

The information given by informants has been verified by asking other interview partners on the same names and in some cases by group interviews where participants correct each other.

³⁶ The most important informants, who supported this research on various hikes into the mountains of Lombadas da Ponta Delgada are:

- a) The farmer, shepherd and stonemason José Carlos Fernandes dos Santos, who has a profound knowledge on local toponymy and the terrain. He is resident in Primeira Lombada, where he also grew up.
- b) The former mayor of Ponta Delgada João Caldeira de Jesus provided next to local knowledge valuable information on ownership of terraces and woodland. Presently he lives in Primeira Lombada.
- c) The farmer Ernesto Martins Fernandes, a resident from Lombada do Meio (between Primeira Lombada and Segunda Lombada), has the most detailed knowledge on microtoponymy and knows the mountains like few other people in Lombadas da Ponta Delgada. His father was an overseer of the local landlord and advisor for the tenant farmers working the land. As a young man he often accompanied his father which gave him a meticulous knowledge regarding all cultivated parts of the land. Furthermore, he had goats up on the mountains himself and knows most of the origins of the names.
- d) The passionate hiker and mountain man Cipriano Bernardo, resident in Funchal. He loved to share his knowledge on local toponyms and their precise location and often was able to explain the origin of the respective names.

In a second step the place names have been compared to the ones listed in “Perfil Toponímico de Ponta Delgada” (Mendes 2008).

The gathered primary data have been interpreted and categorized into feature classes to analyze the commonness of features. The frequency of occurrence of certain feature classes served as base for the interpretation of the importance of certain resources for the local population. For spatial distribution and density analysis, the recorded coordinates of the toponyms have been introduced into a GIS, thus allowing quick visualization of their distribution in the landscape. For a more detailed analysis on the importance of landscape areas for the needs of the local population, the density of toponyms has been calculated applying the point density function of the spatial analyst set of ArcGIS.

4.4 Results

4.4.1 Distribution of toponyms in the landscape, the motivations for naming of places and their significance

The toponyms uncovered and located in Lombadas da Ponta Delgada mountain area are presented in figure 26. Some toponyms are located on or close to the polyline feature “border of research area”. Since the border of the research area follows the ridgelines framing the Lombadas towards east, south and west, these are at the same time the main footpaths thus having quite a number of toponyms along or close to this line. These places have played an important role for the inhabitants of the Lombadas and thus have been included into the map. The settlement areas of Primeira Lombada, Segunda Lombada, Terceira Lombada, Lombinho and Caminho do Bardo have been excluded from the investigations on toponymy. In the map these areas have been included under the designation of “settlement area” to clearly differentiate them from mountain areas, where no toponyms have been attributed.³⁷

³⁷ For detailed information on the toponymy of the settlement area of the Lombadas da Ponta Delgada Mendes (2008) provides lists of the existing toponyms, explanations of their meaning and village maps with the location of the toponyms.

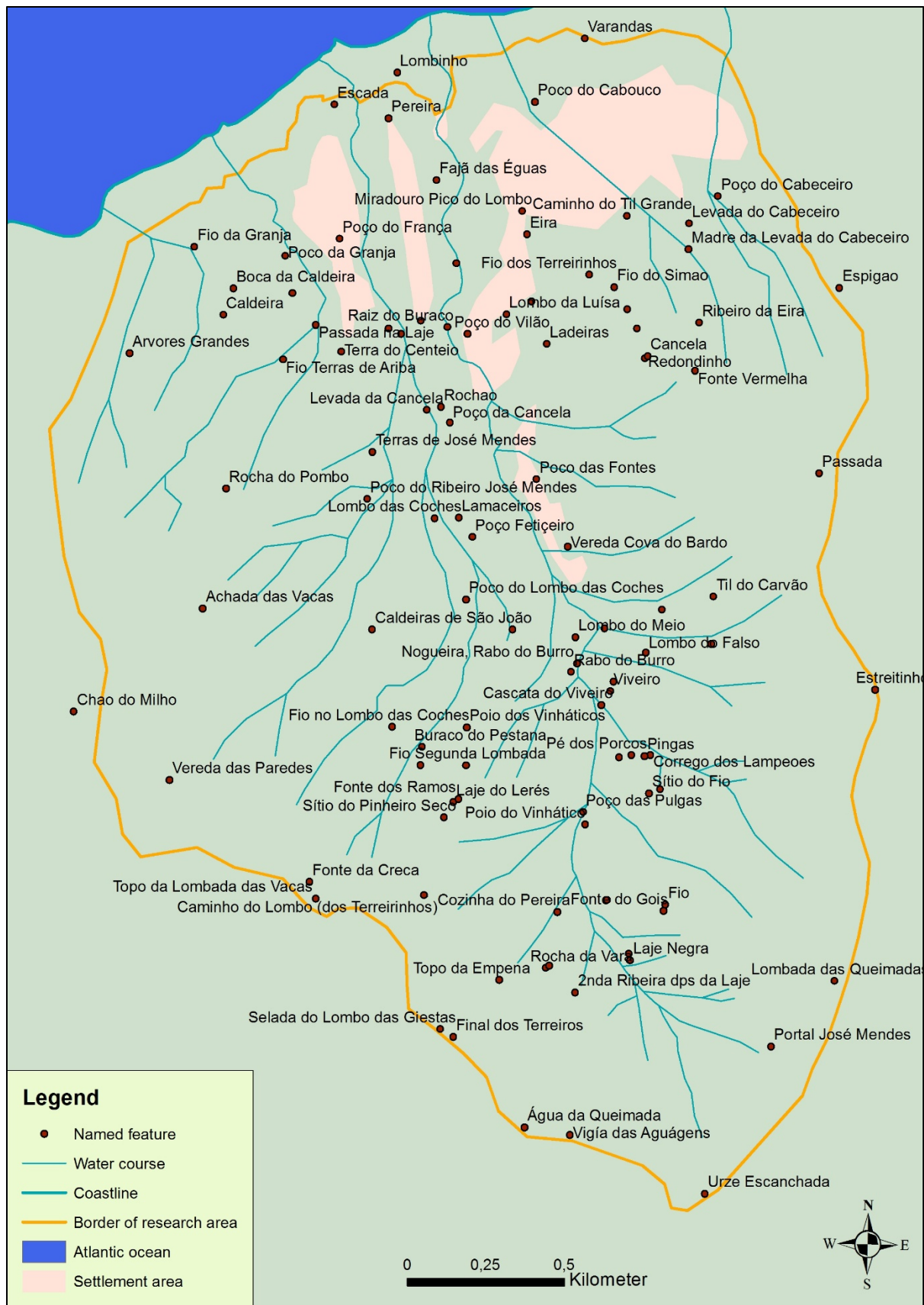


Figure 26: Distribution of Toponyms in Lombadas da Ponta Delgada.

There are 113 recorded toponyms distributed over the mountain area of the Lombadas da Ponta Delgada (Fig. 27). The distribution of feature names shows that, basically all of the mountain area has been named and thus used in some way by the local population. Only the extremely inclined sections of the mountains have not been named. In the western part of the research area, between “Arvore Grandes” and “Chão do Milho” a small plateau, named Lombada das Vacas (mountain ridge of cattle) is located. It shows signs of past human activities and has been partly deforested in former times. Since there were footpaths connecting the northeastern settlements of São Vicente valley, namely Sítio dos Cardais and Pé do Passo with Lombada das Vacas and another trail connecting from Fajã da Areia (small coastal settlement between São Vicente and Ponta Delgada), it is probable that the strongest influence onto toponymy was by the inhabitants of São Vicente valley. Mendes (2008) points out, that the richness of resources such as wood, water and pasture area found at Lombada das Vacas was reason for endless controversies between inhabitants of Ponta Delgada and São Vicente. The informant Ernesto Fernandes explained that calves were carried on shoulders up the steep footpaths from Lombadas area and were raised on the plateau. When it was time to slaughter the adult cattle people gathered and the animal was slaughtered on the mountain and the pieces of meat carried down again on shoulders since the terrain did not permit to bring the animal down the mountain to slaughter in the village.

Peasants often attributed toponyms linked to the economic activity carried out at the respective places. In Lombadas da Ponta Delgada are a number of examples of place names that are, like the one mentioned above, directly related to farming activities or logging:

For example, *Chão do Milho* (flattish area of corn) and *Terra do Centeio* (land of rye) indicate former grain production, whereas *Pereira* (pear) and *Sítio da Nogueira* (place of the walnut tree) indicate local fruit and nut production. The attribution of such activity related toponyms conserved the land use practiced at the respective places by past generations. Often a few years of abandonment of agricultural or forestal activities are sufficient to turn a place inaccessible. The rapid growth of species like bramble (*Rubus spec.*), bracon (*Pteridium aquilinum*), eupatorium (*Ageratina riparia*), white eupatorium (*Ageratina adenophora*) and even shrubs like wax myrtle (*Myrica faia*), soft broom (*Genista tenera*) and prickly goars (*Ulex europaeus*) quickly closes footpaths. After a few years without people passing and cutting parts of the vegetation back the paths change beyond recognition. The same happens to former pasture areas, logging areas and even agricultural terraces, the only reminder of the

former function of these areas are their toponyms, which outlive the period of human land use.

Other examples are names describing natural features that people encountered. Mendes (2008) lists the toponym *Caminho do Til Grande* (footpath of the huge Madeira Mahogany tree) as a street name in Ponta Delgada. The informants José Carlos Fernandes dos Santos, Ernesto Martins Fernandes and Cipriano Bernardo mentioned and showed a formerly well-known path going along a ridge with many pine trees, that is locally referred to as *Lombo dos Cedros* (ridge of pine trees). On the footpath ascending from Primeira Lombada to Coroa do Topo (*Caminho do Lombo dos Terreirinhos*) there is a fountain named *Fonte Vermelha* (Red Spring). The rock, where the water comes out is tuff stone and has an intense red color, having given origin to the name (fig. 27).



Figure 27: *Fonte Vermelha* at the *Caminho do Lombo dos Terreirinhos*.

Assuming that people tended to attribute names to places that they frequented not only once, but several times or even on a daily basis suggests that named areas had been significantly influenced by human activities. The intensity and frequency of usage has varied from place to place. Some areas might have been just passage places that needed to be communicated, while others were used much more intensely like for logging or even for agricultural purposes. Another important factor were the seasons, even being hardly expressed they gave the rhythm of activities throughout the year. According to the informants Ernesto Martins Fernandes (2013) and José Carlos Fernandes dos Santos (2014) most activities on the high mountains took place during late spring, summer and early autumn. The firewood needed for heating and cooking on humid and cold winter days had to be cut in spring/summer, so that

it was dry and ready to use in winter. The grazing on the high mountain pastures took place from spring to end of summer, too. In autumn, bracon (*Pteridium aquilinum*) was cut and left to dry for a few weeks before being transported down into the valley to serve as bedding for the animals. During winter, the high mountain area is known for very unpleasant weather conditions.

Areas, in which many names were attributed, were frequented often and most probably by a large number of people. The more people passed or used an area the more geographical reference points were needed to communicate amongst each other and to avoid conflicts of interests and misunderstandings. Furthermore, different interests in resource usage are reflected in the attributed toponyms. For a shepherd it was important to know where springs existed to have water supply for the animals all year round. In addition, landscape features such as steep rock walls or deep canyons that would serve as natural barriers for the animals would be important to communicate in which area animals were kept or where to bring them. For a lumberjack the distribution of valuable timbers or certain mountain passages to reach the timbers were more important. This professional group would attribute very different toponyms to be able to satisfy their needs on geographical references in communication amongst each other or. The density of toponyms given to places, landscape features and pathways thus, indicates how important to the local community a certain area was. The high density of place names in the mountains indicates that the local population interacted regularly with this territory. Figure 28 illustrates the results of a point density analysis performed with ArcGIS 10.2.

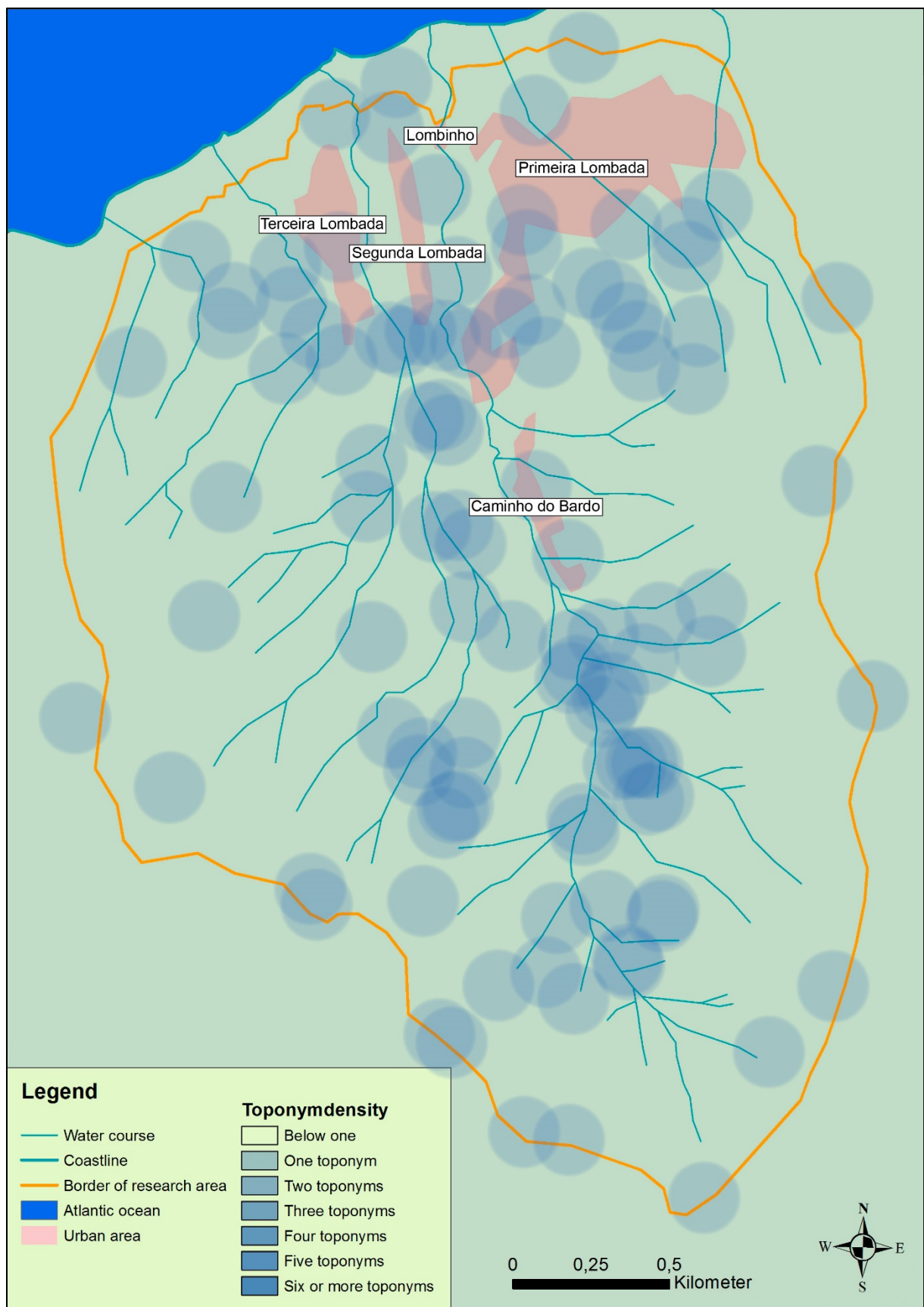


Figure 28: Density of toponyms in the mountain area of Lombadas da Ponta Delgada

In the following part, some exemplary types of toponyms related to distinct landscape features and type of use will be presented. In the interviews, the motivations for naming and some of the meanings of the names have been retrieved from the common local knowledge. Huge parts of local history are guarded in the toponyms of the Lombadas da Ponta Delgada. Generally, terrain conditions in the mountains of Ponta Delgada are so demanding, that many footpaths have various sections where only a tiny path along a rock outcrop or a few small steps dugged into a rock wall permits passage of humans. Everybody who was about to venture into the mountains had to know, where exactly these passages were located and in case one of these crucial passages was damaged by landslide, rock fall or the like the incident had to be reported in the village as soon as possible. Dangerous or instable sections along connecting paths were thus very likely to have a designation. Respectively, a higher density of toponyms reflects the three main routes into the mountains. One route is located on the ridge framing the research area to the east of Ribeira da Camisa valley, passing at Estreitinho, which is called “Caminho do Lombo dos Terreirinhos” often only referred to as “Caminho do Lombo”³⁸, leading to the highest point of the mountain range. From Segunda Lombada the main trail into the mountains, linking to Caminho do Lombo at a place called Urze Escanchada at roughly 1400m a.s.l., has been named “Caminho dos Lamaçeiros” since it leaves the area of agricultural fields at Lamaceiros. From Terceia Lombada there are various routes into the mountains, all linking to the main trail connecting the village of Fajã da Areia to the highest point of this mountain range dividing the valley of Ribeiro do Velho and Ribeira da Camisa from São Vicente Valley. Along these trails, higher densities of toponyms are identified in the landscape, since numerous activities were carried out in the vicinity of these footpaths.

One main activity was logging and cutting of small firewood. These activities often resulted in profoundly altered vegetation communities, which frequently gave origin to new toponyms. The word “Esmoitada” or “Moitada” or “Moitadas” appears in many areas in the north of Madeira Island and twice in Primeira Lombada and once in Terceia Lombada. According to Mendes (2008) such areas were deforested (“desmoitar” in Madeiran dialect), either for the expansion of terraced agricultural land or for pasture. Often the cutting of firewood left high mountain areas with former heather dominated vegetation of tree heath (*Erica arborea*) and

³⁸ Several people of Lombadas village, namely Sr. Fernandes, Sr. Caldeira, and José Carlos from Primeira Lombada and Sr. Tomé from Segunda Lombada, have confirmed this.

besom heath (*Erica scoparia*) deforested. Their wood was appreciated for its high quality and good burning characteristics.

Another reason for deforestation in the mountains was the usage of wood resources for private construction and agricultural purposes like support structures in wine production. Therefore, single trees or big shrubs were selected and cut. Their wood was left for several weeks to dry in the mountains, often under small bits of overhanging rock as a protection against rain. In recent times, this economic activity has been abandoned. Nevertheless, long cargo cables made of steel are still found in many places in the steep sections of the mountains. They are silent witnesses of former wood transport from the mountaintops and ridges down to the village. These cables were strategically positioned on ridges just above vertical sections to avoid that the load would get stuck in the canopy of the forest during the transport down. The cables were called “fios” and make part of the local toponymy. Every “fio” had a name attributed to it, mostly the name of the owner or the person who built it. In case this wasn’t clear or it had been built by a group and served for some villagers, it was generally named after the place where it was installed. The well-known “Fio da Granja” which crossed over the stream Ribeira da Granja, finishing in the village area “Granja” in Terceira Lombada is an example of such a naming.

The economic activities taking villagers furthest into the mountains were without doubt goat and sheep herding. The animals passed natural obstacles like steep rock walls and ridges with loose debris with ease and the shepherds had no choice, but to follow their animals into the remotest corners of the mountains. Names given to remote places often reflect formerly or still existing natural features. Shepherds did not actively change the landscape by constructing infrastructures. Nevertheless, they had to have a basis for communication on whereabouts of their animals. To secure this basis of communication they named many striking landscape features like the famous “Urze escanchada”. It is a heather tree (*Erica arborea*) with a unique shape and grows at a well-fitting location (cf. fig. 29). It grows at a crossing of two major intervillage connection paths in Ponta Delgada’s mountains. Its two main branches are pointing like a road sign towards the path heading to São Vicente valley, to the area of Chão dos Louros and along the central ridge towards Segunda and Terceira Lombada. The stem, pointing in another direction, marks the descending route to Primeira Lombada along the trail “Caminho do Lombo dos Terreirinhos”. Whereas behind Urze escanchada a little known path

heading towards the villages of Achadas da Madeira or Boaventura (via Boca da Lapinha) interconnects.



Figure 29: The popular "Urze escanchada" pointing in the directions where footpaths continue

Other toponyms contain warnings like "Lombo do Falso", "Lombo" means ridge and "Falso" is a tripping hazard, a place where the underground is not as reliable and solid as it appears. In some cases, it might be caused by roots covered with leaves or small branches. More dangerous are places, where the soil underneath the roots has been eroded, leaving holes covered by leaves resting on a fragile network of fine roots. Someone passing unaware over such places can easily make a momentous step (Ernesto Martins Fernandes, 2013)

Furthermore, there are a few names with memory function like "Buraco do Pestana", translated into English "the hole of Pestana" (Martins Fernandes, 2014). The hole is an area of very steep terrain with loose gravel just above the vertical rock walls of a small gorge. According to Martins Fernandes (2014), many years ago, a shepherd with the family name Pestana went to the mountains in search of his goats. He did not return home from this day of work and was found dead only months later at the bottom of the gorge, giving origin to the name "Buraco do Pestana".

4.4.2 Classification of toponyms according to their informative content

The main economic activities within the research area, namely agriculture and forestry, coined most of the place names. Both activities are inextricably linked to nature and its resources. Work days of farmers, shepherds and lumberjacks were spent outside in contact with the

elements and their forces. It seems that this daily interaction with natural features gave origin to the majority of recorded toponyms. In a first analytical step the names can be divided into two categories differentiating descriptions of

- (a) features of natural origin and
- (b) features of anthropogenic origin.

An example for the first category would be “Rocha do Pombo” (rock of the pigeon) being a pure description of a rocky outcrop along a ridgeline descending towards Terceira Lombada, where pigeons used to rest and possibly nested. An example for an anthropogenically created space would be “Poça do Aceiro” (pond at the Aceiro). Locally an Aceiro signifies a small, deforested area within a mountain forest. Generally, these are of anthropogenic origin³⁹. In recent times an “Aceiro” also defines a deforested line serving for demarcation purposes.

Independent of their origin, most toponyms serve as geographic reference points for orientation in space and communication between the inhabitants of the villages. Nevertheless, the toponyms and sometimes their origin, contains information on past use of resources in the area and on the value, which was attributed to some of nature’s resources. The toponyms recorded in the area of the Lombadas da Ponta Delgada have been classified into six thematic areas related to the following origins of names:

- a) Mountain features
- b) Hydrological features
- c) Vegetation features
- d) Use of natural resources
- e) Cultivation of land
- f) Events occurred
- g) Ownership

These thematic areas give a first impression on what was important for inhabitants and what they regarded as noticeable in the landscape. In the areas of the Lombadas there are no ideologically influenced names, which is quite remarkable since the Estado Novo regime of Portugal used toponymy as a political instrument (Sidaway & Power 2005; Jacob 2011). On the southern, the more developed, part of the island, there are several examples of politically chosen names. One of the hydro power stations, probably the most important one in the 1950s, was named “Central Salazar” in honor of the Prime Minister, another one which is located in the north, but serves as main supply for potable water for the capital city of Funchal

³⁹ In recent times an “Aceiro” also defines a deforested line serving for demarcation purposes.

was named “Central Américo Thomaz”⁴⁰. Many buildings in the city of Funchal are built in the “Estado Novo”-architecture style. Some examples are: Banco de Portugal, Mercado dos Lavradores, Customhouse, Empresa da Electricidade da Madeira, and others (Monterey 1977). In Ponta Delgada the source of names were mainly characteristics of landscape features, agriculture (in terms of land use), forestry and ownership of land. The above established thematic areas of names reflect the importance of the landscape and its resources for daily life. Interaction with the natural surroundings was an integral part of life, to have food security and be able to make a living. In the following examples of feature classes will be presented.

a) Mountain features

The occurrence of a huge number of names related to mountain features indicates an intensive interaction with this environment over the past approx. 500 years. On the eastern walls of the spring area of Ribeira da Camisa military maps show the name “Laje Negra” (dark rock). The “Laje Negra” keeps being a reference for people heading out into the mountains (cf. fig. 31). It is a very dangerous passage traversing this inclined sheer rock towering just above a narrow and deep gorge, where one badly placed step might be fatal. This passage was very frequented by shepherds since it is one of the few passages from the eastern to the western side of Ribeira da Camisa valley. In wintertime, when heavy rainfall turns Laje Negra into a waterline, it becomes impassable. Probably the perennial availability of water at the two streams south of Laje Negra contributed to the frequent visits of people and their flocks despite the dangerous terrain conditions.

⁴⁰ Américo Tomás was President of the Portuguese Republic (Estado Novo) from 1958 to 1974. The writing of the name can be Tomás or Thomaz. See <http://www.presidencia.pt/?idc=13&idi=26>



Figure 30: Laje Negra, a difficult traverse of a rock face

A much more time-consuming passage to reach the area of Topo goes along the eastern ridge of Ribeira da Camisa valley, it is simple named “Caminho do Lombo” (footpath of the ridge). This trail passes at a huge, roundish rock, which offers a beautiful view over the Lombadas area, it has been named “Redondinho” (the small round one). Another renown place is the “Empena”, a very steep basaltic dike, where passage on top of the dike is possible, but physically very demanding.

b) Hydrological features

In this context, the necessity to have water supply for people walking and working in the mountains as well as for animal husbandry on the ridges becomes evident. After long and strenuous ascends to the high mountain area people and their animals needed to have fresh water supply. For a shepherd and maybe even more for a lumberjack realizing hard physical work on the mountains it was vital to know, where water was available and which springs would dry out in summer and which springs would have water all year round. To pass that knowledge to fellow workers and in general to people performing jobs on the mountains it was indispensable to have names for the springs and for important water lines. Thus, the names mirror the importance of fresh water sources on the mountains and the importance of water reservoirs at low altitude for irrigation purposes of terraced agricultural land.

c) Vegetation features

Since people apparently knew the mountain forests around Ponta Delgada extremely well it is common to recognize single trees that have a growth habit diverging from the norm of the species. These were frequently used as reference points within the forest and as such received a name, such as the so called “Pau Branco do Muro”, (cf. fig. 32).



Figure 31: A rare growth making this Picconia (*Picconia excelsa*) a renowned landmark

In general, people referred to certain vegetation features that had a scarcity value. For example in an area used for charcoal production some stinklaurel trees (*Ocotea foetens*) escaped local logging activities and this specific place on Lombo da Perdinha became known as “Til do Carvão” (stinklaurel of charcoal) (Mendes 2008).

d) Use of natural resources

References to the use of natural resources were very frequent and most probably with the abandonment of traditional economic activities some toponyms related to these activities have already gotten lost over time. The remaining toponyms often refer directly to past human activities like the place called “Chão do Milho” (flattish area in the mountains for corn). There are two explanations given on the origin of this name. The first explanation given by Mendes (2008) says that farmers planted corn on this little plateau in the 18th and 19th centuries, since it was possible to irrigate this area by the nearby spring close to Rocha do Pombo. In personal interviews with inhabitants

from Terceira Lombada, Terra do Centeio (closest inhabited place to Chão do Milho), they explained that this flat area was used for lunch breaks since it offers a good view and comfortable places to sit. A typical lunch would be grilled corncoobs giving origin to the name. Toponyms with indirect reference to human activities are descriptions of changed landscapes like “Lombo Queimado” (burned ridge), Lombo das Giestas (ridge of soft broom) or “Castanheiro” (sweet chestnut). The last two names indicate plant species that are not native to the island but anthropogenically introduced to it. In case of Lombo das Giestas, a ridge section covered with soft broom, it is clear that humans had removed the indigenous vegetation cover and left an open area. Afterwards this area was rapidly occupied by the invasive soft broom, which started to be a reference amongst village residents of both São Vicente area and Ponta Delgada. This state of vegetation lasts for prolonged periods since it is very unlikely that a closed cover of soft broom will leave enough space and light for other species to grow. The sweet chestnut tree⁴¹ (*Castanea sativa*) is another example of a non-native species that serves as an indicator for human activities in the landscape. It is common in the high parts of the agriculturally used zone since it copes well with colder and humid climate. In past centuries, it has been established as an undemanding crop that grows well even without much care and in places where other crops yield little or nothing at all. In many villages one can find a “Sítio do Castanheiro” (place of the sweet chestnut tree), in continental Portugal there are a few villages named “Castanheira”⁴².

e) Land use

Another popular motive for naming was land use. When farmers frequently planted a certain crop in a certain area, often due to the experience that it grows very well at this specific place, they used to attribute related names to the place. For example: One part of Terceira Lombada is named “Terra do Centeio” (land of rye), according to the inhabitants of this place the main crop cultivated was rye (*Secale cereale*). In Segunda

⁴¹ The Sweet chestnut (*Castanea sativa*) has been introduced to the island of Madeira in the early period of settlement. It had a long tradition in rural northern Portugal, especially in the areas “Norte” and “Centro”, basically reaching north to the Spanish border from a line connecting Leiria, Vila de Rei, Castelo Branco and Idanha-a-Nova.

⁴² There are villages called “Castanheira” in the rural districts of Guarda, of Mogadouro, of Paredes de Coua and of Trancoso. Furthermore, there are some very small villages in the mountains also called “Castanheira”, like in Serra da Freita, or “Castanheira de Pêra” in Serra de Lousa, or “Castanheira do Vouga” close to Aveiro. See www.freguesiasdeportugal.com

Lombada there is a place called Amoreira (brumble). The interview partners Sr. Tomé⁴³ and Sr. Ernesto Martins Fernandes (2014) confirmed that this area used to have many brumbles (*Rubus spec.*). People used to pick the fruits and made jam or liqueur out of it. On a lower level in Segunda Lombada the place Pereira (pear) is located. In this area used to be a little plantation of pear trees (*Pyrus communis*) having given origin to this name.

f) Events occurred

The part of events occurred may encompass not only singular events, but also situations that have led over a longer span of time to certain actions or happenings. Mountains are always places where memorable things use to happen. There is the place of “Buraco do Pestana”, where it is reported that a man named “Pestana” used to search for his goats in this very steep zone, full of loose gravel and small stones. One day he did not return home and was found dead at the bottom of this steep section only month later. In memory of his death the ravine, where he died was named after him. Close to the famous “Laje negra” is one agricultural terrace, which belonged to a man nicknamed “Albino Miséria”. The name indicates misery and having to work land at this altitude is not very productive and extremely tiring just to get to this place. This toponym is already a mixture of reminding of a situation and mentioning ownership of something.

g) Ownership

It was common to give the name of the owner to artificial landscape elements. There are many examples of this like on the Caminho do Lombo. There is a wooden gate to impede passage of animals to the lower grazing grounds. Until today this gate is in place and is called Portão do José Mendes (the gate of José Mendes).

⁴³ The informant Sr. Tomé is local resident of Segunda Lombada and is currently working for the regional forest service of the Madeira Region (Instituto das Florestas e Conservação da Natureza).



Figure 32: Portão do José Mendes

In Terceira Lombada there are several water storage basins of various sizes, the southernmost one is called Poço do João Mendes (basin of João Mendes) since it has been built by Mr. Mendes. A similar situation occurred in the source region of Ribeira da Camisa: A small tributary offered a comfortable flattish space between two waterfalls of only a few meters of height. This place was sunny, had various access routes passing close and due to the proximity of water and its location within the forest was the ideal place for cooking meals. A man with the surname of “Pereira” had the habit of preparing his meals in exactly this place, it is still known as “Cozinha do Pereira” (kitchen of Pereira).

Above the cliffs, towering south of the village of Fajã da Areia exists the small Levada do Abreu⁴⁴ that used to fill some water reservoirs in the mountains. These are known as Poços do Abreu⁴⁵ (basins of Abreu) since they belonged to a family named Abreu.

In the following section all recorded 113 toponyms have been analyzed if they fit into one of the above established feature classes. The toponyms that fit into one of the feature classes have been categorized and listed accordingly in a table. It is however not possible to classify all toponyms into the above established classes, since some do not relate to any of these classes. One example of a toponym not fitting into any of the classes would be the so called

⁴⁴ Manuel de Abreu owned a Levada for irrigation of fields which started at Lombada das Vacas. It served to take water from Ponta Delgada area to São Vicente. Cf. Ribeiro (2005)

⁴⁵ These water storage basins served as reference points even in national publications. Manuel de Nobrega referred in his publication on mosses on the Island of Madeira (Contribuição para a flora das Muscineas da Madeira; Nobrega, 1990) “

“Poço das Pulgas”, which translated into English means “water basin of fleas”. Only taking the name into consideration one would classify it as a part of the hydrological features, but since it is one of hundreds of natural water basins in Ribeira da Camisa stream it does not fit with the other water basins in the list that are of man-made origin and have been used for irrigation purposes. In the interviews, no informant could tell the reason why the natural basin “Poço das Pulgas” was named a “poço” (basin). It might be due to the waterfall that formed the basin itself and makes its waters turbulent and with many oxygen bubbles that reminded people of fleas. Nevertheless, this is only an assumption that villagers made when asked if they could imagine what the origin of this strange name was. From altogether 113 toponyms acquired during interviews and by studying the “Perfil Toponímico de Ponta Delgada” (Mendes, 2008) a total of 98 toponyms could be classified into the established feature classes. In the following table these toponyms are listed according to the feature class they have been included in:

Table 5: Toponyms in Lombadas da Ponta Delada

Mountain features	Hydro-logical features	Vegetation features	Use of natural resources	Culti- vation of land	Events occurred	Ownership of features
Caminho do Lombo	Cascata do Viveiro	Sítio do Pinheiro Seco	Palheiro no Viveiro	Viveiro	Topo das Queimadas	Poio do Albino Miséria
Vereda das Paredes	Poço do Vilão	Poio dos Vinháticos	Fio L.º da Carapuça	Rabo do Burro	Buraco do Pestana	Portal José Mendes
Topo da Empena	Fonte Vermelha	Selada do L.º das Giestas	Fio L.º das Coches	Granja	Cozinha do Pereira	Terras de José Mendes
Pico do Lombo	Levada da Cancela	Urze Escanchada	Fio dos Terreirinhos	Ribeiro da Eira		Laje do Léres
Lombo dos Caldeirões	Poço da Cancela	Lombo das Giestas	Fio Seg. ^{da} Lombada	Chão do Milho		Poço do França
Lombo das Coches	Levada & Poço do Cabeceiro	Caminho do Til Grande	Topo da Lom. ^{da} das Vacas	Eira		Fonte dos Ramos
Lombo da Paredinha	Levada do Lombo	Ribeira da Raiz	Lom. ^{da} das Vacas	Terra do Centeio		Manga do Loiro
Boca da Caldeira	Ribeiro Seco	Poio do Vinhático	Esmoitada	Pereira		Lombo da Luísa
Lombo do Falso	Pingas	Arvores Grandes	Sítio do Fio	Fajã das Éguas		Fonte do Góis
Curral do L.º do Falso	Poço do Rochão	Til do Carvão	Fio	Poio		Fio do Simão
Estreitinho	Poço Feticeiro	Raiz do Buraco	Achada das Vacas			Caldeiras de São João

Escada	Vigía das Aguágens	Ribeiro da Feteirinha	Pé dos Porcos		
Ladeiras	Água da Queimada		Fio Terras de Ariba		
Caldeira	Fonte da Creca		Fio da Granja		
Rocha da Vara	Poço do Rib.º José Mendes		Cova do Bardo		
Laje Negra	Poço do L.º das Cochês		Poça dos Porcos		
Redondinho	Poço da Granja				
Rocha do Frontal	Fundo da Aguagem				
Rocha do Pombo	Poça do Azeiro				
Coroa do Topo	Poço das Fontes				
Boca da Muranha	Levada do Cabouco				
Lombinho					
Picos da Achadinha					
Muralhas					
Casa do Pico					

4.5 Conclusions

In past centuries, when life was closely linked to agricultural activities, the most important function of toponyms was certainly the one to allow a clear localization in the area. As such toponyms were a necessity for local and inter-village communication. In small farming communities, living in remote and strongly structured landscapes, as the ones in the northern part of Madeira Island, it was indispensable to have a common network of names to localize specific places. This becomes evident when considering the work situation of local people, which over the past five centuries included many physically very demanding work tasks. For example: chopping a big tree, constructing a terrace wall, slaughtering an animal on a high pasture, getting firewood down to the valley. To be able to conclude these tasks farmers and lumberjacks used to form small groups and work together. To combine, where a meeting point

was and in which part of the valley a specific job had to be done, people had to speak the same language in terms of local toponyms. Furthermore, for shepherds it was indispensable to be able to communicate amongst each other on the whereabouts of their flocks. Only with common local toponyms known and used equally by community members, clear and unmistakable geographical references could be established.

Since the naming process was almost always linked to an economic activity carried out at a certain place the study of toponymy gives very detailed and precisely located information on past human impact to the landscape. It unravels not only the spatial extend of human influence to the mountains, but provides additional information on the type of resources people used in the mountains and within the area under cultivation.

The density analysis carried out in this study adds information on the variation of intensity of human influence in the different mountain areas of Lombada da Ponta Delgada. Surprisingly, the mountain area shows few zones that have no toponyms and thus might have had a low significance for use of natural resources. Some sections of near vertical rock walls have no names attributed to them, like the area southwest of Terra do Centeio, one section east of Poço das Fontes and a small area between Poço das Pulgas and Lombada das Queimadas (cf. fig. 28). Nevertheless, mountain sections with dangerous access routes, vertiginous passages, often slippery terrain and near vertical ascends or descends were frequently used for various activities like goat herding, logging or arranging firewood for domestic use. In some areas like in the remarkably steep zones of the source region of Ribeira da Camisa and in the rock walls north of Passada, the topography has been entirely disregarded and toponym density is quite high. The informant Sr. Ernesto Martins Fernandes explained the reason in an interview held on 18.03.2014: “We had to go where the goats went and we had to have all these names to tell our neighbors where we spotted their goats, we knew the mountains very well”.

The classification of toponyms into feature classes related to their origin and significance shows that the categories of mountain features, hydrological features and natural resource use are dominating. The named landscape clearly reflects the importance of the mountains, of the hydrological resources and of the vegetation to the economical activities of the population. With the far-reaching abandonment of traditional agriculture and the change from a subsistence based rural life to a modern consumer society, the importance of the toponymy is quickly fading and with it the passage of knowledge that has marked the traditional life in Lombadas da Ponta Delgada since the founding of the village. The loss of the

traditional knowledge of the mountain surroundings with its toponyms, infrastructures like footpaths, shelter caves, artificial springs, bridges and passage places, became evident in the interviews conducted in this study. While the old generation had a highly detailed knowledge on their surrounding mountains and the resources they can provide, most of the young inhabitants have only a very limited knowledge. Sometimes this knowledge is only theoretical; some of them have never been to the mountains and only know the toponyms from stories told in the families. The future of the traditional knowledge on toponymy, best agricultural practices, the use of mountain resources and the accessibility on the century old system of footpaths is depending on the few families that managed to pass it on to the young generation. Hopefully, the few young farmers, who presently work parts of the terraced land will be able to maintain the knowledge on toponymy and the mountains alive.

5 Vegetation analysis as a source of historic information

5.1 Introduction

The parish of Ponta Delgada and the Lombadas have been characterized by scarcity of accessible cropland in combination with the absence of available land close to the settlements. The absence of sufficient land for food and fodder production forced the inhabitants to use as many of the natural resources provided by the mountains as possible. Over more than 500 years, intense human activities have profoundly influenced the Laurisilva ecosystem and modified the composition of species. In part directly by removing woodland and turning it into agricultural land or less rigorously by using only selected wood species for construction of buildings, for naval purposes, in furniture construction, for firewood and some species even as animal fodder. Certain species, providing wood of superior quality were preferentially logged. Very popular for domestic construction purposes was *Picconia* (*Picconia excelsa*), for construction of wine barrels Beefwood (*Heberdenia excelsa*) was popular and Madeira Mahogany (*Persea indica*) was selected to build wooden storage boxes for households (Pereira, 1989). Furthermore, settlers introduced new species to the island occupying niches formerly used by native plants. These species were many times crop plants for alimentation purposes like cereals and vegetables, but included also fruit and nuts. Over centuries the landscape has been transformed from a wild native woodland into a man-made countryside

Very few woodland areas, most of them located between heights of 700 and 1600 m a.s.l. and often in remote gorges, are presently classified as remnants of undisturbed autochthonous woodland. Only in these remote and inaccessible areas, often on close to vertical slopes the Laurisilva ecosystem remained basically in a nearly natural status (Menezes *et al.*, 2004). Scientific projects of vegetation mapping and monitoring have been carried out there. Botanists studied the remaining native Laurisilva areas on Madeira Island in detail, namely the species distribution, range of species and status of extinction danger (Neves *et al.*, 1996).

The data from these investigations can be compared with current vegetation mapping data obtained in the research area of Ponta Delgada, providing detailed spatial information on species composition, allowing to unravel missing details of the environmental history of Ponta Delgada and the usage of wood resources within the parish.

5.2 Research questions

Until present days, the catchment of Ribeira da Camisa has not suffered modification constraints like modern infrastructure measures or big scale development projects like construction of apartment blocks or industrial facilities. The landscape around Ponta Delgada still preserves what inhabitants built up over roughly 600 years (Pereira, 1989) and thus is ideally suitable to investigate the extension and intensity of past interaction between humans and landscape. The traditional usage of local, natural resources modified the local vegetation profoundly. The human influence is reflected in the species composition and the commonness of certain species. A comparison between the data obtained within the zones, out of which natural resources were extracted with zones of hardly modified woodland can reveal the extension of past human influence in the landscape and locate different intensities in past use of mountain resources. The spatial information on the extension of human activities into the mountains illustrates on the one hand the dependency of former generations on the mountain resources and on the other hand clearly illustrates the harsh living and working conditions of peasants. It shows how far they would have walked from their living space to collect necessary resources from the mountains and how much time would they spend to fulfill these tasks. The existence of introduced species such as Walnut (*Juglans regia*) provides information on the alimentation preferences of past generations of farmers. The spatial distribution of non-native fruit and nut trees can clarify which altitudes were preferentially used for which purpose? Has there been a division between areas for terrace construction, for collection of forage, for cutting of firewood or for felling timber?

5.3 Methods

To achieve essential basic information on traditional agriculture and forestry practices two approaches were applied: First, an extended literature study in the local archives was conducted to provide knowledge that would be indispensable to correctly interpret vegetation data and secondly personal interviews were held with local farmers and the mayor. The literature studies included descriptions from early seafarers, historians, botanists, geographers, hydrologists and travel reports from British visitors in the early 19th century. Next to these poems, classical Portuguese literature, historic romances and newspaper reports

were consulted. It was important to identify the crops used in agriculture to understand, which species were planted. Special focus was put onto fruit and nut trees since they persist over a long time after the abandonment of agriculture (Figueiredo, 2008). Especially high growing species like Walnut (*Juglans regia*) or Sweet Chestnut (*Castanea sativa*) resist over a long time in secondary forests. Invasive non-native crop plants that had been introduced into the agricultural economy of Madeira were important to detect remains of formerly used land within areas that are covered with forests today. Furthermore, traditional use of plants had to be researched to know, which species were procured for medical purposes. Often this can be a reason for species to be less frequent close to houses and paths than in places of difficult access. Other species have been introduced with a purpose, like New Zealand Flax (*Phormium tenax*) with the characteristic long, fibrous leaves has been planted near ridgelines to serve as ropes to tie loads together that were transported off the mountains.

Another concern were local preferences for certain tree species, which used to be popular for certain purposes and thus experienced more intensive logging than most other tree species.

The research area is characterized by very steep terrain, in some parts close to vertical mountain faces more or less covered by forest. This terrain seems inaccessible and certainly is without prior knowledge of old footpaths used by peasants for centuries. To collect information on these formerly used infrastructures and on the environmental history of the research area personal interviews with local farmers and shepherds were held. The aim of these interviews was to learn more of traditional agriculture and especially of areas where two or three generations ago, family members used to work land in the mountains and how they got there. Furthermore, information on traditional use of forest resources and access to remote areas was obtained. In a pre-field work campaign and during fieldwork the system of old footpaths was recoded with a handheld GPS device.

Additionally, pre-field work campaign reconnaissance was conducted. Aerial photos provided by Direção Regional de Informação Geográfica da Madeira at a scale of 1:10,000 together with the land use classification map gave a generalized overview on the present plant associations, on the type of land use and on infrastructure. This documentation was the basis for the selection of the vegetation mapping plots, trying to cover all mountain slopes framing the village. This approach has been successfully applied in forest ecosystems (Franklin, 1995; Hasmadi, 2010). In a second step, the selection of investigation areas was combined with the

information obtained during interviews, regarding the accessibility of the terrain. The early field reconnaissance was to verify the actual condition of described paths and in many cases to reopen the path with a machete, allowing easy passage during the mapping campaign.

For the execution of the vegetation mapping campaign some considerations had to be taken into account. Many historical details of the vegetation cover cannot be accessed by common methods like interpretation of aerial photography or other means of remote sensing. According to Jacobi (1989) one of the most important steps in the preparation of vegetation maps is in-field survey. Detailed in-field vegetation survey with its high resolution of local heterogeneities is a unique source to fully understand the dynamics of interaction between humans and landscape over time. It provides locally refined information on species distribution (Capelo et al. 2004) and builds a differentiated picture of anthropogenic influence to this former native ecosystem. Accordingly, the vegetation mapping method had to be adapted to the specific needs of environmental history. The first decision had to be taken on the scale of the map. The research area of Ribeira da Camisa and Ribeiro do Velho has a size of about 15 km². Any small-scale map would be too generalized to detect human-landscape interactions on a detailed level. Taking into consideration that plant associations and individual trees have to be shown the map needs a high resolution. Thus, a scale of 1:10,000 was chosen.

Furthermore, the vegetation survey was conducted according to the specific territorial setting of Ribeira da Camisa and Ribeiro do Velho catchment area. The catchment of Ribeira da Camisa is facing mostly northward. Ridges of relatively easy access and slopes segments with nearly vertical rock walls are common. Rock walls not only create natural divisions between altitudinal vegetation belts but they offer very specific habitat conditions. To detect natural and anthropogenic variations within the forest vegetation a number of plots have been placed close to territorial boundaries. In total 45 plots were surveyed on altitudes between 97 m and 1315 m a.s.l.

Species inventory assessments executed in the traditional way of vegetation ecology encompass total listing of all plant species present. To sufficiently understand the interaction of past generations of farmers, loggers and shepherds with the landscape the focus shifts from a listing of all present plant species to an assessment of indicator species, who's long-term development reflects anthropogenic disturbances or absence of anthropogenic activities. The survey plots have to vary in size due to the ecosystem characteristics (Dierssen 1990; Buck &

Paysen 1984). Open terrace land area with a low vegetation cover density can be described with smaller plots than a plot in a woodland with the typical larger structures.

The plots investigated in open terrace and shrub land vary between 10 x 10 m and 25 x 25 m. The plots were adapted to characteristics of terrain, avoiding vertical or instable places, which lead to rectangular and in some cases circular plots. Under forest canopy the plot size was extended to 50 x 50 m as proposed by Dierssen (1990) and in the national field guide for forest inventory of Guinea-Bissau (Instituto de Investigação Científica Tropical, 2009).

For vegetation survey a huge number of publications has been helpful for the determination of species (Neves et al. 1996; Quintal 2005; Capelo et al. 2004; Fontinha et al. 2006; Costa et al. 2004; Menezes et al. 2004; Fontinha et al. 2011; Franquinho & Costa 2008).

Visualization of survey plots and interference intensity classes has been elaborated with ArcGIS 10.2 on orthophoto maps with a scale of 1:10.000 provided by Direção Regional de Informação Geográfica da Madeira.

5.4 Results and conclusions

Vegetation survey clearly mirrors varying intensities of past and present human activities. Several areas of distinct use of either land or forest resources have been identified. In general, the delimitations of cropping activities reach very high into the mountainous sections of Ribeira da Camisa valley. Generally, the second altitudinal belt of transition forest has been altered remarkably and shifted by humans to a mix of crop and native plants. Within the valley the arable terrace area is fragmentary, on the less inclined areas atop the ridges are terrace systems extending to nearly vertical terrain. This situation is found along most parts of the slopes near the north coast (Ribeiro, 1985), but very refined within the research area. During vegetation survey remnants of former terraces with alien species have been found up to 650 m a.s.l., which is surprising due to the fact that these terraces have a northern exposition and thus a very limited amount of sunshine per day. These zones are less productive and not suitable at all for a large number of crops (Quintal & Vieira, 1985; Kegler, 1993; Leça, 2011) requiring higher temperatures and less rainfall. From east to west going clockwise around the village of Lombadas, terrace remnants and their respective exotic vegetation were found as high as in the areas of Fio dos Terreirinhos (433 m), Lombo do Falso (608 m), Sítio do Viveiro (548 m), Rabo do Burro (503 m), Caminho dos Lamaceiros (561 m), Lombo das Coches (507 m), Terras José Mendes (410 m), Ladeira (456 m) and Caldeira (553 m). The laborious

establishment of agricultural terraces at such marginally productive and remote sites is a silent testimony of the harsh living conditions and the scarcity of cropland that people had to deal with. On the lower terraces surrounding the village of Lombadas cropping still takes place, farmers continue with century old agricultural practices on terraces extending from 100 m a.s.l. to average of 350 m a.s.l. A great number of common crops of tropical and subtropical origin and only a few adapted to colder climates are grown there. During the vegetation survey on cropland surrounding the Pico of Terceira Lombada (170 m), the following cultural plants were identified: Common fig (*Ficus carica*), Avocado (*Persea americana*), Taro (*Colocasia esculenta*), Custard apple (*Annona cherimola*), Strawberry Guava (*Psidium guineense*), Guava (*Psidium guajava*), Sweet potato (*Ipomoea batata*), Sugar cane (*Saccharum officinarum*), Peach (*Prunus persica*), Lemon (*Citrus ssp.*), Pepinella (*Sechium edule*), Plum (*Prunus domestica*), Maize (*Zea mays*), Potatoes (*Batata ssp.*), Pumpkin (*Cucurbita ssp.*), Turnip (*Brassica rapa*), Loquat Tree (*Eriobotrya japonica*), Carrot (*Daucus carota*), Banana (*Musa ssp.*), Papaia (*Carica papaia*) and Beans (*Phaseolus spec.*).

At higher altitudes the amount of tropical and subtropical crops diminishes suddenly, already at Chapada – Terceira Lombada at an altitude of 350 m a.s.l. crops such as Banana (*Musa spec.*), Custard apple (*Annona cherimola*), Peach (*Prunus persica*), Papaia (*Carica papaia*), Guava (*Psidium guajava*) and Lemon (*Citrus spec.*) are not successfully cultivated. They are substituted by plant species with lower thermal comfort zones, like Grapes (*Vitis vinifera*), Apples (*Malus spec.*), Willow (*Salix viminalis*), Walnut (*Juglans regia*) and Sweet chestnut (*Castanea sativa*). Amongst field crops most often Potatoes (*Batata spec.*), Sweet potatoes (*Ipomoea batata*), Beans (*Phaseolus spec.*), Maize (*Zea mays*), Carrots (*Daucus carota*) and Pumpkin (*Cucurbita spec.*) are present.

In the higher altitudes around 500 m a.s.l. at places like Sítio do Viveiro, Poço Fetiçeiro or Nougueira only a few crop plants remain within the secondary forest. Small species are not competitive when the canopy of the succession forest closes more and more. So they are most probably underrepresented regarding their former extension and quantitative appearance. Species indicating former land use even within a recent succession forest are Loquat Tree (*Eriobotrya japonica*), Apple (*Malus spec.*), Peach (*Prunus persica*), Bastard passion fruit (*Passiflora x exoniensis*), Sweet chestnut (*Castanea sativa*) and Walnut (*Juglans regia*). Due to their size, they can compete successfully in a growing secondary forest and preserve the information on human – landscape interactions for decades, maybe even centuries.

The heather forests of the altitude provided wood for domestic use as fire wood and for small constructions like roofs on stables, benches and chairs (Gouveia 2008). During World War I

and II pit coal transport to the island was limited and people installed charcoal kilns in the high-country areas. Huge amounts of heather forest have fallen victim to this mostly illegal charcoal burning (Pereira, 1989). Moreover, the highest parts of the ridges leading up to Topo das Vacas were used for raising sheep, goats and in few areas even cows, as the name indicates⁴⁶.

On the formerly wooded areas neophytes are found frequently, so that semi-natural plant associations prevail in most parts of the research area.

Land use and use of woodland resources vary with altitude. At low altitude, human impact is highest. Not only has the natural distribution of plant communities been changed by human activities, but the topography, too. At lower altitudes people established large terrace systems, covering most of the slopes near the coast. At higher altitude and on steeper slopes, the effect of human modification is less intense. In table 6, common crops for the different altitudinal belts with their microclimatic characteristics are listed:

Table 6: Common crops and some common introduced species in the four main altitudinal belts⁴⁷

	Vegetation belt 1	Vegetation belt 2	Vegetation belt 3	Vegetation belt 4
Common perennial crops	Banana Mango Custard Apple Avocado Papaia Loquat	Avocado Grapes Cherry Peach Plum Loquat	Cherry Apple Pear Walnut Sweet chestnut	
Common introduced tree and shrub species	Acacia Palm trees	Acacia Pine Eucalyptus Pittosporum	Acacia Pine Eucalyptus	Prickly Goarse Bracon Soft Broom
Common surface structure	Bench terraces	Bench terraces	Bench terraces	
Common use of terraces	Horticulture crops	Horticulture crops	Perennial crops	

Above the high terrace systems the information on former land use is less obvious, only a few indicator plant species for human activities and a diverse forest remained. Nevertheless, other

⁴⁶ The Portuguese designation Topo das Vacas translated into English means “top of the cows”.

⁴⁷ Cf. chapter 2, subsection “2.4 Vegetation”

witnesses of human activities can be found in many places. Steel cables for cargo transport were frequently mounted to overcome vertical terrain and not having to carry voluminous or heavy loads down the mountain. Around many of these “Sítios do fio” a fiber rich plant, known as New Zealand Flax (*Phormium tenax*), is found. According to the local population, this neophyte was introduced for its strong, fibrous and long leaves. Planted next to beginnings of cargo cables the flax provided natural rope material for all kinds of cargo that had to be sent down into the valley. The existence of these cargo cables underlines the dependency of the rural population on forest resources. It was a very challenging and time-consuming building project to mount a single cable like the one shown in figure 33 in a forest ecosystem.



Figure 33: Cargo steel cable and New Zealand Flax planted near it

A ridge top had to be cleared from vegetation and a thin light cord with a stone at its beginning had to be thrown from this place towards the place where the cable should lead to in future. According to local farmers, this task alone was complex since many times it did not work out the way people had hoped for and the line had to be removed from the forest canopy several times before it finally got to the predefined place. Often, the thin cord had to be cut, when it was not possible to remove it from the trees. Not seldom, it took several days to get the line in place and start tying steel cable pieces, one by one onto the line and slowly sending them down to the valley, until the entire length of the line was replaced by a steel cable. This

tremendous work was only justified when the “fio” was used frequently for heavy or voluminous cargo transport.

In the high altitudes vegetation mapping revealed areas full of rare, mostly endemic plants in some spots in an unexpected abundance. At the same time these spots can be characterized by an absence of species that should be present within the natural Laurisilva (Neves et al., 1996; Vieira, 2002; Menezes et al., 2004). While the high abundance of endemic species indicated a low human impact, the total absence of certain species indicated that under natural circumstances the woodland would have a different species composition. Precious wood species are often not found in adult state or their presence is reduced to inaccessible areas.



Figure 34: *Picconia* growing in a rock fissure

An example of a typical but lately not very frequent species is *Picconia* (*Picconia excelsa*). Over centuries the wood of this tree with high resistance to abrasive forces has been used for vine presses (Pereira 1989) and other equipment that required strong and lasting wood. Apart of some well-protected spots, where access is nearly impossible and even fewer spots, where the growth itself did not permit copping, adult trees are not present in the woodland around the Lombadas. Comparing the presence and frequency of species recorded in the Lombadas of Ponta Delgada with vegetation surveys carried out by Neves (1996)⁴⁸, it becomes obvious that species like Madeira Beefwood (*Heberdenia*

excelsa) and Madeira Mahogany (*Persea indica*) would be present in the zone of the Lombadas without human impact. While physical growing conditions for these trees are excellent, only a small number of plants is currently present. Small trees of Madeira Beefwood are relatively common, adult trees rare. This is an additional indication to former use of forest resources and the selectiveness of interaction, which was applied in the logging process.

⁴⁸ The study was carried out in areas of little human disturbance within the Nature Park of Madeira. Some investigations were carried out in one of the least touched zones of the island, at Caldeirão do Inferno.

According to some interview partners the high ridgelines to the west and to the north of Lombadas village have been used for raising livestock. Furthermore, *besom* and tree heather were valuable firewood for domestic purposes. They have a high energy density and thus burn down slowly giving heat for a prolonged period of time. It has been reported in scientific sources and contemporary romantic literature, that most of the high mountain zones of the island have been exploited for their wood resources (Silva, n.d.; Gouveia, 2008). This is supported by the vegetation survey results listed in table 2-4, the species registered often indicate more open conditions, than the ones an old heather forest would provide. Furthermore, young trees dominate existing heather forests and some areas show exclusively plants of very recent natural succession processes.

For a comparable and easily understandable overview of species composition in the research area, three tables for different altitudinal belts are presented. The first table shows five representative survey plots from 98 m up to 450 m a.s.l. This belt suffered strong alterations during the past 500 years, which is clearly visible in the vegetation composition. Many open land species are present and in no other altitudinal belt higher rates of neophytes in the vegetation composition were registered. Next to a variety of crop plant species there are several species of ornamental value present. Moreover, the amount of endemic plants recorded is very low, with less than 20% in all survey plots. The five selected survey plots are:

Plot 1: Caminho do Lombo (317 m a.s.l.)

Plot 2: Terceira Lombada, Chapada (342 m a.s.l.)

Plot 3: Caminho da Cabouco (97 m a.s.l.)

Plot 4: Caminho do Bardo (430 m a.s.l.)

Plot 5: Ribeira da Camisa (452 m a.s.l.)

In the tables below (table seven, table eight and table nine), the following abbreviations are used for the different classifications of species:

O: Not present in this plot

X: Present in this plot

N: Neophyte

M: Endemic to Madeira

M/C: Endemic to Madeira and Canaries

M/C/P: Endemic to Madeira, Canaries and mainland Portugal

Table 7: Species present at five sample plots at altitudes ranging from 97 to 452 m a.s.l.

Plot	1	2	3	4	5
Plant specie					
<i>Adiantum capillus veneris</i>	O	O	O	X	O
<i>Ageratina adenophora</i>	N	O	O	O	X
<i>Agrimonia eupatoria</i>	X	O	O	O	O
<i>Amarillis belladonna</i>	O	O	N	O	N
<i>Annona cherimola</i>	O	O	N	O	O
<i>Arundo donax</i>	N	N	N	O	N
<i>Asparagus umbellatus</i>	O	M	O	O	O
<i>Athyrium filix-femina</i>	X	O	O	O	O
<i>Atricum tenellum</i>	O	O	O	X	O
<i>Barbula unguiculata</i>	X	O	X	O	O
<i>Bidens pilosa</i>	O	O	O	O	X
<i>Brachipodium hirsutum</i> cf.	O	X	O	O	O
<i>Brachipodium spec.</i>	X	O	O	X	O
<i>Brachitetium rutabulum</i>	O	O	X	X	O
<i>Briza maxima</i>	X	O	O	O	O
<i>Bryum capilare</i>	O	O	O	X	O
<i>Calla aethiopica</i>	O	O	O	O	N
<i>Castanea sativa</i>	N	N	O	N	O
<i>Ceratodon pupuraeus</i>	O	O	O	X	O
<i>Clethra arborea</i>	M/C	O	O	M/C	M/C
<i>Conocephalum conicum</i>	X	O	O	O	O
<i>Convolvulus</i> cf. <i>massonii</i>	M/C	O	O	O	O
<i>Conyza canadensis</i>	O	N	O	O	N
<i>Cucurbita spec.</i>	O	O	O	X	O
<i>Cyperus spec.</i>	N	O	O	O	N
<i>Dicranum scoparium</i>	O	O	O	X	O
<i>Digitalis purpurea</i>	O	O	O	O	X
<i>Digitaria ischaemum</i>	O	O	O	O	X
<i>Digitaria sanguinalis</i>	X	X	O	O	O
<i>Dryopteris austriaca</i>	O	N	O	O	O
<i>Duchesnea indica</i>	N	N	O	N	N
<i>Erica scoparia</i>	M/C	O	O	M/C	O
<i>Erigeron karvinskianus</i>	N	N	N	N	O
<i>Eriobotrya japonica</i>	O	N	O	O	O

<i>Erysimum bicolor</i>	O	M/C	O	O	M/C
<i>Eucalyptus globulus</i>	O	O	O	N	O
<i>Euphorbia mellifera</i>	O	O	O	M/C	M/C
<i>Eurychium praelongum</i>	O	X	O	X	O
<i>Ficus carica</i>	N	N	N	O	O
<i>Fissidens luisierii</i>	M	O	M	M	O
<i>Fragaria vesca</i>	X	O	O	O	O
<i>Fuchsia boliviana</i>	N	O	O	O	O
<i>Geranium madeirense</i>	O	O	O	O	M
<i>Geranium robertianum</i>	O	O	O	X	X
<i>Globularia salicina</i>	M/C	O	M/C	O	O
<i>Hedichium gardnerianum</i>	N	O	O	N	O
<i>Holcus lanatus</i>	O	O	O	O	X
<i>Hydrocotilae spec. cf.vulgans</i>	O	O	O	X	O
<i>Hypericum grandifolium</i>	M/C	M/C	O	M/C	O
<i>Hypericum perforatum</i>	X	O	O	O	O
<i>Hypnum cupressiforme</i>	O	O	X	X	X
<i>Laurus novocanariensis</i>	M/C	O	M/C	M/C	O
<i>Lobaria pulmonaria</i>	O	O	O	X	X
<i>Madoteca laevigata</i>	X	O	X	X	O
<i>Malus spec.</i>	N	O	O	O	N
<i>Mercurialis annua</i>	X	O	O	O	O
<i>Montbretia crocosmiiflora</i>	N	O	O	X	X
<i>Myrica faia</i>	M/C/P	M/C/P	M/C/P	M/C/P	M/C/P
<i>Ocotea foetens</i>	O	M/C	O	O	M/C
<i>Oxalis pes-caprae</i>	N	O	O	O	O
<i>Oxalis purpurea</i>	N	O	O	O	O
<i>Passiflora x exoniensis</i>	N	O	O	O	O
<i>Peltigera canina</i>	O	O	O	O	X
<i>Persea americana</i>	N	O	N	O	O
<i>Persea indica</i>	O	O	O	M/C	M/C
<i>Philonotis fontana</i>	O	O	O	X	O
<i>Phyllis nobla</i>	M/C	M/C	O	O	M/C
<i>Pinus pinaster</i>	O	N	O	N	N
<i>Pittosporum undulatum</i>	N	O	N	O	O
<i>Plagiochila spec.</i>	O	O	O	X	O
<i>Plantago coronopus</i>	N	O	O	O	O
<i>Plantago major</i>	X	O	O	O	X
<i>Polygonum capitatum</i>	X	O	O	O	O
<i>Polygonum mite</i>	X	O	O	O	O
<i>Polygonum persicaria</i>	O	O	O	X	O
<i>Polytrichum serratum</i>	O	O	X	X	O
<i>Prunella vulgaris</i>	X	O	O	O	X
<i>Prunus</i>	O	O	O	N	N
<i>Pseudoscleropodium purum</i>	X	O	O	O	O

<i>Pseudoscleropodium purum</i>	O	X	O	O	O
<i>Psidium guineense</i>	N	N	N	O	N
<i>Pteridium aquilinum</i>	X	X	X	O	O
<i>Ranunculus repens</i>	X	O	O	N	O
<i>Rubia peregrina agostinhoi</i>	O	M/C	M/C	O	M/C
<i>Rubus spec.</i>	O	O	N	N	N
<i>Salix canariensis</i>	O	O	O	M/C	M/C
<i>Salix cf. viminalis</i>	N	O	O	O	O
<i>Salvia spec.</i>	X	O	O	O	O
<i>Sellaginella spec.</i>	X	O	X	X	X
<i>Semele androgyna</i>	O	M/C	O	O	O
<i>Setaria spec.</i>	X	O	O	O	O
<i>Sibthorpia peregrina</i>	M	M	O	M	M
<i>Solanum mauritianum</i>	O	O	O	O	N
<i>Stellaria media</i>	X	O	O	O	O
<i>Syzygium jambos</i>	N	O	O	N	O
<i>Teline madeirensis</i>	O	M	O	O	O
<i>Tortula muralis</i>	N	O	O	O	O
<i>Urtica spec.</i>	O	O	O	X	O
<i>Vaccinium padifolium</i>	O	O	O	M	O
<i>Vitis vinifera</i>	O	N	N	O	O
<i>Woodwardia radicans</i>	O	O	O	M/C	O
<i>Zymbalaria moralis</i>	X	O	O	O	O
Number of neophytes	21	11	10	10	12
Number of endemic species	10	10	5	12	11
Percentage of neophytes	38,9	42,3	45,5	30,3	33,3
Percentage of endemic species	18,5	38,5	22,7	36,4	36,4

The surveyed plots in the altitudinal belt of the Laurisilva between 550 – 650 m a.s.l. contain a few introduced tree species like Walnut (*Juglans regia*), Loquat Tree (*Eriobotrya japonica*), Cryptomeria (*Cryptomeria japonica*), Sweet chestnut (*Castanea sativa*), Apple (*Malus spec.*) and Pine (*Pinus pinaster*). The relatively high altitude, where these species were planted, proves how strong past generations of humans depended on the scarce land they managed to cultivate. Just to reach the land by foot signified a climb of around 300 m in height from the living area and took a long time to pass on the small and steep footpath linking the houses to the mountain areas. For the children this was particularly difficult since they had to bring lunch for the men working on the fields. The five selected survey plots are:

Plot 1: Sítio do Viveiro (548 m a.s.l.)

Plot 2: Cascta do Viveiro (542 m a.s.l.)

Plot 3: Poço do Fetiçeiro (482 m a.s.l.)

Plot 4: Caminho dos Lamaçeiros (695 m a.s.l.)

Plot 5: Nogueira (508 m a.s.l.)

Table 8: Species present at five sample plots at altitudes ranging from 482 to 695 m a.s.l.

Plot	1	2	3	4	5
Plant specie					
<i>Pseudoscleropodium purum</i>	O	O	X	O	O
<i>Ageratina adenophora</i>	N	O	O	O	O
<i>Aicrysum divaricatum</i>	O	O	O	O	X
<i>Argyranthemum pinnatifidum</i>	O	O	O	O	O
<i>Asplenium adiantum nigrum</i>	O	O	X	X	O
<i>Asplenium cf. onopteris</i>	O	O	X	O	O
<i>Athyrium filix femina</i>	X	X	O	O	O
<i>Atrichum undulatum</i>	O	O	X	O	O
Bärlauch?	X	O	O	O	O
<i>Blechnum spicant</i>	O	O	X	O	O
<i>Carex cf. avenalla</i>	O	O	O	X	O
<i>Castanea sativa</i>	O	O	N	O	O
<i>Cedronella canariensis</i>	M/C	O	O	O	O
<i>Clethra arborea</i>	M/C	M/C	M/C	M/C	M/C
<i>Conocephalum conicum</i>	O	X	O	O	X
<i>Cryptomeria japonica</i>	N	O	O	O	O
<i>Dactylorhiza foliosa</i>	O	O	O	O	O
<i>Diplazium caudatum</i>	O	O	O	O	O
<i>Dryopteris austriaca</i>	O	O	O	X	O
<i>Dryopteris filix-mas</i>	O	O	N	O	O
<i>Erica arborea</i>	O	O	O	O	O
<i>Erica scoparia</i> ssp. <i>Platycodon</i>	O	M/C	O	O	O
<i>Erigeron karvinskianus</i>	N	O	O	O	N
<i>Eriobotrya japonica</i>	N	O	N	O	O
<i>Erysimum bicolor</i>	O	O	O	M/C	O
<i>Eucalyptus globulus</i>	O	O	X	O	O
<i>Euphorbia mellifera</i>	O	O	O	O	M/C
<i>Eurynchium praelongum</i>	O	O	X	O	O
<i>Festuca donax</i>	M	M	O	M	O
<i>Fissidens luisierii</i>	O	M	M	M	O
<i>Genista tenera</i>	O	O	O	O	O
<i>Gennaria diphylla</i>	O	O	M	O	O

<i>Geranium madeirense</i>	O	O	O	O	M
<i>Geranium palmatum</i>	O	O	O	O	M
<i>Geranium robertianum</i>	X	O	O	O	O
<i>Heberdenia excelsa</i>	O	O	M/C	O	M/C
<i>Hydrangea macrophylla</i> ssp. <i>macrophylla</i>	N	O	O	O	O
<i>Hymenophyllum peltatum</i>	O	X	O	X	O
<i>Hypericum grandifolium</i>	M/C	O	O	O	O
<i>Hypnum cumpressiformae</i>	O	O	X	X	O
<i>Ilex perado</i>	O	M	O	O	O
<i>Isoplexis sceptrum</i>	O	O	O	O	O
<i>Juglans regia</i>	O	O	O	O	N
<i>Laurus novocanariensis</i>	M/C	M/C	M/C	M/C	M/C
<i>Lejeunea carvifolia</i>	O	O	X	X	O
<i>Leucobryum glaucum</i>	O	O	O	X	O
<i>Lobaria</i> cf. <i>Pulmonaria</i>	O	O	O	O	X
<i>Lunularia cruciata</i>	O	O	O	O	O
<i>Madoteca laevigata</i>	X	X	X	X	X
<i>Malus domestica</i>	N	O	O	O	N
<i>Melanoselium decipiens</i>	O	O	O	O	O
<i>Montbretia crocosmiliflora</i>	O	O	N	O	O
<i>Muschia wollastonii</i>	O	O	O	O	M
<i>Myrica faia</i>	O	M/C	M/C	O	O
<i>Ocotea foetens</i>	O	M/C	O	M/C	M/C
<i>Passiflora x exoniensis</i>	N	O	O	O	O
<i>Persea indica</i>	M/C	M/C	O	O	M/C
<i>Phormium tenax</i>	N	O	O	O	O
<i>Phyllis nobla</i>	O	O	O	M/C	O
<i>Pinus pinaster</i>	N	O	N	O	O
<i>Plagiomnium undulatum</i> var. <i>Madeirense</i>	O	M	O	O	M
<i>Polypodium macaronesicum</i>	M/C	O	O	O	O
<i>Polypodium serratum</i>	O	O	X	O	O
<i>Polytricum commune</i>	O	O	O	O	O
<i>Porella inaequalis</i>	O	O	O	O	O
<i>Pteridium aquilinum</i>	X	O	O	O	O
<i>Quercus ilex</i>	O	O	O	O	N
<i>Ranunculus grandifolius</i>	O	O	O	O	O
<i>Rosa mandonii</i>	O	O	O	O	O
<i>Rubia peregrina</i> subsp. <i>agostinhoi</i>	M	O	M	M	O
<i>Rubus grandifolius</i>	M	O	O	O	M
<i>Rubus spec.</i>	N	O	N	N	O
<i>Ruscus streptophyllus</i>	O	M	O	M	M
<i>Salix canariensis</i>	M/C	M/C	O	O	M/C
<i>Sambucus lanceolata</i>	O	O	O	O	M
<i>Selaginella spec.</i>	X	X	X	X	X

<i>Semele androgyna</i>	O	M/C	M/C	O	O
<i>Sibthorpha peregrina</i>	M/C	M/C	M/C	M/C	M/C
<i>Smilax aspera</i>	O	O	O	O	O
<i>Tamus edulis</i>	O	O	O	O	O
<i>Teline madeirensis</i>	O	O	O	O	M
<i>Thamnobryum allopecurum</i> var. <i>Madeirensis</i>	O	M	O	O	M
<i>Usnea</i> cf. <i>Articulata</i>	O	M/C	O	M/C	O
<i>Vaccinium padifolium</i>	O	M	M	M	O
<i>Viola</i> cf. <i>Hirta</i>	O	O	X	O	O
<i>Woodwardia radicans</i>	O	M/C	M/C	O	M/C
Number of neophytes	10	0	6	1	4
Number of endemic species	11	18	11	12	18
Percentage of neophytes	38,5	0	20	4,6	14,8
Percentage of endemic species	42,3	78,3	36,7	54,5	66,7

The highest vegetation survey area includes plots at altitudes between 650 – 1350 m a.s.l. Species well adapted to open land conditions are frequently registered on the ridge tops and in huge areas the absence of high growing tree species still proves the disturbance and possibly even the eradication of forest with creation of patches of open land. The following table shows the results of vegetation mapping from five plots within representative areas in the vegetation type of the heather forest of the altitude:

Plot 1: Fio Lombo da Carapuça (717 m a.s.l.)

Plot 2: Redondezas da Laje Negra (890 m a.s.l.)

Plot 3: Fonte Vermelha (785 m a.s.l.)

Plot 4: Redondezas Poço das Pulgas (652 m a.s.l.)

Plot 5: Urze Escanchada (1015 m a.s.l.)

Table 9: Species present at five sample plots at altitudes ranging from 652 to 1015 m a.s.l.

Plant specie	Plot				
	1	2	3	4	5
<i>Adiantum reniforme</i>	O	O	O	X	O
<i>Ageratina adenophora</i>	N	O	O	O	O
<i>Ageratina adenophora</i>	O	O	O	O	O

<i>Aicrysum divaricatum</i>	O	M/C	O	M/C	O
<i>Argyranthemum pinnatifidum</i>	O	O	O	O	M/C
<i>Asplenium cf. onopteris</i>	O	O	O	O	O
<i>Athyrium filix femina</i>	O	X	O	O	O
<i>Atrichum undulatum</i>	O	O	X	O	O
<i>Blechnum spicans</i>	O	O	X	O	X
<i>Cedronella canariensis</i>	O	M/C	M/C	O	O
<i>Clethra arborea</i>	M/C	M/C	M/C	M/C	M/C
<i>Conocephalum conicum</i>	O	X	X	O	O
<i>Cryptomeria japonica</i>	O	O	O	O	O
<i>Culcita macrocarpa</i>	O	O	O	X	O
<i>Dactylorhiza foliosa</i>	O	O	O	O	O
<i>Diplazium caudatum</i>	O	M/C	O	M/C	O
<i>Erica arborea</i>	O	O	O	O	X
<i>Erica scoparia ssp. Platycodon</i>	M/C	O	M/C	M/C	M/C
<i>Erigeron karvinskianus</i>	N	O	O	O	N
<i>Eriobotrya japonica</i>	O	O	O	O	O
<i>Erysimum bicolor</i>	M/C	O	O	M/C	O
<i>Euphorbia mellifera</i>	O	M/C	O	M/C	O
<i>Eurynchium praelongum</i>	O	X	X	O	X
<i>Festuca donax</i>	M	M	M	M	M
<i>Fissidens spec.</i>	O	X	X	X	O
<i>Genista tenera</i>	O	O	O	O	O
<i>Gennaria diphylla</i>	O	O	O	O	O
<i>Geranium palmatum</i>	O	M	O	O	M
<i>Geranium robertianum</i>	O	O	O	O	O
<i>Heberdenia excelsa</i>	O	M/C	O	M/C	O
<i>Hydrangea macrophylla ssp. macrophylla</i>	O	O	O	O	O
<i>Hymenophyllum peltatum</i>	O	X	O	O	O
<i>Hypericum grandifolium</i>	O	O	M/C	O	O
<i>Hypnum cumpressiformae</i>	O	X	O	X	O
<i>Ilex perado</i>	O	M	O	O	O
<i>Isoplexis sceptrum</i>	O	M	O	M	O
<i>Laurus novocanariensis</i>	M/C	M/C	M/C	M/C	O
<i>Lobaria cf. Pulmonaria</i>	O	X	O	X	O
<i>Lunularia cruciata</i>	O	X	O	O	O
<i>Madoteca laevigata</i>	X	O	O	O	X
<i>Malus domestica</i>	O	O	O	O	O
<i>Melanoselium decipiens</i>	O	O	O	M/C	O
<i>Muschia wollastonii</i>	O	O	O	O	O
<i>Myrica faia</i>	M/C	O	M/C	O	M/C
<i>Ocotea foetens</i>	M/C	M/C	O	M/C	O
<i>Passiflora x exoniensis</i>	O	O	O	O	O
<i>Persea indica</i>	O	M/C	O	M/C	O

<i>Phormium tenax</i>	N	O	O	O	O
<i>Phyllis nobla</i>	M/C	M/C	M/C	M/C	M/C
<i>Picconia excelsa</i>	O	O	O	M/C	O
<i>Pinus pinaster</i>	O	O	O	O	O
<i>Plagiomnium undulatum</i> var. <i>Madeirense</i>	O	M	O	M	O
<i>Polypodium macaronesicum</i>	O	O	M/C	O	O
<i>Polytricum commune</i>	O	O	X	O	X
<i>Porella inaequalis</i>	O	O	O	O	O
<i>Pseudoscleropodium purum</i>	X	X	O	O	O
<i>Pteridium aquilinum</i>	X	O	X	O	X
<i>Ranunculus grandifolius</i>	O	M/C	O	O	O
<i>Rosa mandonii</i>	O	O	O	O	O
<i>Rubia peregrina</i> subsp. <i>agostinhoi</i>	M	M	M	M	O
<i>Rubus grandifolius</i>	O	O	O	M	M
<i>Rubus spec.</i>	N	O	O	N	N
<i>Ruscus streptophyllus</i>	O	M	M	M	O
<i>Salix canariensis</i>	O	O	O	O	O
<i>Selaginella spec.</i>	O	X	O	X	O
<i>Semele androgya</i>	O	O	O	O	O
<i>Sibthorpha peregrina</i>	M/C	M/C	M/C	M/C	M/C
<i>Smilax aspera</i>	O	O	O	O	O
<i>Tamus edulis</i>	O	O	O	M/C	O
<i>Teline madeirensis</i>	M/C	O	O	O	O
<i>Thamnobryum allopecurum</i> var. <i>Madeirense</i>	O	M	O	M	O
<i>Usnea cf. Articulata</i>	M/C	M/C	M/C	M/C	M/C
<i>Vaccinium padifolium</i>	M	M	M	O	M/C
<i>Woodwardia radicans</i>	O	M/C	O	M/C	O
Number of neophytes	4	0	0	1	2
Number of endemic species	13	23	14	25	11
Percentage of neophytes	20	0	0	3,1	10,5
Percentage of endemic species	65	69,7	66,7	78,1	57,9

Based on vegetation mapping results, inclination of terrain and in-field verification of interpretation of orthophoto maps, three classes of intensity of human activities in the landscape have been defined. The first class includes urban areas, terrace land under cultivation, abandoned terrace land and planted stands of Pine and Eucalyptus. All parts of the landscape that have been totally transformed by human actions are included in this class. It represents the area of highest human impact. The second class includes areas of former

logging, collecting of animal fodder, high mountain pasture and places where remains of cargo cables were recorded. The human influence in the areas included in this class is strong, species composition has been intensely modified by selective logging and usage of certain species for animal fodder collection. Nevertheless, human impact in the area included in this class can be described as medium, since an existing ecosystem has been modified, but not entirely removed and replaced by non-native elements. The third class includes all areas with very little or no visible traces of human intervention. The investigated plots in this class show a high number of endemic plants and a broad variety of native plants in various states of development. In this class there are parts, where for example mature trees of Madeira elder (*Sambucus lanceolata*) are present. Other tree species such as Madeira mahogany (*Persea indica*), Pau Branco (*Picconia excelsa*) or Madeira beefwood (*Heberdenia excelsa*) are also present in mature state.

Research area with vegetation mapping plots and footpaths

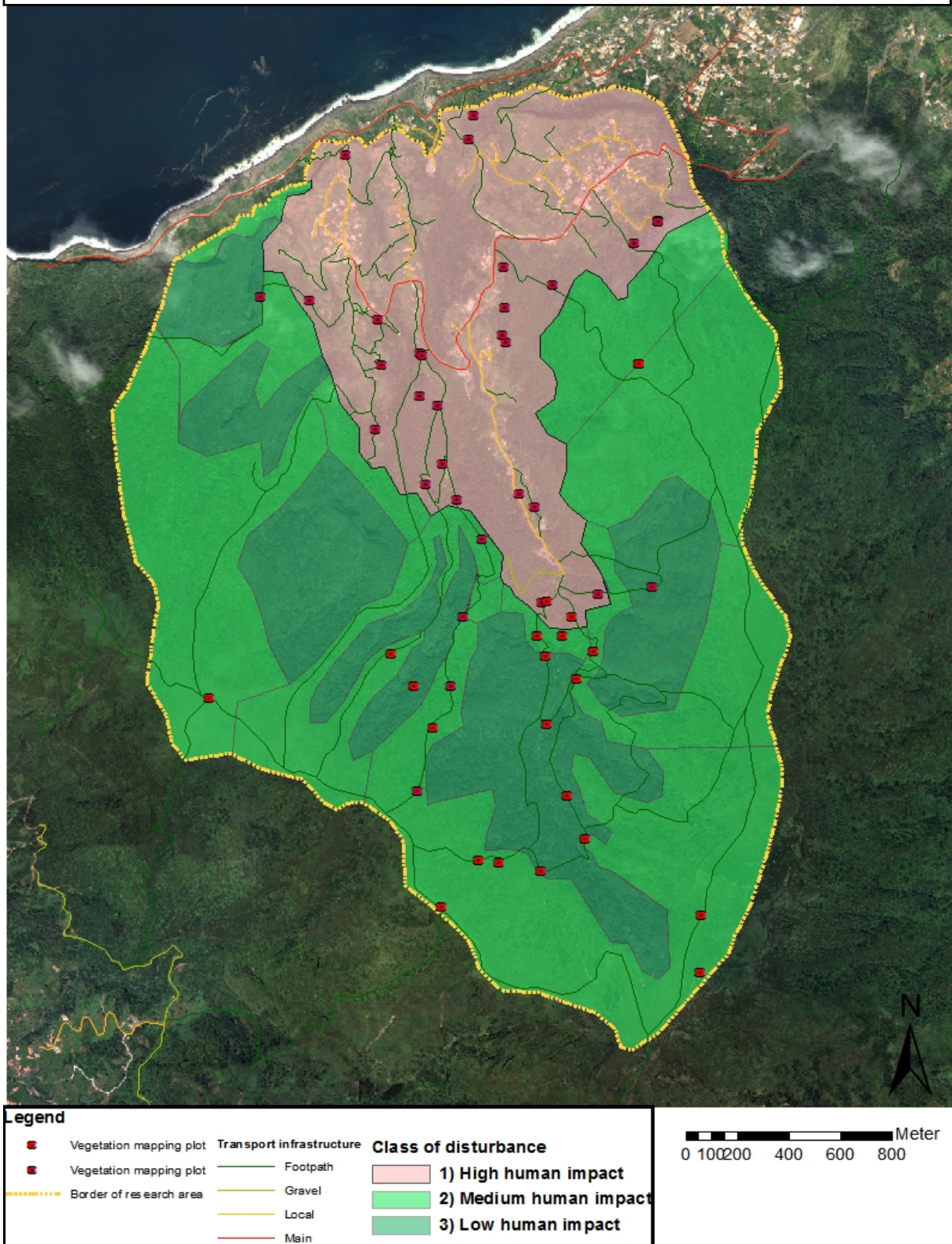


Figure 35: Intensity of human impact reflected in the vegetation

Figure 35 clearly shows how strongly connected to the natural resources people lived. The structure of the mountains defined how intense the usage of the resources was. People accessed all of the highest ridges, where the terrain was less inclined either to collect firewood from the remaining heather woodland or to collect bracon (*Pteridium aquilinum*) or even to bring domestic animals up to the high pasture. As Ernesto Martins Fernandes⁴⁹ (2018) and Maria da Terceira Lombada (2014) explained: “the calves were carried up on shoulders and brought down in pieces”. This description refers to a place called Topo das Vacas, a relatively spacious and flattish area on the western ridge dividing Ponta Delgada territory from São Vicente territory. An astonishing network of footpath was created in the mountains to facilitate access and to make the natural resources available for human use. Every ridge had one wide, well maintained footpath, most of them made with stone steps, connecting to the main ridge, either on the eastern side or to the western side. Hundreds of meters of altitude difference had to be overcome by these trails. To reach the intersection atop the western ridge allowing to connect to Ribeira Grande and Encumeada it took inhabitants from Terceira and Segunda Lombada approximately one and a half to two hours of fast walking. Next to such main connections, that were important for trade between south and north coast via Chão dos Louros and the Encumeada pass, too, many secondary footpaths permitted accessing every single ridgeline within the Lombadas da Ponta Delgada mountain area. Goat herding was common practice in the mountains and shepherds had to be able to reach even the most remote corners in order to capture their goats and bring them back down to the valley in the rainy season. The necessary time investment to reach the high mountain pastures and places of goat herding was between one and two hours one way. Ernesto Martins Fernandes, who used to have goats in the mountains, when he was a young man, explained that from time to time they had to spend the night up on the mountains. When an animal was sick or when the herd had escaped to even higher mountain terrain and needed to be taken down again, the work could not be finished within a day. In these cases it was more convenient to over-night in a shelter cave, often padded with moss or bracon (*Pteridium aquilinum*), than to hike down to the valley and back up on the next day.

Presently, the dense network of footpaths is highly endangered to disappear. Only few of the elderly people, who exactly know the footpaths, are still in good physical condition to pass

⁴⁹ Interview held on 9th November 2018

this knowledge on to the young generation. Many paths are already invisible and overgrown by vegetation, without clear and structured description of their location, it is not possible anymore to rediscover them. Processes such as landslides, rock and tree fall contribute to the disappearing of trails in the landscape and in the common local knowledge.

Overall, it is remarkable how most of the mountain area and its resources were used to support human survival. Only very few areas are not part of the actively used landscape, mostly due to terrain conditions, not permitting logging or other activities. Most of these areas consist of either vertical rock walls or deep gorges.

5.5 Discussion

Traditional methods of investigation do not allow determination of the spatial extension and exact location of past human activities in the landscape. Written sources might mention the type of activity performed or the area, but will rarely be precise enough to give a spatially correct geographical picture. Since any anthropogenic change in the landscape inevitably caused disturbances in the vegetation, detailed survey permits an understanding of past processes at a high spatial resolution and is independent from the uncertain quality of written records. The possibility to extract not only the type of human interaction, but more importantly the spatial dimension is a strong argument to apply this kind of research in the field of environmental history, regarding human-landscape interactions. To be able to read the information guarded in the present vegetation, it is essential to know what the natural vegetation without human interference would consist of. Furthermore, a profound knowledge of former agricultural practices, of introduced and used species, of woodland resources traditionally extracted is required. Ideally, interviews with locals and study of written sources are conducted to achieve a level of local knowledge that permits understanding the reasons for the present elements of vegetation in the landscape and the former activities carried out, that have caused the present state of the vegetation. These pre-requirements are one of the biggest disadvantages of this kind of investigation. It is very time consuming and the local knowledge is often valid for only a small geographical area and cannot be transferred for similar studies in other parts of the globe.

Nevertheless, for local case studies this intense assessment of human-landscape interaction is probably the one that provides the most detailed and spatially correct information. By

choosing a terrain adapted distribution of the survey plots, which permits identifying borders of different intensities of land and resource usage the workload can be optimized in terms of time efficiency. For future research and questions on the spatial relations of former settlements and the area they used to sustain the population, this method can help answer key questions. After introducing the spatial data in a GIS questions on distance between places, travel time to reach sites of cultivation, possible advantages of certain locations considering their exposition, altitude and wind shelter can be addressed. The knowledge of the spatial dimensions of human activities and usage of resources contributes to a better understanding of the living conditions of past generation, too.

6 Soil profiles and terrace systems

6.1 Introduction

This chapter focusses on the investigations undertaken on the terraced slopes in Lombadas da Ponta Delgada. The Lombadas area is one of the better-preserved examples of traditional Madeiran terrace agriculture, with numerous terrace systems next to each other. Each of them with very peculiar characteristics. In this study, an interconnected area of terraces is considered as a terrace system. Generally, they are constructed on one ridge or slope and are limited by orographic conditions of the terrain, such as watercourses, deep gorges, steep or vertical rock walls or other limitations, like huge boulders of several meters of height. A terrace system often has one common levada, providing water for all terraces and thus interlinking the terraces⁵⁰.

Presently, the existing terrace systems remain under cultivation in the vicinity of the houses, while the steeper slopes and the more distant terrace systems are semi- or fully abandoned. The continuous existence of terrace agriculture into present days allows studying the typical land use with its traditional farming practices and the development of the human-made landscape.

The slopes in the Lombadas of Ponta Delgada have been modified in various ways and with different intensities over more than five centuries. This resulted in slightly modified to highly transformed slope surfaces on all lower mountain ridges and some higher ridges, too. Some of the ridges, mainly the less inclined ones, have been fully terraced, while others have only been terraced partly. The dry-stone walls supporting the terrace bodies are composed of basalt stones of varying sizes, shapes and degrees of arrangement. Some are built just with the natural stones that have not undergone any hewing, while others are individually shaped to fit best, giving the highest possible stability to the dry-stone wall. The composition of materials of the walls also differs. There is even the extreme case of an entire terrace system with walls erected without supporting stones. Accordingly, not only does the intensity of human-landscape interaction change within this tiny area, but also the techniques used for

⁵⁰ In general, one main levada conducts water towards a terrace system and smaller tributary channels provide the link onto sub areas of the terrace system or even onto single terraces.

modification of slope surfaces seem to have been different from ridge to ridge. It is highly probable, that farmers have adapted their technologies of terrace construction to the distinct characteristics on each ridge. Certainly, the inclination played a major role in this context, but other influencing factors such as soil characteristics, availability of fertile soil and proximity to water courses were taken into consideration, too.

The terraced landscape in the Lombadas da Ponta Delgada does not show instable terraces or a high number of collapsed dry-stone walls. Within the area presently used for agricultural purposes like crop growth or pasture the dry-stone walls are well maintained and there are no traces of rebuilt walls visible. In some other areas on the globe, like in Ethiopia dry-stone walls of agricultural terraces are traditionally rebuilt every few years (Bork & Assefa 2014). The remarkable stability of the Madeiran terraces most probably origins in the high degree of adaptation to local conditions. Even dry-stone walls of terraces that have been abandoned decades ago remain in good state of conservation. In case degradation and partial collapse occurred in abandoned terrace systems, the reason that can most often be observed is root growth in the immediate vicinity of the wall or into the wall itself. Roots of trees push single stones away, destabilizing the entire dry-stone wall. This destabilization does not occur in areas that are still farmed, since any secondary trees or bushes are regularly removed from terraces. Another cause for damaged dry-stone walls that was observed during field work were fallen trees. During storm events or simply by rotting of roots or dying of the trees heavy trunks collapse onto terrace walls, destroying parts of them⁵¹.

⁵¹ Lately the Maritime Pine (*Pinus pinaster*) on Madeira Island has been severely affected by the pinewood nematode (*Bursaphelenchus xylophilus*), cf. Fonseca *et al.* This disease has led to the death of numerous trees and subsequently to a large number of fallen trees



Figure 36: Damaged dry-stone wall due to a fallen trunk, Fajã Fernandes, São Vicente



Figure 37: Secondary woodland covering former agricultural terraces with trees growing close to the dry-stone wall, Ribeira Grande, São Vicente

The soils of the terraces still under cultivation show a brownish to dark brown color indicating a high soil organic matter content. Most terrace soils in Ponta Delgada are of fine, crumbly texture and do not show signs of soil compaction. Farmers have tried to maintain the high fertility of their terrace soils to ensure the most efficient production of crops. A high content of organic matter is crucial for an outstandingly high soil fertility. According to several interview partners, farmers were aware of this beneficial effect of organic matter and of the stabilizing effect, it has to the soil and respectively to the stability of the entire terrace system. The surface of the terraces is generally arranged in a manner that small furrows following the contour lines cover the terrace. This allows relatively comfortable irrigation of the crops and prevents soil erosion at the same time. Such methods of traditional farming practiced over centuries seem to have resulted in a sustainable way of using the land. It is also noticeable that only a few terraces have a high stone content in the upper soil layer, which is worked frequently⁵².

6.2 Research questions regarding the agricultural terraces

The investigations undertaken in the terraces of Lombadas da Ponta Delgada were designed to answer questions on (a) the formation of this human-made landscape in the past, including investigation of the spatio-temporal extension of the agricultural terrace systems into the mountains and to detect the motivations having driven farmers to choose certain locations in favor of others.

Furthermore, the analysis is designed to (b) unrevealed which traditional construction methods and wall architectures have caused the outstandingly high stability of the dry-stone walls. Which different types of wall structure and terrace filling were used under which local terrain condition? How locally adapted have they been?

In this context (c) the soil characteristics of the terrace soils are an additional source of information, contributing to a more profound understanding of terrace stability. Certain soil parameters, like high content of organic matter and a well-developed pore system play a major role in either supporting terrace stability or diminishing it. The determination of these characteristics was therefore included in the analysis of all opened terrace profiles.

⁵² Depending on the cultivated crops and the crop rotation selected, several harvests can be obtained on one terrace. For example sweet potatoes (*Ipomoea batatas*) can be harvested twice a year under the climatic conditions prevailing in Lombadas da Ponta Delgada.

If the analysis proves the high soil organic matter content suggested by the soils colour, (d) which traditional agricultural practices have supported and enhanced the quality of the terrace soils and which mutual benefits resulted from the divers agricultural activities carried out, like crop farming and animal husbandry?

6.3 Location of soil profiles in the terrace systems

In the valleys of Ribeira da Camisa and Ribeiro do Velho five terrace systems have been analyzed in detail. For the opening of soil profiles in the terrace systems, semi-abandoned or abandoned terraces have been selected. In some cases, the analyzed terrace makes part of a terrace system, which was still in use in other parts. The investigated terrace systems are:

- (1) Caminho do Bardo
- (2) Lamaceiros / Poço Fetiçeiro
- (3) Levada da Fonte
- (4) Lombo das Cochês
- (5) Poios da Ladeira

Next to these terrace systems two terraces have been analyzed for a smaller set of parameters, namely one selected terrace in the terraces systems of (6) Poios de José Mendes and (7) Poios de Albino Miséria. One terrace system has been selected for a high-resolution analysis: the abandoned terrace system at Caminho do Bardo. The detailed investigation included the opening of three soil profiles spread over the entire terrace system. This permitted to discover even small differences in construction within one terrace system. In order to uncover the development of the terraced landscape and to determine the temporal frame of the first anthropogenic big scale landscape modification, a good spatial distribution of the sample sites was of main concern for site selection. A semicircular line of sampling sites around the main valley of the Lombadas, the Ribeira da Camisa and the smaller Ribeiro do Velho was established. All major ridges, presenting wider areas suitable for agriculture, are crossed by this line and on each non-interconnected ridge one sample site has been positioned at altitudes ranging from 380 m to 580 m a.s.l. Furthermore, on some ridges with pronounced former agricultural activity and visible differences in wall structure or material an additional sampling site has been selected. Outside the main agricultural area, the terraces at the remote

sampling site Albino Miséria (880 m a.s.l.) have been included in this study to illustrate extreme positions far from the settlement. The accessibility of the particular terraced areas ranges from 300 m of distance and 50 m of elevation to 4000 m of distance and 430 m of elevation from the nearest road. These differences result in a necessary time investment for a one-way trip to the terraces of approximately 15 minutes at the closest site and one hour to reach the southernmost one.⁵³

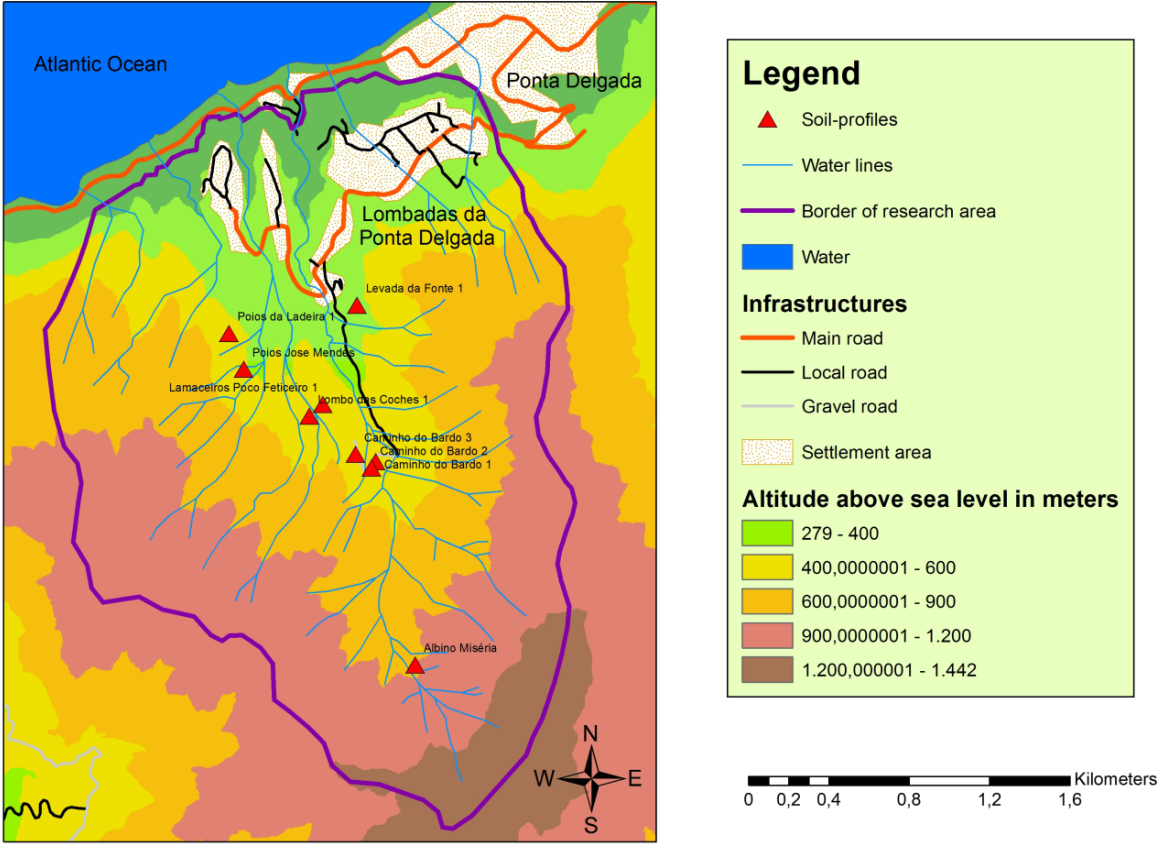


Figure 38: Location of investigated terraces

⁵³ This calculation of travel time is based on the presently existing road infrastructures. Before the construction of the cement road Cova do Bardo in 2005, the access to the agricultural terraces in Ribeira da Camisa valley took considerably longer.

6.4 Material and Methods

In each selected terrace system, one or more single terraces, mostly terraces that had damaged or collapsed walls either of natural origin or due to road construction activities, have been investigated. At every site, a profile of the terrace has been manually opened with the help of the following tools: various spades with different shapes, a shovel, a crowbar and a hoe.⁵⁴

The soil profiles for investigation of the full set of parameters have all been opened in the following way:

- 1) Cutting off the surrounding vegetation to gain access to the dry-stone wall and to have space for deposition of material from the terrace opening, like stones and soil.
- 2) Removing vegetation, mostly bramble and herbs from the dry-stone wall
- 3) Partly breaking down of the dry-stone wall and excavating the base of the terrace and the dry-stone wall
- 4) Removing of material from the terrace filling body over the entire depth of the profile to create a shear soil profile wall for investigation, sampling and structure analysis of the wall and the filling body itself.
- 5) Cleaning of the terrace soil profile for investigation. The fine cleaning has been done with a bricklayer's trowel and a medium-hard, long-bristled brush.

The lengths of the soil profiles vary from 2.60 m to 8.60 m. They have been adapted to the given conditions of each terrace system and of the terrain. The height of each soil profile was determined by the height of the dry-stone wall of the respective terrace and ranged between 1.60 m to 3.00 m.

After opening of the terrace in the above-described way, the uncovered terrace body was cleaned carefully for detailed study. During this cleaning process, the removed soil was carefully searched for charcoal pieces that would permit ¹⁴C dating.⁵⁵ The charcoal pieces found were placed in a plastic bag and their origin marked in the profile and later on in the profile drawing. The preferred location was as low in the profile as possible and ideally

⁵⁴ The traditional hoe used on Madeira Island is locally known as *enchada*. The shape of this hoe varies according to the prevailing soil type in a valley and the percentage of stones on the average terraces.

⁵⁵ For an analysis of ¹⁴C a certain amount of material is needed, in case of charcoal the AMS-¹⁴C laboratory at Kiel University requires a minimum size of 3 mm in diameter.

underneath parts of the dry-stone wall. This would indicate that most probably the wood was burnt before the respective terrace was constructed or at approximately the same time. It is very unlikely that any material containing charcoals was introduced under or into an already existing terrace wall since it would require the removal of the entire wall. Samples of sufficient size could only be taken at four profiles: Lombo das Coches, Lamaceiros/Poço Feiticeiro, Caminho do Bardo 2 and Poios da Ladeira. For visualization of the temporal dynamics of the terrace area extension into the mountains, the data have been included in GIS Arcmap 10.4.1. For the stratigraphic analysis the layers constituting the filling of the agricultural terrace, being either a small number of soil layers or soil and stone layers mixed with each other were identified. The distinction between them was done according to three main characteristics: a) changes in material b) changes in bulk density c) changes in color. Afterwards the division between the layers was enhanced by carving tiny lines following the division line between the singular layers into the profile-wall. Furthermore, the profile-wall was searched for special features like deposits of charcoal, roots, remarkable stones or big pores created by rotten roots.

Subsequently the profile-wall was prepared for the documentation in form of a technical drawing on scale paper. Therefore, a horizontal zero line has been rigorously installed in the profile-wall, using a water level. To this line, a measuring tape has been added to determine the position in the profile. Whenever possible this line was established at a depth corresponding to approximately 1/3 of the entire profile-wall height. In case a profile had a height, exceeding 3m a second level baseline has been installed to assure accurate measurement of extension of profile wall starting from the level baseline, as visible in the image below.



Figure 39: Zero line at profile C-B-3 and second baseline (second red line below measuring tape). Photo by Hans-Rudolf Bork, 2013

Accordingly, all drawings include:

- a) the stratigraphy of the different soil or stone layers
- b) the amount and distribution of stones of various sizes in the profile-wall
- c) the amount and distribution of roots with more than 2 cm of diameter in each layer
- d) the finding places of charcoal pieces

After finishing the fieldwork, all profile drawings have been digitalized using the software Adobe Illustrator.

For the pedological analysis, two types of samples were taken: (a) undisturbed samples and (b) disturbed samples. The places where undisturbed samples were taken have been documented on the drawings; disturbed samples were taken in each stratigraphic layer. The undisturbed samples have been collected with a core steel sampling ring with a volume of 100 cm³. This method prevents compaction of the soil and thus distortion of the original volume used for analysis. In this study, the bulk density of the soil was the parameter in question since it contributes to soil quality and stability of terrace systems. The bulk density has been analyzed by oven drying the samples for 24h at 105°C. Afterwards the dried samples were

cooled down and their dry weight measured. The density was calculated with the following formula: $Bulk\ density\ (g/cm^3) = dry\ weight\ (g) / soil\ volume\ (cm^3)$

The disturbed samples in this study have been used to perform analysis of soil organic matter, nitrogen and phosphorous content of the terrace soils. The organic carbon and nitrogen content has been analyzed with a Euro EA Elemental Analyzer 3000. For this process, the samples first had to be dried, then hand ground and finally ground in a planetary mill before being introduced into the EA analyzer. Additionally, the samples have been analyzed by loss on ignition analysis. Therefore, of each sample three subsamples have been taken, analyzed and an average value has been calculated. The P content has been analyzed in selected soil layers, by chemical phosphorus content analyzation for a) total P-content and b) soluble P-content.

Infiltration was measured in the field at three exemplary locations, which represent different types of terraces. One site for infiltration measurement was on a terrace with merely an earth wall (Lombo das Coches), the second one on a terrace with a thin dry-stone wall of only one layer of stone (Lamaceiros / Poço Feiticeiro) and the third one on a terrace with a dry-stone wall of over one meter of width (Caminho do Bardo 3). Infiltration was measured with a double ring infiltrometer according to Parr & Bertrand (1960). This device consists of two different sized plastic rings. In this case, one ring had a diameter of 30 cm and the second one a diameter of 60 cm. The big ring is placed on the soil and pressed into it until approximately 15 cm of the ring are in the soil. The remaining 15 cm stay above the soil surface. The smaller ring is now placed in the center of the big one and also pressed approximately 15 cm into the soil. Before measuring, water was poured into the rings to wet the surface. The measurements were then started by filling the outer ring with water, which was kept at a stable level by refilling it during the measurements. Afterwards one liter of water was poured into the inner ring and the time until it was fully infiltrated into the soil was measured. This procedure was repeated five times or until infiltration took longer than 20 minutes.⁵⁶

⁵⁶ The field measurements on water infiltration have been done by the author, Claudia Valeria Fárez Roman and Hans-Rudolf Bork

6.5 Stratigraphy, genesis and soil characteristics of selected agricultural terraces

6.5.1 Stratigraphy C-B-1

Profile C-B-1 is situated at the top part of a berm of the new forest road along Caminho do Bardo, approximately 100 m northwest of Rabo do Burro, for exact geographical location, cf. figure 26 in chapter 4.3. It is at the foot of a small ridge, close to the terraced area of Rabo do Burro. The small ridge interconnects towards the main ridge dividing Ponta Delgada area from the valley of São Vicente. Profile C-B-1 is located next to the Ribeira da Camisa stream, which flows approximately 100 m to the east in the main valley of Lombadas da Ponta Delgada. A few terraces west of C-B-1 soil profile C-B-2 is located. A little further uphill a small brook, a tributary of Ribeira da Camisa, was most probably used for water supply of the terraces, since the remains of a small water reservoir⁵⁷ are still visible. Between the profiles C-B-1 and C-B-2 the foundation walls of a former cowshed are still in place. Most likely, the farmers used to fetch water for their animals and for the terrace from this water reservoir.

Profile C-B-1 is a cut through an agricultural terrace close to its upper side, just below the wall of the terrace adjoining above. All terraces above have been abandoned and are presently covered by secondary vegetation of different succession stages. The central part of the profile shows the terrace filling with its layers down to the unweathered volcanic bedrock, on which the terrace was constructed. Profile C-B-1 is 2.60 m long, up to 1.72 m deep and exposed to the northwest. It was dug up, investigated and sampled in October 2013.

⁵⁷ These small water reservoirs are locally called *poço* and can be owned by a single person or by a group of farmers. In former times, the name often indicated the ownership or the location of the water reservoir. In recent times, the municipality has built some modern public water storage tanks. For more detailed information on this topic cf. Mendes (2008 & 2010) and Fárez Román (2015).



Figure 40: Profile C_B_1 (Caminho do Bardo 1). Photo by Hans-Rudolf Bork 2013

The profile consists of seven layers that build up an agricultural terrace with its fertile infilled soil on top and its supporting structure. The lowest layer ICv has its highest thickness of more than 1.38 m on the right side, near a huge stone. Layer ICv consists of intensively weathered bedrock. The second layer IBv,t is rich in stones and serves as the basis of the terrace filling, most probably the dry-stone wall that was removed during road construction was built on top of this layer. The next layer Y1 is the first of the terrace. On Y1, charcoal band Y2HK is exposed. It runs uphill from left to right, starting at a depth of 32 cm below soil surface to a depth of 14 cm below surface. The subsequent layer Y2 has its maximum thickness at 2.05 m profile length. From 0.9 m to 2.18 m layer Y3, which has its maximum width of 12 cm between 1.42 m and 1.72 m, covers it. To the right end of the profile, the top layer Y4 is laying directly on top of layer Y2.

On the right two large rocks margin the profile. The lowest rock extends from layer ICv to layer Y1 and the second from Y1 to the top of the profile. The human made layers contain pieces of charcoal, layer Y3 has the highest density of charcoal pieces mixed into the soil. The table below shows the finding places of charcoal pieces within the profile. The layers Y1 HK and Y3 are not described in detail because they are so rich in charcoal that charcoal is present allover.

Table 10: Finding places of charcoal pieces in the terrace soil layers

Layer	Profile length in m	Profile depth from ground level in m
Y1	2.34	0.58
Y2	2.38	0.36
Y2	2.28	0.49
Y2	2.00	0.56
Y2	1.93	0.46
Y4	1.98	0.18
Y4	1.10	0.25
Y4	0.51	0.23

Figure 41 shows the terrace soil profile C_B_1 with the elements constituting it

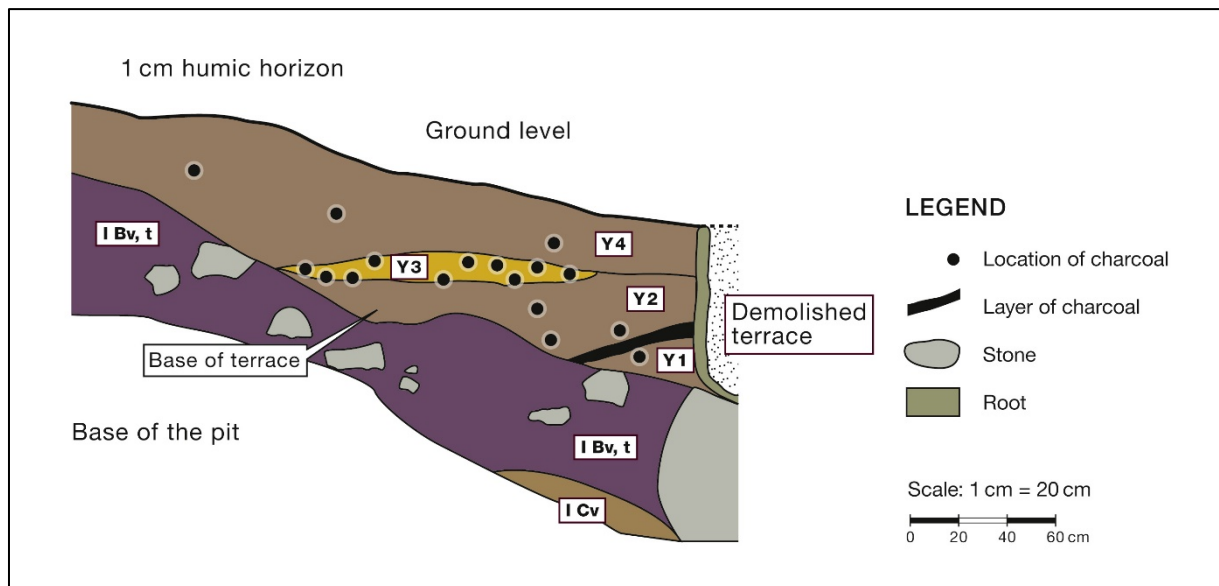


Figure 41: Drawing of profile C_B_1, graphic design by Doris Kramer

The layers I Cv and I Bv, t have not been modified during the activities of terrace construction. Only the upper parts of I Bv, t have been modified and are presently integrated into the man-made layers above. The I Bv, t layer contains many large stones with diameters of over 1 m and approximately 20 % of stones with over 10 cm of diameter. Approximately 50 % are stones of 2 mm to 10 cm of diameter.

The fine soil (particles <2mm size) of layer Y1 accounts to approximately 30 % of the layer. It has a clay content of 9.7 %, a silt content of 37.2 % and a sand content of 53.2 %. The content of C_{org} in the fine soil is 9.4 %.

The thickness of layer Y2 HK varies very little from three to six centimeters, enlarging towards the right. This layer is very rich in charcoal and has a very dark brown color. It is possible that

this layer has been a former top layer, which has been buried when the terrace became its present size. The overlaying layer Y2 is of much less dark color, but also presents a few pieces of charcoal and has a C_{org} content of 10.4 %. The fine soil of Y2 (particles <2mm size) has a clay content of 10.5 %, a silt content of 55.9 % and a sand content of 33.7%.

The thin layer Y3 has a thickness of around 12 cm, getting thinner towards both sides. It contains numerous charcoals and has a high content of C_{org} of 21.4%. The fine soil of Y3 (particles <2mm size) has a clay content of 16.6 %, a silt content of 64.3 % and a sand content of 19.1 %.

The uppermost layer Y4 was added last. It has a stone content of 20 to 40 % consisting of small sized stones from 2 mm to 10 cm. The fine soil of Y4 (particles <2mm size) has a clay content of 20.8 %, a silt content of 77.4 % and a sand content of 1.8 %.

After abandonment of the terrace system, a tiny humic horizon has formed on top of the terrace soil.

Results of laboratory analysis

Table 11: Results laboratory analysis of profile C_B_1

Sample layer	Depth in cm	N% total	C% total	Carbonates %	Organic matter %	Water volume	Bulk density
Y4	0-15	0.277	3.47	0	17.8		
Y3	16-24	0.548	8.103	0	21.4		
Y2	25-56	0.216	2.543	0	10.4	27.94	0.96
Y1		0.161	1.849	0	9.4		
Bv,t	56-106			0	9.3	32.42	1.03
Cv	106-unbek.	0.075	1,148	0	3.8		

Remark: The organic matter values result from loss on ignition analysis

6.5.2 Stratigraphy C-B-2

Profile C_B_2 is situated at the top part of a berm of a new forest road at the foot of a small ridge, which is connected with the mountain ridge that divides Ponta Delgada area from the valley of São Vicente. It is located just west of the permanent stream of Ribeira da Camisa, the largest valley in the area of the Lombadas da Ponta Delgada. To the west of C_B_2, another,

but much smaller watercourse passes close to the profile. Most probably, the water from this brook was used for irrigation of crops. A small water reservoir a few meters upstream proves the use of this watercourse.

At the right (western) part of profile C_B_2 the stone wall of an undisturbed abandoned agricultural terrace is exposed. In the middle of the profile, a small and steep footpath leads onto the terrace. To the left, the stone wall of the terrace has fallen down the berm and the terrace filling is exposed there. At the far-left side of the profile the stone wall is still intact. Profile C_B_2 is 4.5 m long, up to 1.89 m deep and exposed to the north. It was dug up, investigated and sampled in October 2013.



Figure 42: Profile C_B_2, photo by Hans-Rudolf Bork, 2013

The profile consists of four layers that build up the agricultural terrace with its fertile infilled soil on top and its supporting structure below. The lowest layer Y1 has its highest thickness of more than 1.38 m on the far-left side, near a huge support stone in the terrace wall. This layer is characterized by the inclusion of several stone blocks, with sizes of over 1 m x 1m (block on the lower left part of the profile) or 80 cm x 49 cm and 78 cm x 52 cm and another one measuring 74 cm x 43 cm in the central section of the profile. To the right, the profile finishes at a block of 73 cm x 64 cm. Approximately, 20 % of the material of layer Y1 consists of these large blocks. Furthermore, there are approximately 50 % of small stones in Y1 ranging from 2

cm to 10 cm in diameter, causing a total stone content (all particles ≥ 2 mm) of 70%. The fine soil of Y1 (particles <2 mm) has a clay content of 9.5 %, a silt content of 78.1 %, a sand content of 12.4 %. The content of C_{org} in the fine soil is 12.5 %. Within layer Y1 many elongated hollows between the numerous stones are visible. Some of them permitted a measurement of their length, which is shown in the table below.

Table 12: Length of hollows in the stone wall in layer Y1

Profile length	8cm to 16 cm	30 cm to 37 cm	46 cm to 52 cm	67 cm to 70 cm	135 cm to 145 cm	174 cm to 178 cm	174 cm to 177 cm	279 cm to 289 cm
Depth below top of layer Y1	78 cm to 80 cm	78 cm to 92 cm	80 cm to 83 cm	85 cm to 91 cm	73 cm to 77 cm	25 cm to 28 cm	37 cm to 41 cm	20 cm to 25 cm
Length of hollow	23 cm	36 cm	48 cm	51 cm	95 cm	93 cm	45 cm	21 cm

In the left central part of the profile, three thin and interrupted charcoal bands (Y1HK) with lengths ranging from 20 to 26 cm are located within layer Y1. One has been found 19 cm and two 16 cm below the top of Y1. At the far-right end between 3.51 m and 4.0 m profile length a charred stump is visible (Y2HK) on the top of layer Y1. The fine soil of Y2HK (particles <2 mm size) has a clay content of 21.9 %, a silt content of 75.8 % and a sand content of 2.3 %. The fine soil of Y2 layers (on the far-left side of the profile) has a clay content of 27.4 %, a silt content of 70 % and a sand content of 2.7 %.

Layer Y3 consists mostly of fine soil and small stones, within this layer another charcoal band (also Y2) is found at a length of 3.87 m reaching to 4.03 m with a width ranging between four to five cm.

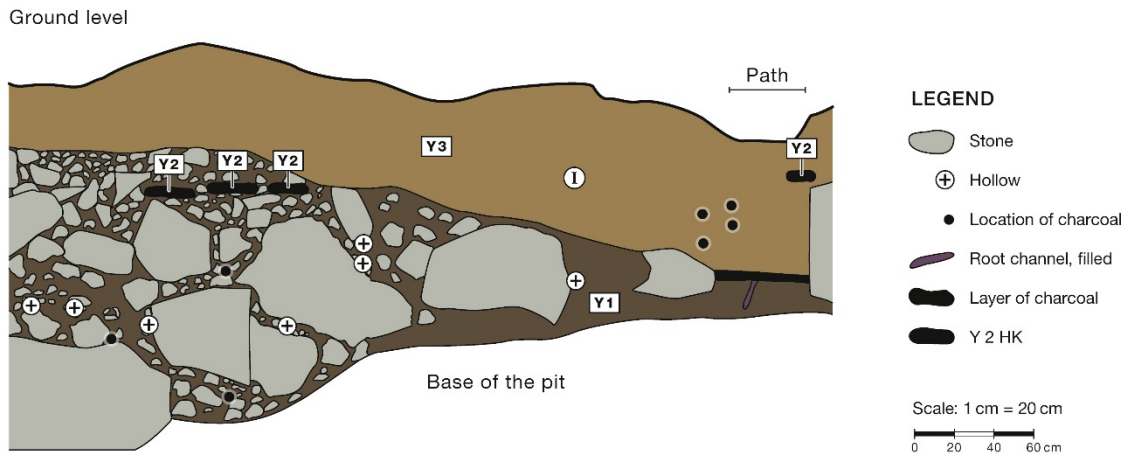


Figure 43: Drawing of profile C_B_2, graphic design by Doris Kramer

The thickness of layer Y1 varies from 140 to 20 cm. The stone content (particles $\geq 2\text{mm}$) of Y1 is very high. Stones of 10 cm of diameter cover 20 % and small stones of 2 mm to 10 cm cover 50 %, while hollows cover 5 % and fine soil only 25 % of this layer. The content of C_{org} of the fine soil is 12.5 %. Within the layer several hollows are found (see table 13) and at three places charcoal pieces have been found and collected, one at 1.78 m of depth, one at 1.37 m of depth and another at a depth of 1.13 m. Furthermore, there are three small charcoal bands extending between a profile length of 0.65 m to 1.46 m. Another charcoal band at a profile length of 3.51 m to 4 m divides layer Y1 and Y2 from each other. The uppermost layer Y3 is characterized by fine soil. Below the path connecting the terrace to the higher ones a small layer of charcoal Y2 is located. At profile length of 3.45 m to 3.60 m and a depth of 35 cm to 55 cm below surface four pieces of charcoal have been found.

Table 13: Finding places of charcoal pieces in the profile

Layer	Profile length in m	Profile depth from ground level in m
Y1	1.07	1.56
Y1	0.48	1.36
Y1	0.23	0.72
Y1	0.33	0.65
Y1	1.07	1.16
Y3	3.60	0.34
Y3	3.60	0.44
Y3	3.45	0.48
Y3	3.46	0.63

The uppermost layer Y3 has a maximal thickness of 78 cm. It contains less than 10 % of stones with diameters over 10 cm and no larger stones. In addition, it contains approximately 30 % of small stones from 2 mm to 10 cm of diameter. The fine soil is a dark brownish silty loam, containing 12.4 % organic carbon. The fine soil of Y3 has a clay content of 29.6 %, a silt content of 68.3 % and a sand content of 2.1 %.

The numerous pieces of charcoal found at various depth within the profile have permitted to perform several radiocarbon analysis to determine the period of construction of this terrace system. All pieces of charcoal have been looked at under the microscope to determine whether they origin from branches or trunk or root wood. For dating only the pieces originated from branches have been used to minimize the possible dating error.

Table 14: Results of radiocarbondating of profile C_B_2

Location in C_B_2	Sample code	Probability	Cal AD	Probability
Inside terrace wall	KIA50386	95.4 %	1520 - 1575	43.1 %
			1630 - 1660	52.1 %
Left side of the terrace wall	KIA50387	95.4 %	1520 - 1595	58.9 %
			1620 - 1655	36.5 %
In charcoal layer Y2HK	KIA50388	95.4 %	1440 – 1525	69.3 %
			1555 – 1565	0.5 %
			1570 – 1635	25.6 %
In charcoal rich spot Y3	KIA50389	95.4 %	1480 – 1645	95.4 %
In terrace wall, near large stone	KIA50390	95.4 %	1635 – 1670	90.1 %
			1780 – 1800	5.3 %
Inside terrace wall	KIA50391	95.4 %	1460 – 1525	52.4 %
			1555 – 1565	1.4 %
			1570 – 1635	41.5 %

The radiocarbondating results vary in their precision, but all samples indicate an age not younger than 1670, exerpst KIA 50389, which gives a slight possibility of the charcoal piece originating from 1780 to 1800 cal AD (probability of 5.3 %). Since no other sample has any

probability to origin from this period and the low probability of this sample really being from 1780 to 1800, it can be excluded from being considered a possibility.

Since the settlement of the land is documented to have started not before 1480, all dates before 1480 cal AD also have to be excluded from consideration. Most samples give a possible period up to 1635 cal AD (KIA 50388 and KIA 50391) to max. of 1660 cal AD (KIA 50386). The sample KIA 50390 gives a period between 1635 cal AD and 1670 cal AD as age of the sample with a probability of 90.1%. Since the other samples are all older, this period has to be shortened to 1635 cal AD to 1660 cal AD.

Five out of 6 samples give a high probability to have originated from the early 16th century, some with a very high probability: KIA 50388 (1440 to 1525 cal AD) with a probability of 69.3 %, KIA 50387 (1520 to 1595 cal AD) with a probability of 58.9 % and KIA 50391 with a probability of 52.4 %. Most probably KIA 50389, which gives a probability of 90.1 % of the sample being from the period of 1480 to 1645 cal AD has to be included in the early part of construction.

From the results described above it can be concluded that the terrace system has most likely being built in the early phase of the 16th century, but for sure no later than 1670 cal AD. The sample KIA 50389 indicates that it has not been built after 1645 cal AD. Therefore it can be concluded that the terraces of the terrace system at Caminho do Bardo have been under cultivation for over 350 years.

Over this century long period, the terrace has withstood against erosive forces, which might have led to a collapse of the sustaining wall. Only the peculiar architecture of the terraces has made this enormous stability and resistance possible.

The sequence clearly proves some intentions of the farmers that built the terrace: The lowest layer Y1 contains many large stones with diameters well above 10 cm (25 %) and small sized stones of 2 mm to 10 cm (50 %), while fine soil makes only 25 % of the material. Amongst the large stones are 3 stones with over 80 cm of length. In this layer, there are many large pores, permitting quick passage of infiltrated water and an outstandingly high saturated water conductivity. This architecture of the terrace body and sustaining wall provides great stability and resistance against erosive forces, even an over flooding of the nearby brook would not destroy the terrace, maybe only cause small damage.

A fire pit, located below the present walking path, proves that construction work was interrupted shortly. Clearly, the loamy uppermost layer (the "garden soil") was deposited as

a fertile substrate for growing cultural plants. Most probably, the stones were removed from this layer while digging it off and have been incorporated into the layer Y1, creating a smooth layer with a low stone content for farming activities.

Genesis of profile C-B-2

- Phase 1: Clearing of woodland and burning of small branches producing charcoal.
- Phase 2: Removal of the soil separately horizon by horizon. Charcoal was mixed or fell in pieces into the removed material.
- Phase 3: Construction of the lowest part of the terrace wall, using stones from the site, most probably also the ones removed from the future top layer and stones from nearby areas.
- Phase 4: Moving the very large stones into a position in the terrace wall, where they would not disturb. Deposition of the stony layer Y1 behind the new stone-wall and continuation of stone wall construction.
- Phase 5: Burning of a tree trunk in situ, charcoal from the trunk continues into root ways.
- Phase 6: Deposition of charcoal on the Y1 layer and filling more Y1 material onto the charcoal.
- Phase 7: Continuation of terrace wall construction.
- Phase 8: The fertile loamy soil material, which had been removed during phase 2, was now brought on top of layer Y1 and the burned trunk.
- Phase 9: Then, the topsoil layer (“garden soil”) was used to grow crops.
- Phase 10: Centuries later, the terrace was abandoned; succession established a deciduous woodland until today with a thin humic horizon.

Results of the laboratory analysis

Table 15: Results of laboratory analysis profile C_B_2

Sample layer	Depth In cm	Color Munsel	N% total	C% total	Total P mg/kg	Soluble P mg/kg	Organic matter %	Water volume	Bulk density
Y3	0-56	7,5 YR 2,5/3	0.32	3.88	1837	4,43	12,4	28,1	0,89
Y2 (HK)	67-70	10YR 2/1	0.37	5.66	2313	4,79	15,2		
Y1	57-91	7,5 YR 2,5/2	0.37	3.97	2256	4,97	12,5	30,47	0,77

Remark: The organic matter values result from loss on ignition analysis

6.5.3 Stratigraphy C-B-3

Profile C-B-3 is situated at the upper part of a berm of a new forest road near the foot of the central ridge between two valleys with permanent streams (cf. figure 38). The stream to the east is the main stream of the Ribeira da Camisa. The profile consists of a stonewall of an abandoned agricultural terrace, which was broken at the left side during road construction. Thus, on the left side of the profile the inside of the terrace – the terrace filling – is visible. Profile C-B-3 is 9.0 m long, up to 2.45 m deep and exposed to the east. It was dug up, investigated and sampled in October 2013.



Figure 44: Profile C_B_3, photo by Hans-Rudolf Bork, 2013

The profile consists of four layers that build up an agricultural terrace. The lowest layer Y1a has its highest thickness of more than 80 cm near the stone wall. Uphill, towards the root of the terrace thickness is decreasing. The stone content (particles $\geq 2\text{mm}$) of Y1a is 90 %. The fine soil of Y1a (particles $< 2\text{mm}$ size) has a clay content of 9.1 %, a silt content of 35.3 %, a sand content of 55.7 %. The content of C_{org} in the fine soil (7.8 %) is the lowest in this profile, but still a high value.

The thickness of layer Y1b varies from 20 to 40 cm near the stone wall to a maximum of 96 cm further inside. The stone content (particles $\geq 2\text{mm}$) of Y1b is still considerable with 85 %. The fine soil of Y1b (particles $< 2\text{mm}$ size) has a clay content of 25.5 %, a silt content of 51.8 %, a

sand content of 22.7 %. The content of C_{org} of the fine soil (16.9 %) is high. A piece of charcoal extracted from the fine soil of layer Y1b (KIA50995) was dated to 190 ± 20 years BP. Due to radiocarbon plateaus the probable age of the piece of charcoal varies between approx. 1660 to 1931 AD with a probability of 95.4 %. With a probability of 51.6 % it originates from 1806 cal AD.

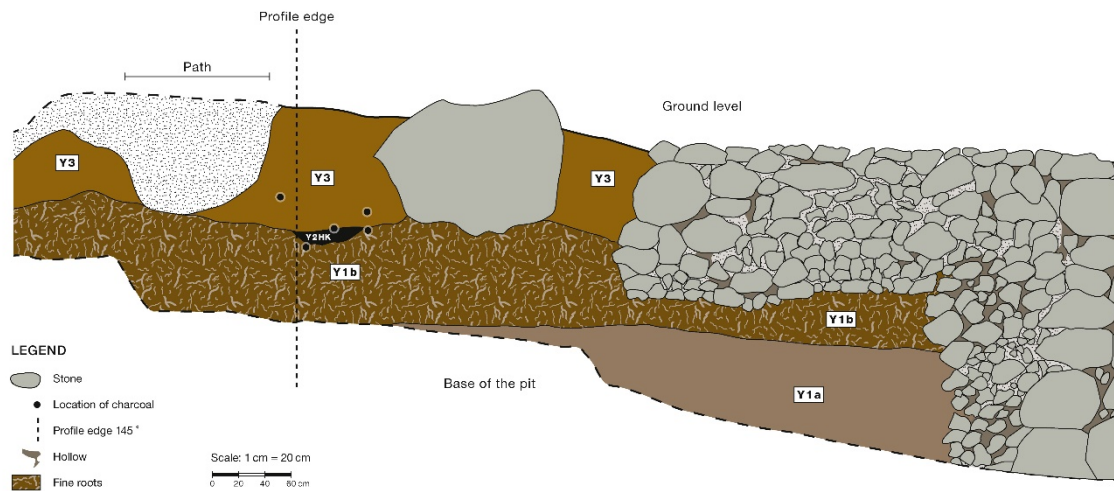


Figure 45: Drawing of profile C_B_3, graphic design by Doris Kramer

At a profile length of 2.50 to 3.05 m on top of layer Y1b a tiny layer rich in charcoal was found: Y2HK. It is probably a relic of a fire pit, which was created and used during construction. The fine soil of Y2HK has a clay content of 20.9 %, a silt content of 48.8 % and a sand content of 30.4 %.

The uppermost layer Y3 has a maximal thickness of 92 cm. It contains 25 % of stones with diameters of 2 mm to 10 cm and no larger stones. The fine soil consists of a dark brownish silty loam. The fine soil of Y3 has a clay content of 23.1 %, a silt content of 51.7 % and a sand content of 22.7 %.

Layer Y3 is rich in charcoal. The content of C_{org} of the fine soil (15.4 %) is also high. The fine soil of Y3 has a clay content of 23.1 %, a silt content of 68.3 % and a sand content of 2.1 %.

In this layer, like in the layer below (Y1b), there are charcoal pieces found close to the firepit.

Their exact locations are listed in table 16.

Table 16: Finding places of charcoal pieces in the profile

Layer	Profile length in m	Profile depth from ground level in m
Y1b	3.18	0.88
Y1b	2.65	1.12
Y3	2.74	0.98
Y3	3.10	0.72
Y3	2.44	0.66

This sequence clearly proves some intentions of the farmers that built the terrace: The two lowest layers Y1a and Y1b contain mostly large stones with diameters above 10 cm (15-25 %) and medium sized stones (65-70 %). Thus, both layers have very high infiltration capacities and saturated water conductivities. The fire pit proves that construction work was interrupted shortly, maybe for preparation of lunch. Clearly, the loamy uppermost layer (the “garden soil”) was deposited as a fertile substrate for growing cultural plants.

Genesis of profile C-B-3

- Phase 1: Clearing of woodland and burning of small branches producing charcoal.
- Phase 2: Removal of the soil separately horizon by horizon. During this activity charcoal produced in phase 1 was mixed into the fertile topsoil material.
- Phase 3: Construction of the lowest part of the terrace wall, using stones from the site and nearby areas
- Phase 4: Deposition of the stony layer Y1a in the hollow behind the new stone wall
- Phase 5: Construction of the central part of the terrace wall
- Phase 6: Deposition of the stony layer Y1b in the hollow behind the stone wall
- Phase 7: A fire pit develops
- Phase 8: The fertile loamy soil material, which had been removed during phase two, was now brought on top of layer Y1b and the fire pit
- Phase 9: Then, the topsoil layer (“garden soil”) was used to grow crops
- Phase 10: Centuries later, the terrace was abandoned; succession established a deciduous woodland until today with a thin humic horizon

Results of laboratory analysis

Table 17: Results of laboratory analysis of profile C_B_3

Sample layer	Depth in cm	Color Munsell	N% total	C% total	Carbonates %	Organic matter %	Water volume	Bulk density
Y3	0-94	7,5 YR 3/2	0.43	4.54	0	15,4	36,2	0,66
Y2HK	94-102	10 YR 2/2	0.59	7.6	0	22,2		
Y1b	102-160	7,5 YR 3/2	0.49	5.46	0	16,9		
Y1a	Below 160	7,5 YR 3/3	0.12	1.25	0	7,8		

Remark: The organic matter values result from loss on ignition analysis

6.5.4 Stratigraphy L-P-F-1 (Lamaceiros – Poço Fetiçeiro)

Profile L-P-F-1 is located west of the deep Ribeira da Camisa valley and south of the settlement of Segunda Lombada, near the main footpath leading from Segunda Lombada into the mountains, connecting to the area between Urze Escanchada and Topo das Queimadas . To the west, one of the four main tributary streams to Ribeiro do Velho is situated. The area of Lamaceiros/Poço Fetiçeiro is part of the catchment area of Ribeiro do Velho. Profile L-P-F-1 lies approximately 20 m east of the footpath within a terrace system that covers a small valley (cf. figure 38).

The inclination of the slope following the valley downhill in northern direction is comparably low. These good terrain conditions allowed terracing of the entire area and the construction of large terraces compared with other locations on Madeira Island. All terraces in this small valley are exposed towards the north and are of similar size. Approximately 100 m southwest of the profile, above the highest terrace of this terrace system, there is a big water storage basin, the Poço Fetiçeiro. This water storage basin has an approximate water storage capacity of 30 m³. It used to be filled with water from a nearby stream, a tributary of Ribeiro do Velho, which provides water all year round. For this purpose, a small Levada of approximately 200 m of length had been built. The levada was dug as a slightly ascending channel into the scarp until it reaches the stream. There is a stone and cement wall built across the stream, damming up water and diverting it into the levada.

The profile L-P-F-1 consists of two small parts of the dry-stone wall of the abandoned agricultural terrace above, framing the profile on both sides. In the central part of the profile, the terrace filling with its four layers is visible. The profile L-P-F-1 extends over 4.20 m and has a maximum depth of 2.21 m. It was dug up, investigated and sampled in May 2014.

The profile consists of six layers that build up the filling and the top soil of the agricultural terrace. The lowest layer Y1 is the base layer; it starts in this profile at a depth of 2.10 m and is of strong brown color. The fine soil of Y1 has a clay content of 5.1 %, a silt content of 38.7 % and a sand content of 56.2 %.

Above it lies layer Y2, consisting of fine soil with very little stone content. Its' width varies from 45 cm to 11 cm. A stone layer lies directly above layer Y2, it consists mainly of stones of 5 cm to 10 cm of diameter, the holes between the stones are filled with fine soil. Its' maximum width is 24 cm. Layer Y3 is a thin layer of fine soil covering the layer of stones, above it layer Y4 is situated with a maximum width of 84 cm and a dark brown color. This layer contains many pieces of charcoal, one big root and several root channels. The fine soil of Y4 has a clay content of 14.9 %, a silt content of 48.2 % and a sand content of 37 %.

The top layer Y5 is similar to Y4, it contains many root channels and a few pieces of charcoal, its' color is dark brown. Its' width is approximately 70 cm. Both layers consist of fine soil without stones. The fine soil of Y5 has a clay content of 24.2 %, a silt content of 71.6 % and a sand content of 4.2 %.

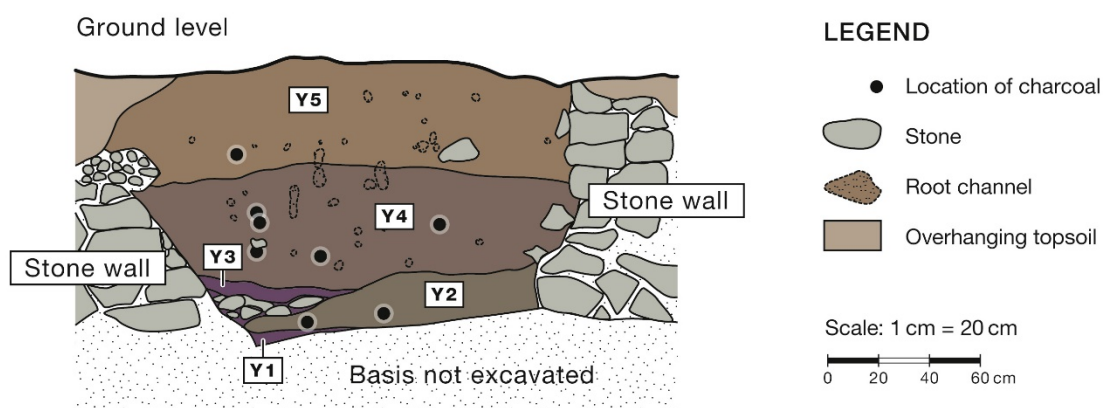


Figure 46: Drawing of profile L_P_F_1, graphic design by Doris Kramer

This sequence clearly proves intentions of the farmers that built the terrace: The small layer Y3 is a deposit of stones of medium size, ranging from 5 cm of diameter to 15 cm of diameter. This layer is discontinuous and as such has only a limited function as a drainage layer. The three upper layers of Y3, Y4 and the top-layer of Y5 have a remarkably low stone content. Most probably, the terrace soil was cleared from stones in the phase of removing it from its original position and depositing it aside from the new terrace. Thus, the main motivation of the farmers was to have a soil with as little stones as possible. Where crop cultivation takes place, it is clearly advantageous to have a soil, which can easily be worked with the local tools, mainly a special type of hoes, the *Enchada*. In all layers of the terrace filling small pieces of charcoal are found, indicating that burning of bushy material or remains of trees took place during construction (some pieces have been found even at the base of the terrace wall) and afterwards.

Table 18: Finding places of charcoal pieces in the profile

Layer	Profile length in m	Profile depth from ground level in m
Y2	1.80	2.05
Y2	2.42	1.95
Y4	1.20	1.18
Y4	1.90	1.55
Y4	1.40	1.42
Y5	1.07	0.65
Y5	2.86	0.77

The effect of soil improvement by charcoal addition was certainly known to farmers and seems to have been used from an early stage on. In layer Y4, at a depth of 1.20m the charcoal found was in very good condition for radiocarbon dating. The result of this analysis (KIA50772) is that with a probability of 82.7 % this terrace dates from the period between 1445 to 1515 cal AD and with a probability of 12.7 % to the period between 1600 – 1620 cal AD. Compared to the other terraces investigated in this study, this terrace proves to be one of the oldest terraces within the area.

The upper layers Y5 and Y4 of this profile are intensely rooted by young and old, already rotten roots.

Genesis of profile L-P-F-1

- Phase 1: Clearing of woodland and burning of branches to produce charcoal
- Phase 2: Removal of the soil horizon by horizon. Removal of large and medium-sized stones. Charcoal was mixed with the soil.
- Phase 3: Construction of the lowest part of the terrace wall, using stones from nearby areas and maybe from the site.
- Phase 4: Deposition of the removed stones, creating the base layer Y1.
- Phase 5: Deposition of layer Y2 and the stone layer above.
- Phase 6: Deposition of layer Y3 behind the dry-stone wall
- Phase 6: Construction of the central part of the dry-stone wall with big stones
- Phase 7: Deposition of Y4
- Phase 7 Construction of the upper part of the wall
- Phase 8: The fertile loamy soil material Y5, which had been removed during phase2, was now brought on top of layer Y4
- Phase 9: Generations of farmers used this topsoil layer (the “garden soil”) to grow crops
- Phase 10: Centuries later, the terrace was abandoned; succession established deciduous woodland. Until today, a thin humic horizon formed.

Results of laboratory analysis

Table 19: Results of laboratory analysis of profile L_P_F_1

Sample layer	Depth in cm	Color Munsel	N% total	C% total	Carbonates %	Organic matter %	Water volume	Bulk density
Y5	0-77	5 YR 3/4	0.51	7.11	0	20.7	37.8	0.67
Y4	78-165	7.5 YR 2,5/3	0.57	7.93	0	22.3	40.2	0.63
Y3	166-181	7.5 YR 3/4			0			
Stone layer	181-205							
Y2		7.5 YR 5/6	0.52	7.02	0	15.8	45.9	0.61
Y1	Below 205	7.5 YR 3/4			0			

Remark: The organic matter content results from loss on ignition analysis

6.5.5 Stratigraphy P-L-1 (Poios da Ladeira)

Profile P-L-1 is situated on one of the highest terraces in the steep Ladeira⁵⁸ terrace system, which is located on the eastern side on the foot of the mountain ridge dividing the municipalities of São Vicente and Ponta Delgada. Ladeira area lies south of the hamlet of Terceira Lombada and was built and worked by farmers from there. A good, cobbled footpath leading from Terceira Lombada to the area of Poios de José Mendes gives access to another small, cobbled path ascending steeply to the Ladeira terraces (cf. figure 38).

The investigated terrace has been abandoned for over a decade, which is easily perceptible when studying the recently established secondary vegetation. Profile P-L-1 consists of a stone wall of an abandoned agricultural terrace, which most probably collapsed due to root growth. Consequently, the original terrace wall on both sides frames the profile. The central part of the profile exposes the inside of the terrace: the terrace filling. Profile P-L-1 is 3.80 m long, up to 2.70 m deep and is facing east. It was dug up, investigated and sampled in October 2014.



Figure 47: Opening of profile P_L_1, photo by Hans-Rudolf Bork, 2014

⁵⁸ The toponym Ladeira means a ladder, indicating the extreme steepness of the terrain and respectively, of the footpath ascending.

The profile consists of five layers that build up an agricultural terrace. The lowest layer Y1 has its highest thickness of approximately 95 cm near the left side of it, closer to the right border with the terrace wall it decreases to approximately 80 cm. The stone content (particles $\geq 2\text{mm}$) of Y1 is locally varying between 75 to 80 %. The content of C_{org} in the fine soil is 3.6 %.

The thickness of layer Y2 does not vary much over the profile, it ranges from 30 to 41 cm. The stone content (particles $\geq 2\text{mm}$) is still considerable with 90 %. The content of C_{org} of the fine soil (5.5 %) is low, too.

The following layer Y3 is thicker on the left side of the profile with an extension of 52 cm and is getting thinner towards the right side of the profile, where its thickness is limited to 20 cm. The stone content is between 60 and 70 %, most stones have a diameter of approximately 2 to 3 cm. The content of C_{org} of Layer Y3 is 5.5 %.

Layer Y4 has a thickness of approximately 80 cm on both sides, getting thin towards the middle with 27 cm of thickness. It has a number of stones of up to 12 cm of diameter, while most stones have a diameter of 6 to 7 cm. The total stone content is between 75 to 80 %. The content of C_{org} of Layer Y3 is 6 %.

The uppermost layer Y5 has a maximal thickness of 63 cm. It contains 50 to 60 % of small stones with diameters of 1 to 2 cm and no larger stones. The content of C_{org} of the fine soil (6 %) is, compared with the other profiles in the research area not a high value.

Throughout the profile, numerous tiny pieces of charcoal were identified during cleaning of the profile wall, but larger pieces were only found in layer Y2.

Table 20: Finding places of charcoal pieces in the profile

Layer	Profile length in m	Profile depth from ground level in m
Y2	1.10	1.50
Y2	1.60	1.40

The practice of adding or mixing charcoal into the soil has been applied in this terrace, too. On the terraces above and on some of the lower terraces apple trees are cultivated. According to the circumference of the stem, the trees are only a few decades old and have not been the original form of land use.

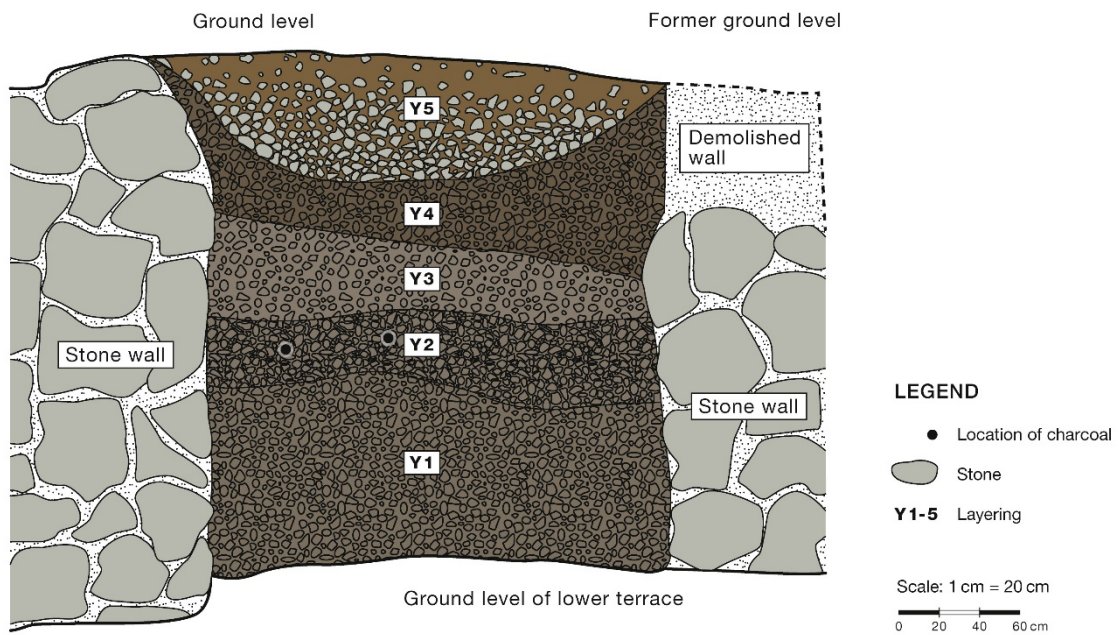


Figure 48: Drawing of profile P_L_1, graphic design by Doris Kramer

This profile proves most impressively how scarce the land was. Farmers had to build very high terrace walls to cope with the steepness of the terrain and additionally they had to work a soil that was extraordinarily rich in stones of minor size. Traditional agricultural practices like hoeing the soil before sowing, were physically demanding tasks considering the given soil conditions. The rewards for the hard work invested were poorer harvests than on terraces with a soft, loamy uppermost layer. Root growth of the cultural plants was severely limited in this stony soil. In the area of Ladeira, there are no remains of an irrigation system or of a water storage tank visible. It is possible that the terraces were only used for crops, which required no irrigation. The term used in Portugal for crop cultivation on land that has no possibility for irrigation, but is fully depended on rainfall as source of water is “*culturas de sequeiro*”. In the Lombadas da Ponta Delgada, Ernesto Martins Fernandes (Interview, October 13, 2014) referred to the existence of a few terraces used for *culturas de sequeiro*.

Genesis of profile P-L-1

- Phase 1: Clearing of woodland and burning of small branches producing charcoal.
- Phase 2: Removal of the soil separately horizon by horizon. Separation of larger stones. Charcoal was mixed into the extracted finer material.
- Phase 3: Construction of the lowest part of the terrace wall, using formerly separated stones from the site and stones from nearby areas.
- Phase 4: Deposition of the stony layer Y1 in the hollow behind the new stonewall.
- Phase 5: Further raising of the stonewall and deposition of layer Y2 behind the new wall.
- Phase 6: Deposition of the stony layer Y3 in the hollow behind the stonewall.
- Phase 7: Again raising of the wall and filling of the hollow behind with layer Y4.
- Phase 8: Final raising of the terrace wall and filling of the hollow behind with top soil layer Y5.
- Phase 9: Then, the topsoil layer (“garden soil”) was used to grow crops.
- Phase 10: During agricultural activities, small stones were partly removed from the surface.
- Phase 10: A few years ago, the terrace was abandoned; until today secondary vegetation like brumble has established. The terrace soil shows a thin humic horizon on top.

Results of laboratory analysis

Table 21: Results of laboratory analysis of profile P_L_1

Sample layer	Depth in cm	Color Munsel	N% total	C% total	Carbonates %	Organic matter %
Y5	0-62	10 YR 3/6	0.274	2.992	0	6
Y4	63-96	10 YR 4/6	0.266	3.007	0	6
Y3	97-137	10 YR 3/3	0.259	2.77	0	5.5
Y2	138-168	10 YR 2/2	0.25	2.759	0	5.5
Y1	168-262	7.5 YR 2.5/3	0.159	1.813	0	3.6

Remark: The organic matter values are calculated from the Corg content

6.5.6 Stratigraphy Lev-F-1 (Levada da Fonte 1)

Profile Lev-F-1 is the lowest of all profiles, situated next to Levada da Fonte, which is still in use, guaranteeing water supply for the terraces in the area of Lombada do Meio and of the southeastern part of Primeira Lombada. It is located approximately 200 m to the east of the permanent stream Ribeira da Camisa. The terrace constructed along Levada da Fonte, only a few inches to the east of the irrigation channel, offered an exposed profile. At a small part, the dry-stone wall had collapsed. This collapse was extended and profile Lev-F-1 was created. The mountain slope, carrying the terrace with Lev-F-1 is ascending in southeastern direction towards the viewpoint of Redondinho and the main footpath Caminho do Lombo dos Terreirinhos (cf. figures 38 and 26).

The terrace had been abandoned only a short time before our investigations, since there was still no sign of secondary shrub vegetation, but only a dense herbal layer. The relatively recent abandonment of this terrace might be due to two factors namely (1) easy access from the cement road of Camino do Bardo and (2) no threat of dry stress for crops due to proximity of the Levada with its origin in a permanent stream.

Profile Lev-F-1 is framed on both sides by a 1.60 m high dry-stone wall supporting the agricultural terrace above. Since a part of the terrace wall has collapsed, the profile exposes not only the filling of the terrace with its layers, but also the structure of the supporting dry-stone wall. The central part of the profile shows the terrace filling with the fertile “garden soil”. The length of Lev-F-1 is 2.40 m, and its maximum height is 1.60 m and it is exposed to the west. The profile was dug up, investigated and sampled in October 2013.

The profile consists of three layers and the dry-stone wall that build up this agricultural terrace. The lowest layer Y1a has its highest thickness of more than 0.42 m near the right end of the profile, next to the stone wall. The stone content (particles $\geq 2\text{mm}$) of Y1a is 90 %; most of the stones range between sizes of 5 cm to 10 cm of diameter. The fine soil of Y1a (particles $< 2\text{mm}$ size) has a clay content of 15.1 %, a silt content of 38.8 %, a sand content of 46.2 %. The content of C_{org} in the fine soil of this layer is 2.5 %.

The thickness of layer Y1b varies from 0.31 m to 0.97 m in the left and in the central part of the profile. In this part of the profile, Y1b is the top layer, which was used for agricultural production. The stone content (particles $\geq 2\text{mm}$) of this layer is slightly lower with 80 %. The fine soil of Y1b (particles $< 2\text{mm}$ size) has a clay content of 24.5 %, a silt content of 68.7 %, a sand content of 6.8 %. The content of C_{org} of the fine soil is 3.1 %.

On the right side of the profile the uppermost layer Y2, is visible. It has a maximal thickness of 0.62m and very little variation (from 0.50 m at 1.70 m into the profile to 0.62 m at 2.30 m into the profile). It contains some stones, mostly with small diameters ranging from 2 cm to 8 cm; the total stone content is approximately 60 % and the C_{org} content is 3 %.

The dry-stone wall of this profile is up to 0.70 m thick and to the inside of the wall many small stones are deposited. In this profile, there were no traces of former fire pits found, and no visible pieces of charcoal. Furthermore, there were no root channels and no larger roots visible. This is due to the fact, that the terrace has not been abandoned long enough for a shrubby secondary vegetation to establish.

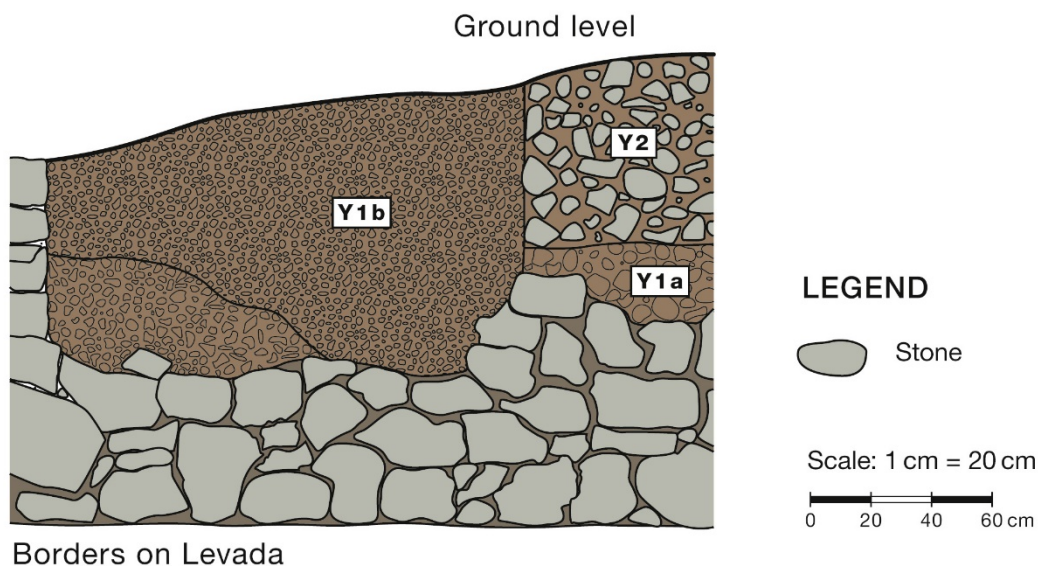


Figure 49: Drawing of profile Lev_F_1, graphic design Doris Kramer

This sequence clearly proves some intentions of the farmers that built the terrace: The comparatively thick wall with the small stones placed to the inside of it, most probably served as a deposit for the small stones, which were extracted from the soil. This way of building the terrace has contributed to the stability of the terrace, since infiltration capacity and saturated water conductivity are very high in this material. The uppermost layers Y1b on the left side of the profile and Y2 on the right side of the profile have clearly been deposited as a fertile substrate for growing cultural plants. The extraction of many stones facilitated working the soil.

Stratigraphy of profile Lev-F-1

- Phase 1: Clearing of woodland.
- Phase 2: Removal of the soil horizon by horizon and partly separation of stones.
- Phase 3: Construction of the lowest part of the terrace wall, using stones from the site and nearby areas.
- Phase 4: Filling of the separated stones behind the lower part of the terrace wall.
- Phase 5: Beginning of deposition of the stony layer Y1b and Y1a in the hollow behind the new stone wall.
- Phase 6: Construction of the central part of the terrace wall.
- Phase 7: Deposition of the stony layers Y1b and Y1a in the hollow behind the stone wall.
- Phase 8: Step by step raising of the stone wall and filling of the terrace body with layers Y1b and in the upper parts with Y2.
- Phase 9: Then, the stony topsoil layer was used to grow crops.
- Phase 10: Centuries later, the terrace was abandoned.

Results of laboratory analysis

Table 22: Results of laboratory analysis of profile Lev_F_1

Sample layer	Depth in cm	Color Munsel	N% total	C% total	Total P mg/kg	Soluble P mg/kg	Carbonates %	Organic matter %
Y2	0-60	7,5 YR 3/1	0.15	1.48	2127	7,98	0	3
Y1 b	0-68	7,5 YR 3/1	0.16	1.55	2198	5,5	0	3.1
Y1 a	60-102	7,5 YR 3/1	0.15	1.27	2176	9,58	0	2.5

Remark: The organic matter values are calculated from the Corg content

6.5.7 Stratigraphy L-C-1 (Lombo das Coches)

Profile L-C-1 is located west of the deep Ribeira da Camisa valley and south of the settlement of Segunda Lombada, near a steep shepherd's path leading onto the mountain range dividing the municipalities of Ponta Delgada and São Vicente. This path runs approximately 35 m west of L-C-1. It provides access to all terraces of the Lombo das Coches terrace system. The terrace system is located on a narrow, flattish ridge descending in northeastern direction. To the east and the west it is delimited by nearly vertical drops. Both lead to tributary streams that join each other at the foot of Lombo das Coches ridge forming the second most important stream of the valley system, the Ribeiro do Velho (cf. figure 38).

The Lombo das Coches ridge offered a thick layer of fertile soil, where the terraces could be built on. These excellent conditions of a fertile topsoil rich in organic matter, in some places with a total soil thickness of over one meter and a ridge with very little inclination in some parts let farmers experiment with terraces without any supporting dry-stone wall. All terraces of Lombo das Coches are exposed towards the north and are of similar size. Approximately 100 m southeast of profile L-C-1, close to the highest terraces of this terrace system, there is a long time abandoned water storage basin, Poço das Coches. This Poço has a width of 5 m, a depth of 2.80 m and is 8.00 m long, thus having a water storage capacity of 112 m³. The water storage basin used to be filled with water from the permanent brook bordering the agricultural terraces in the west. For this purpose, a small Levada of approximately 200 m of length had been dug into the rock wall, where the flattish area terminates at its southernmost point. This Levada has its source at a place where the brook that passes west of the terrace area runs down a vertical wall. On the ridge of Lombo das Coches the Levada runs next to the footpath to the storage basin.

Profile L-C-1 consists of a central part exposing the five soil layers of the terrace filling and the base. On both sides, the profile is framed with parts of the terrace wall, consisting only of deposited fine soil with no supporting stones. The abandoned agricultural terrace above is covered by secondary woodland, dominated by blueberry (*Vaccinium padifolium*), besom heath (*Erica scoparia*) and the non-native eucalyptus tree (*Eucalyptus globulus*). On this terrace, there are remains of a former fio⁵⁹. Most likely, this was the bottom station, where

⁵⁹ A fio is a steel cable that was used for transport of goods from the mountains to the valley. Often fios were installed on top of (nearly) vertical rock walls to transport firewood down into the valley. There were also shorter fios connecting high terrace systems with lower places. These were used to transport agricultural produce, too.

the cable that started on the highest part of the ridge ended. The eastern part of the terrace was used for cropping, while the western part was used for the operation of the cargo cable and the management of the transported material as well as the possible storage of firewood from the high mountain areas.

Profile L-C-1 extends over 2.80 m and has a maximum depth of 1.59 m. It was dug up, investigated and sampled in May 2014 and was reopened for further sampling in 2015.



Figure 50: Soil profile L_C_1 (Lombo das Coches)

The profile consists of five layers that build up this agricultural terrace. The lowest layer Y1 has a maximum thickness of 0.45 m. This layer has a very low stone content of less than 5 %. The fine soil of Y1 (particles <2 mm size) has a clay content of 7.8 %, a silt content of 57.4 %, a sand content of 34.8 %. The content of C_{org} in the fine soil (18.6 %) is very high. A piece of charcoal extracted from the fine soil of layer Y1 (KIA50996) was dated to a radiocarbon age of 140 ± 20 years BP. Due to radiocarbon plateaus the probable age of the piece of charcoal varies between approx. 1707 cal AD to 1942 cal AD. Calculated with a 95.4 %

probability the piece dates back to 1778 cal AD with 24.6 % and to 1886 cal AD with a probability of 25.7 %. A second radio carbon dating (KIA50997) provides nearly the same results: it was also dated to a radiocarbon age of 140 ± 20 years BP. Calculated with a 95.4 % probability the piece dates back to 1779 cal AD with 27.2 % and to 1886 cal AD with a probability of 35.6 %.

The thickness of layer Y2 varies from 0.02 m to 0.12 m. There are no stones found in layer Y2. This layer presents a bright yellow color. The fine soil of Y2 (particles <2mm size) has a clay content of 5 %, a silt content of 36.1 %, a sand content of 59 %. The content of C_{org} of the fine soil (23.9 %) is outstandingly high.

The layer Y3 is the thinnest of all layers. It has a width that varies from 0.01 m to 0.05 m and the layer is interrupted at 2.25 m to 2.45 m into the profile. Its' color is dark orange to red-brown. The content of C_{org} of the fine soil is 7.1 %. The fine soil of Y3 has a clay content of 9.2 %, a silt content of 25.2 % and a sand content of 65.7 %.

The thin layer Y4 varies in its' width between 0.03 m to 0.17 m maximum. It covers the Y3 layer and lies directly on layer Y2 where layer Y3 is interrupted. It is of dark brown, nearly blackish color. The content of C_{org} of the fine soil (17.4 %) is outstandingly high. The fine soil of Y4 has a clay content of 47.3 %, a silt content of 49.5 % and a sand content of 2.8 %.

The uppermost layer Y5 has a maximal thickness of 1.08 m. It contains no stones. This layer is vigorously rooted. Most of these roots are fine roots, but there are also several root channels of noticeable diameter (cf. drawing below). Furthermore, there are some parts in this layer, where material from below lying layers is mixed into this layer. The content of organic matter in the fine soil is 27.2 %. The fine soil of Y5 has a clay content of 22.1 %, a silt content of 74 % and a sand content of 4 %.

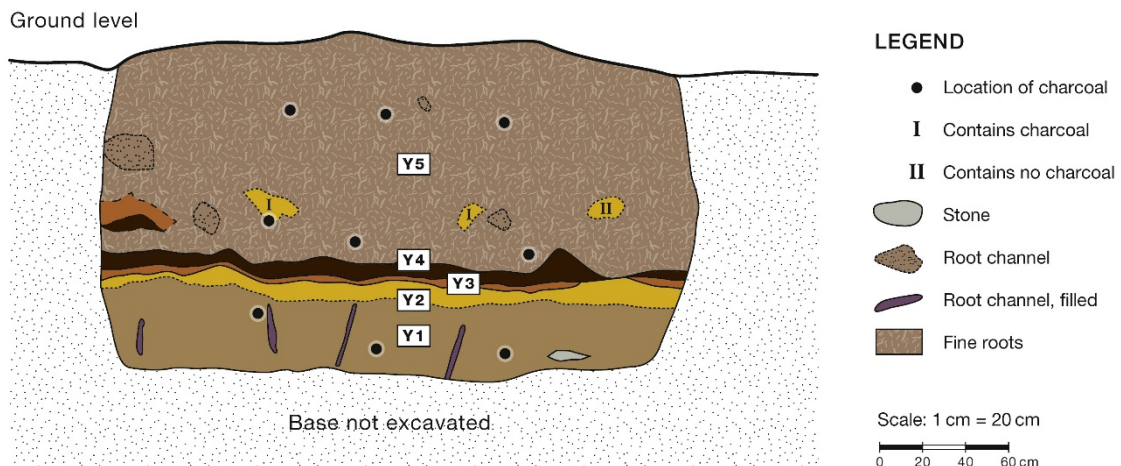


Figure 51: Drawing of profile L_C_1, graphic design by Doris Kramer

The good terrain and soil conditions the ridge offered to farmers, when they constructed the terraces permitted a much simpler and less work intense way of terrace building. No dry-stone walls are found within this terrace system, not even at the outer borders towards the chasm on both east and west side. Since there are no stones or deposits of stones found anywhere on the ridge or below in the streams, it can be concluded that there were hardly any stones on the ridge in the time of construction of the terraces. This suited the traditional agriculture well: crop cultivation took place only with tools used by hand, there was no mechanization at all. With this in mind, it is clearly advantageous to have a soil, which can easily be worked with traditional tools.

In all layers of the terrace filling small pieces of charcoal are found, indicating that burning of shrubs or remains of trees took place during construction (some pieces have been found even at the base of the terrace wall) and afterwards. Some of the larger pieces were found at the following positions in the profile:

Table 23: Finding places of charcoal pieces in the profile

Layer	Profile length in m	Profile depth from ground level in m
Y1	0.85	1.26
Y1	1.30	1.46
Y1	1.89	1.47
Y5	0.81	0.83
Y5	1.20	0.98
Y5	2.01	0.99

Y5	0.56	0.53
Y5	0.91	0.31
Y5	1.30	0.40

The effect of soil improvement by adding charcoal and ashes was certainly known to farmers and used from an early stage on. It is very likely that this terrace was used for burning of wood pieces over a long time. Since the cargo cable or the fio was used for wood transportation from the high mountain areas down to this terrace, it is very likely that some of the smaller branches broke and parts of the bark fell off at the fio. These small remains accumulated near the fio and were burnt from time to time.

Stratigraphy of profile L-C-1

Phase 1: Clearing of shrubs and trees and burning of branches to produce charcoal.

Phase 2: Removal of the soil horizon by horizon. Charcoal was mixed with the soil

Phase 3: Deposition of Y1 on the base of the terrace.

Phase 4: Deposition of material up to the approximately the height of Y4.

Phase 5: For some time, terrace building was interrupted and the site was used for non-agricultural purposes. Most probably, fires caused the heating and oxidation of iron minerals in the upper part of layer Y1, resulting in the formation of the orange layer Y2 and the red layer Y3.

Phase 6: The very dark layer Y4 was deposited on layer Y3 (maybe Y3 is the remnant of thicker layer, where the upper part was dug off later for the construction of neighboring terraces).

Phase 7: The fertile loamy soil material, which had been removed during phase 2, was now deposited as top layer Y5. This layer includes some patches of Y2 that are rich in charcoal and also one patch of combined Y2 and Y3 material.

Phase 8: Many generations of farmers used topsoil layer Y5 (the "garden soil") to grow crops, the very homogeneous soil material indicates long-time agricultural usage of the uppermost layer.

Phase 9: Centuries later, the terrace was abandoned; Eucalyptus trees were planted and in the open spaces between the trees succession established a secondary woodland. Until today a thin humic horizon developed.

Results of laboratory analysis

Table 24: Results of laboratory analysis of profile L_C_1

Sample layer	Depth in cm	Color Munsell	N% total	C% total	Carbonates %	Organic matter %	Water volume	Bulk density
Y5	0-104	5 YR 3/3	0.34	6.58	0	27.2	41,6	0,51
Y4	104-110	2YR 2,5/1	0.32	6.02	0	23.9		
Y3	111-114	7,5 R 2,5/a			0	7.1		
Y2	115-122	5 YR 4/6			0	17.4		
Y1	Below 123	7,5 Yr 4/4	0.31	6.45	0	18.6	47,8	0,56

Remark: The given organic matter values result from loss on ignition analysis

6.6 Terrace soils and their contribution to terrace stability

During the elaboration of the first soil map of Madeira Island in 1984, the soils of Madeira Island have been surveyed intensely by Ricardo et al. (Ricardo et al. 1992).

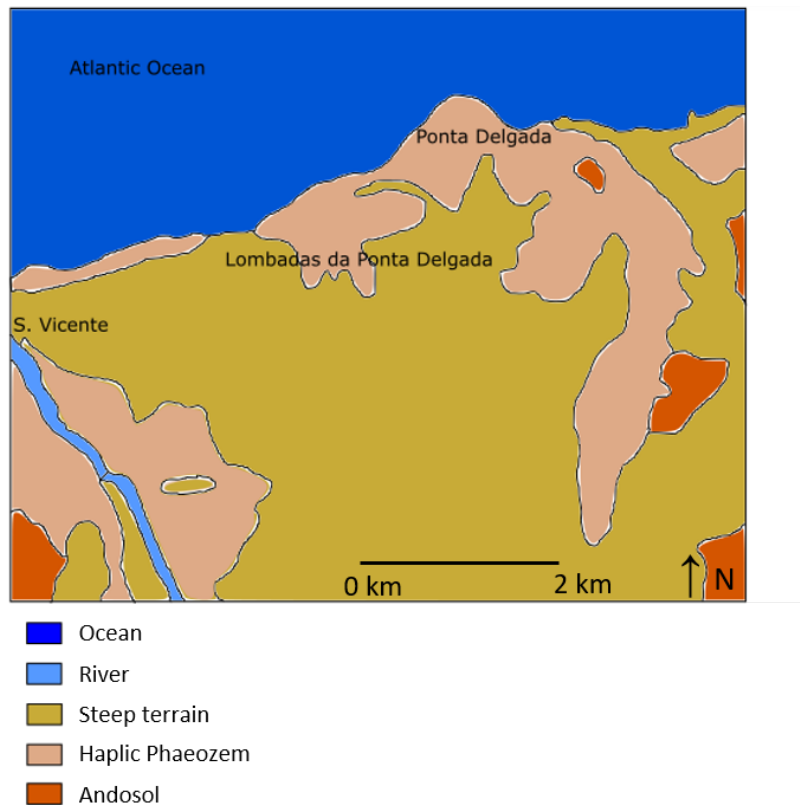


Figure 52: Soil map of Lombadas da Ponta Delgada area, adapted from Carta dos Solos, Ricardo et al., 1992

In this assessment the soils in the area of Ponta Delgada and Lombadas da Ponta Delgada have been classified as Haplic Phaeozem (Abbreviation used: PHh, survey areas 169, 168 and 166). These soils are characterized by a dark brownish to greyish, mollic surface horizon of 30-50 cm thickness over a brownish cambic horizon. The organic matter content of the surface layer of Phaeozems outside Madeira is typically around 5 percent. Furthermore, they are porous, well-aerated soils with moderate to strong, very stable, crumb to blocky structures (FAO, 2001). Almost all areas above 400 m a.s.l. on Madeira have not been surveyed and have consequently been classified as steep terrain without any additional information⁶⁰ on soil type. This classification has continued into the final edition of this soil map from 1992 (Ricardo *et al.*, 1992).

⁶⁰ Steep terrain in portuguese: “terreno acidentado” (abreviation: TA)

In general, the vast majority of soils on Madeira Island have been classified as Andosols (Ricardo *et al.*, 1992). Mata (2004) mentions that approximately two-thirds of the island soils are Andosols. They are characterized as black soils of volcanic landscapes with parent material being mainly volcanic ash, tuff, pumice, cinders and other volcanic ejecta (FAO, 2001). Due to their volcanic parent material, Andosols are usually found in undulating to mountainous terrain and are often consisting of an AC- or ABC-profile. Andosols result from an often rapid weathering of the aforementioned porous volcanic materials and consequently can result in high total pore volumes ranging between 50 and 75 % of the total volume (FAO, 2001). According to FAO (2001), many of the world's Andosols are intensively cultivated and used for a wide range of crops, although Andosols have a considerable capacity to render Phosphorous unavailable to plants. Furthermore, the FAO (2001) mentions that another, often serious constraint is the steep topography where Andosols generally occur.

The studies carried out by Mata (2004) have shown that the Andosols on Madeira Island are by far the main reason for the huge stock of organic C in the soil. The maximum quantity found was of 73 kg/m², one of the highest values in the world (Mata, 2004).

Since the area of Ponta Delgada and Lombadas da Ponta Delgada is almost entirely terraced, it is currently not possible to find any accessible piece of unaltered surface to verify the original soil type. The construction of the agricultural terraces has profoundly changed the original soil, regardless of whether it was Phaeozem or Andosol. The presently dominating type of soil is Anthrosol.

The investigated terrace soils of most profiles, except the stone rich profiles Lev_F_1 and P_L_1 show properties that are quite similar to the parent material, of Andosol or Phaeozem. Low bulk densities characterize both soils. In general, Andosols have a bulk density below 0.9 g/cm³ and values of 0.3 g/cm³ were even measured (FAO, 2001). A Haplic Phaeozem was measured with 1.35 g/cm³ (Bahn *et al.*, 1995) and a Rendzic Phaeozem was measured with an average value of 1.11 g/cm³ over a period of 10 years from 1996 to 2005 by Pranagal and Podstawka-Chmielewska (2012).

In Lombadas da Ponta Delgada, the measurement of bulk density has been carried out for the terrace systems of Lombo das Coches, Lamaçeiros/Poço Fetiçeiro and Caminho do Bardo. The bulk density of the layer Y5 (0-104 cm depth) of the profile L_C_1 is very low with 0.51 g/cm³ and even the lowest layer Y1 (below 123 cm of depth) still has a very low bulk density of 0.56 g/cm³. In profile Lamaçeiros/Poço Fetiçeiro the bulk density of the layer Y5 (0-77 cm

depth) is 0.66 g/cm³ and in Caminho do Bardo_2 the bulk density of the layer Y3 (0-56 cm depth) is 0.89 g/cm³, while below (57-91 cm of depth) the bulk density is 0.77 g/cm³. These low values indicate that it is more probable that a local Andosol was used to build these agricultural terrace systems and not a Phaeozem. As a result, soils with such a low bulk density have a porosity that allows large quantities of water to penetrate quickly. Almost all profiles showed several large pores in addition to well-developed small and medium-sized pores. Root channels of 0.5 cm (profile C_B_3) to 10 cm of diameter (profiles L_C_1 and C_B_2) are often found. Infiltration measurements on the terraces corresponding to the profiles of C_B_3, L_C_1 and L_P_F_1 have proven very high infiltration capacities:

Terrace above profile C_B_3:	1146 mm/h ⁶¹
Terrace above profile L_C_1:	394 mm/h
Terraces above profile L_P_F_1:	181 mm/h

A very important factor supporting the high infiltration capacity is the way farmers work the terraces. In the process of field ordering no heavy machinery is used, all tasks are performed manually. As a result, there are no compaction zones in any one of the soil profiles, as it is common under machine-treated soils (Blume *et al.*, 2010). The network of large pores is intact and interlinks the upper soil with the lower layers of the profile, significantly raising the amount of water penetrating the soil.

Precipitation rates measured in the past on Madeira have never exceeded the infiltration rates measured in this study. The often-hazardous surface runoff is not generated on these terraces. Due to these characteristics, the terraces are very resilient against erosive forces. If surface runoff from the mountains above flows onto the terrace systems, erosion damage is possible. The possibility of erosion damage and landslides increases, if the terraces have been abandoned and the dry-stone walls are already destabilized or if the terrace surface is inclined. In the Lombadas area no damage to the supporting dry-stone walls by water erosion could be observed, where as it was observed in other areas of the island.

⁶¹ Most probably, this extraordinarily high value is the result of a dense network of large pores and is not representative for the entire terrace system.



Figure 53: Landslide damage above and within agricultural areas, image on the right by Bork, 2013

Another important factor contributing to aggregate stability of soils is the content and the type of organic matter (Baldock & Nelson, 1999; Boix-Favos, 2001; Chaney & Swift, 1984). The dark color of the investigated soil profiles does already indicate that they are rich in organic matter, additionally contributing not only to the stability of aggregates, but as a result to the stability of the pore system and as such to the entire terrace soil. All profiles show a dark color reaching down to the base of the terraces. According to the Munsell color chart, the profile C_B_2 is of very dark brown color in the upper layers down to a depth of 91 cm and below it is of dark yellowish brown due to the amount of less weathered parent material. Profile L_P_F_1 has a dark reddish-brown color down to 77cm of depth and below it has a very dark brown color. Profile C_B_3 is also of dark brown color down in the entire profile with the exception of a tiny layer of charcoal, which is of very dark brown color. There is no profile, which does not have layers of dark brown or very dark brown color.

Hence, all soil profiles are characterized by similarly high values of C org. It is remarkable to have not only the topsoil, but also the lowest layers of the profiles very rich in organic matter. The material used for construction of the terraces must have been already rich in organic matter. Furthermore, the century long use of the agricultural terraces has been done in a soil conserving way, adding huge amounts of organic material to the terraces on a regular basis,

so that the annual losses of organic matter have been compensated by these measures. In the following table, the organic matter contents of the upper soil layer and the first layer below are displayed for selected profiles. The soil profiles are ordered in a way that the distance from the terrace to the settlement is diminishing from left to right.

Table 25: Organic matter contents of upper soil layers

Layer \ Profile	Organic matter in % at C_B_3	Organic matter in % at C_B_1	Organic matter in % at L_P_F_1	Organic matter in % at P_L_1	Organic matter in % at Lev_F_1
Yx	15.4 %	17.8 %	20.7 %	5.1 %	6.6 %
Yx-1	22.2 %	21.4 %	22.3 %	6 %	7.3 %

Table 25 shows that the first three profiles contain a high amount of organic matter, ranging between 15.4 % and 20.7 % in the top layer, which has been used actively for agriculture. The layer directly below has a slightly higher content of organic matter, ranging between 21.4 % to 22.3 %. This is even for an Andosol an outstandingly high value that is only reached under specific climatic conditions, which according to Arnalds (2008) allow an accumulation of 12 to 20 % of organic carbon. The terrace soils on the higher locations of Lombadas da Ponta Delgada even exceed the values reported by Arnalds.

The terraces P_L_1 and Lev_F_1 have organic matter contents of 5.1 % and 6.6 % in the uppermost layer. Most probably, the material used for the construction of the terraces has been of a lower organic matter content than the aforementioned terraces. Since they are comparatively close to the settlement, they might also have been used more intensely. Nevertheless, the values of C-org are high and the values of the soil layer directly below the actively used horizon are high in comparison with many other agriculturally used soils. The difference of approximately 1 % in organic matter from the top layer to the layer below also indicates very good soil conservation practices. Most agricultural soils have much lower levels of organic matter. In Germany, for example the average value of organic matter content of a Haplic Chernozem under agricultural use is 2.2 %⁶² (BGR, 2007). On the Moldavian Plateau

⁶² This value is the mean of 86 sampling points in Chernozem in Germany in the frame of a sampling campaign of the German Federal Institute for Geosciences and Natural Resources (Bundesanstalt für Geowissenschaften und Rohstoffe).

Bireescu et al. (2018) have measured an organic matter content of 6.2 % in the A horizon (0-25cm) under oak forest.

The type of agriculture practiced on Madeira Island has been very different between the north and the south side. In the late 15th, 16th and early 17th century, many areas in the south were used for cultivation of sugar cane. These plantations were managed in monoculture system and there are a number of reports mentioning the diminishing of soil quality (Ackermann, 1821; Ribeiro, 2005; Natividade, 1953). In those reports it is generally not recorded, where these problems have caused bad harvests. Nevertheless, in Ponta do Sol valley the cultivation of sugar cane has been the push factor for the expansion of the terraces into the mountains and it has been the first place of big scale sugar cane plantation on the island (da Silva, 1933). Therefore, in the frame of this study, a few samples have been taken in this valley: Rib_PS_1 (Ribeira da Ponta do Sol_1), Rib_PS_2 (Ribeira da Ponta do Sol_2) and Lev_P_S (Levada da Ponta do Sol). All sampled terrace systems show comparatively low amounts of organic matter, as described in table 26. In the neighboring valley of Tabua the two samples Tab_1 (Tabua_1) and Tab_1_A (Tabua_1_A) were taken. In this higher part of the valley, no monoculture sugar cane production has taken place and the amount of organic matter in the soil is significantly higher. The differences in organic matter content of Madeiran agricultural soils thus is huge.

Table 26: Organic matter contents of differently used terrace soils in the valleys of Tabua and Ponta do Sol

Depth in cm	Organic matter in % (Tab_1)	Organic matter in % (Tab_1_A)	Organic matter in % (Rib_PS_1)	Organic matter in % (Rib_PS_2)	Organic matter in % (Lev_P_S)
0-20	5,5	4,1	3,3	2,3	1,5
20-40	5	5,6		3,2	1,9

The generally high amounts of organic matter (Madeira, 1994), have given origin to the question what an apparently unaltered soil and terraces with a short period of use would look like. Therefore, during this study an unaltered soil in a laurisilva forest at approximately 1000 m a.s.l. near Encumeada in the area of Folhadal has been sampled. Furthermore, the terrace systems at Albino Miseria, José Mendes and at Levada das Fontes have been sampled. All of these terrace systems have been constructed in the mid of the 20th century and were abandoned in the last decade of the 20th century. In table 27 the organic matter content of the samples from the aforementioned terrace systems are shown. There are no signs of

decrease in the amount of organic matter. The only terrace system where a small decrease in organic matter is visible is at Caminho do Bardo (C_B_1).

Table 27: Organic matter contents of unaltered forest soil (Folhadal), distant terraces and a standard agricultural terrace in Lombadas da Ponta Delgada

Depth in cm	Organic matter in % (Fol_1)	Organic matter in % (Alb_Mis_1)	Organic matter in % (J_Mendes_1)	Organic matter in % (Lev_F_2)	Organic matter in % (C_B_1)
0-15	55,9	49,2	44,8	43,1	17,8
15-25	35,8	43,2	44,7	33,3	21,4

The laboratory results of the soil analysis indicate that the traditional agriculture practiced on these terrace fields is fulfilling all requirements for a sustainable use of the soil, it can even improve the quality of the soil. In the following chapter, the most common traditional practices are described.

7 Land use dynamics and traditional agriculture

7.1 The world-wide applied art of terracing gets to Madeira

Most mountainous regions, climatically suitable for agricultural activities, have been used and modified by humans in the past to create usable agricultural space on hillsides and many areas are still in a process of regular human intervention (Kladnik et al., 2017). Plant production on inclines often required the creation of flattish surfaces to minimize erosion of fertile topsoil by avoiding or at least reducing surface runoff and at the same time improve water retention on the land. Furthermore, fieldwork operations such as soil tillage, sowing, irrigation, plant protection, manuring and harvesting are facilitated on relatively even surfaces on terraces. Throughout many regions of the world, such as the Mediterranean (Bevan, 2011; Asins, 2006), in Asia (Johnston et al. 1982; Conklin, 1980; Henck et al., 2010), some African mountain ranges (Assefa & Bork, 2014), the Andes (Denevan, 1980 & 2001) and lowlands of Central and South America (Turner, 1983; Contreras, 2007) terraced slopes reaching from valley grounds far up into the mountains are witnessing millennia of human interaction.

Independently from each other, many cultures have developed the art of terracing in their region. The resulting terraced landscapes are as diverse as the regions they are implemented in. Varying from dry stone bench terraces in semi-arid climates, such as parts in the Andes, to specific earth wall constructions retaining water for rice cultivation in China, on the Philippines and many other humid Asian regions, agricultural terraces have been adapted to the geographical conditions prevailing in the area. They are an integral part of the cultural identity of the societies having built them. The importance of agricultural terraces becomes evident when considering that the basic alimentation needs of most mountain societies were satisfied with the produce grown on terraces. The well-being and in extreme cases the survival of these societies were directly linked to the resilience of the terraces against destructive forces⁶³. Consequently, the higher the terrace building skills, the knowledge and conception of irrigation systems in dry areas, the more secured was the survival of the resident group of people.

The phase of European discoveries in the 15th and 16th centuries with the colonization of formerly uninhabited land, which was mostly limited to remote islands, located far out in the

⁶³ The term “destructive forces” includes not only erosive forces such as water and wind, but also events like earthquakes or fires.

ocean, brought new impulses to terracing. In the case of Portugal and its discoveries of uninhabited island groups like Madeira (1419), Azores (1431), Cape Verde (1460), São Tomé & Príncipe (1471) and Ano Bom (1475) the traditional knowledge and art of terrace building was partly transferred from mainland Portugal to those islands that required terracing due to the presence of steep slopes. Many of the settlers being attracted to the new lands were used to terrace agriculture in their home region⁶⁴. Presumably, the construction of agricultural terraced landscapes proceeded slowly. The first settlers began cultivation of some parts of the land to satisfy their alimentation and economic needs. Over time, a growing local resident population had higher needs of food and cash crop production. The extension of arable land into formerly not cultivated zones continued with population growth.

The island of Madeira is a perfect example of this slow successive process of taking more and more land into cultivation to feed a growing local resident population. It is reported by numerous authors that land was given to noble men in order to make use of it over several decades after the initial settlement. How exactly this process took place, which parts of the allotted land were taken into cultivation in which period, how old are the terraces and which preferences for land use did people have, remains unknown. The dynamics of extension of agricultural terraces in the prosperity period of agriculture and the recent process of land abandonment also remain widely unknown. Furthermore, the traditional agricultural practices applied in maintenance of soil fertility, stability of soil and terraces and the traditional crop spectrum have not been object of research. It is the aim of this chapter to contribute to a more detailed understanding of past and present land use dynamics and the spatial dimension of created terraced landscape in the central northern area of Madeira Island, in the Lombadas da Ponta Delgada. The detailed analysis of some exemplary terrace systems illustrates the extraordinary (agri-) cultural heritage created by generations of Madeiran farmers.

7.2 Methods

For reasons of clarity, the description of the methods applied to investigate the land use dynamics and the traditional agricultural practices has been divided in two sections. Since this chapter focuses on the analysis of the total extension of agricultural terraces on one hand,

⁶⁴ Terrace agriculture is very common in all mountain regions of Central and Northern Portugal.

and on the other on traditional agricultural practices used on these agricultural terraces, the methods of investigation are distinct. The first section describes the methods used for the assessment of the terraced arable land, while the second describes the methods used for the investigation of traditional agricultural practices.

7.2.1 Methods used for the assessment of the terraced arable land

The initial assessment of land use history of Ponta Delgada was through an intensive literature study. At first online research was done, but most regional and many national publications could not be accessed. They were merely listed in the online catalogs of national and regional libraries and research centers. Personal investigation in the following libraries and research centers completed the literature study of the land use history of Madeira in general and Ponta Delgada in particular:

- a) Centro de Estudos de História do Atlântico, Funchal
- b) Arquivo Regional da Madeira, Funchal
- c) Biblioteca Pública Regional da Madeira (Fundo local⁶⁵), Funchal
- d) Biblioteca Nacional de Portugal, Lisbon

In 2010 the entire Portuguese terrain was included in a national remote sensing campaign; the coastal and most densely populated areas were photographed in a scale of 1:5000. In the Madeira region, the campaign included taking orthophotos with a scale of 1:5000. These images served as base for the assessment of the present land cover and land use situation in the Lombadas da Ponta Delgada.

The extension of formerly used terraced land could not be assessed by photo interpretation. Under the climatic conditions prevailing on Madeira Island abandoned agricultural terraces quickly begin to overgrow with shrubs and secondary woodland establishes rapidly, hiding terrace walls beneath them. In the 20th century, farmers often planted pine trees (*Pinus maritima*) on marginally productive terraces, which dropped out of the traditional cultivation system. Both of these secondary woodlands cover former terraces and make it impossible to investigate the true extension of terraced land by means of photointerpretation. To investigate the extension of terraced land the surrounding zone, framing the actual cultivated areas, was subdued to intense in field investigations.

⁶⁵ Fundo Local is the collection of both scientific and non-scientific publications regarding local heritage including biological, natural, cultural, urban and social heritage.

Since the secondary mountain woodland in the research area covers large parts of formerly used terrace fields the planning of the personal in-field investigation required previous knowledge of:

- a) The location and the approximate size of abandoned terrace systems
- b) The trail infrastructure that provided access to the terrace systems
- c) The present state of weed overgrowth on trails and terrace systems

The only source that could provide the information needed were older inhabitants of the Lombadas. In nine in-depth personal interviews with farmers and former shepherds in Primeira, Segunda and Terceira Lombada data on the location of formerly used terrace systems presently hidden under vegetation cover, were collected. During these interviews it turned out, that without a person knowing the formerly used access routes precisely, it would be impossible to find most of the long-term abandoned terrace systems. Most of the trails were narrow in former times and are so densely overgrown, that they were not walkable anymore. Passage would only be possible in a group with several machetes to clear small shrubs and weeds, mainly prickly gorse (*Ulex europaeus*) and various invasive bramble species (*Rubus spec.*).

Consequently, group mountain excursions with locals, who enjoyed sharing their knowledge, including José Carlos, Cipriano Bernardo, Ricardo Fernandes, Marco Livramento and the mayor of Ponta Delgada Sr. Caldeira were undertaken to record the trail infrastructure of the Lombadas da Ponta Delgada. Some other trails were investigated following the valuable and very precise trail descriptions of the shepherd and former mountain man Ernesto Martins Fernandes from Lombada do Meio. On all trails covered during these group mountain excursions and on solo hikes GPS-tracks were recorded with the hand-held GPS device "Garmin Oregon". The recorded GPS-tracks were introduced into a GIS-system (ArcGIS) for planning the investigation of the total terraced area in the Lombadas.

The abandoned and semi-abandoned terrace systems along the mountains south of Primeira Lombada, the valleys of Ribeira da Camisa and Ribeiro do Velho and many small, often isolated patches on the mountain ridges have been investigated. The location of each terrace system has been recorded with the Garmin GPS device and the approximate size has been

measured⁶⁶. The processing of the collected spatial data has been performed in ArcGIS, too. For GIS-analysis of dynamics of land use seven land use classes have been established.



Figure 54: GPS-recording of formerly terraced fields and steel cables for cargo transport to the settlement; behind the group a formerly used steel cable is visible

The following four terrace systems with very peculiar structure of sustaining walls, reaching from hewn basalt stone to mere earth walls have been chosen for detailed surveying:

- a) Lombo das Coches (contains soil profile LC_1)
- b) Lamaceiros / Poço Fetiçeiro (contains soil profile LPF_1)
- c) Cova/Caminho do Bardo (contains soil profiles CB_1 and CB_2)
- d) Caminho do Bardo (contains soil profile CB_3)

⁶⁶ Some terrace systems were partly overgrown in a way that did not permit to access their exact extension on the slopes. In these cases, the penetrable sections were GPS recorded and searched for natural barriers to the extension of the terrace system, like rock walls or gorges close by. The missing information on the border of such a terrace system has been estimated, based on the maximally possible extension, which the terrain conditions permitted.

All of these terrace systems include minimally one terrace, where a soil profile has been opened within the terrace filling and the structure of the wall, the structure of the terrace filling, certain soil parameters and if possible the age of the terrace have been determined⁶⁷.

The survey of the selected terrace systems provides:

- a) The existing spectrum of variations of sustaining walls constructed in Lombadas da Ponta Delgada mountain area
- b) An overview of the size of agricultural land that was gained by this laborious way of constructing bench terraces
- c) The similarities and differences of terrace systems under varying terrain conditions.

The terrace systems selected for intense surveying are located in the southern terraced areas of Ribeira da Camisa valley at an altitude of approximately 500 m a.s.l. at Cova do Bardo and Caminho do Bardo. The second set of terrace systems is located in the southernmost part of the terraced area along Ribeiro do Velho valley at approximately 550 m a.s.l. near Lombo das Coches. The exposure of the terrace systems is mainly north, only terraces of Caminho do Bardo terrace system are facing east.

⁶⁷ Cf.: Chapter 6.5 Stratigraphy, genesis and soil characteristics of selected agricultural terraces

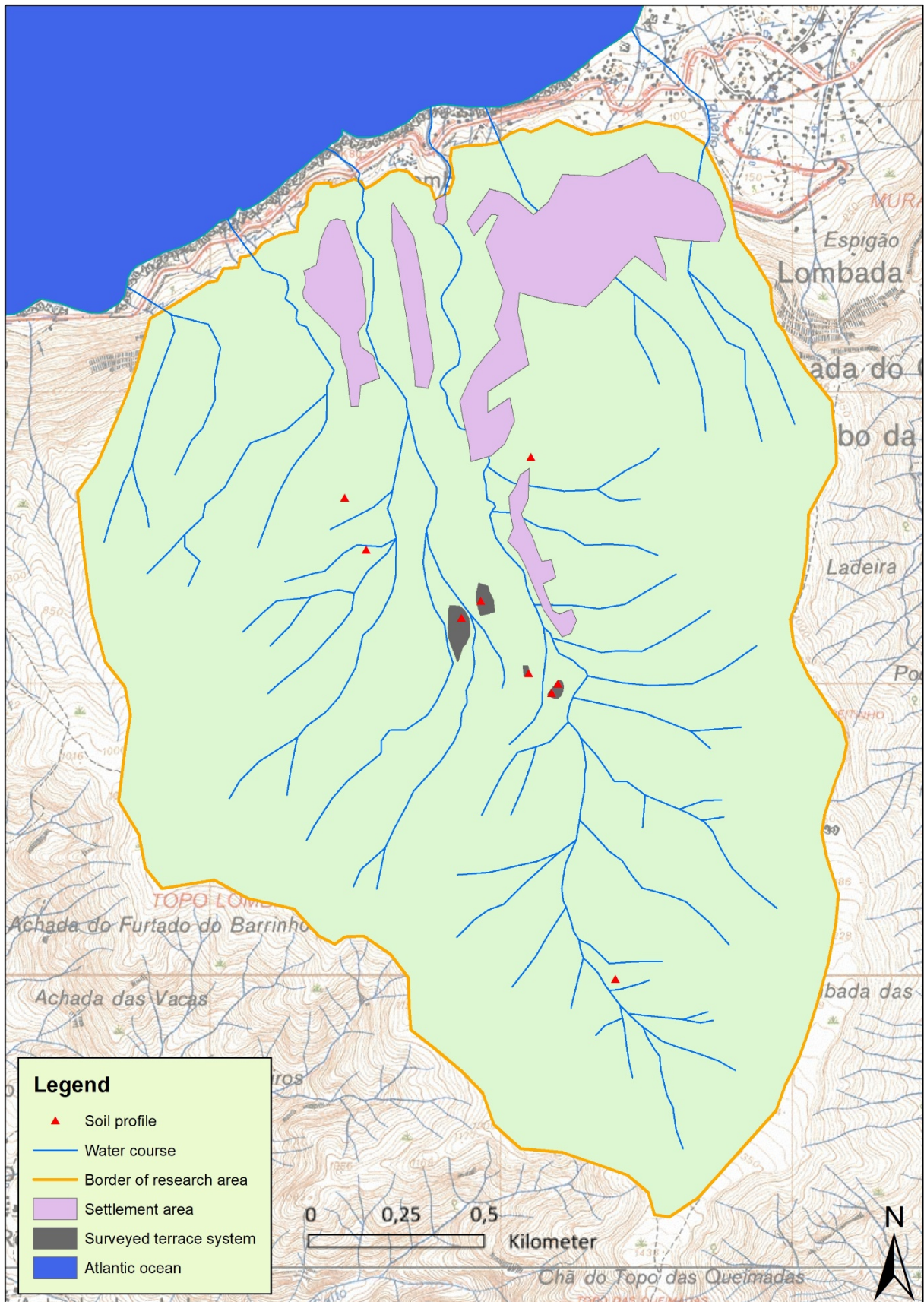


Figure 55: Location of surveyed terrace systems, own figure with topographical base map from: Portugal, Serviço Cartográfico do Exército, scale 1:25 000, Lisboa 1975

These exemplary terrace systems have been surveyed as follows: The height and width of every sustaining wall was measured at different positions. The length and width of the agriculturally usable platform of each terrace was measured, too. Furthermore, infrastructure objects such as irrigation channels, water storage basins, animal stables, cargo cable installations or staircases have been surveyed. The resulting data have been used to elaborate drawings of the terrace systems with Adobe Illustrator. The terrace systems and included infrastructure objects have been sketched as top view and as cross section.

To determine the temporal frame of the extension of the agricultural terrace systems into the mountains radiocarbon dating was applied. Each of the soil profiles opened for the analysis of soil quality parameters and terrace soil and wall structure (cf. chapter 6) has been searched for charcoal pieces of more than 3 mm of diameter. The desirable location of them would be as low in the profile as possible and ideally underneath parts of the dry-stone wall. This would indicate that most probably the wood was burnt before the respective terrace was constructed or at approximately the time of construction. It is very unlikely that any material containing charcoals was introduced under or into an already existing terrace wall since it would require the removal of the wall. Not at all sampling sites charcoal that would fit the necessary dimensions for ^{14}C analysis was found. Samples were taken at four profiles: Lombo das Coches, Lamaceiros / Poço Feiticeiro, Caminho do Bardo 2 and Poios da Ladeira. At each soil profile the locations, where charcoal pieces were found, have been documented on the drawing including the size of piece and depth (cf. chapter 6). After selecting, which of the charcoal pieces were suitable for ^{14}C analysis⁶⁸, the samples were taken to the AMS- ^{14}C laboratory at Kiel University, where the analysis took place.⁶⁹

7.2.2 Methods used for the investigation of traditional agricultural practices

The assessment of traditional agricultural practices was based primarily on interviews with local resident farmers and shepherds. The interviews were personal in-depth interviews lasting from only a few minutes to several hours. In these interviews, the interview partners have been questioned on the following topics:

⁶⁸ For ^{14}C analysis the age of the material is of importance. For example, if a tree is 200 years old and a piece of the stem is taken for analysis it is possible that the ^{14}C in the material has been stored when the tree was only a few years old. This could result in a distortion of the age by the life time of the tree.

⁶⁹ The lab is named Leibniz Laboratory for Radiometric Dating and Stable Isotope Research

- a) Location of their terraces and state of use (arable/pasture/permanent culture/abandoned)
- b) Location of the terraces they still remember to be cultivated by their parents and grandparents
- c) Reasons for abandonment
- d) Spatial distribution of irrigation systems
- e) Type of irrigation systems used
- f) Time investment to reach terraces
- g) Quantity and type of currently produced field crops
- h) Quantity and type of formerly produced field crops
- i) Change in crop spectrum and/or crop rotation
- j) Spatial preference of particular crops
- k) Traditional methods of field cultivation
- l) Farming tools used for tillage
- m) Manuring of terraces
- n) Utilization of organic crop residues
- o) Animal holding (animal species and number)
- p) Forage collection

Whenever possible the interviews were conducted in groups, often consisting of various family members or neighbors. This way of conducting interviews diminishes bias in the information since group members correct themselves and add information where one informant might know less about a topic or in less detail (Gaskell, 2000). Some interviews were conducted, when helping farmers do practical field work on the terraces. Parts of the traditional agricultural methods applied were observed on the spot and generally explained by the farmers. Personal on-the-spot field investigations contributed to a better understanding of current cultivation methods, crop rotation and state of use of terraces.

In addition to the interviews, the municipal records on crop production and sale have been consulted and publications regarding agriculture and the history of the municipality of São Vicente contributed valuable information on past land use and cultivated crops.

7.3 Characteristics and spatio-temporal development of selected terrace systems

This chapter is divided into two sections. Section 7.3.1 contains the results of the in-depth analysis of four terrace systems. This provides an understanding on the various terrace systems constituting the research area. It clarifies how terrace systems were laid out under various spatial constraints, mainly imposed by rough terrain conditions. It shows how

irrigation systems are integrated into the terraces. Furthermore, the total arable area gained by the construction of terraces can be estimated with great certainty from the drawings. Section 7.3.2 shows the spatio-temporal development of terrace systems, when they were created and which parts of the mountains were cultivated first. Farmers' preferences become evident, when studying the areas firstly selected for terracing. Furthermore, the dynamics of land use over time are elaborated and presented in maps. The predominating phenomenon of current land use change, the land abandonment, is quantified.

7.3.1 Terrace systems in detail

1) Lombo das Coches

The terrace system constructed on the ridge of Lombo das Coches has very peculiar characteristics compared to all other terrace systems in the municipality of Ponta Delgada. The terrace walls are constructed without any supporting material, such as stones. They consist solely of soil. Nevertheless, the terrace walls have average heights ranging from 1.10 m on the highest southernmost terraces (T1 and T2) and the lowest northernmost terraces (T8 and T7) up to 1.60 m on the central terraces (T3 to T6). The walls are still clearly visible, mostly intact and show just small deposits of soil and organic material in various states of decomposition on the base of the terrace walls. The earth wall supporting the arable platform on the terraces seems to be sufficiently resilient to withstand erosive forces acting on cultivated terraced land. Some terrace walls currently show small sections of collapsed walls as a result of secondary tree growth, which developed after abandonment of the agricultural activities. In case the trees grew closely to the sustaining wall, root growth displaced soil from the vertical section of the wall to its basement. In a few cases, the weight of the tree destabilized the earth wall to such an extent that it collapsed. Even near such collapsed sections, no rill or gully formation was found and no extension of the collapsed area was observed.

The terrace system has a water basin with a volume of approximately 30 m³, which was formerly filled with water from a nearby brook. In the upper part of the terrace system, a small levada was built to lead water into the basin. The levada was an open channel with a cross section of approximately 30 x 30 cm at ground level. When it reaches the nearly vertical rock wall, at which the terrace system finishes, it continues as a channel carved into the rock. After approximately 100 m horizontally along the steep rock, it arrives at the brook.

Most probably there has been a levada alongside the footpath, leading water to the terraces below the water storage basin, but due to water erosion along the footpath, it is currently not visible any more. On terrace T4 the foundations of an animal stable with a dimension of approximately 1.60 m x 1.60 m inner size surrounded by a wall of approximately 60 cm of width, are visible. The stable is located in a strategically favorable position, very close to the water basin, but not directly below. Water had to be carried over a small distance only and at the same time the animal or animals were in a safe position in case the water basin would overflow, leak or break. Another infrastructure element is a fix point with a steel cable for effective transport of produce down to lower altitudes and closer to the village.

Lombo das Coches terraces cover all possible space on the ridge. Towards the eastern and western side, the terraces extend as close as possible to the scarp. Towards the south, the terraces extend to a section, where the ridge measures merely 2 m of width and terminates at a rock face. To the north, terracing also terminates at a narrow section, where the ridge turns into a narrow and steep slope.

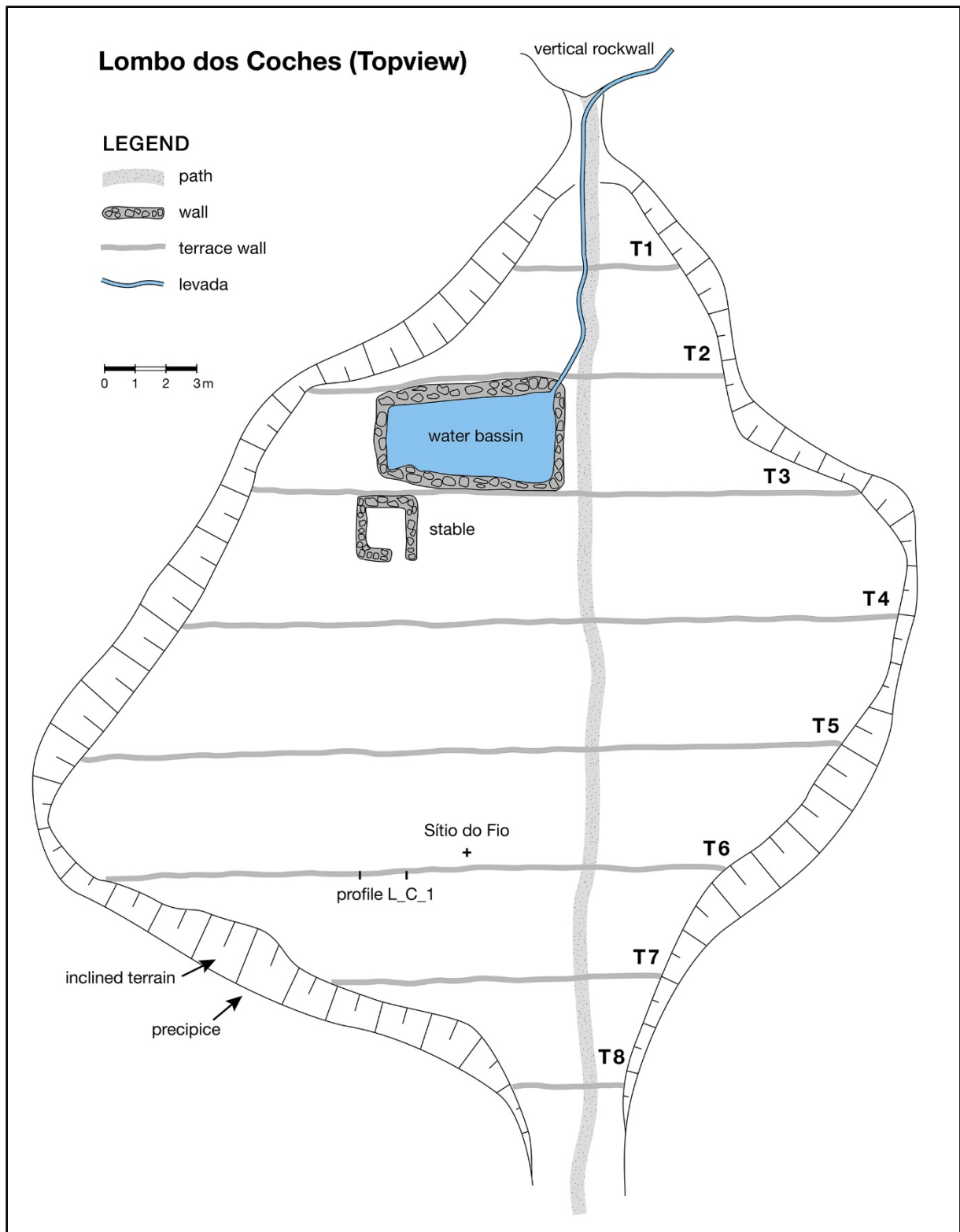


Figure 56: Top-view of terrace system Lombo dos Coches (not geo-referenced), graphic design by Doris Kramer

The terraces vary considerably in size. The east-west extension shifts from 7.7 m to 49.2 m, while the width of the terraces is kept relatively constant, varying between 6.1 m and 8.4 m. For the calculation of net agricultural area the width has been reduced by 0.5 m taking into account that the edges of the field cannot be ordered. Infrastructure elements on the terraces

have also been deducted. The construction of the agricultural terraces on Lombo das Coches provided 1597 m² of arable land.

Table 28: Dimensions of Lombo das Coches terrace system

Terrace	T1	T2	T3	T4	T5	T6	T7	T8	Total
East-west extension (m)	7.7	16.6	30.4	43.7	48.2	49.2	27.0	10.8	
Average width (m)	6.1	6.8	7.5	8.0	8.4	8.0	6.9	6.3	
Gross size (m ²)	46.6	112.9	228.0	347.4	402.5	393.6	186.3	68.0	
Net surface area (m ²)	42.7	104.6	212.8	325.6	378.4	369.0	172.8	62.6	
Infrastructure elements (m ²)			60.0	12.0					
Net agricultural area (m ²)	42.7	104.6	152.8	313.6	378.4	369.0	172.8	62.6	1596.5

2.) Caminho do Bardo

The terrace system Caminho do Bardo, constructed at an incline approximately 100 m above the floor of Ribeira da Camisa shows structural characteristics common for terraces systems in this section of Lombadas da Ponta Delgada. The terrace walls are constructed as dry-stone walls with supporting stones of various sizes. Some walls, such as the one of the analyzed terrace profile C_B_3 also include small boulders, which might have been in place before terrace construction or at least close by. The dry stone construction is clearly visible and in good state of conservation, just in some parts small deposits of soil and organic material in various states of decomposition on the base of the dry-stone walls have accumulated. The dry-stone wall, supporting the arable platform on the terrace is sufficiently resilient to withstand erosive forces acting on cultivated terraced land. Some sustaining walls currently show small sections of damaged walls because of trees, which grew after abandonment of the agricultural activities. In case trees grew close to the sustaining wall, root growth displaced some stones, which accumulated at the walls' basement. The dry-stone wall of the lower terrace, including the profile C_B_3, has been partly destroyed during the construction of the dirt road below.

On the northern side of the terrace system, a stone staircase links the terrace platforms. On the southern side, there are remains of a stone staircase visible, located outside of the agricultural terraces.

In the terraces of Caminho do Bardo no water storage basin exists, but their location close to a permanent water course allowed irrigation of crops in dry periods. Farmers would have to carry water to their terraces, but only over a few tenth of meters. The brook represents the southern boundary of the terraces. To the west steep mountain terrain limited further expansion, to the north a small boulder field. Possibly the terrace system extended further to the east, but due to the construction of the dirt road some terraces have either been covered by excavated material or destroyed.

The following figure shows the terraces of Caminho do Bardo in top-view. The analyzed soil profile C_B_3 is included in the dry-stone wall of the lower terrace. The upper terrace is divided into 2 segments, the terrace itself and a tiny terrace on its upper south-western corner. Due to steeper terrain, it would have been impossible to create a platform without incline on this part of the terrace. The low intermediate terrace wall helped to overcome the difference in height and allowed even surfaces on both parts of the upper terrace. This method of partitioning terraces between the main dry-stone walls has only been observed in this terrace system in the research area.

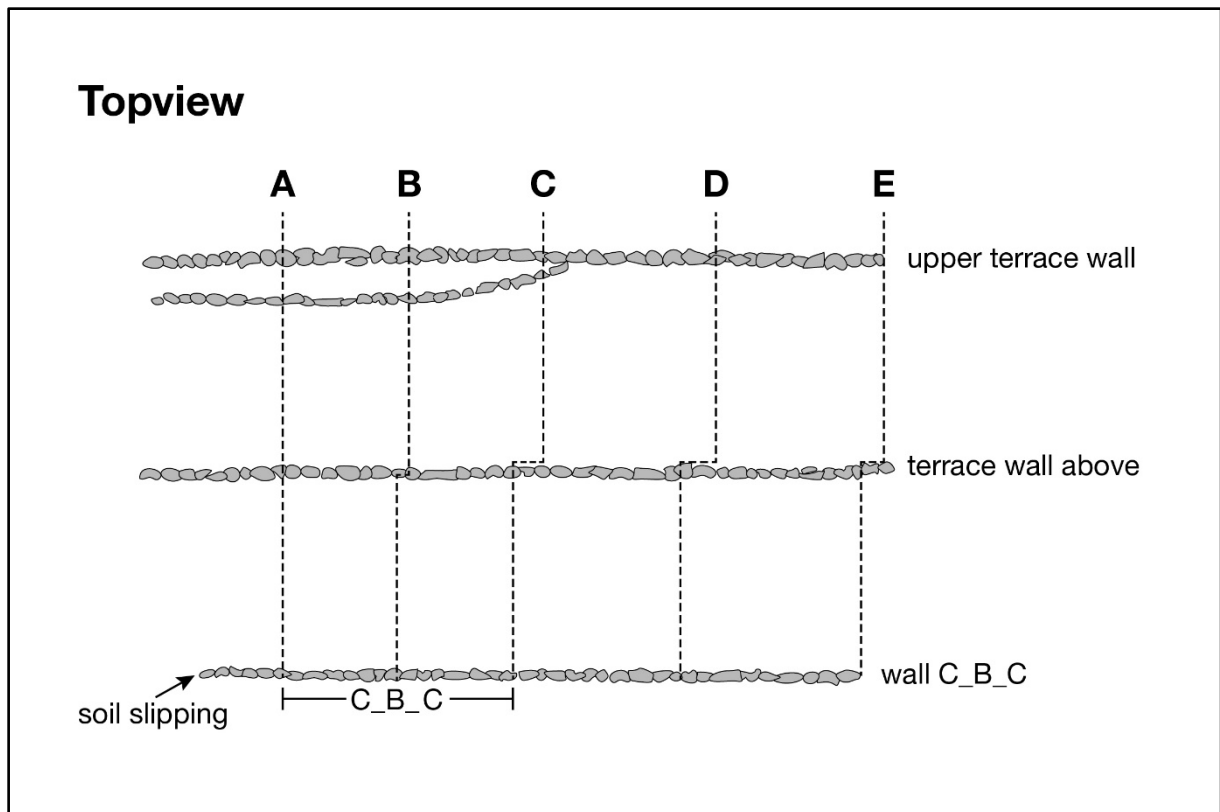


Figure 57: Top-view of terrace system Caminho do Bardo (not geo-referenced, not to scale)

The following five cross sections (A to E) of Caminho do Bardo terrace system help to understand its structure. For the cross sections C to E it was not possible to survey in a straight line, but dense vegetation on the abandoned upper terrace implied to survey laterally offset. The height of the lower dry-stone wall is approximately 2.45 m, while the terrace wall above measures 2.20 m of height. The upper terrace wall measures 1.85 m of height and the section with the small intermediate wall and the main terrace wall together measure 2.30 m.

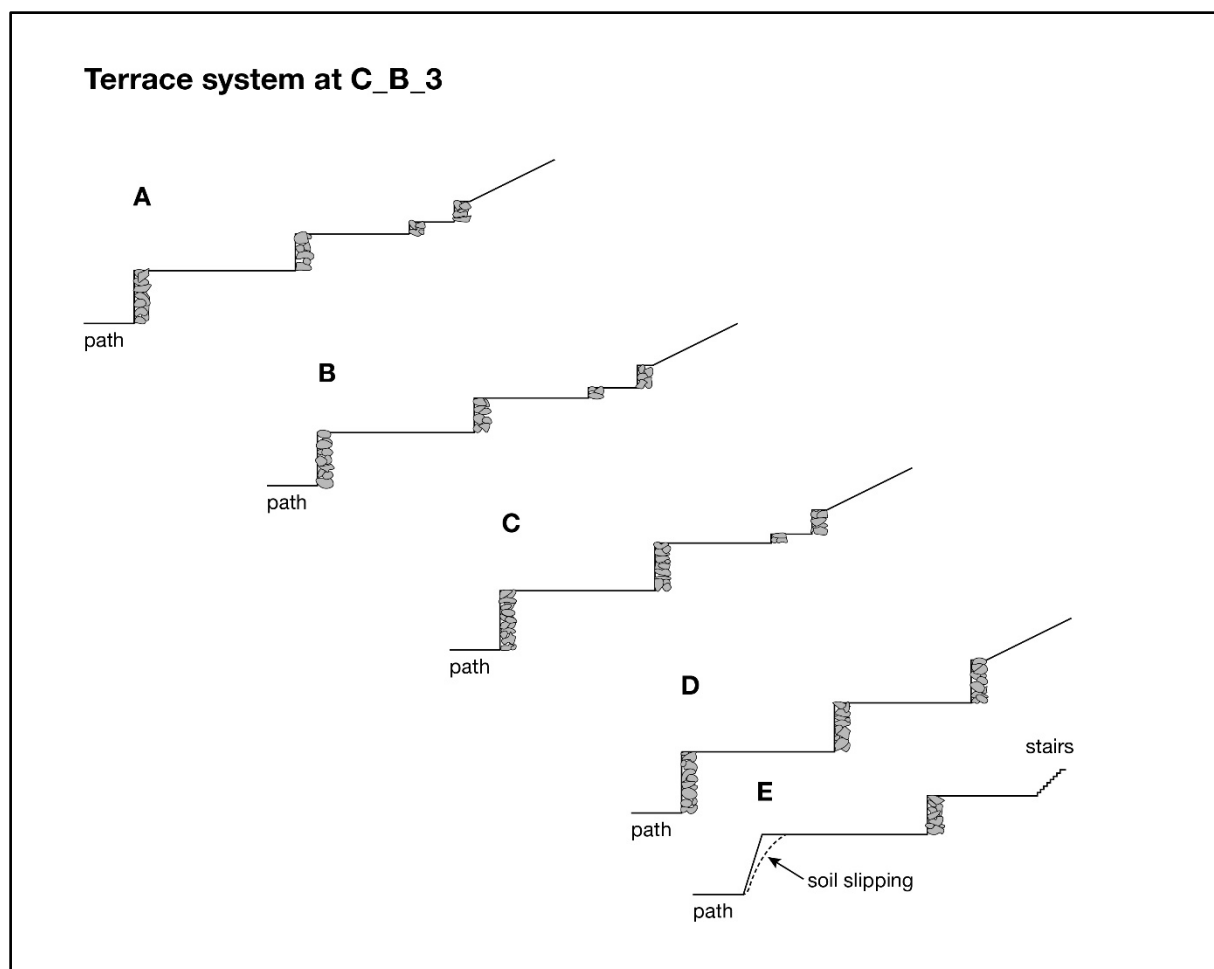


Figure 58: Cross section of terrace system Caminho do Bardo (not geo-referenced, not to scale)

The terraces do not vary much in size. The north-south extension shifts from 25.8 m to 27.4 m, the width of the main terraces is relatively constant, varying between 6.8 m and 7.5 m. For the calculation of net agricultural area the width has been reduced by 0.5 m taking into account that the edges of the field cannot be ordered. The intermediate wall on the upper terrace has been deducted from the net area of the upper terrace and classified as infrastructure element. The construction of the agricultural terraces at Caminho do Bardo provided 344.2 m² of arable land.

Table 29: Dimensions of Caminho do Bardo terrace system

Terrace	Lower terrace	Upper terrace	Total
North-south extension (m)	25.8	27.4	
Average width (m)	7.5	6.8	
Gross size (m ²)	193.5	186.3	
Net surface area (m ²)	180.6	172.6	

Infrastructure element (m ²)	0	9.0	
Net agricultural area (m ²)	180.6	163.6	344.2

3.) Cova do Bardo

The terrace system Cova do Bardo, deep in Ribeira da Camisa valley shows structural peculiarities in the construction of its` dry-stone walls, which are quite rare amongst the terrace systems in the research area. The dry-stone walls consist of supporting stones of various sizes. Small boulders are frequently integrated into the wall structure, like it is documented in both profiles C_B_1 and C_B_2. Furthermore, the dry-stone walls have a deposit of stones behind the basis of the wall of up to 2 m of depth reaching horizontally into the terrace filling.

Terrace walls are clearly visible and in good state of conservation, just in some parts small deposits of soil and organic material in various states of decomposition on the base of the dry-stone walls have accumulated. Like in the previously described terrace systems the dry-stone walls seem to be sufficiently resilient to withstand erosive forces acting on cultivated terraced land. Some sustaining walls currently show small sections of damaged walls because of trees, which grew after abandonment of cultivation. In case trees grew close to the sustaining wall, root growth displaced some stones, which accumulated at the walls` basement. The dry-stone wall of the lower terrace, including the profile C_B_1 has been entirely removed during the construction of the dirt road and at the profile C_B_2 the dry-stone wall has been damaged. On the south-western side of the terrace system a stone staircase links the terraces amongst each other and connects the dirt road to a former stable.

There is no water storage basin installed in the terraces of Caminho do Bardo. A reservoir was built in the nearby brook, just south-west of the terrace system. Water for irrigation and animal holding was available, but had to be carried to the fields and the stable. The brook and its` steep surroundings represent the south-western boundary of the terraces. Below, the terraces reach the dirt road, while to the north-east and above they end at a scarp.

The following figure shows the terraces of Caminho do Bardo in top-view. The analyzed soil profile C_B_1 is situated below the dry-stone wall of the lower terrace. The profile C_B_2 is located in the dry-stone wall of the lower terrace.

Profiles C.B.1 und C.B.2 (Topview)

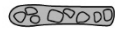
LEGEND



cliff



path



wall



stone wall



stairs



wiese

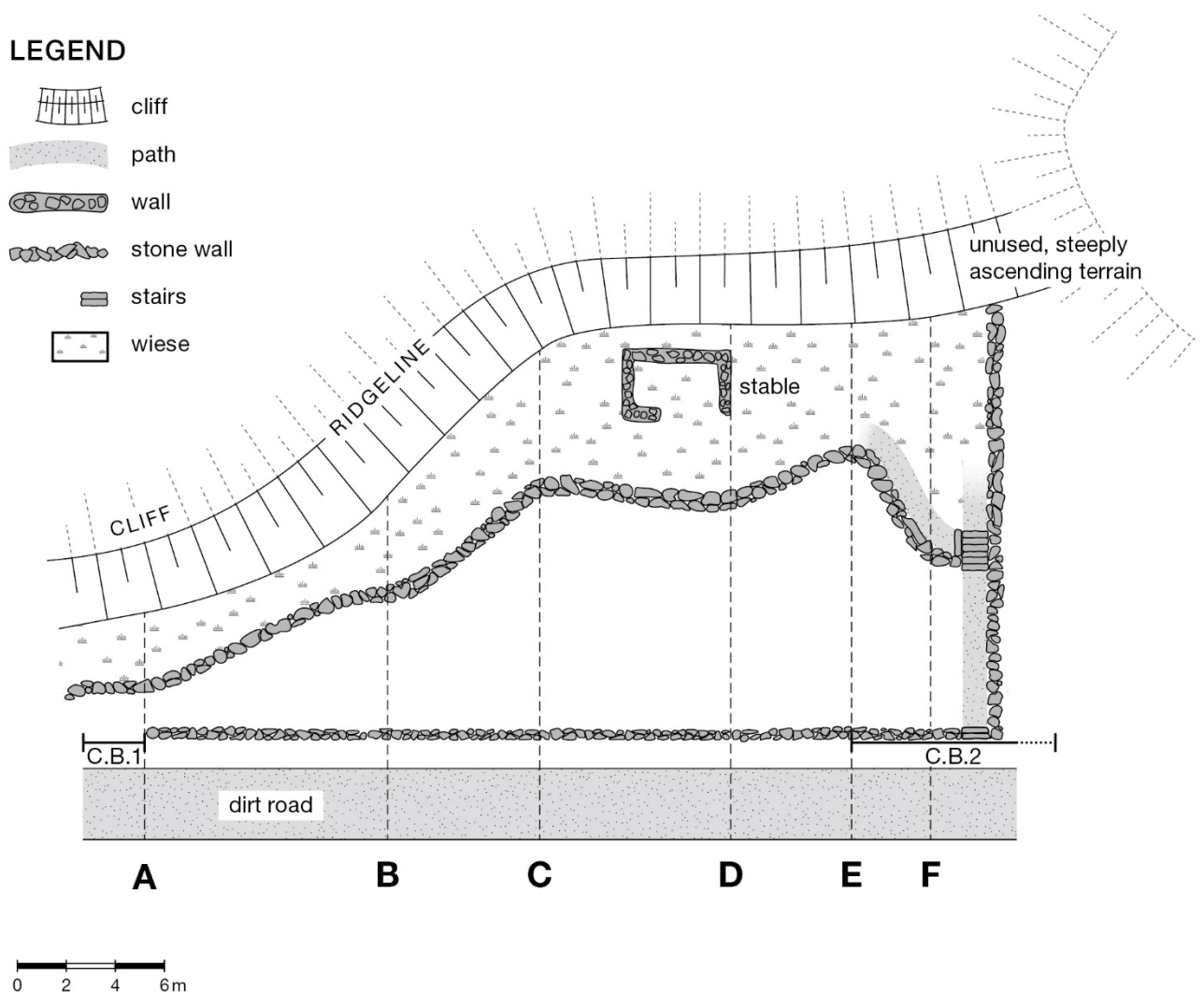


Figure 59: Top-view of terrace system Cova do Bardo (not geo-referenced)

In the terrace system six cross sections (A to F) have been created to survey the dimensions. Towards the lowest point the dirt road Caminho do Bardo limits the terrace system, therefore the lowest part is approximately a straight line. The structure of the land has been different to most other terrace systems. Only the lowest remaining terrace served for crop production, while the upper area was used as pasture. On the schematic illustration (figure 60) it becomes clear how people were determined to use every bit of available space for agricultural production. The width and height of the walls vary in way that is perfectly adapted to the given terrain structure and does not and does not waste a square meter.

Terrace system Cova do Bardo C.B.1 and C.B.2

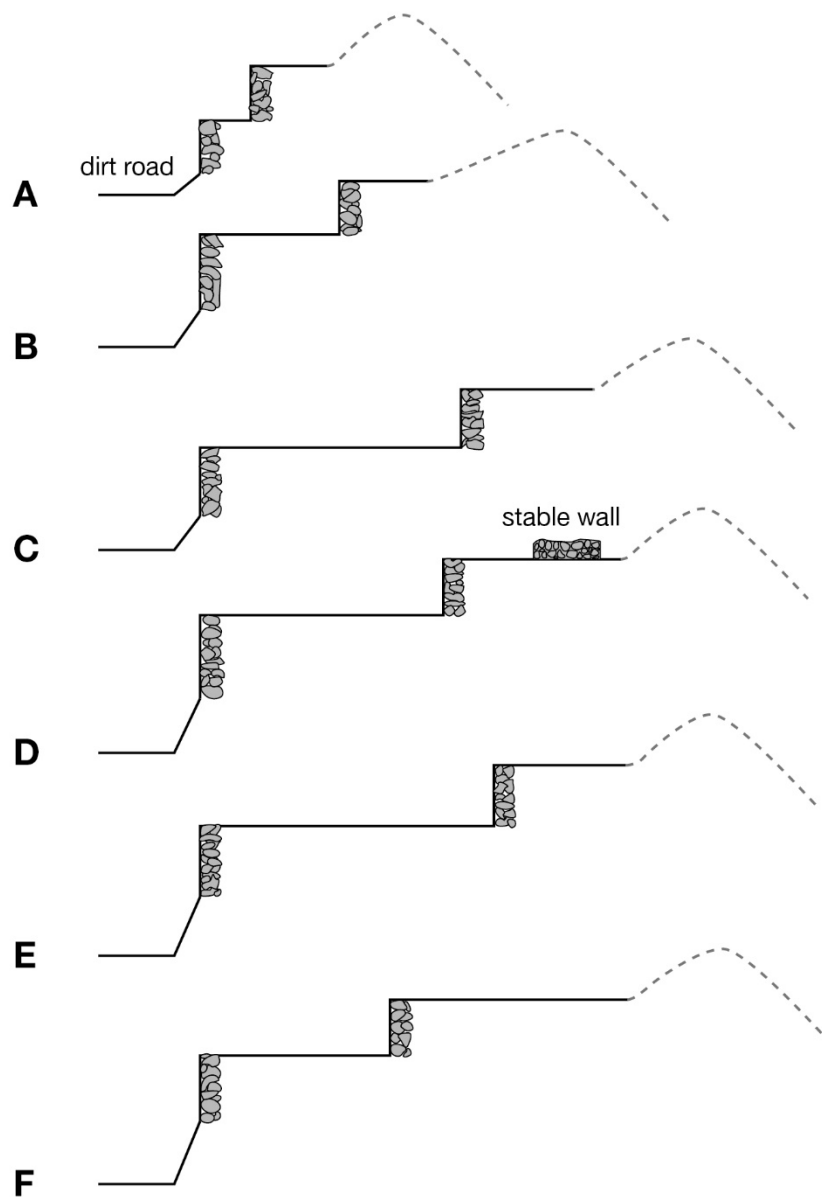


Figure 60: Cross section of terrace system Cova do Bardo (not geo-referenced, not to scale)

The size of the terraces at Cova do Bardo is very similar. The linear expansion shifts from 26.5 m to 30.4 m, the width of the main terraces is relatively constant, varying between 5.6 m and 6.8 m. For the calculation of net agricultural area the width has been reduced by 0.5 m taking into account that the edges of the field cannot be ordered. Infrastructure elements on the terraces have also been deducted. The construction of the agricultural terraces at Cova do Bardo provided 302.7 m² of arable land.

Table 30: Dimensions of the terrace system of Cova do Bardo

Terrace	Lower terrace	Higher terrace	Total
East-west extension (m)	30.4	26.5	
Average width (m)	5.6	6.8	
Gross size (m ²)	170.2	180.2	
Net surface area (m ²)	155.0	167.0	
Infrastructure element (m ²)	0	19.3	
Net agricultural area (m ²)	155.0	147.7	302.7

7.3.2 Spatio-temporal dynamics of the agricultural terraced landscape

In the centuries following the initial push in cultivating the land with the help of new settlers under Manuel Afonso da Sanha in 1469, the process of terracing new land for cultivation proceeded. At first the easily accessible, relatively even headland of Ponta Delgada was deforested and terraced, later Primeira Lombada with its' plateau like surface was taken into cultivation. In the 16th century with the sugar cane industry flourishing on the island⁷⁰ arable land became a more and more scarce resource and farmers had to extend agricultural terraces farther and farther into remarkably steep mountain terrain. During the interviews with local farmers it became very clear, how scarce and valuable the land has been in past centuries. Even in seemingly inaccessible areas high above huge rock faces and on very steep slopes reaching down from the ridgelines agriculture was practiced on extended terrace systems. When informants pointed out recently wooded areas, where they still cultivated land in their youth or remembered their parents or grandparents cultivating, it was hard to imagine what drove farmers to walk up the extraordinarily steep and slippery slopes, to remove the native woodland and build terraces for cultivation. During the interviews, some sections, which were pointed out to have been cultivated in the past, seemed to be an invention of the informant. The following field survey revealed that even the most inaccessible areas that were described as formerly cultivated were indeed terraced and most of the dry-stone walls were still in place. It was reported by Maria da Terceira Lombada⁷¹ (65) that when she was a girl it was

⁷⁰ Cf. chapter 2.7

⁷¹ Interview conducted on 22.09.2013

traditionally a task for kids to bring lunch for the men working on the terraced fields. She had to walk up from Terceira Lombada to Caldeira⁷² to bring lunch. It took her about 45 min to get to the fields the family cultivated up there. Many other terrace systems required approximately 30 to 45 min of walking time to reach them. The challenging character of the trails and the high altitude differences illustrate the harsh conditions farmers had to cope with. It was not only hard physical labor on the terraced fields, but already getting to the fields was physically challenging. The difficulties imposed by the terrain conditions become even more clear, when considering that agricultural produce had to be carried down the mountain to the settlement for payment of feudal rent, for storage, for sale and for consumption. The most distant land, where terrace walls are still present, is located in the source area of Ribeira da Camisa, near Laje Negra⁷³. To reach these terraces a farmer had to walk for 1.5 h on dangerous single-file mountain trails. The owner and builder of these terraces had the nickname Albino Miséria, indicating that this farmers life was seen as miserable even under the predominating circumstances of the rural population in the research area. Both interview partners Sr. Caldeira⁷⁴ (58) and Sr. Ernesto Martins Fernandes⁷⁵ (74) explained that these terraces were built in the “difficult time after the Second World War”. Sr. Martins Fernandes could also inform that when he was a young man, he helped building the terraces at Rabo do Burro⁷⁶ and a few additional terraces at Viveiro. The mayor Jesus Caldeira⁷⁷ (58), who also remembered accounts on the construction of these terraces, confirmed this statement. It can be concluded that the Rabo do Burro terraces were built in the 1950s and the Viveiro terrace system existed before and was amplified in this economically difficult period. In Terceira Lombada similar reports have been made by Maria da Terceira Lombada (65) and by Sr. Agostinho⁷⁸ (92) da Terra do Centeio, both mentioned terrace construction “in the big crisis”, meaning the 1950s. Like in Primeira Lombada, the southernmost areas of the ridge have been extended in this time. In Terceira Lombada the terrace systems José Mendes⁷⁹ and Caldeira have been amplified. These last extensions of terrace systems were certainly driven by the risen necessity of self-sufficiency due to very limited food imports to the island in this period. The already

⁷² Cf. chapter 4, figure 26

⁷³ Cf. chapter 4, figure 26

⁷⁴ Interview conducted on 24.09.2013

⁷⁵ Interview conducted on 09.04.2014

⁷⁶ Cf. chapter 4, figure 26

⁷⁷ Interview conducted on 24.09.2013

⁷⁸ Interview conducted on 26.09.2013

⁷⁹ Cf. chapter 4, figure 26

occupied space within the research area did not leave much room for further extension of terraces, so that inhabitants were forced to construct them in less suitable locations, mostly deep in the valleys with reduced insolation intensities and often on north facing slopes. Since solar radiation is an important factor for crop growth, it becomes evident that such locations could not provide high-yielding harvests. Certain crops could not be successfully cultivated at all there.

In the phase following the initial terrace construction on relatively plain terrain such as the headland of Ponta Delgada and plateau of Primeira Lombada, it seemed likely that farmers at first choose locations of good access and rich soils, where high yields could be expected. The ¹⁴C-analysis made from charcoal pieces, that were buried under or in the sustaining walls of the soil profiles

- a) Lamaceiros/Poço Feiticeiro
- b) Cova do Bardo
- c) Ladeira

reveal a different land use history, resulting from the preferences tenant farmers and land owners had set in this period.

In the soil profile at Lamaceiros/Poço Feiticeiro (L_P_F_1) charcoal was found at a depth of 120 cm at the base of the terrace wall. Consequently, the piece of charcoal was most probably deposited there in the initial phase of the construction of the terrace system at L_P_F_1. According to the dating of the sample (KIA50772) the charcoal origins, with a certainty of 82.7 %, from the period between 1445 and 1515 AD. Combining this information with historic sources that Manuel Afonso da Sanha only received the land in 1469 and settlement and agricultural activities only started from this year onwards, the period of construction can be narrowed down to the period between 1470 and approximately 1515. Most probably the year of construction of this terrace lies somewhere between 1475 and approximately 1515. Farmers surely took some years to deforest and terrace the lower and more favorable areas in Ponta Delgada and the Lombadas before they reached this distant location. This early period of construction indicates that farmers did not make their decisions based on the travel distance from the houses to the fields, but they were more concerned about the terrain conditions. Flattish areas with thick layers of soil were preferred to areas with a likely better solar exposure, but less favorable terrain conditions. It is quite remarkable that the ridge at L_P_F_1 was terraced in such an early period, since it is quite far from the village and the

terraces are exposed to the north. A factor that might have supported the decision of cultivating this area so early is the availability of water all year round. A tributary of the main stream Ribeira da Camisa provides sufficient quantities of water to feed the irrigation system installed in the terraces at Lamaceiros/ Poço Feiticeiro (cf. chapter 6.5.4). Another important factor is the strategically valuable location of the ridge. The main route from Segunda Lombada into the mountains, used for collection of firewood and probably even more important for the collection of leaf-hay passes along the agricultural terraces. Under the climatic conditions of Madeira, leaf-hay from Lilly-of-the-valley-trees (*Clethra arborea*) could be harvested all year round, from Sweet chestnut (*Castanea sativa*) only during spring, summer and early autumn. Consequently, the trail was highly frequented all year round. The obligatory passage certainly influenced farmers' decision to turn this part of the indigenous woodland into arable land early on. It was practical to combine work tasks for example fodder collection and irrigation of crops with only one ascend from the settlement.

The ¹⁴C-analysis of the terraces at Cova do Bardo indicate that they are more recent. The soil profile that provided the best datable charcoals was C_B_2. Two samples were analyzed, KIA50391 from a depth of 120 cm below the top of the dry-stone wall and KIA50388 from a depth of 80 cm. With a probability of 52.4 % KIA50772 origins from the period between 1460 and 1525 AD, with a probability of 41.5 % from the period between 1570 and 1630 AD. The analysis of KIA50388 provided more precise information, with a probability of 69.3 % this tree was felled in the period from 1440 to 1525 AD. The next highest probability, with 25.6 %, origins from the period between 1570 and 1635 AD. For both samples terrace construction before the year 1470 has to be excluded due to historical sources of land allocation. It can be concluded that the Caminho do Bardo terraces have most probably been installed slightly later than the earliest terraces at Lamaceiros/Poço Feiticeiro.

The third area of terraces under investigation has provided two datable pieces of charcoal: one from a depth of 140 cm (KIA50998) and the other (KIA50999) from a depth of 130 cm below the terrace surface. While KIA50998 did only provide data dispersed over a very long period the second sample KIA50999 revealed that the tree was felled, with a probability of 55.0 %, in the period from 1805 to 1894 AD. Combining the two samples, it is very likely that the terraces at the steep Ladeira site were constructed in the nineteenth century. Although this area is closest to the village and facing east, it was terraced last – probably due to a difficult access to irrigation water and the steepness of the terrain. The terrace filling at the profile

P_L_1 shows very stone rich soil layers consisting of approximately 90 % stones in the lower layers. In the upper part of the topsoil layer a reduced stone content of approximately 70 % was determined. Tillage by hand tools such as the traditional hoe⁸⁰ is labor intense under the given conditions and root development of crops is limited, resulting in a reduced rotation pattern⁸¹ and generally lower harvest.

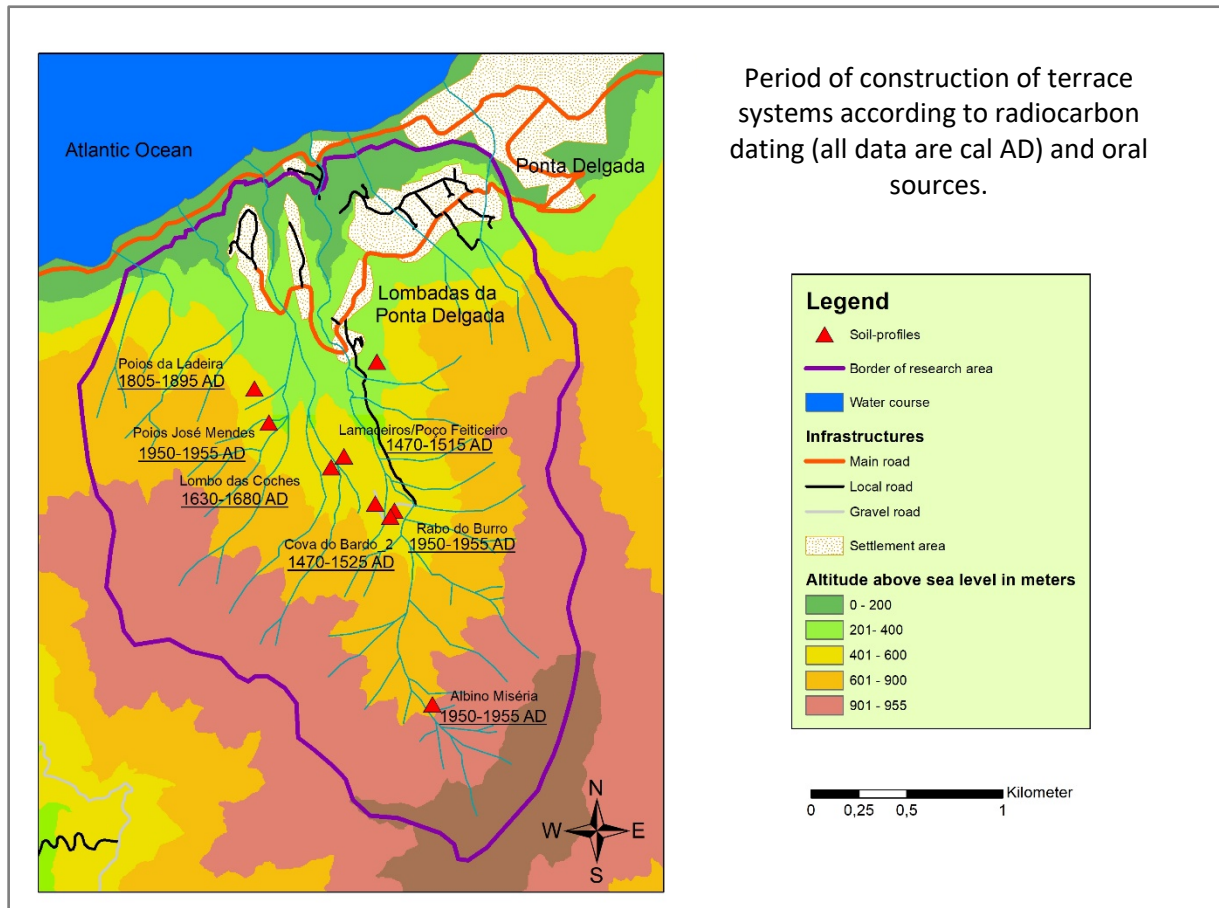


Figure 61: Period of construction of selected terrace systems according to radiocarbon dating and oral sources

In Figure 61: Period of construction of selected terrace systems according to radiocarbon dating and oral sources, the most probable periods of construction of the investigated terrace systems according to both radiocarbon dating and the information obtained during personal interviews with elderly informants from Lombadas da Ponta Delgada are displayed. The preferences of farmers and land owners, where they could construct terraces and cultivate crops, become evident. Once the easily accessible areas in the vicinity of the settlement had been terraced, the decision to expand the arable land is based primarily on the consideration of promising external factors such as good soil quality and structure, high solar radiation,

⁸⁰ Locally the hoe used for tillage is called enchada and is available in different shapes for various types of soil.

⁸¹ Some crops cannot be grown successfully in higher altitudes

water availability and the lowest possible slope of the terrain. Soils without stones or at least without many stones were the best to cultivate. They offer good conditions for root growth. The construction of extensive terrace systems in the very beginning of the 16th century reflects the pressure that was put on arable land by monoculture sugar cane production on the high yielding slopes in the south of the island. Food crops quickly became a scarce commodity. As a result, farmers began to occupy locations with difficult and time consuming access and lower expected crop yield due to higher altitudes and northern exposition for food crop production. It is quite remarkable that the terraces at Lamaceiros/ Poço Feiticeiro and at Cova do Bardo are the oldest terrace systems in the mountains of the Lombadas. Both are distant from the respective settlement (Primeira Lombada/Lombo do Meio in case of Cova do Bardo and Segunda Lombada in case of Lamaceiros/ Poço Feiticeiro). To reach Cova do Bardo it took about 30 to 40 minutes and for the ascent to Lamaceiros/ Poço Feiticeiro a farmer had to calculate about 30 minutes. Nevertheless, the area was popular for cultivation. There are two more terrace systems very close by, which most probably origin from a similar period. The terrain conditions suggest that they might even be older. Both are located below Lamaceiros/ Poço Feiticeiro and one of them a few meters west of the main trail into the mountains. On the route up from the settlement, the access to these systems is slightly quicker, while other external factors, such as soil quality and thickness of soil layer, insolation and water availability, are mostly identical. A selective survey of these terraces proved that the A-horizons on all of the seven locations were free of stones.

The terraces located in this central part of the valley are well protected from the strong winds from the Atlantic and have a comparably long period of sun exposure during day-time. All of them had an irrigation system in the past, securing crop growth in case of drought. The data indicate that other factors such as distance to the settlement and height difference to be covered to reach the terraces were generally neglected. The table below illustrates which time investment farmers took upon themselves to reach the investigated terrace systems.

Table 31: Walking time in minutes to reach selected terrace systems from the nearest settlement

Terrace system	Levada da Fonte	Lamaçeiros Poço Feiticeiro	Cova do Bardo	Caminho do Bardo	Lombo das Coches	Poios da Ladeira	Poios José Mendes	Poios Albino Miséria
Time to reach terraces	10 min	30 min	35 min	40 min	35 min	20 min	25 min	90 min

Over time, almost every piece of land in the Lombadas that permitted terracing in a more or less effortful way was terraced and turned into arable land. The extension of the agricultural terraces far into the mountains and very close to sheer cliffs often near streams, clearly indicate the extraordinarily high importance of agriculture for the local population. It was the basis for the survival of the family and the only source of income was the sale of a small part of the production. The following map shows the maximum extension of terraces and gardens within the research area⁸².

⁸² In this context it cannot be differentiated between a garden, usually around a house and an agriculturally used terrace since most people used the space directly next to the house for crop production as well, while some people could afford to keep some ornamental plants around the houses. Gardens and agricultural areas are both terraced.

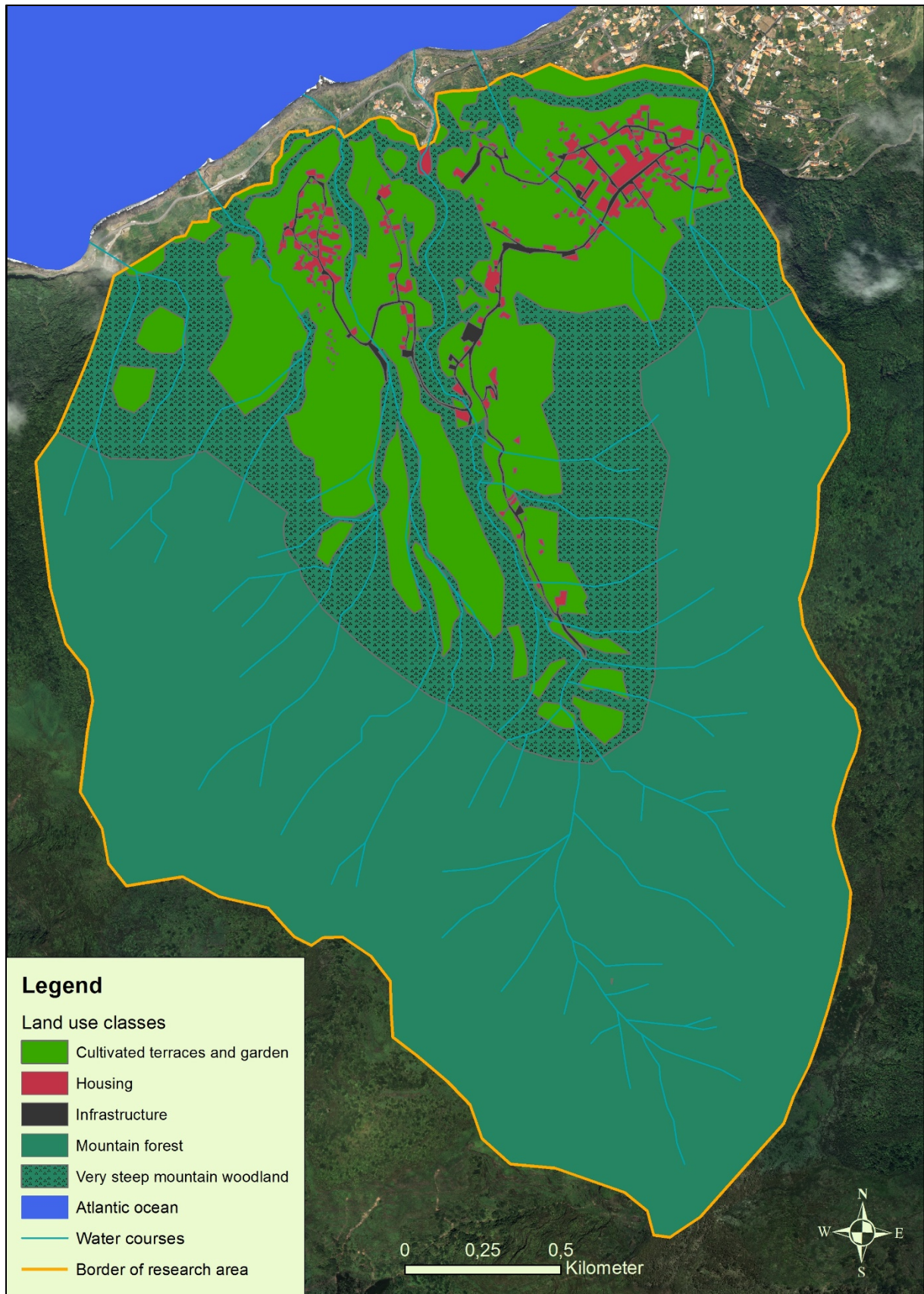


Figure 62: Maximal extension of agricultural terraces and former land use

The areas marked with light green show the terraced parts in the Lombadas area. Almost everywhere they border on very steep mountain woodland, where the construction of

terraces was impossible. The other typical border of terrace systems are rivers. Often the rivers are located in deeply carved out gorges, not leaving room for the construction of terraces on the neighboring slopes. In other cases, farmers did not built terraces very close to the watercourses to avoid flooding of their terrain and destruction of the sustaining walls towards the river. Only in Primeira Lombada, a small watercourse crossing the terraced area of the village has been channeled. The agricultural terraces were used for production of grain, legumes, vegetables and fruits. On marginally productive locations, fodder for domestic animals was grown, too. The land use class housing displays the current situation since it is not possible to determine in which way the land below the present constructions was used before. The same counts for the land use class of infrastructure, where currently existing roads and parking areas are mapped. The land use class mountain forest includes different types of woodland, mainly Laurisilva woodland and heather woodland of the high altitudes. There is no differentiation between different intensities of use of woodland resources or even total removal of heather woodland on the flattish parts of the ridges for animal pasture.

The maximum extension of terraced agricultural land resulted in an area of 136 ha in the Lombadas da Ponta Delgada. Additionally, many slopes that were too steep for terracing or climatically not suitable for profitable cultivation of field crops, were used for growing walnut (*Juglans regia*) and sweet chestnut (*Castanea sativa*). Therefore, the net utilized agricultural area was considerably larger than 136 ha.

The intensity of land use has changed dramatically over the past 50 years. While over centuries terrace systems were extended and new ones built, there were several crises (cf. chapter 2) that severely shook the agricultural sector. The local farming population had no choice than to adapt to these crisis situations. Generally, intensification in production and an extension of agriculturally used area was a way to ease the crisis. Another way to improve difficult economic situations in agriculture was a change in the main cash crop. Nevertheless, periods of famine and extreme poverty made part of the island's reality. In the late 19th century a new option for farmers living under miserable conditions appeared: regular passages to Central and South America. Many farmers opted for this chance to begin a new life overseas. There

are sources such as a poem from Manuel Gonçalves⁸³, describing that “there are crops rotting on the fields since there were not enough people to harvest them on time”.

Over the following century emigration, due to very difficult economic periods in agriculture and the prevalence of the ownership system and the *colônia* contract (cf. chapter 3.6) played a major role in the shift of intense land use towards land abandonment (cf. section 7.3.3). Next to land abandonment, a shift of land use from labor intense crops towards non-labor intense crops took place.

There is a circle of mainly pine trees surrounding the Lombadas before the Laurisilva woodland begins. When agriculture was not profitable any more, or when land was not cultivated due to emigration farmers often planted trees on the terraces that dropped out of cultivation. They could at least make use of the wood for domestic purposes or could sell parts of the wood on the market. The following map illustrates the land use situation in the Lombadas da Ponta Delgada in 2014.

⁸³ Manuel Gonçalves (1858-1927) was a famous poet and folksinger, born and raised in the Madeiran parish of Arco de São Jorge, approximately 3 km east of Ponta Delgada. He earned his living as a farmer and often thematized topics related to agriculture in his poems.

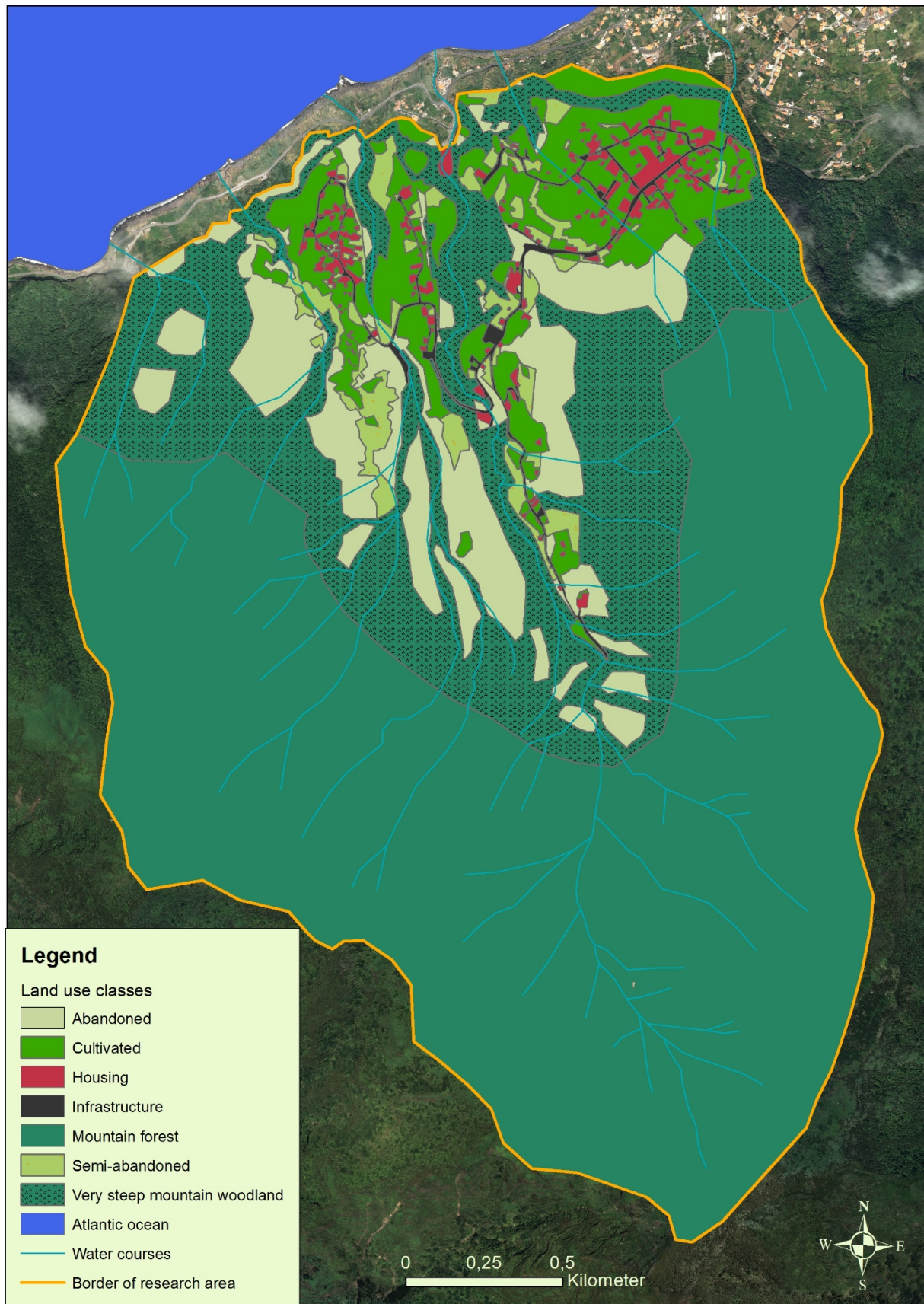


Figure 63: Present land use (2014)

The most obvious change in land use is the abandonment of formerly cultivated areas. The abandoned areas are colored in very light green. There are 64 ha of terraces currently abandoned, making 47 % of the total terraced area. Almost all of the terraced fields located distant from the main road are abandoned. There is only one exception of a high terrain at Segunda Lombada that is cultivated. Even this terrain only remains cultivated since there is a very steep dirt road that can be used by 4-wheel drive cars connecting the terrain with a main road. On an area of 19 ha the terraces are semi-abandoned, small bushes or bramble cover

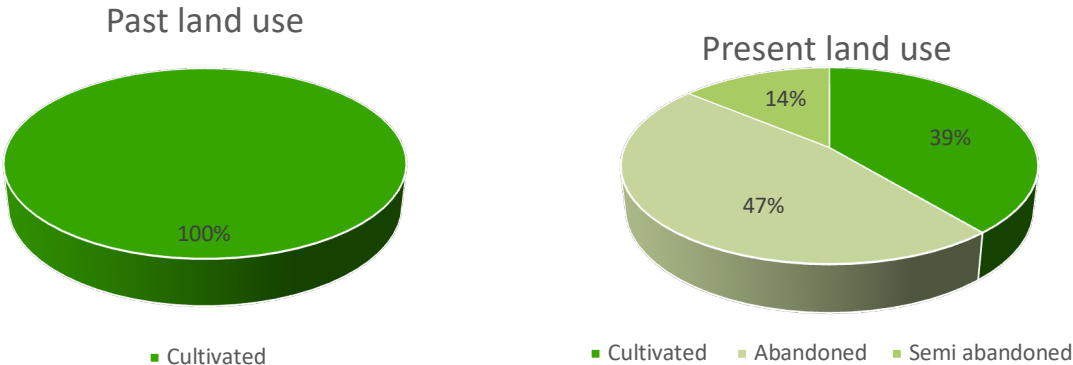


Figure 64: Past (around 1950) and Present land use (2014)

most of the surface. As a result, there is a decline of 61 % of agricultural land use. Only 39 % of the land remains under cultivation. The true area of agricultural production is even smaller, since this land use class also includes gardens around the houses, which are not always vegetable gardens.

This fundamental change in the intensity of agricultural use of the terrace systems happened within a very short time frame. In the 1950s, land abandonment was still a rare phenomenon and as described above some terrace systems were still extended. At first, farmers who emigrated and thus abandoned their fields were replaced by other farmers who kept the terraces under cultivation. When emigration became more and more severe there were not enough farmers to cultivate all the abandoned land. The terraces with more time-consuming access routes were abandoned first and, in some cases, planted with trees after abandonment. This allowed a minimum revenue and did not require much care during the year. In the initial phase of growth, it might have been necessary in dry summers to irrigate the young trees, but after a few years, the roots had developed in such a way that irrigation was not necessary any more. Almost every farmer planted pine trees, mostly *Pinus maritima*.

In Segunda Lombada Senhor Tomé⁸⁴ explained that “all ridges going up until the highest terraces at Lombo das Coches were turned into pine forest about 40 to 50 years ago. Most of the other pine forests are of similar age.” Senhor Ernesto Martins Fernandes explained that he and his father planted cryptomeria trees (*Cryptomeria japonica*) on a piece of land quite far away from the settlement in the area of Viveiros⁸⁵ in the 1960s. They hoped for the trees to grow well and they knew the value of this wood on the market. In 2014, a mighty stock of trees had established on their terraces at Viveiros. Since the area is fully abandoned since many years, there is no viable access to those trees. He added that “close to the cargo cable at Primeira Lombada trees were planted later”. In Terceira Lombada Senhor Agostinho remembered, that “we planted pine when the grand children were small, they were playing on the terrace while we planted”. Since Senhor Agostinho was 92 when the interview was conducted, the trees were most probably planted around 1960 to 1970.



Figure 65: Traditional agriculture and abandoned fields in the area of Lamaceiros.

⁸⁴ Senhor Tomé from Segunda Lombada (58 in 2015) is a forest police officer in the district of São Vicente and thus responsible forest guard of the mountain forests around the Lombadas. Interview held on 23.05.2015

⁸⁵ cf. Chapter 4, figure 26

Figure 65 shows the gradual retreat of agricultural cultivation from the mountains into the valley. At first, the distant land on the ridge in the background was abandoned. The ridge makes part of Segunda Lombada, including the terrace system Lamaceiros/ Poço Feticheiro. When it was abandoned, it was still common practice to plant maritime pine (*Pinus maritima*), when cultivation was given up. Currently, the pine trees are wilted and thus easy to distinguish within the canopy of the woodland. They suffered from pine wilt disease. This disease is caused by the pinewood nematode (*Bursaphelenchus xylophilus*) and was first discovered on Madeira in 2009 (Fonseca *et al.*, 2012). Lower in the valley most terraces are abandoned and a secondary woodland has already established on some of them. Only in the foreground traditionally cultivated terraces with the typical Palheiro and a small residential house remain. The terraces below the residential house are used as cattle pasture. The cows are tied to a peg, which is moved every second or third day to a new pasture place. On the left of the image and near the house, fruit trees are cultivated. Behind the buildings, potato cultivation takes place within neatly arranged vineyards. The produce from the terraces has to be carried down to the valley ground, where a small cement road provides access for motorized transport. It becomes evident that abandonment is the predominating factor in recent land use change.

7.3.3 Driving forces behind recent land use change

Presently, the predominating change of land use is the shift from cultivated terraced fields towards abandonment and consequently the establishment of secondary woodland. It is partly reversing the initial process of extension of arable land. In the early centuries after settlement the demand for land was rising, farmers had no alternative to working the land. Certainly, there is not one general cause for the ongoing process of land abandonment witnessed within the research area and in most other parts of the island. Rather, it is a combination of various factors of economic origin, of extended opportunities for local inhabitants and of changing social values over time. Nevertheless, emigration has had a profound impact to land use and demography.

Generally, islands have often been emigration hot spots, many times in the course of history small islands proved to be instable in maintaining a resident human population. Island populations depend on limited resources, often putting in question food security, economic prosperity and consequentially social stability. Minor changes in such highly adapted systems

can have disastrous consequences, forcing populations to search for work in the maritime sector or emigrate, as recorded in the history of most islands. This phenomenon has been frequently observed on small islands, but even big islands like Ireland had to face mass emigration when crop failure of the most important crop, the potato, struck in the 1840s (Royle, 2001). Next to crop failure, economic downturns have often forced islanders to leave their homeland.

Madeira is no exception to this rule, each crisis of crops or a difficult global market situation made living conditions on the island very precarious. Inhabitants of the southeastern part of the island, living in close proximity to the port of Funchal observing ships at the port were more likely to be attracted to emigrate in the first period of emigration in the 19th century. Already Ackermann (1821) described strict port regulations in the port of Funchal to avoid illegal emigration:

1) Seaman or soldiers were not allowed to leave ship without a written permission by the captain or commanding officer. In case such a person was picked up by a patrol he was imprisoned and kept on a diet of water and bread until the captain paid 2 dollars per day to relieve him.

2) Each vessel anchoring in the port had to be inspected by a government official prior to departing to sea. After the inspection, no communication with the shore or other vessels was permitted. In case it took place, a second inspection was necessary.

3) Each captain of a ship was required to read out to the crew the two preceding articles:

“No vessel is to carry from Madeira, any person or persons, excepting those who came with her, without a regular passport; as, in case of detection in making such an attempt, the master is liable to a fine of one hundred dollars, and three months’ imprisonment.

In cases where the captain of a vessel shall be judicially notified not to carry any particular persons from the island, and he does, notwithstanding, receive him or them on board, he becomes liable for all debts such persons may owe.”

In 1841, Paulo Perestrello da Camara also reported on the problem of rising emigration “they [the Madeirans] depart by the hundreds” and during “a difficult economic situation on the island”.

Next to the official numbers of emigrants, who left according to the law with a passport and permission, there were thousands of illegal emigrants (Pereira, 1989). Furthermore, he reports, that “the safest door for clandestine emigration were the Deserta Islands”. People were taken to the islands by night in small fishing boats and the big sailing vessels after departing from the port Funchal stopped on their way to South America at the islands and picked up the waiting emigrants⁸⁶. In the early time of emigration often the poorest members of society departed, since they did not have a chance to make a living under the conditions the island offered. This situation changed by the mid-19th century, when skilled workers and people with a basic education started to leave the island and its´ growing misery. “Often, the spirit of adventure played a role as important as the necessity of escaping the misery. This explains the elevated number of emigrants even at a time, when the island was not as densely inhabited as today⁸⁷. It is estimated, that between 1845 and 1855 approximately 40.000 people emigrated” (Ribeiro, 1985). The emigration became a necessity for many after the great famine in the winter of 1846/1847. “A good part of the Madeiran population died and the horror of famine was feared by all” (Da Silva, 1921). Emigration was further pushed by the crisis of the Madeira wine in 1852. Additionally, political issues and the social conditions with the prevalence of the colonia contract made life on the island difficult.

Until the mid-19th century farmers had little chances to change their living conditions on the island, the colonia contract prevailed in most rural communities and made a farmer depended on his landlord. The farmer did not own land and thus had nothing to sell in case he wished for starting a new life elsewhere. For selling his meager possessions like the house, the stables, the trees or even the walls of the terraces he would need the consent of the landlord. In most cases the landlord would just not allow him to sell his belongings or make a ridiculously low

⁸⁶ It is reported by Perreira (1989), that at one occasion the vessel heading towards South America did not show up at the date agreed and all emigrants taken to the Deserta Islands died of famine. Their bodies were found by fishermen and buried at a place called Sítio das Campas.

⁸⁷ The publication of Orlando Ribeiro (1985) analyzes the conditions on the island up to the mid-20th century. When he writes „as today“, he does not refer to the situation in 1985, but to the one by the end of the 1950s. Nevertheless, Madeira continues to be an overpopulated island that would not be able to aliment its population without massive food import. In 1973, Wolf Dieter Blümel published a work titled “Madeira. Demographie, Sozialstruktur und wirtschaftliche Situation einer überbevölkerten Insel” (Madeira. Demography, social structure and economic situation of an overpopulated island) in *Karlsruher Geographische Hefte* 4.

offer to buy the possessions of the farmer. Without the possibility to have at least a small initial credit for a new start most farmers could not dare to take this step. They lived on the edge of survival in many cases. Often bad harvests made a farming family suffer from severe hunger, as reported in the archives of passport emissions in the regional archive on Madeira Island⁸⁸. One way to escape from this life-threatening situation was to ask the landlord for a loan and not deliver half the produce as established in the contract, but keep it for the alimentation of the family. In case some poor harvests succeeded each other, farmers got deep in debt and had no possibility to get out of the debt (Gouveia, 1975). Their survival depended on the good will of the landlord and thus made them obedient tenant farmers. Asking for a sale of their property to search for new opportunities might not please the landlord and was basically impossible for a farmer not wanting to risk his and his family's life. This situation changed with the upcoming regular maritime trade and the frequent passages to South and Central America. In the mid-19th century, South America offered many job opportunities for Madeiran farmers. They quickly gained the reputation of being hard working and reliable. The farm work on Madeira had prepared them for the harsh labor conditions overseas, especially in the sugar cane fields. The employers overseas generally paid the passage for a farmer to be able to recruit him as a worker. Business owners seeking for more workers often asked their Madeiran workers, if they knew someone from their villages of origin, who would like to come over to work as well. This new situation made emigration more accessible to peasants and certainly pushed emigration from both islands, Madeira and Porto Santo.

Next to these factors pushing inhabitants to leave, there was a growing number of factors attracting them overseas. There were the accounts of the first emigrants, who made good money overseas and were able to send money back home for the family members remaining on Madeira. Many, mainly British companies, advertised for working in their overseas colonies like British-Guyana, mainly Demerera. Saint Vincent Islands, Trinidad and Tobago as well as Hawaii were popular destinations for workers. There were a number of agencies in Funchal, advertising for emigration to British overseas colonies and promising them a fixed work

⁸⁸ The regional archive of Madeira Island is called Arquivo Regional e Biblioteca Pública da Madeira (ABM). Every citizen, who wanted to emigrate or leave the Island for other reason had to apply for a passport at the central passport register in Funchal. In this register all data regarding the individual were collected, such as name, family name, date of birth, age, school education, profession, destination and in the last column each emigrant had to give a reason why he planned to emigrate. Most emigrants in the 19th century gave *hunger* and *not possible to sustain my family* as main reason for emigration.

contract for 3 years, accommodation and half the passage was paid by Britain (Ribeiro, 2006). Furthermore, the author informs, that the agency of James Taylor, a British citizen living in Funchal, “would pay 5000 réis to whoever could persuade a colonist to emigrate”.

In the district of São Vicente Ribeiro (2006) reports on 2036 people having left legally to Demerera in the 1840s. In 1847, the council of São Vicente sent a letter to the governor of Madeira, pleading him to take efficient measures to set a stop to clandestine emigration⁸⁹. The leaving of skilled workers made a strong impact to the agricultural sector, since there was no one left to cultivate the land. There was a lack of workmanship “due to the calamity of emigration” and this lack made the present crop a little over half what the council used to have. From 1880 onwards, inhabitants seeking to leave the island were obliged to apply for a passport at the Governo Civil do distrito autonomo do Funchal⁹⁰, the studies of these registers reveal the part of legal emigration, that took place from 1880 to April 1975, when the carnation revolution ended the period of dictatorship in Portugal.

In the beginning of the emigration period, the motive for the decision to emigrate was most often the inability to aliment a family and resulting periods of famine. In later times, a frequently mentioned motive was the reunion of families. In general, a young husband would emigrate alone and built up a life for him and his family. After a few years, he would be able to pay the passage for his wife and kids to join him overseas. Furthermore, there are records of elderly couples leaving Madeira to live overseas together with their kids. The passport register thus displays entire family histories and shows the dramatic changes this had on the development of population on the island and consequently on the intensity of land use.

In the parish of Ponta Delgada emigration was a very important factor contributing to the development of land use. Since the parish is a relatively small community, a number of young men emigrating makes a considerable change to the community. The following part describes exclusively the emigration having taken place in Ponta Delgada. The countries of destination varied over time. Wherever demand of workers was high and a connection to Portugal and Madeira existed, be it by the language (Brasil and Spanish speaking countries) or by the close ties with Britain, people from Ponta Delgada chose as destination. In a first period of

⁸⁹ Ribeiro (2006) reports that people walked from São Vicente to land belonging to Arco de São Jorge, passed over Torrinhas pass towards the fishing village of Câmara de Lobos, where they were taken by fisher boats to the sailing vessels heading overseas.

⁹⁰ Local bureau for civil affairs, including migration

emigration, reaching from 1880 to 1930 the dominating countries of destination were Brazil, United States, Hawaii and British Guyana.

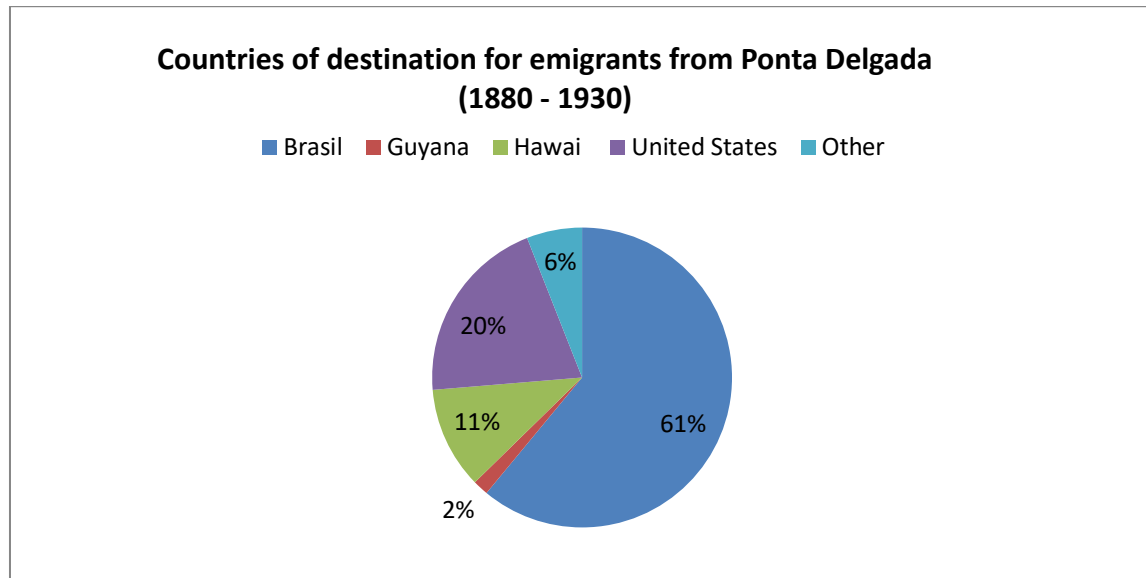


Figure 66: Destination countries for emigration from Ponta Delgada (1880 to 1930), data from A.R.M.

Between 1880 and 1930 a total of 418 people emigrated legally from Ponta Delgada. The main destination Brazil received 255 people, while the second most important destination United States mainland received 85 and the islands of Hawaii 46 emigrants. There are seven people registered to have gone to British Guyana and 25 have not declared their destination. The emigration did not take place as a constant process, but was influenced by the economics, politics and the overall situation of agriculture. The dynamics of emigration between 1880 and 1930 are displayed in the following graph:

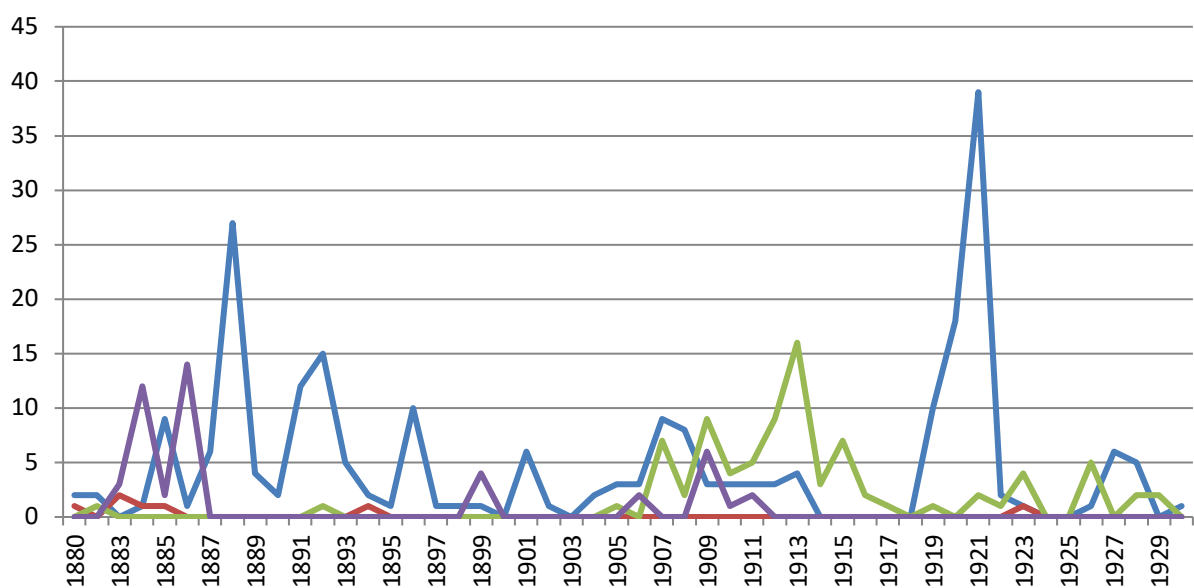


Figure 67: Emigration fluxes from 1880 to 1930 from Ponta Delgada, data from A.R.M.

The second period of emigration reaches from 1931 to 1975. In this phase, a total of 1188 people applied for a passport for emigration. In this period, the countries of destination changed according to the economic opportunities offered overseas. While Brazil was the dominating country of destination in the first period of emigration, it lost importance in the second period. The islands of Hawaii stopped being a destination in 1911, British-Guyana was not an attractive destination for people from Ponta Delgada from 1894 onwards. In 1938, Curaçao became an important destination for emigrants from Ponta Delgada. In 1947, emigration to Venezuela began and a total of 226 people started a new life over there. In 1954, another country became an important destination: South Africa. Until 1975, a total of 110 people chose this destination⁹¹. There was only one country, which kept being a popular destination over both periods of emigration: The United States. From 1880 to 1975, they became the new home for 176 people from Ponta Delgada. Next to Hawaii, there were two very popular places of destination: San Francisco and Great Falls.

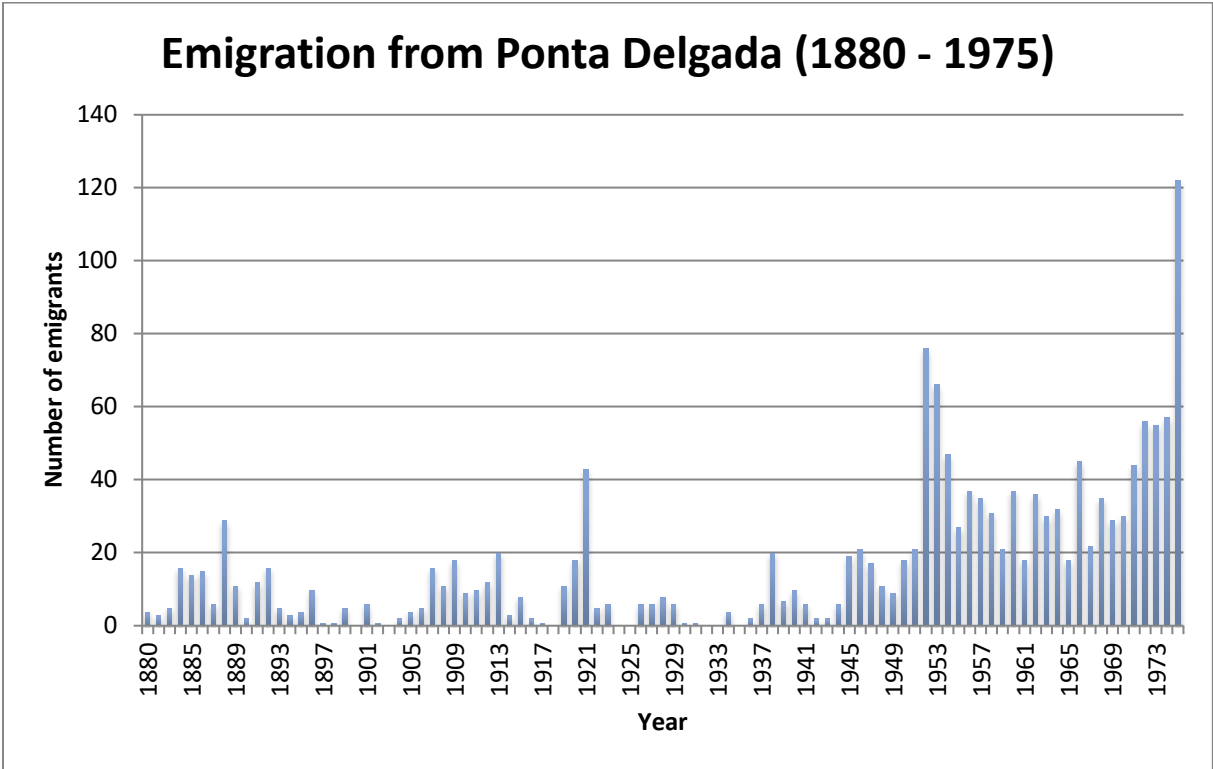


Figure 68: Legal emigration from Ponta Delgada in the period of 1880 to 1975, data from A.R.M.

⁹¹ South Africa became the most important destination for Madeiran emigration, it is recoded for the period of 1945 to 1975 that 8906 Madeirans emigrated to South Africa (This number includes the emigrants from Ponta Delgada).

From the parish of Ponta Delada 1584 inhabitants searched for new opportunities overseas within approximately 100 years. The massive recession following World War II promoted emigration like no other event before. From 1961 onwards, the Overseas War of Portugal⁹² was a strong motive for young men to emigrate before they were called for military service. The rising instability of the regime and the fear of what would happen after the Carnation Revolution were a strong motivation for emigration, over 120 people emigrated within 11 months⁹³.

7.4 Traditional agriculture practiced in Lombadas da Ponta Delgada

This section contains the accounts of peculiar traditional agricultural practices, which farmers` applied successfully to maintain and improve soil fertility and structure over centuries (cf. soil quality parameters, chapter 6). Another very important issue for the subsistence farmer was to minimize the risk of crop failure and thus avoid periods of famine for the family. Consequently, a very wide range of arable crops was cultivated. In case one crop would fail for some reason, another crop might produce well in the same year and support the family. Statistics of agricultural produce and sale, contemporary reports on the agricultural market, on economic difficulties and most of all the results from the personal in-depth-interviews on currently cultivated crops and changes in the spectrum of crops over time as perceived by farmers` make part of this section.

7.4.1 Role of terraces in preservation of traditional agriculture

Terraced landscapes throughout the world often safeguard century old knowledge of agricultural practices and techniques of land use. The general structure of the supporting dry-stone walls with the relatively small arable platforms in most terrace systems preserved small scale agriculture. Mechanization was limited due to the available size of the stripes of arable land. In case it was not economically feasible to remove existing terrace systems and rebuilt them in a way that permitted the use of modern agricultural machinery, the only way to work the terraces was to continue applying traditional agricultural methods.

⁹² The Portuguese Colonial War, often referred to as Overseas War (Guerra do Ultramar) was a colonial war between Portugal and its African Colonies of Mozambique, Angola, Guinea-Bissau.

⁹³ The records in the Arquivo Histórico Regional da Madeira terminate on the 25th November 1975.

On Madeira Island most of the steep slopes on which the terrace systems are established did not leave room for amplifying the arable platforms. Mechanization of main tasks such as soil tillage, sowing and harvest remains impossible. Owners of plots easily accessible from a road might have bought a motor plough, but even with this device, it remains to be a manual operation. Farmers still have to walk behind the plough and turn it around by hand at the end of the short terrace field. This procedure is only effective, when the plough can be transported easily to and off the terraced field. In the southwestern part of the Island with its' larger and mostly easily accessible terraces fields, it became a very popular piece of equipment. In the research area very few farmers invested into a plough. The adverse terrain conditions and the bad infrastructure, mostly consisting of footpaths', does not make the use of a motorized plough feasible. The effort to carry the plough up the steep trails towards the terraces makes it ineffective. Consequently, the orographic conditions of the valleys Ribeira da Camisa and Ribeiro do Velho preserved the traditional agriculture practiced in this area since the beginning of cultivation. Many approaches applied within traditional agriculture are shared by sustainable organic farming methods, such as intercropping, crop rotation and the integration of livestock and crop production.

7.4.2 Traditional structure and management of smallholdings in Ponta Delgada

The structure of typical smallholdings in the parish of Ponta Delgada consists of spatially very small explorations. Most of them having a size of less than 0.5 ha, like 77 % of all agricultural explorations on Madeira Island (INE, 2010). Since farmers over centuries worked the land of their landlords and created the small structures that could be ordered by the family, in this description the farm structures are described, while the situation of the landownership is presented in chapter three. However, it has to be mentioned that farmers in some areas, like on the headland of Ponta Delgada and in some low areas of the Lombadas, were limited in their decisions on crop selection and had to grow, what the land owner demanded (Gouveia, 1975). This was predominantly limited to cash crops throughout the island and in this northern location to vineyards. In case a farmer cultivated areas destined for grape production, he was obliged to produce grapes and was only allowed to practice intercropping with potatoes during winter. Other food crops were cultivated on more distant terraces, not suitable for wine production, or the farmer had to buy the food crops his family needed.

Non-cash crop farming in Ponta Delgada had to produce mostly everything the farming family needed for survival. Only very few items, that could not be produced on the farm, were

purchased on the market. This included farming tools, like the machete and the hoe, which were used for mostly every manual farming operation and often in the household, like for shredding of firewood. Consequently, the variety of cultivated plants was huge, not only food crops were cultivated, but also plants delivering fibers like linen or flax. The spectrum of crop plants included annual and perennial crops. Over time, the variety of crop plants rose. In the early years of settlement, farmers cultivated the crops they knew from mainland Portugal. Alimentation was based on grains, mostly on wheat (Nepumuceno, 1994). The maritime explorations of Portugal and the curiosity if food crops cultivated in the recently discovered parts of the world would grow in Portugal and on Madeira, extended the variety of crops cultivated⁹⁴ (Mendes Ferrão, 1994) and even shifted the basis of alimentation from grains towards tubers (Perreira, 1989). In mid-17th century, the sweet potato from South America was introduced and in 1845, a special variety from British-Guyana was introduced, too. The potato arrived on the island in 1760 (Menezes, 1909; Leça, 2011)⁹⁵. Another important tuber is taro, which was introduced to Madeira in 1640. This plant is very popular in the more humid northern part of the island until today (Leça, 2011).

In the parish of Ponta Delgada, the documentation on crops and markets begins in the mid-19th century. The following description regards the period from the 1850s onwards. Very popular annual crops included tubers, vegetables, legumes and grains. The basis of alimentation were tubers, like potato, sweet potato and taro (Gouveia, 1975). Gouveia further reports, “many times food was so scarce that not even a potato was available to satisfy the hunger in the morning”. Thus, the first daily meal of the farmers were potatoes or sweet potatoes prepared for lunch. The second most important type of crops were vegetables and legumes. Under the climatic conditions of the research area and the influence of higher altitude of many terraces very popular food crops were flat beans, broad beans, pumpkin, cabbage, peas, turnips, carrots, onions and salads.

Amongst the grains, traditionally wheat, rye and barley were of high importance (Vieira, 1997). According to Ernesto Martins Fernandes the production of rye and wheat was dominating. This is also reflected in the local toponymy: A large area above Terceira Lombada is named

⁹⁴ For detailed information on the link between maritime discoveries of Portugal and the introduction of alien species to Portugal cf. “A aventura das plantas e os descobrimentos portugueses” by Mendes Ferrão, 1994

⁹⁵ The seed potatoes arrived on Madeira from the Canary Islands. Leça (2011) proposed that the regional name “*semilha*” originates from the Spanish designation of “*semilla*”, meaning seeds. On mainland Portugal the potato is called “*batata*” and not “*semilha*”, on Madeira the term “*batata*” refers to sweet potato.

“*Terra do Centeio*”, land of rye. There are still some cereal silos visible in the Lombadas da Ponta Delgada. Traditionally cereals were stored in “*Matamoras*”, which are small caves dug into porous rock. According to Pereira (1989) and to the interview partner José Carlos Fernandes dos Santos (2014) they were lined with dry straw, filled with wheat or another cereal, covered with dry straw again and on top a layer of soil was placed to keep the stored cereals fresh. After the introduction of corn, this grain became a very important part of the subsistence agriculture, too.

The supply of clothing had to be organized within the context of the terraces, too. Only a small part of the clothing could be manufactured with the wool provided by sheep. Most of the clothing was made out of linen. The linen plant (*Linum usitatissimum*) was cultivated by the families on their terraces. On Madeira the process from planting linen to having the pulled thread in hand was known as the torment of linen (Mendes, 2010), since it was a very work intense process. Traditionally, linen was sown on the first Friday of March. The field needed a good preparation of soil and a sufficient amount of manure well incorporated into the topsoil before sowing. After sowing, a stick of giant reed was placed on the terrace, which was sticking 80 cm out of the soil surface. This was the mark for the farmer to know when the linen was ready to be harvested. Most of the time the harvest took place between São João and São Pedro⁹⁶, only when the prevailing weather conditions during the vegetation period were colder and wetter than usual, the harvest was delayed. The linen was pulled out with the root in order not to lose any of the valuable fiber. The next step is the rippling of the linen. In this process it is pulled between iron nails in order to strip off leaves and seeds from the stalk. Afterwards the stalk is placed into a pond for approximately 9 days. In this time the non-fibrous parts of the plant rot and it becomes easier to extract the fiber from the stalk. Afterwards the linen is placed to dry in the sun for another 9 days. The next step is to smash the woody outside part of the plant to extract the fiber, this was either done with stones or in a mill⁹⁷. This rough work is refined by beating the linen with a wooden stick and at the end pulling it through a fine comb-like structure of nails arranged in a plank. After this treatment, the linen-fiber is finally freed from the stalk and ready to spin the linen thread, which has to

⁹⁶ São João (Saint John) is on 24th June and São Pedro (Saint Peter's Day) is on 29th June.

⁹⁷ There are reports that in case the wooden structure would not break, the linen was placed in water mixed with bovine urine for another 9 days, washed and placed into the sun for drying for 9 days.

be washed before being ready to wave cloth. The demand for linen to manufacture textile was quite high, consequently the cultivation of linen occupied a considerable part of the terraces. Amongst the perennial crops, grapes were widespread; farmers cultivated them for sale and for private consumption. Additionally, fruit trees and nuts were very common. The fruit trees originated from temperate to tropical climates. Very common were apples (*Malus domestica*), pears (*Pyrus communis*), quinces (*Cydonia oblonga*), plums (*Prunus domestica*), guavas (*Psidium guajava*), custard apples (*Annona cherimola*), avocados (*Persea americana*), papayas (*Carica papaya*), tamarillos (*Solanum betaceum*), figs (*Ficus carica*), rose-apples (*Syzygium jambos*), lemons (*Citrus × limon*) and oranges (*Citrus × sinensis*). The most popular nut trees were walnut (*Juglans regia*) and sweet chestnut (*Castanea sativa*).

Most farmers used to have one or two cows and their offspring as farm animals. Goat keeping in the mountains was also common practice and many farmers used to raise one or two pigs, which were kept in small corals near the house and the stable. Furthermore, chicken were kept around the farm buildings, supplying the family with eggs and occasionally with chicken meat. Not every farmer had the financial and the spatial possibility to keep all of the above-mentioned animals. According to Senhor Agostinho, farmers, who could not afford to keep cows used to keep their goats near the living house instead of raising them on the mountains and used goat milk instead of cow milk.

The tenant farmer usually possessed three buildings, which he either inherited or was allowed to build on the land of the landlord (cf. chapter 3). One of the buildings was a small house, where the family would sleep and store the few belongings they owned. This building barely offered enough space for everyone to sleep. The children slept in the attic, just beneath the pitched roof, while the remaining family members slept in the room on ground level. The kitchen was in an even smaller house, usually on one side of the family's house. Inside used to be a fireplace, a backing oven and space to store firewood. In some settlements, a backing oven existed outside the houses and was shared by various families.

In the 19th century, many farmers had no kitchen building, but a fireplace close to their house, where the daily cooking took place. In addition, a stable with a pitched roof belonged to the farm. This building and all others used to have a thatched roof, made of wheat or rye straw. This is where the Portuguese name for this type of stable "*Palheiro*" originates from⁹⁸. Only in

⁹⁸ The designation „*Palheiro*“ comes from the word for straw: "*Palha*"

recent times zinc or tiles were used. The palheiro was built on a terrace, if possible in a way that one side of the roof permitted easy access to the attic, which was used as storage for hay and bedding for the animal. Inside was space for one or two cows and their calves. On the side towards the upper terrace wall was a stonewall of approximately 80 cm to 100 cm of height and approximately 80 cm of width that served as trough. Water had to be brought to the animals several times a day by the family members. In close vicinity of the buildings people used to have some fruit trees that would also offer shade during the warm period of the year. The farm would be surrounded by agricultural terraces that would be used for fodder and crop production. If the location offered good conditions for profitable cultivation of cash or food crops, it was not used for fodder production. In this case, fodder was produced on terraces higher up in the mountains, offering less favorable climatic conditions. Figure 67 shows a typical farm with its buildings and the terraces surrounding it. The building on the left is the palheiro, in the center is the house and the small building covered with roof tiles on the right is the kitchen. Until present days, there are many farmhouses, which do not have an access to a road. The only infrastructure to reach the house continues to be a footpath in more or less good conditions. All crops produced on the farm had to be carried down to the village, if they were destined for sale on the market or the part of the harvest that had to be handed over to the landlord.



Figure 69: Traditional smallholder farm in Ribeira Seca, Machico

The traditional smallholding in the research area is a mixed farm. Next to livestock production, there is always plant production. This mixed farming system has certain advantages compared to specialized farming, as it is present in few areas in the headlands of Ponta Delgada. The tenant farmer could not afford external inputs for plant production, such as chemical fertilizers or pesticides. The only way to maintain soil fertility and acceptable yields was to raise the input of labor and apply the best-known farming skills. This automatically led to the application of integrated farming methods including soil conservation practices. The farm animals deliver the nutrient resources for crop production; it is one of the few sources of plant nutrients available to the farmer. Consequently, the manure that accumulated in the palheiro, was spread on a terrace after the preceding crop was harvested and immediately worked into the topsoil of the terrace (Martins Fernandes, 2014; Caldeira de Jesus, 2014; Sr. Agostinho, 2014). This measure reduced nutrient loss due to denitrification. A large or the entire amount of the bedding material used in the palheiro was dried bracon, collected on the high mountains. This contributed further to an enrichment of the soil with organic matter and nutrients from outside the farm area. The fodder for the bovines and goats was often collected in areas not belonging to the farm. Herbs and grass were cut along the footpaths and the feeding with leaf hay from twigs of sweet chestnut (*Castanea sativa*) and Lilly-of-the-Valley-Tree (*Clethra arborea*) was common practice (Perreira, 1989; Interview Martins Fernandes, 2015; Interview Gonçalves, 2015). An important side benefit of this laborious practice of fodder collection was the additional input of organic material to the farm.



Figure 70: Transport of leaf hay from the mountains towards the settlement. Image by Andreas Kautzsch

The farm animals benefitted from a number of resources from the plant production segment on the farm. Plant remains from harvesting crops could often serve as fodder resource. For example, the upper parts of sweet potato were entirely fed to goats, pigs and bovines. When the corn cobs were picked the remaining plant was used as animal fodder. In grain production the part of the straw that was not needed for repair works on the roofs or for renewing of the filling of beds also served as fodder resource. The daily organic waste from cooking was valued as resource for pig and goat feeding (Interviews Maria da Terceira Lombada, 2014; Gonçalves, 2015 and Martins Fernandes, 2015).

Next to these inner farm cycles, where absolutely no resources were wasted, a number of steps was taken to maintain the soil fertility despite intense farming activities all year round. The daily cooking on open fire and the weekly baking of bread produced a notable amount of ash. Additionally, some organic waste, which was not suitable as fodder, such as nut shells from walnut and sweet chestnut, were burnt in the fireplace of the house. The ash was collected and spread out on the terraced fields. There are reports of farmers (Interviews Gonçalves, 2015 and Maria da Terceira Lombada, 2014), who have cut weeds along footpaths

and on abandoned fields and brought them to a terrace that was prepared for new sowing. The collected plant residues were dried in the field and burned on the spot. The resulting ash was then distributed on the field.



Figure 71: Ash from burnt plant remains on a terrace ready to be prepared for sowing. Photo by Hans-Rudolf Bork, 2013

The field ordering has been adapted to the given conditions over generations. A very common practice, not only in the parish of Ponta Delgada, but on the entire island is to use the vineyards during wintertime as potato fields. After the vines drop their leaves there is sufficient amount of light reaching the soil surface. Potatoes are commonly planted in February, just after the pruning of the vines. Farmers combine the tasks of pruning and of planting of new potatoes. Before the pruning starts farmers digged small trenches for planting potatoes. The shoots of the vines, which were cut off, were placed in the trenches. This method saved time since they did not have to be removed from the terrace. Potatoes were then placed on top of the cut off shoots in the trenches and finally covered with soil. The addition of these small shoots added organic material to the soil, which could decompose slowly and provide some nutrients for the crop. The soil covering the shoots often left some big pore spaces along the shoots, which facilitated lateral root development. Maria da Terceira Lombada (2014) mentioned in favor of this method of planting potatoes that, “the potatoes grow better and have stronger roots”.

Another special measure of field ordering was applied in the planting of sweet potato. After raising the slips for planting somewhere close to the house, they were taken to the terrace that was ready for planting. The terrace was ordered in a way that one small ditch was divided by a low earth wall from the next small ditch. Generally, the ditches were dug in way that they were perpendicular to the slope of the terrace. This facilitated irrigation during the crop cycle. Respectively the slips were planted on the bottom of the ditches. After planting, the ditches used to be covered with collected bracon leaves to protect the small plants from direct sun exposure and thus diminish the evapotranspiration rate during the first days after planting, when the roots of the young slips were not well connected to the soil. The bracon leaves remained on the terrace and were successively overgrown by the sweet potato plants. According to Sr. Agostinho (2014) “the sweet potatoes had less problems with rotting”. This method of planting sweet potato added organic material to the terraced field, which would otherwise not have been introduced into the terrace soil. In modern conservation agriculture this kind of mulching is known under the term cut-and-carry mulching system (FAO, 2005).



Figure 72: Agricultural terrace recently planted with sweet potato. Photo by Hans-Rudolf Bork 2013

Next to these specific methods of crop cultivation, an important measure was mixed cropping. On one terrace farmers used to cultivate different crops at the same time. It was common practice to plant collard greens on limitation of the terrace. They did not occupy much space,

provided wind shelter for the other crop plants on the terrace, especially wind sensitive plants such as peas and beans and provided a valuable food resource for humans⁹⁹ and after flowering the plant still served as animal fodder.

The traditional agriculture practiced in Lombadas da Ponta Delgada has adapted over centuries to the given conditions, its limitations and possibilities. The input and the output of organic material to the terrace fields have been managed in a way that maintained soil quality and fertility at a high level. A farm with animal and plant production has many inner-farm cycles, where one sector provides resources for the other sector. Manure produced by animals provides organic matter and nutrients for the terrace soils and supports plant production. On the other hand, remains of harvested plants were used as fodder resource for the animals. The older varieties of wheat, barley and rye had a comparably low harvest index, thus providing more plant material in relation to the harvested crop. These integrated management techniques were further supported by high inputs from the mountain woodland area. This includes not only the woodland resources, but also the resources utilized on deforested ridges. In figure 73 the most important input and output factors within a typical, local smallholder farm are illustrated.

⁹⁹ The traditional Portuguese dish “*Caldo Verde*” is a soup made of sliced leaves of collard green and some other vegetables. Until present days, this dish is very popular in the island’s cuisine.

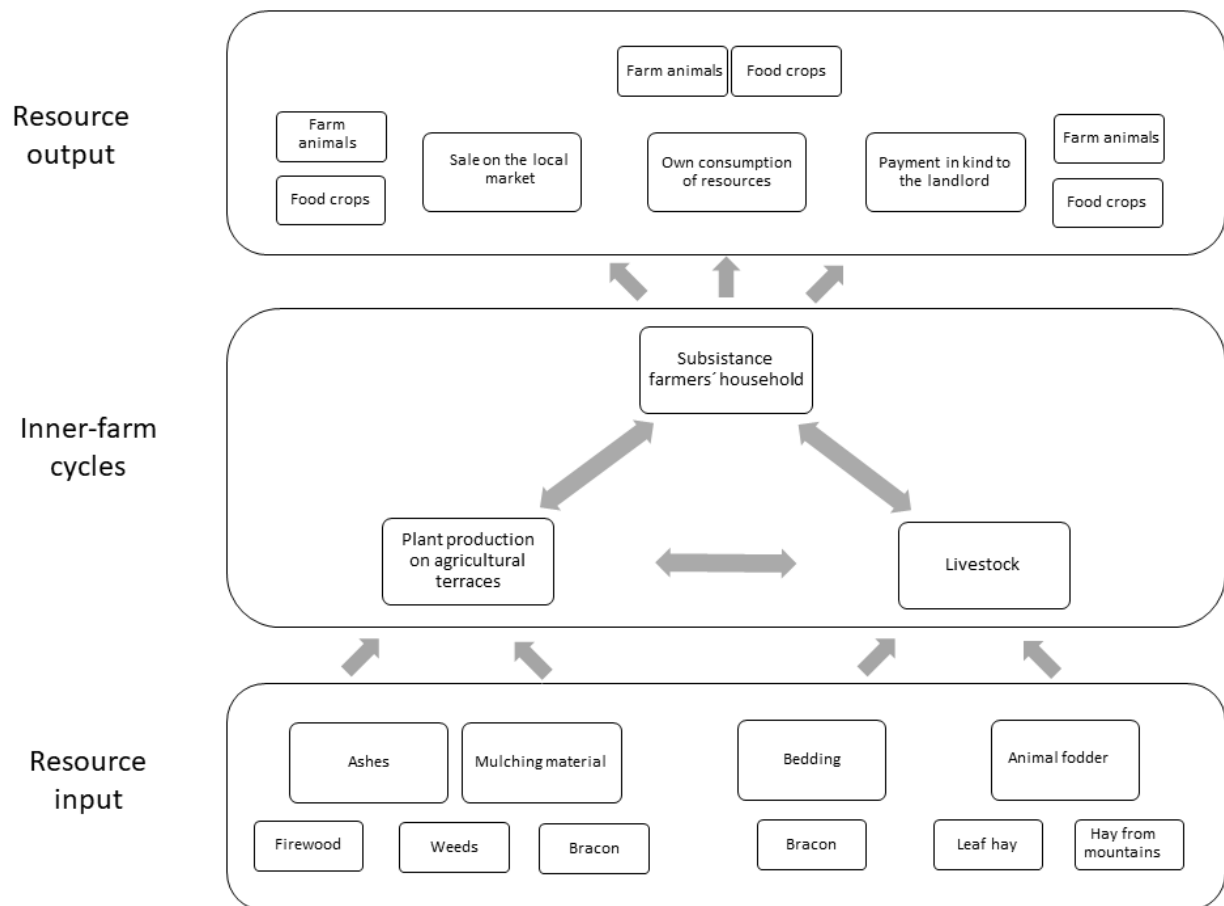


Figure 73: Important input and output factors of a smallholding in Lombadas da Ponta Delgada

Since mineral fertilizers were unavailable for farmers, they were forced to use as much of the resources the natural surrounding provided, as possible. The importance of the native and introduced woodlands becomes evident in figure 73. The only resources from outside the farm, which are utilized to maintain and even to improve soil fertility and soil stability, to raise cation exchange capacity, water storage and infiltration capacities are collected in the mountain woodland area. Except for the application as mulching material they are applied after having served another purpose. The leaf hay is first used as animal fodder and is afterwards brought to the terrace as manure. The firewood used in the household first fulfills its main task as a source of energy and is afterwards applied to the terraces as ash, providing valuable nutrients for plant growth. The constant input of organic and mineral material and a comparatively low output of it are the pillars of the traditional agricultural production system.

8 Conclusions

8.1 Introduction

Over approximately the past 600 years, intense interaction between the resident human population and the landscapes of Madeira Island has profoundly changed the formerly natural environment. The insularity and the resulting partial isolation and detachment of the population from mainland Portugal have given rise to very peculiar local traditions and ways of adaptation to the islands' environmental conditions. Particularly food production on steep slopes required special techniques to modify the unfavorable given conditions. Thus, the food production system had to be highly adapted. After the initial phase of settlement, Madeirans were on their own and had to grow the food they needed. The growing population depended entirely on their capacity to modify the natural woodland, which had covered the island upon arrival of the first settlers into an agricultural landscape that would provide the necessary resources for their survival. The slopes of most areas of the island were too steep for the cultivation of crops. Over the last six centuries, almost all the sites suitable for agricultural production have been converted into terraced agricultural land.

8.2 Development of agricultural terrace systems

The agricultural terrace systems proved to be very resistant to erosive forces, and even centuries after their construction, hardly any destroyed terrace walls are visible. In some parts of the island, the abandonment of terraces has already led to the establishment of secondary woodland on the old terrace structures. Even in such areas, where maintenance of the dry-stone walls has been given up decades or even centuries ago, the sustaining walls of the abandoned terrace systems are in most cases still in place. The traditional knowledge on terrace construction passed from one generation of farmers to the next. It became more and more refined over time until it reached an outstanding level of adaptation to the given conditions at each site. It has proven that those terraced slopes are an efficient measure against natural disaster risk, such as landslides and water erosion. Therefore, the terraces are one of the most valuable features of the present cultural landscape.

To understand, which constructional peculiarities of the sustaining terrace walls have resulted in this high stability, the research area in Lombadas da Ponta Delgada was very suitable, since

the interaction between the local population and the landscape is still strong today. Many inhabitants use to maintain a number of terraces under cultivation and thus, keep traditional agricultural practices alive. The abandonment of terraces is comparatively recent. The great majority of terraces was abandoned from the mid-20th century onwards. This provided not only ideal conditions for studying the terrace systems themselves, but also for a better understanding of the processes and activities that have formed and maintained the unique agricultural landscape of the Lombadas da Ponta Delgada with its features and functions.

The study on the development of the terrace systems at the Lombadas proved that the period of construction of the terraces reached from the initial settlement in the late 15th century to the mid-20th century. It was not a constant process of extension, but rather a process with highly shifting intensities over time. Social and economic factors were mainly determining the speed of the extension of cultural landscape into the mountains. Mainly two factors drove the extension of terrace systems into the mountains: population growth and economic factors. In the initial phase of settlement, comparatively big amounts of land were taken into cultivation to meet the growing need of food of a rapidly increasing number of inhabitants. The easily accessible land at the flattish headland of Ponta Delgada and the plateau of Primeira Lombada were turned into agricultural land first. The successive extension of farming and thus of terrace systems into the mountains was surprisingly not determined by proximity to the settlement or ease of access, but by physical parameters of the future arable land. The inclination of the land, the proximity to the watercourses, the thickness of the soil and the solar radiation at the site were obviously the determining factors, while the distance to the settlement was of little importance. The central area of Ribeira da Camisa valley with several small plateaus, was taken into cultivation around 1500. The surrounding slopes were successively terraced over approximately the following 200 years. In these later phases, mainly economic trends of the agricultural commodities market gave impulses for a change in land use and food crop production. In the late 15th and 16th centuries large-scale sugar cane production, which occupied much of the fertile terraced land at low altitudes, was forcing inhabitants to extend the terraced space further into the mountains in order to satisfy the local demand for food crops. A similar effect was caused by the extension of vineyards in the late 18th century. In the research area vines grow well and produce sweet grapes up to an altitude of approximately 300 m a.s.l., which again caused competition for land. Furthermore, there were several periods in Madeiran history, when food crop import broke down due to

external circumstances, causing periods of famine amongst the local population. These events resulted in an extension of agricultural terraces, aiming towards an increase in food production and thus ensuring the survival of the inhabitants. For example, the steepest slopes rising up close to the hamlet of Terceira Lombada have only been terraced in the mid 20th century, when food supply of the island was very scarce due to the negative effects of World War II on maritime transport.

8.3 Stability of agricultural terrace systems

The agricultural bench terraces on Madeira Island are highly resilient against erosive forces and do not require permanent renewal, like terraces in some other parts of the globe, for example in Konso, Ethiopia. The construction of the terraces in Lombadas da Ponta Delgada was adapted to the conditions of the individual sites, which was clearly shown by the examination of the soil profiles. Farmers have carefully inspected the place before starting construction works and have decided how the structure of the future terraces would have to be designed in order to construct a stable system of supporting dry-stone walls under the given conditions of the site. They clearly used different approaches for each terrace system and even for single terraces within a terrace system.

During the investigations of terrace profiles in various terrace systems, three types of bench terrace construction have been identified:

- Type 1: Bench terrace without supporting dry-stone wall
- Type 2: Bench terrace with simple dry-stone wall construction
- Type 3: Bench terrace with complex dry-stone wall construction and drainage layer

The type 1 terrace has only been identified on one ridge within the research area, on Lombadas Coches (profile L_C_1). This proves that next to constructing a resilient terrace system farmers tried to build the terraces as efficiently as possible and saved input costs such as work force or construction material whenever possible. The rare case of a ridge that had no significant inclination and was not endangered by flooding from mountain streams made it possible to avoid the arduous construction of dry-stone walls. The terrace in which the profile L_C_1 is located dates from the period between 1650 and 1680 and to this day shows hardly any signs of decay, as does the entire terrace system. It withstood a number of high intensity rainfall events and floodings, such as the flood from February 20, 2010 with 58.6 mm of precipitation between 9 am and 10 am and 105 mm of precipitation between 10 am and 11

am (recorded at Pico do Arieiro meteorological station, approximately 3 km from Lombo das Coches).

In less than 300 m of distance to the northeast at Cova do Bardo the physical conditions are very different. Steep terrain extending from a watercourse towards a ridgeline running in east-northeastern direction was selected for terracing. The watercourse might affect the terraces during strong precipitation events, in particular after creating the terrace platform, which allows the water to flow over quite an extended part of the terrace. This particular situation required a very different architecture of the bench terraces, which has led to the construction of terraces of type 3. Farmers knew that proper drainage and strong dry-stone walls were the keys to create a resilient system of terraces at this place. The terrace profile opened at Cova do Bardo (C_B_2) shows a layer of large stones at the bottom of the terrace, which adjoins to the dry-stone wall. This layer in combination with the dry-stone wall provides an interconnected net of large pores allowing highly efficient drainage. This avoids also the accumulation of excessive weight close to the terrace wall, which can lead to its collapse. This stone layer is covered with two thick layers of soil. The less fertile soil sediment was placed on top of the stone layer and the fertile soil sediment for agricultural production is the top layer of the terrace.

Any intermediate conditions between not too steep terrain and no immediate danger of pronounced water erosion have led to the construction of terraces of type 2. Consequently, this is the most frequent type of terrace construction in Lombadas da Ponta Delgada. It combines an acceptable level of stability of the terrace wall and thus of the the entire terrace system with a much less labor-intensive construction method compared to type 3. The type 2 terraces have been identified at Levada da Fonte (profile Lev_F_1), at Lamaceiros (profile L_P_F_1), at Cova do Bardo (profile C_B_1) and at Ladeira (profile P_L_1). In these profiles, the thicknesses of the dry-stone walls vary greatly. The profile at Lamaceiros has only two rows of stones that form the dry-stone wall, while the wall at Levada da Fonte has four to five rows of stones (slight variation due to different sizes of stones used to build the dry-stone wall).

The agricultural bench terrace systems at Lombadas da Ponta Delgada testify to a high degree of adaptation to the physical conditions prevailing at each single site, where they have been constructed. These adaptations include the differences in terrace structure, in architecture of the drystone-wall and in the adaptation of wall height and platform size to slope inclination.

Additionally, the water availability at the terraced ridges has been considered fundamental for crop production. At most terraced ridges, an irrigation system is integrated into the terrace system. Most probably, these irrigation systems have been included during the initial construction of the terraces. The terrace systems at Lombo das Coches, Lamaceiros, and Levada da Fonte are all equipped with a water storage basin or in case of Levada da Fonte linked to an irrigation channel with various water storage basins and numerous springs further uphill. Terrace systems investigated at Cova do Bardo, Caminho do Bardo and Ladeira have received water from nearby brooks through small channels dug into the terraces.

During the construction phase of the terraces, farmers have tried to maintain soil quality by removing layer by layer, so that the original order of the layers with the most fertile horizon atop could be restored at the end of the construction. First, the topsoil was placed aside, and then the lower layers were dugged off and placed aside as well until the terrace foundation had the desired depth and shape. Subsequently, layers could be placed back in the original order behind the supporting dry-stone wall. During the process of removing the layers larger stones found in the soil were removed and used either in construction of the dry-stone walls or as part of the drainage or simply buried under the future terrace. This time-consuming task left farmers with a fertile soil that was easy to work with the traditional hoe.

8.4 Traditional agricultural practices and resource use

The effort of constructing such terrace systems resulted in a high valorization of the gained agricultural ground. Thus, the traditional agricultural practices that have developed over time in the Lombadas da Ponta Delgada therefore have focused on maintaining and improving the quality of the terrace soils. The analysis of the soil organic matter has shown extraordinarily high contents of organic matter throughout all profiles. Farmers knew about the beneficial functions of organic matter to the fertility of the soil. Over generations, farmers have developed practices that ensured adding sufficient organic material to the terraces, to keep the soils in good condition. The carbon of the crops harvested on the terraces was largely compensated by the addition of new organic material (Kiesow & Bork, 2017).

There used to be two types of input of organic material: internal and external input. The internal input was plant residues from crops left on the terrace field after harvest. During field order works these residues were incorporated into the soil, where they served as green manure amending the soil. Next to this practice, farmers used different ways of raising the

amount of organic material added to the terrace fields by accessing external input. Animal husbandry provided manure and organic bedding material. This was collected on the high mountains and after being used, it was taken onto the terraces and incorporated into the soil. Furthermore, the animals were fed partly with leaf hay cut in the laurisilva mountain woodlands. The remains from this fodder were also added to the terraces, this included wilted leaves and small branches.

These traditional practices have modified most of the mountain woodland surrounding Lombadas da Ponta Delgada. All of the high ridges with a slight hillslope have been deforested. Some of them served as pasture, while most of them were used as source for animal bedding. The local population used all possible resources of the mountain woodland to improve their supply situation. This dependence on woodland resources not only for firewood and construction material, but for daily needs has profoundly changed the natural vegetation composition of both the native laurisilva woodland and the heather woodland of higher altitudes. This modification encompasses basically the entire mountain terrain of the Lombadas da Ponta Delgada, excluding only the inaccessible sections of the mountains. The vegetation mapping results show very few areas, which do not reflect human modification and resource extraction during the past centuries, but even in these areas it cannot be excluded that some kind of use took place.

Organic waste generated on agricultural land, like thin branches from pruning trees and vines, was another source to maintain a high organic matter content in the terrace soils. All of these traditional methods were very labor intensive and rooted in a notorious shortage of agricultural land. Farmers were forced to produce as much food as they possibly could on their small agricultural terraces. The production was the basis for survival and the quality and amount of the harvest decisively influenced the well-being of resident farming families. That is why they have made as much effort as possible to practice sustainable management. Thus, they have developed such labor-intensive agricultural practices. Traditional agriculture had to work with the existing local input possibilities. Next to the above described practices, it was common to burn biomass (such as parts of plant remains, thick branches of the leaf hay and often weeds collected along footpaths) to gain nutrients contained in the plants. After burning, the ashes were evenly distributed on the terraces and worked into the upper layer of the terrace soils. Furthermore, the ashes accumulated at fireplaces were also distributed on the terrace fields.

In terms of crop management, farmers have largely opted for polyculture on the agricultural terraces, allowing a more thorough use of the limited resources available. In addition, polyculture has a number of advantages for the subsistence farmer. The overall yields are higher than in a monoculture cropping system and the harvests of different crops can be spread over an extended period. Farmers in Lombadas da Ponta Delgada have carefully selected the best combination of crops and the right sequence of planting them, in order to be able to harvest some kind of crop all year round. Furthermore, intercropping brings a certain level of security, in case one crop fails, there are still other crops to harvest, which might produce successfully. The sowing period and the length of the vegetation period vary according to the changing climatic conditions mostly due to exposition and height of the terrace above sea level. The traditional agricultural practices have been perfectly adapted to these variations in climatic conditions. Certain crops like wheat have developed local variants, which were ideally adapted to the valley where they were cultivated. Combinations of crops, sowing period and harvesting regime have been adapted to the less favorable conditions at higher altitudes.

Within this perfectly locally adapted system it was common practice that crop rotation was carefully planned and, in few locations like on the highest terraces, where less biomass was added than on the very intensely used terraces close to the settlements and stables, every five to seven years a fallow year was included into the crop rotation. Farmers who lived on the land they worked had a very close relationship to nature. They could read the smallest weather signs. They would see a slightly deviating plant development on their crops and could react and adapt very quickly to changes.

8.5 Recent trends in traditional agriculture and their implications

Since several years, the most eminent ongoing process in agriculture in Lombadas da Ponta Delgada is land abandonment. Animal production has largely been given up. Only a few farmers continue goat keeping on former agricultural terraces. In the mountains it is forbidden to practice any goat or sheep herding since 2003. The field work of this project has shown that plant production has diminished dramatically. Between 1950 and 2014 the utilized agricultural surface has diminished by 47 %, from 136 ha down to 72 ha. In the initial phase of abandonment, the main driver of this process was massive emigration that took place in the late 1940s and during the 1950s. Farmers and workers left the Lombadas in great numbers

and the ones who stayed could not cover the missing work force. At first, less suitable terraces or terraces with difficult access were abandoned. In present days the abandonment of terraces includes highly productive areas close to the settlement. Next to the land abandonment the spectrum of cultivated crops shrunk. As food import increased, the local food crop production became less and less remunerative. Many farmers who still produced for the local market in the late 20th century diminished their production to a mere subsistence production. Very labor intense crops such as linen are not cultivated any more. Another factor, which is presently threatening the traditional agriculture, is the overaging of the population. There are hardly any young people working in agriculture, most of the cultivated terraces are worked by retired farmers. Often, they have emigrated during their active working life and returned to their village of origin after retirement.

This recent trend shows how strongly threatened the local terrace agriculture and its traditional and highly adapted practices are. The generation of farmers, recalling the traditional practices of land use and applying them in their small production, has often not had the chance to pass their knowledge on to the next generation, since most of them emigrated at young age. Consequently, a huge amount of traditional knowledge, gained over approximately 500 years of agricultural activity in the Lombadas da Ponta Delgada is presently standing at stake. Losing this traditional knowledge has far-reaching consequences not only for agricultural production, but for the functionality and continuation of the cultural landscape itself.

This causes partial or total loss of numerous benefits brought by this century old and perfectly adapted system of interaction between humans and nature. Some of the most important benefits presently being threatened are high biodiversity, the fertile agricultural soils with their extraordinarily high contents of organic matter and a functional soil structure providing high infiltration rates and low bulk densities and a high-quality local food production. Furthermore, the genetic resources of locally adapted land races are about to disappear due to the constantly diminishing production and a respectively shrinking genetic pool. The combination of diminishing benefits and services formerly provided in abundance by a well-maintained traditional agricultural system and the ongoing loss of knowledge about traditional practices gradually decreases the general resilience of this land use system, which has allowed the persistence of human settlements under the demanding conditions of the mountainous landscape for approximately five centuries.

Many of the recent modifications in social life are rooted in the abandonment of traditional agricultural practices. The local culture, the identity with the place and the way of life in the village community has always been directly linked to the annual cycle of agricultural production. Common tasks such as honey extraction were carried out in a group and strengthened social cohesion within the village community. The proceeding abandonment of specific agricultural practices leads towards a weaker sense of community and partial loss of social cohesion. In present days the most important opportunities for improving social cohesion are the agriculturally based festivities such as the annual wine festival in Ponta Delgada or the annual soapbox race from Primeira Lombada to Ponta Delada.

9 Outlook

The recent development of land use on Madeira Island has been characterized by a pronounced increase of land abandonment. All municipalities with exception of Câmara de Lobos and Santa Cruz have registered pronounced land abandonment in the period between 2000 and 2020. The utilized agricultural area has gone down from 8817 ha to 6679 ha (Direção Regional da Estatística da Madeira 2001 and 2021). At higher elevations, hardly any terrace system is presently under cultivation. In a few locations, terrace systems have been transformed into animal pasture or are used for fodder collection. This type of land use prevents the establishment of secondary vegetation. The abandoned terraces however quickly overgrow under the given environmental conditions and subsequently turn into secondary forest.

The process of land abandonment is associated with an ongoing degradation of infrastructures like terrace walls, footpaths, water storage basins and irrigation channels. The degradation of terrace walls merits special attention since it eventually leads to a destabilization of the slopes. Such destabilized slopes, with partly collapsed wall structures and no constant slowing down of surface runoff by horizontal terrace soil surfaces, is likely to cause severe damage on infrastructures and settlements in case of a heavy precipitation event. According to the IPCC Climate Change 2014: Synthesis Report (2014) strong precipitation events will become more frequent in the near future.

The effects of a heavy rainfall event have just recently been observed in Ponta Delgada and the Lombadas. On 25th December 2020 numerous landslides, many of which have had their origin in or slightly above abandoned terrace systems, have destroyed or damaged houses, roads, irrigation channels and terrace infrastructure (Diário de Notícias, 2020, Correio da Manhã, 2020).

The threat of being affected by natural hazards can only be diminished by a well maintained, functioning terrace landscape, which reduces both the amount of surface runoff and runoff speed significantly. The landscape created over centuries is currently standing at stake. With it, the traditional ways of cultivation, the knowledge on best practices of soil tillage, crop selection and crop rotation are threatened. Until today, some farmers still practice traditional agriculture on the terraces close to the houses and almost every member of the older generation of farmers still remembers the traditional techniques and best practices. Sadly, only very few of them had the chance to pass on this knowledge to the younger generation.

The most probable future development is further extension of abandoned land with all its related implications on landscape, biodiversity and society. Under current economical and societal circumstances, agricultural activities on the terraces of Lombadas da Ponta Delgada will gradually disappear. Possibly small vegetable gardens will remain in the direct vicinity of the houses. This dramatic change will most likely take place within the next 15 to 20 years since the vast majority of farmers are aged above 60. For the elaboration of figures 74 and 75, it has been assumed that the currently observed land use trends and the economic framework conditions of the agricultural sector continue with little alterations.

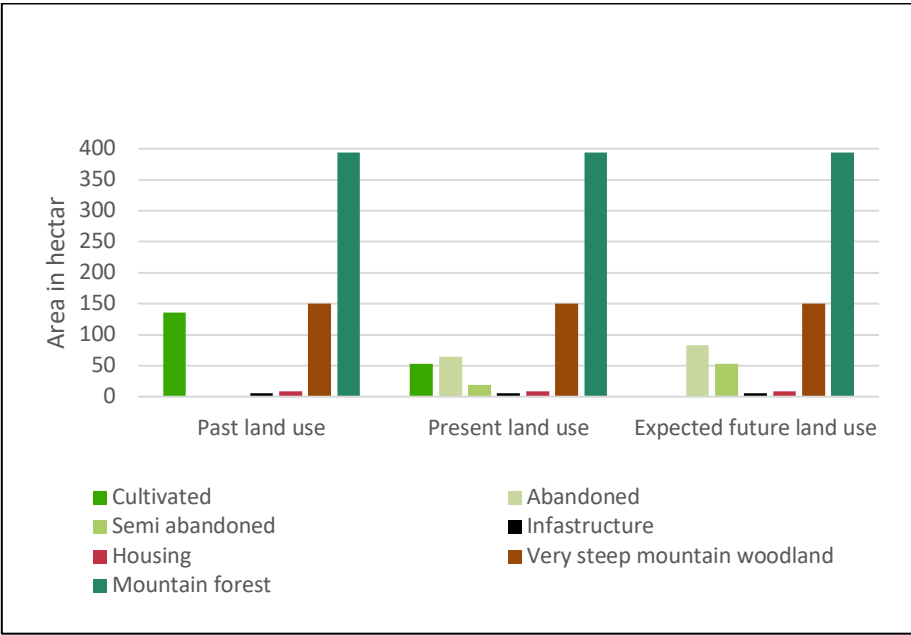


Figure 74: Development of land use in the past (around 1950), in the present (2014) and future perspective of land use in Ponta Delgada¹⁰⁰

¹⁰⁰ In the prediction of “expected future land use” the class of “semi abandoned” includes gardens by the houses. The class of housing has not been considered as a changing land use class, since there is hardly any new construction activity and old houses are simply abandoned and not removed.

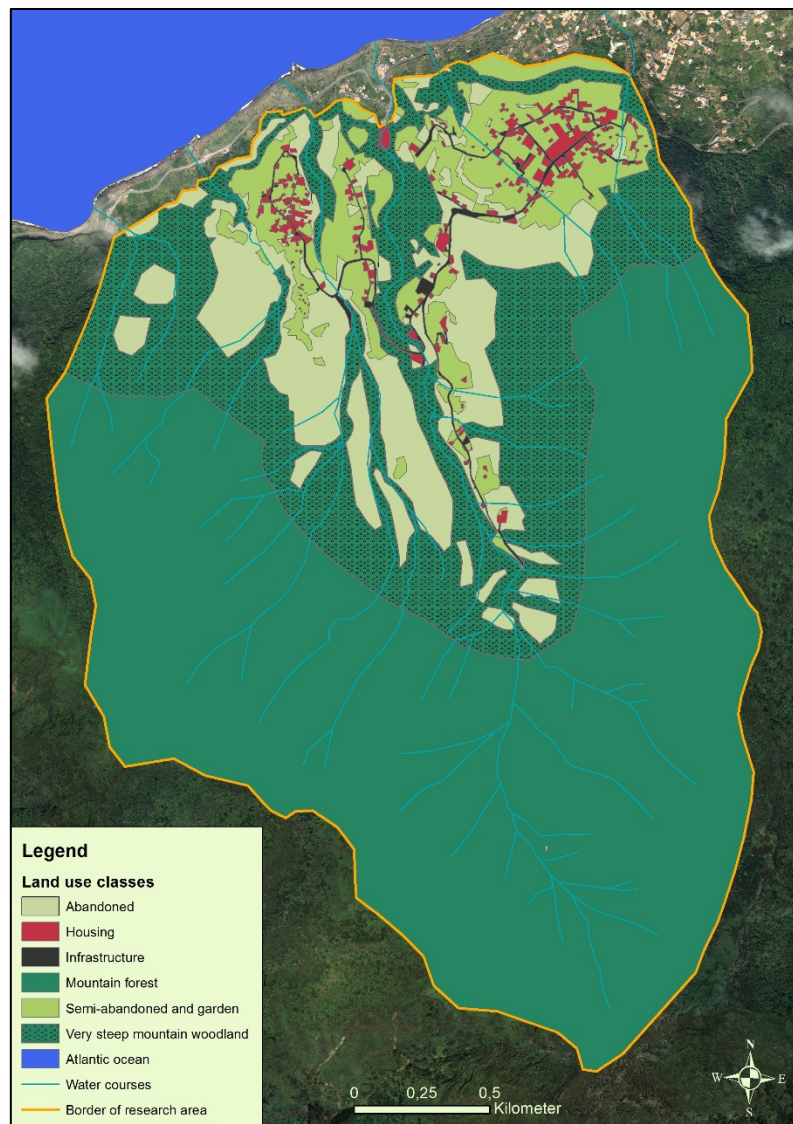


Figure 75: Most probable future land use situation

Figure 75 shows the expected future land use situation in Lombadas da Ponta Delgada as map view, which allows a quick assessment of the dimension of change in the landscape. Approximately 61 % of the formerly cultivated terraces will be abandoned in the near future. The very light green shows these areas, while the light green areas are semi-abandoned terraces and gardens, where some gardening might still take place.

The degradation of these terraced slopes brings along a loss of agricultural heritage, of traditions, of local identity, of agro-biodiversity, of open land-habitats and most of all it implies losing the knowledge of traditional terrace building and of sustainable agricultural practices. Furthermore, Madeira is a region that strongly depends on tourism, having created approximately ¼ of its GDP from tourism in 2018. Tourism is also the most important sector on the job market, with approximately 20 % of jobs in the region (DREM, 2019). The main

tourism attractions on the island are the stunning mountains and the agricultural landscapes with the world famous levadas. The most popular touristic activities are outdoor sports practiced in these fascinating landscapes.

The maintenance of the cultural landscapes and its features, like the terraces and the levadas, contributes not only to agriculture itself, but is of supreme importance for the highest remunerating economic sector of the island.

The regional agriculture is also contributing to food security in times of crisis. When a severe crisis, such as a global pandemic, happens, people can support their family income or at least diminish their living expenses by cultivating crops on the terraces they own. Maintained terraces, even if not permanently cultivated, but in a good state of conservation, concerning the terrace walls and irrigation system, can quickly be returned into productive area.

On global level, the present development of decreasing food production security, aggravated by the effects of climate change on crop and animal health as well as on productivity will lead to a reduced overall food production. In sharp contrast to this development of diminishing food resources stands the population development of humans on the globe, which keeps rising further and further. Without doubt, the supply of basic alimentation for the rising population is going to be a challenge for the near and distant future.

The present FAO report on the state of food security and nutrition provides the information that; the number of people affected by hunger in the world continues to increase slowly. This trend started in 2014 and extends to the end of 2019 (FAO, 2020). Projections are that the number of people affected by severe food insecurity continues rising and that the goal of zero hunger in 2030 will not be met. Actually, the opposite is the case; malnutrition and hunger are described as the big challenges for the future (FAO, 2020).

The perspective of rising demand for agricultural produce in order to satisfy the alimentational needs of a still rising world population stands in sharp contrast to the recently observed changes in climatic conditions. Globally, agriculture is facing a rising climatic instability, one important factor is rising temperatures, which brings changes in precipitation regime with it. According to Nelson et al. (2009) especially in developing countries climate change will cause yield declines for the most important crops.

These changes are also very relevant in some of the most productive areas of the world, like the EU, China, USA, India and Russia (Vigani *et al.*, 2015). Since productive land is becoming a scarcer resource, the value of a functioning regional agriculture for Madeiran society should be taken into consideration when discussing the issue of the future of the terraced landscapes on Madeira Island.

The results obtained by this research project show that the traditional agriculture practiced on these terraced slopes is highly sustainable in terms of maintaining soil fertility. The combination of crop rotation practiced for centuries and intercropping contributes to a comparably high yield reliability. The more varied the crops are, the less probable becomes a total loss of harvest by an extreme event. The elaborated and perfectly locally adapted ways of terrace wall and drainage system construction of the investigated terrace systems contribute strongly to slope stability. Therefore, the terraces diminish or prevent the local population and the government from enormous costs that a natural disaster with respective landslides would cause.

For these and the aforementioned reasons, it becomes clear how varied the services of the small-scale agricultural production on the investigated terraced slopes in the Ponta Delgada region are for society's well-being.

Further investigations should be undertaken in order to achieve a deeper understanding of the traditional agricultural practices and their exact services to society within the entire Madeira region. The studies should include an investigation of the different traditional methods applied in agriculture throughout the island and the long-term effects these have had on the respective terrace soils. For comparison of the traditional agricultural practices and agricultural practices that aimed over centuries at profit and not on soil conservation a special focus should be placed on the soils in the central southern part of the island, where monoculture sugar cane production took place. The different climatic zones along the south and the north coast should be analyzed for the type and architecture of terrace systems present, for the type of agricultural management in each zone and for the soil quality of the terrace soil. For such a study, the different altitudinal belts have to be taken into consideration. In addition, the level of sustainability of the agricultural practices should be investigated further. Respectively it is important to investigate the age of the terrace systems

to determine how long soils have been used for crop production and how long the dry-stone walls have resisted to erosive forces.

Such investigations are necessary when it comes to the point of deciding on the value of the terrace systems and the traditional small-scale farming in the Madeira region.

In addition, further research is required on the value society attributes to the landscape and on the value, tourists attribute to it.

The information of these studies can serve as a base for the amount of possible monetary support that should be invested in rural development and farm support programs.

To attract farmers to continue or possibly even restart cultivating the lands of their families, there has to be the opportunity to make a living from the land. Production under the given circumstances of small-scale family agriculture has to be made more economically attractive and thus socially just.

There are interesting programs from the FAO, like the GIAHS¹⁰¹ program to activate local small-scale farming: Within these programs, farmers in the areas accepted in the program, are provided with up-to-date knowledge on practical farming, advisers are employed to support the farmers and they receive support for marketing their produce at a better price than the world market price. This sometimes happens by the creation of a label of origin (FAO, 2019). Madeira Island as a region known and appreciated by people from many countries has a favorable position for developing a market for regional high-quality products as a means of maintaining the regional traditional agriculture with the unique cultural terraced landscape with all its' benefits for society and for maintaining biodiversity at a high level.

¹⁰¹ GIAHS stands for globally important agricultural heritage systems

Appendix

Soil profile	Layer	Clay (0-2 µm) in %	Silt (2-63 µm) in %	Sand (63-2000 µm) in %	Classification FAO-WRB	German Classification, KA5
C_B_1						
	Y4	20.8	77.4	1.8	SiL silt loam	Ut4 stark toniger Schluff
	Y3	16.6	64.3	19.1	SiL silt loam	Uls sandig-lehmiger Schluff
	Y2	10.5	55.9	33.7	SiL silt loam	Uls sandig-lehmiger Schluff
	Y1	9.7	37.2	53.2	SL sandy loam	SI3 mittel lehmiger Sand
	IBv,t	13.1	49.5	37.4	L loam	Slu schluffig-lehmiger Sand
	ICv	9.9	32.4	57.7	SL sandy loam	SI3 mittel lehmiger Sand
C_B_2						
	Y3	29.6	68.3	2.1	SiCL silty clay loam	Tu4 stark schluffiger Ton
	Y2	27.4	70.0	2.7	SiCL silty clay loam	Tu4 stark schluffiger Ton
	Y2HK	21.9	75.8	2.3	SiL silt loam	Ut4 stark toniger Schluff
	Y1	9.5	78.1	12.4	SiL silt loam	Ut2 schwach toniger Schluff
C_B_3						
	Y3	23.1	51.7	25.3	SiL silt loam	Lu schluffiger Lehm
	Y2HK	20.9	48.8	30.7	L loam	Ls2 schwach sandiger Lehm
	Y1b	25.5	51.8	22.7	SiL silt loam	Lu schluffiger Lehm
	Y1a	9.1	35.3	55.7	SL sandy loam	SI3 mittel lehmiger Sand

Soil profile	Layer	Clay (0-2 µm) in %	Silt (2-63 µm) in %	Sand (63-2000 µm) in %	Classification FAO-WRB	German Classification, KA5
L_P_F_1						
	Y5	24.2	71,6	4,2	SiL silt loam	Ut4 stark toniger Schluff
	Y4	14.9	48,2	37,0	L loam	Slu schluffig-lehmiger Sand
	Y3	finger test			SL sandy loam	
	Y2	finger test			SL sandy loam	
	Y1	5.1	38,7	56,2	SL sandy loam	Su3 mittel schluffiger Sand
L_C_1						
	Y5	22.1	74.0	4.0	SiL silt loam	Ut4 stark toniger Schluff
	Y4	47.3	50.0	2.8	SiC silty clay	Tu2 schwach schluffiger Ton
	Y3	9.2	25.2	65.7	SL sandy loam	Sl3 mittel lehmiger Sand
	Y2	5.0	36.1	59.0	SL sandy loam	Su3 mittel schluffiger Sand
	Y1	7.8	57.4	34.8	SiL silt loam	Us sandiger Schluff
Lev_F_1						
	Y1a	15.1	38.8	46.2	L loam	Sl4 stark lehmiger Sand
	Y1b	24.5	68.7	6.8	SiL silt loam	Ut4 stark toniger Schluff
	Y2	23.3	71.9	4.7	SiL silt loam	Ut4 stark toniger Schluff
Albino_M						
	Of	21.9	58.8	19.4	SiL silt loam	Lu schluffiger Lehm
	Ah	22.7	64.5	12.8	SiL silt loam	Lu schluffiger Lehm
	Yx	21.9	58.1	20.0	SiL silt loam	Lu schluffiger Lehm

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List of Interviews conducted during field work:

Ernesto Martins Fernandes	(25.09.2013, 1.10.2013, 2.10.2013, 14.10.2013, 6.04.2014, 9.11.2018)
José Carlos Fernandes dos Santos	(05.10.2013, 22.03.2014, 07.04.2014)
Egídio Fernandes	(2.10.2013)
João Avelino Martins	(26.09.2013, 22.03.2014)
João Diogo Jardim Caldeira de Jesus	(23.03.2014)
Duarte Mendes	(5.10.2013, 22.10.2013, 26.03.2014)
Maria da Terceira Lombada	(5.04.2014)
Sr. Agostinho da Terceira Lombada	(5.04.2014)
Gonçalves, Gil	(19.05.2015)

In addition to these long personal interviews, many farmers willingly shared their knowledge on certain topics of traditional agriculture while working on their fields.

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Herewith, the author of this dissertation (Sandra Kiesow) declares and confirms the following:

1. Apart from the supervisors' guidance, the content and design of the thesis is all the doctoral researcher's own work, only using the sources listed.
2. The thesis has been submitted neither partially nor wholly as part of a doctoral examination procedure to another examining body and has not been published or submitted for publication.
3. The thesis has been prepared subject to the Rules of Good Scientific Practice of the German Research Foundation.
4. No academic degree has ever been withdrawn.

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