# 7 Forest Landscape Evolution in Eritrea Throughout the Last Century—A Review

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**Abstract**

The purpose of this review is to present the changes in the forest landscape in Eritrea over a period of approximately 120 years. Data on Eritrean forest resources with their status, distribution and challenges were gathered and compiled after assessing all available published documents pertinent to forests in Eritrea. The review has identified that a number of earlier Italian botanists played a crucial role in identifying vegetation types of Eritrea and reporting its changes over time. Moreover, referring to the reviewed documents, the present work provides a synthesis of the principal phyto-geographical descriptions of Eritrean vegetation and the historical cumulative environmental drivers that contributed to the degradation of existing Eritrean forests. Very credible reviewed documents also depicted that Eritrean woodland cover has decreased significantly in the past century despite the efforts from the Eritrean government to cover the country, especially the highlands with dense forests. Generally, the output of this review can serve as a basis for further overall and in-depth floristic composition investigation of Eritrean forests. Readers are referred to original articles on Eritrean forests for detailed analytical methods and interpretation of results; all resources used for this review are also duly cited.

**Keywords**

Forest landscape • Environmental history • Bioclimatic zoning • Eritrea

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## 7.1 Introduction

A *National Biodiversity Strategy and Action Plan* (NBSAP) was prepared by Eritrea in 2000. As part of a quinquennial plan (2011–2015) for the *Great Green Wall Initiative* (GGWI), the government of Eritrea developed a *Sustainable Natural Resources Management* (SNRM) plan aimed at increasing vegetation cover by 35% and soil fertility improving by 10% with respect to situation described by the Action Plan of the Ministry of Land, Water and Environment in 2012. The stabilization of soil erosion (gully erosion) was projected through hillside terracing and tree planting on degraded lands. The objective was to cover the land with one million tree seedlings and 20,000 mangrove seedlings to stabilize 400 ha of coastal dunes. Moreover, 1000 ha of marginal lands were afforested with *Acacia seyal* and *Acacia senegal,* considered as profitable trees. Recently, the *Revised National Biodiversity Strategy and Action Plan* (2014–2020) was launched again in line with the *Strategic Plan for Biodiversity* (2011–2020). A complementary aim was also to increase the awareness of the Eritrean people about the value of biodiversity, its conservation and sustainable use. The planners' intention was to halve deforestation or possibly reduce it to zero by 2020 in order to restore at least 15% of the degraded ecosystems. For this purpose, the development of five protected areas, covering a total area of 392,214 ha, was scheduled (MLWE 2012).

The "environmental needs" that have accumulated over the Eritrean territory for years are an indirect consequences of decades of war. The occurrence of impoverished regions in East Africa is both structural and incidental. An historical approach towards understanding the main environmental drivers leading to deforestation and land degradation is proposed in the present chapter. The prevailing vegetation cover existing in the past is known from data collected particularly during the Italian colonial period (1882–1941). Moreover, changes over time up to the recent years are documented. Additional data were produced across a 120-



P. Billi (ed.), *Landscapes and Landforms of the Horn of Africa*, World Geomorphological Landscapes,
https://doi.org/10.1007/978-3-031-05487-7_7

year interval by the former Istituto Agronomico per l'Oltremare (IAO) (Overseas Agronomic Institute) of Firenze in Italy within its institutional monitoring activities. The documents of the IAO, archives including articles, monographs, maps and photos, provided a unique set of information that was used to describe the forest landscape changes in Eritrea over the last century. It is worth noticing that the current dramatic environmental constraints have been recurrent in the recent past. Cycles of deforestation and reforestation have characterized the forest history in Eritrea in response to changing and contrasting socio-economic interests.

## 7.2 Geobotanical Features of Eritrea: An Overview

Eritrea has a surface area of 117,600 $km^2$ (World Bank Data 2022). It is located in the northern part of the Horn of Africa, between 12°22′ and 18°02′ N latitude and 36°26′ and 43° 13′ E longitude. Its extension includes various islands and a coastline spanning some 1900 km (MLWE 2012). The country shares borders with Sudan to the north and west, Ethiopia to the south, Djibouti to the south-east and the Red Sea to the east, respectively. In Eritrea, there are approximately 390 islands, among which the Dahlak Archipelago is the most prominent (MLWE 2014). The country is divided into six administrative regions, namely Maekel, Debub, Anseba, Gash-Barka, Northern Red Sea and Southern Red Sea (MLWE 2012).

The country exhibits a varied topography and climate, with elevations ranging from 120 m below sea level to over 3000 m asl (Ghebrezgabher et al. 2016). Mean annual temperature ranges from 15 °C in the moist and arid highlands to 32 °C in the desert areas. Annual precipitation varies from less than 200 mm in the deserts to 1100 mm in the subhumid areas in the south-eastern part of the country. The rainfall pattern is extremely variable, both within and between years, and with marked variations over very short distances. The south-west monsoon winds are responsible for both the major and minor summer rains, whereas the northern and north-eastern continental air streams are responsible for winter rains along the coast and in the southern part of the central highland escarpments (MLWE 2014). The northern and north-eastern winds are dry in nature, but acquire moisture while crossing the Red Sea.

### 7.2.1 Botanical Explorations in Eritrea

Before the colonial era, there was very scarce information on the classification of forests and other types of vegetation. Various Italian botanists played a crucial role in identifying vegetation and reporting its changes over time.

A systematic field survey of both woodlands and woody plants of Eritrea was carried out in 1909 by the Italian botanist, Adriano Fiori. The work of this author made partial reference to the initial observations of Georg August Schweinfurth (1901), regarding useful plants from Eritrea. Fiori provided the description of vegetation of Eritrea, designating eight vegetation zones (Maritime, Lowlands, Inland Danakil, Wooded Areas on the Eastern Slopes, Marginal Areas of the Highlands, Main Highlands, Valley Areas of Western Slope Zones and the Sudanese Plain Zone). These eight vegetation zones corresponded to eight climatic zones that were classified on the basis of average annual temperature, daily thermal variation, relative humidity and atmospheric precipitation. Today, this classification scheme is considered as an *ante litteram* bioclimatic classification because the vegetation cover and the edaphic properties influence the climatic zoning. Fiori defined the zones on the basis of the different vegetal landscapes he encountered during his journey in Eritrea in January–April 1909. This author also included a particular zone, classified as the Sudanese Plain Zone, which was in turn subdivided into three further zones and five sub-zones based on the traditional Abyssinian land use. The additional three zones included the *Quolla* zone (0–1700 m a.s.l), situated on the western side of the Eritrean Abyssinian Plateau, the *Woina-Degà* zone (1700–2400 m a.s.l), characterized by a Mediterranean climate, and the *Degà* zone (2400–3700 m a.s.l) (Fiori 1937). In the first version of this classification, Fiori included an additional zone named the Samhar and Sudanese lowland zone ranging from 0 to 600 m a.s.l. In turn, this zone was subdivided into four subzones. The *Quolla* zone was the richest in terms of flora, with 311 botanical species and twenty endemisms (Fiori 1912). Along an increasing altitudinal range, the *Woina-Degà* zone vegetal landscape was characterized by the following key species: *Olea europaea* subsp. *cuspidata* (former *Olea chrysophylla* or wild olive*), Acacia etbaica*,*Acacia abyssinica* and *Juniperus procera,* dominant between 2200 and 3000 m a.s.l (Fiori 1937), which also included a part of the *Degà* zone. According to Fiori (1912), on the top of the Eritrean Mountains, only a few wooded species were present. In general, in all of the above-mentioned bioclimatic zones, evergreen species with persistent leaves were reported to prevail. They included 60, 53 and 61 species in the *Quolla* zone, *Quolla-Woina-Degà* intermediate zones and *Woina-Degà* zone, respectively (Fiori 1912).

Fiori identified a total of 430 wooded species (including suffrutices and succulents with woody stems) belonging to 76 botanical families and 226 genera. He was essentially focussed on the causes of deforestation and on government measures for the protection of woodlands in the Eritrean Colony. He was concerned with providing a solution to rebuild forests, arboreta and homestead tree plantings (Fiori 1912).

By contrast, the objective of the Italian agronomist Baldrati (1907) was to provide ecological classification of the Eritrean territory, with the purpose of extending coffee plantations. On the basis of rainfall data and temperature gradient (about 0.7 °C per 100 m of altitude), Baldrati identified seven floristic and climatic-agricultural zones or regions, i.e. Coastal Region, Eastern Lowland, Eastern Escarpment, Main Highland, Western Escarpment, Western Lowland and Danakil Region (Baldrati 1928). This classification scheme was used by Nastasi (1993) for a synthetic research on floristic and climatic areas in Eritrea (Table 7.1).

For Fiori and Baldrati, Eritrea represented a transitional region among Abyssinia, Sudan and Arabia, as regards both climatic and vegetal aspects. However, they did not provide quantitative data on the actual extension of the vegetal zones. Another Italian botanist, Negri (1940), further elaborated on an existing phyto-geographical map of the Horn of Africa (Eritrea, Ethiopia and Somalia). Previous authors, such as Schweinfurth (1868), Dove (1890), who mapped the northern part of Abyssinia and Ethiopia, were all cited by Negri (1940). The main classification scheme developed by Negri (1940) consisted of vegetation units defined on the basis of their physiognomy, which represents “a characteristic reaction of the vegetal life to the environmental condition”. Even if the forest landscapes proposed by Negri (1940) were not exclusive for the Eritrean territory, they nonetheless represent a valid general description.

Another, more comprehensive vegetation map was produced about twenty years later by the Italian botanist, Pichi-Sermolli (1957), who described the vegetation landscape of the Horn of Africa (including Eritrea, Ethiopia and Somalia). Through an analysis of the photos archived in the former IAO, he adopted a physiognomy criterion to describe the vegetation cover. Moreover, he studied more than 900 papers published by the first explorers, travel and technical reports and unpublished official documents dealing with East Africa. Regarding this work, Friis et al. (2011) were quoted as saying. “In spite of Pichi-Sermolli’s decision to map the vegetation as it appeared at the time of the mapping, this author did not indicate the widespread and extensively cultivated areas in the highlands, but classified farmlands by the surrounding vegetation, a highly man-imposed landscape”. This is a valid assumption for the Eritrean territory as a whole, because human impact (agriculture and pasture) remains embodied in the vegetal landscape. This characteristic was observed and documented by all the above-mentioned naturalist explorers. Pichi-Sermolli produced a vegetation map (1:5,000,000) without providing corresponding vegetation types in the English language (a translation of the original Italian denomination was recently compiled by Friis et al. 2011). In total, Pichi-Sermolli included twenty-four vegetation types. Pichi-Sermolli reported that in “aiming at listing the various types of vegetation, I took into consideration first the climatic formations and then if they are typical and edaphic”. With these last words, he explained synthetically how the vegetation formations were grouped.

According to Fiori (1912), the geographic characteristics would provide Eritrea with the capacity to potentially sustain a full forest cover. In the past, the natural rate of forest regeneration was maintained below the rate of deforestation. This is attributed to a predatory farming system whereby extensive land use was increased around the villages. Fiori (1912) reported that “The herbaceous plants are devoured

**Table 7.1** Comparison between the bioclimatic zones of Fiori (1912) and Baldrati (1928) and Nastasi (1993)

| Fiori’s (1912) bioclimatic zones | Agro-climatic classification of Baldrati (1928), Nastasi (1993) | Main tree and small tree species |
|---|---|---|
| Maritime Zone | Coastal Region | *Avicennia* spp.<br>*Commiphora* spp. |
| Eritrean Lowland | Eastern Lowland Region | *Acacia orfota; Acacia spirocarpa; Acacia mellifera; Dobera glabra; Salvadora persica; Balanites aegyptica; Tamarix nilotica; Cassia angustifolia* Vahl |
| Inland Danakil | Danakil Region | *Acacia spirocarpa; Acacia orfota; Hyphaene dankaliensis; Avicennia* spp. |
| Wooded Areas on Eastern Slopes | Eastern Escarpment Region | *Acacia* spp.; *Ficus* spp.; *Combretum* spp. *Loefl; Teclea nobilis; Trichialia emetica; Mimusops kummel; Stereospermum kunthianum; Celtis kraussiana; Juniperus procera* |
| Marginal Highland | Main Highland Region | *Ficus vasta; Ficus palmat; Ficus* spp.; *Acacia albida; Acacia abyssinica; Acacia spirocarpa; Croton macrostachys; Erica arborea; Cordia abyssinica; Eucalyptus* spp.; |
| Main Highland | | |
| Valley and Western Slope Zone | Western Escarpment Region | *Acacia* spp.; *Adansonia digitata; Erytrina abyssinica; Bauhinia reticulata; Ximenia americana; Ficus sycomorus; Tamarindus indica* |
| Sudanese Plain | Western Lowland Region | *Acacia seyal; Acacia Senegal; Balanites aegyptica* |

before seed production; trees and shrubs are bowed and twisted, whereas rain waters wash away the organic matter, thereby sterilizing the soil. […] When the herbaceous vegetation is arid and exhausted, the shepherds cut down the young trees, especially Acacia species, feeding livestock with the tender leaves and branches".

### 7.2.2 Geobotanical Studies and Maps

In Fig. 7.1, a vegetation transect starting from Massawa at the Red Sea level, on the east side, to the Sudanese Plains (1000 m asl) on the west side is shown (Abul-Haggag 1961). Similarly to Fiori (1912) (Table 7.1), eight main vegetation types are recognized. The Samhar and Sudanese Plains (lowlands) are situated on the eastern and western sides of the highlands, respectively. The eastern slope ranging from 1000 up to 2350 m asl (Asmara) is characterized by deciduous, non-thorny woods and, then, by thorny bushes and acacias, euphorbias and evergreen woods with olive trees and dense underground at the highest altitude. On the less inclined western slopes, there is a vegetation gradient characterized by euphorbia, thorny woods and steppes, acacias and sycamores. Baobab trees (*Adansonia digitata*) and doum palms (*Hyphaene nodularia*) are found in the valleys. On the plateau, there are instead thickets of the highly deforested surface with rare occurrence of junipers and olive trees.

In Fig. 7.2, a map of the forest cover of the Eritrean territory is shown. This map was elaborated in 1998 by the FAO National Food Information System (NFIS) (1998) for Eritrea. In this map, part of the Central Highland Zone—Northern Midland subzone with the North-Western Zone are dominated by Grassland, Wooded Grassland, Bushland and Shrubland. The Coastal Plain Zone is represented by areas of barren soil, Bushland and Shrubland, Grassland and Wooded Grassland. In the Green Belt Zone only in part Closed and Medium Closed Forest are present. The most densely forested area in Eritrea, commonly referred to as the green belt, is found between Asmara and Ghinda and extends to the north as far as Merara on the Eastern Escarpment, about 43 km north of Asmara (MEM 2004) (Fig. 7.3). The map of the woody areas of Eritrea was prepared by Di Gregorio and Weepener in 2002 (Di Gregorio and Weepener 2002), and it is a thematic map of the FAO Land Cover Map of Eritrea. In the years 2000–2001, the IAO produced a land cover map of Eritrea at 1:100,000 scale, based on photointerpretation of Landsat satellite images (Sarfatti 2005), within an agreement with FAO regarding the AFRICOVER project. In this map, the vegetation classes are a generalization of the original 62 *Africover* classes for Eritrea and the vegetation is classified into: Closed Trees, consisting of both evergreen broadleaved and needle leaved trees, Open Trees, Closed Woody Vegetation distributed in thickets, Areas with Sparse Trees, Open and Closed Shrubs and Closed Mangrove.

Bein et al. (1996) classified the Eritrean territory into six agro-climatic zones: (1) the Coastal Plains; (2) the Eastern Escarpment; (3) the Central Highlands; (4) the Western Escarpment; (5) the South-Western Lowlands and (6) the North-Western Lowlands (Fig. 7.4). These zones are mainly based on the FAO (1994) document on Eritrea. Bein et al. (1996) were quoted saying "This zone (The Eastern Escarpment) is a unique area where annual rainfall exceeds 1000 mm. It encompasses numerous micro-ecological zones determined by the interrelationship of altitude, rainfall, exposure and soils […]. The relief is steep and requires terracing for successful farming". This zone also includes the so-called green belt because of vast annual and permanent tree crops, such as coffee, and part of the 53,000 ha of

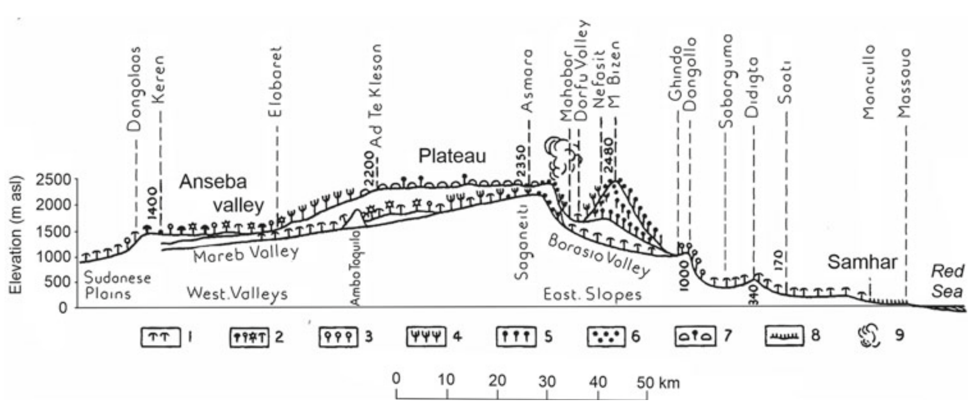


**Fig. 7.1** A latitudinal west–east vegetation transect of Eritrea. The altitudes range from below sea level (Red Sea) up to 2480 m asl of Mount Bize. The vegetation units are represented by the following types: (1) thorny bushes and acacias, and doum palm; (2) thorny wood and steppe with acacias, sycamores and baobabs in the west (Anseba Valley); (3) deciduous, non-thorny woods; (4) euphorbias, acacias and other trees species; (5) evergreen woods and wild olive trees; (6) mist bushes and mist-trees in the eastern slopes, especially junipers; (7) thickets of highly deforested summit surface of the plateau; and (8) semi-desert of the coastal zone (Samhar), western limit of winter mists and mist vegetation (modified from Abul-Haggag 1961)

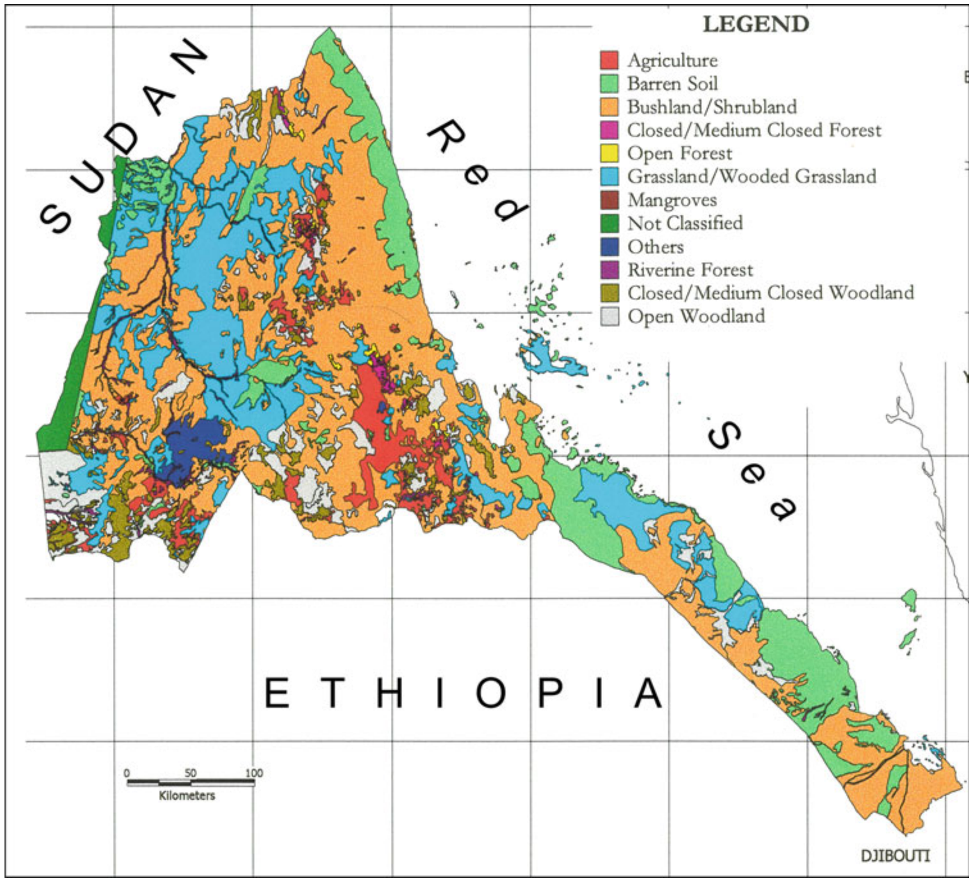


**Fig. 7.2** Forest cover of Eritrea. Modified from FAO-NFIS (1998) Map 1:4,000,000 (Archive of the former Istituto Agronomico per l'Oltremare 1998)

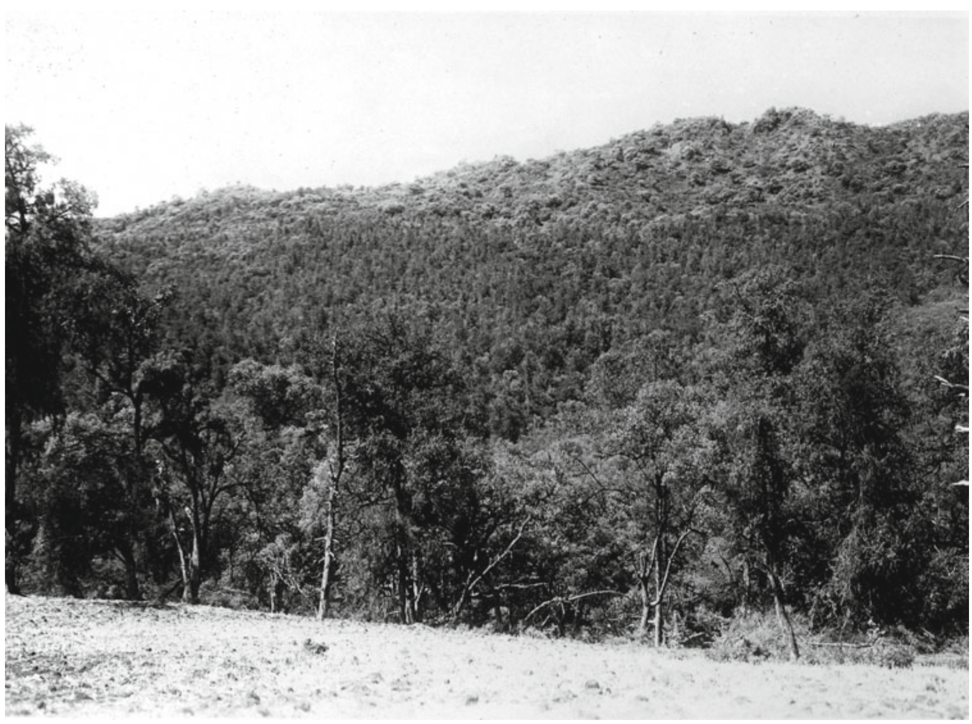

**Fig. 7.3** A forest area in Merara, on the Eastern Escarpment, about 43 km north of Asmara (Photographic Archive of the former Istituto Agronomico per l'Oltremare 1928)

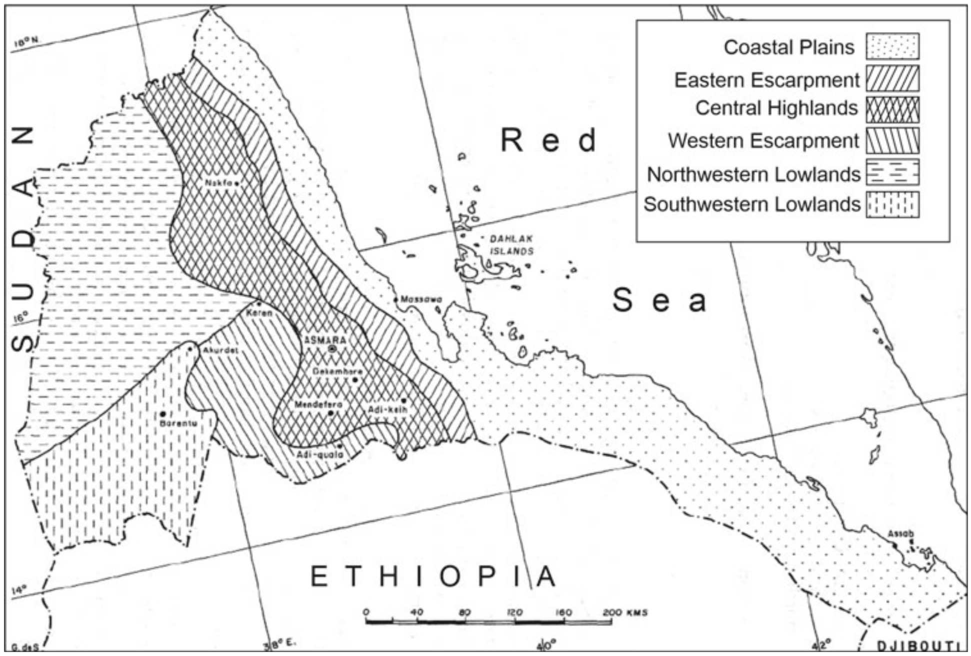


**Fig. 7.4** Main agro-climatic zones of Eritrea (modified from Bein et al. 1996)

coniferous forest that once covered a large proportion of the highlands (Bein et al. 1996).

The Coastal Plain zone records less than 200 mm of annual precipitation, and, similarly to the highlands, the annual evapotranspiration may exceed 1800–2000 mm. The Coastal Plain zone is characterized by agro-pastoralism as the most important type of farming system. Agro-pastoralism practices include the seasonal nomadic movements towards the uplands (in mid-April) and the return to the wadis (lowland ephemeral streams) (in mid-September). In the Highlands, rainfed cereal/pulse-based farming systems and irrigated horticultural systems prevail. According to Bein et al. (1996) "The Western Escarpment lies at an altitude of 600–1500 m asl and has a warm-to-hot semi-arid climate. It is a transition zone between the highlands and the western lowlands […]. The dominant production system is agro-pastoralism". The South-Western Lowlands, at an altitude of 600–750 m a.s.l., are generally flat, with hot semi-arid conditions, and an annual rainfall of 400–600 mm. In this region, the farming systems include nomadic pastoralism, semi-sedentary agro-pastoralism, mixed crop and livestock production. The North-Western Lowlands lie between 400 and 1500 m asl, and the climate is hot and arid, with an average annual rainfall of 300 mm. Evapotranspiration is between 1500 and 2000 mm. The principal type of farming system is nomadic pastoralism, very similar to the one practised in the South-Western Lowlands (Bein et al. 1996).

For comparative purposes, the FAO National Food Information System (NFIS) (1998) map of the agro-ecological zones of Eritrea is reported in Fig. 7.5. This classification is more detailed and includes eight zones. The Central Highland Zone was subsequently split into two sub-zones: the Northern Midland and the Southern Midland, which are less elevated (1500–2000 m asl) than the main Central Highland Zone (over 2000 m asl). These two sub-zones are distinguished by differences in rainfall, as the Northern Midland receives an annual precipitation of about 700 mm, whereas the Southern Midland is essentially arid, with less than 400 mm. In Fig. 7.5, the Green Belt Zone, localized in between the Central Highland Zone and the Coastal Plain Zone, is evident.

Eritrea is also rich in flora. In the Central Highlands, the most widespread tree species in the scattered forest patches include *Juniperus procera* and *Olea europaea* subsp. *cuspidata* community mixed with deciduous trees like *Acacia abyssinica*, *Rhus abyssinica*, *Carissa spinarum, Terminalia brownii, Mimusops kummel* and *Combretum molle*. According to Bartolommei Gioli (1903), the flora found between 900 and 2000 m asl along the Eastern Escarpment was characterized by *Olea europaea* subsp. *cuspidata* (former *Olea crysophylla*). After first attempts in 1892, in 1908 some trees of *Olea europaea* were imported from Central Italy (Pescia) and introduced to Addiché, a few kilometres to the south-west of Asmara. The acclimatization of these trees failed because of the strong winds and felling activities by the local people (Pajella 1934). In 1919, in Adi Caieh, a town located 80 km to the south-east of Asmara, olive trees imported from Sicily (Catania) were planted (Pajella 1947). Once again, this endeavour resulted in failure due to incorrect selection of planting sites, traditional land tenure regulations, lack of knowledge on the biology of *Olea europaea* subsp. *cuspidata* (former *Olea crysophylla*) and a lack of

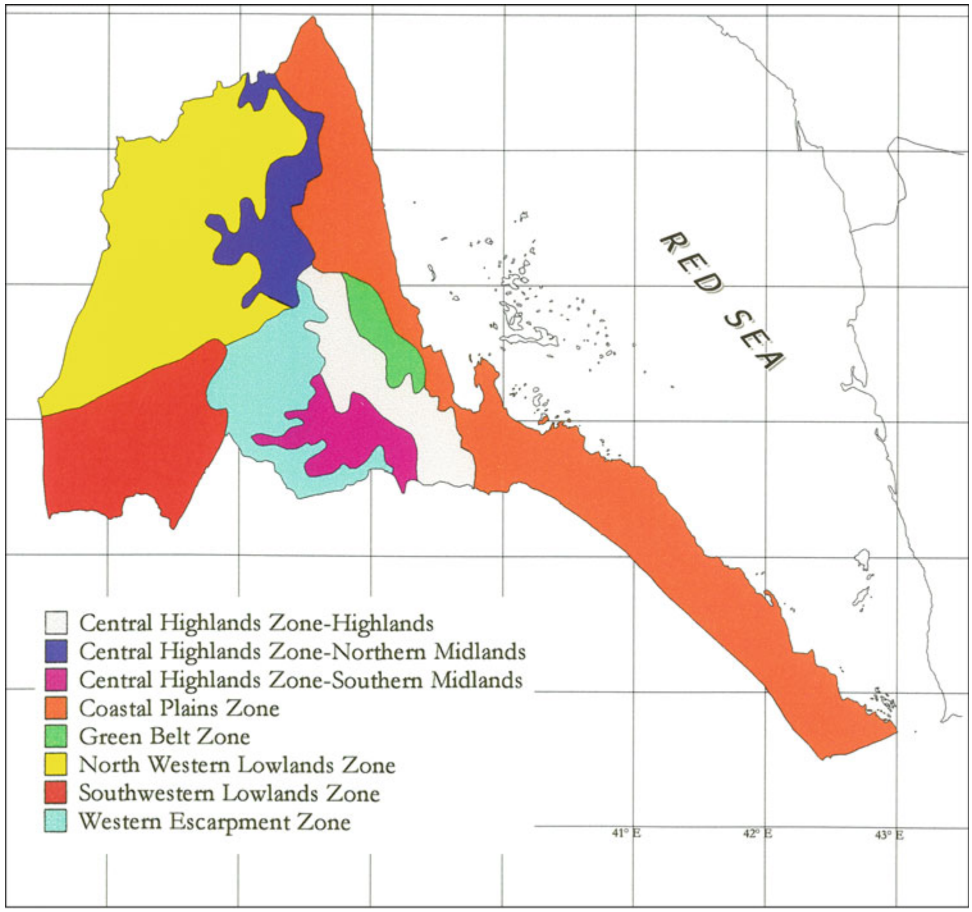


**Fig. 7.5** Main agro-ecological zones of Eritrea. Modified from FAO-NFIS Map 1:4,000,000 (Archive of the former Istituto Agronomico per l'Oltremare 1998)

cultivation skills of the local farmers (Pajella 1947). In Fig. 7.6, a rocky slope in Anagulè (a few kilometres north of Asmara) with wild olive trees is portrayed. Towards the edge of the Eastern Escarpment, however, groves of olive and juniper are found, which tend to be particularly abundant in areas with higher rainfall. Trees are often grown in household compounds, while many villages also have small plantations of eucalyptus. Larger plantations of eucalyptus still exist on lands once occupied by former Italian concessionaires and in the vicinity of towns, where they were originally planted by the Italian colonial government (Boerma 2005b). Figure 7.7 shows a village surrounded by a plantation of eucalyptus trees.

### 7.2.3 The Mangrove Formations

The vegetation of the Coastal Plains is diverse. It includes swamps along the seasonal rivers, acacia woodlands, semi-desert acacia woodlands, bushland and thickets, desert scrubs and mangrove swamps (Haile et al. 1998). Along the Eritrean Red Sea coast, three mangrove species prevail, namely *Avicennia marina* (Forsk.) Vierh., *Rhizophora mucronata* Poir. and *Ceriops tagal*. The first two species are indigenous and concentrated along the muddy coasts, whereas the third one is limited to the northern coast with a few sparse individuals. In 1994, the mangrove forest covered an area of approximately 8900 ha, which declined by 7.7% in 2014 (Hailemichael 2015). Large continuous mangroves are also found in the Asseb Bay. The major threats to the mangroves are represented by water quality deterioration, rapid and short floods, land-filling for development and changes in coastal dynamics. High sedimentation rates, as observed in Zula, tree felling, dying mangrove trees and the increasing frequency of droughts are noticeable threats along Eritrea's coast. Grazed or cut mangrove forest is characterized by short, dwarf stunted trees and scattered old mangrove (Hailemichael 2015). Natural mortalities are caused by sediment movement, cut-off of fresh water flow due to sand deposition or bank erosion or dieback diseases (Hailemichael 2015).

**Fig. 7.6** Wild olive trees in Anagulè, a few kilometres north of Asmara. Photo by Maugini 1933 (Photographic Archive of the former Istituto Agronomico per l'Oltremare)

**Fig. 7.7** Village protected by a eucalyptus plantation (photo by Billi 2011)

Tree felling, severe grazing of camels, sheep, goats and donkey and the impact of large settlements are additional degradation factors. Recently, pollution was observed to affect the mangrove areas in the form of polythene bags and bottles, plastic and metal can waste, which are disposed in small quantities by the coastal towns and villages. This may have a serious physical impact by covering the young seedlings and pneumatophores, blocking the tidal channels and causing disturbance to the mangrove associated fauna. Oil pollution is due to a few oil spills from shipping routes and commercial fishing activities, especially in the area of Massawa (MLWE 2014).

In 2003, a mangrove plantation was conducted by the Manzanar Project situated on an area near the port of Massawa. Around 700,000 mangrove seedlings, chiefly *Avicennia marina*, were grown on the treeless mud flats (Sato et al.

2005). Since Eritrea's coast is characterized by gradually sloping beaches, shallow bays and low-energy waves, mangrove forests could be established on at least 10,000 ha of the intertidal zone. It has been proposed to plant 10 million trees in this area to ensure thick canopies at maturity. Since the tidal zone extends inland for about 500 m, the forests could eventually cover 50,000 ha. Harvesting these trees for lumber in a sustainable way would bring annual revenues of US$200 million and significantly boost the Eritrean economy (Opec Fund Newsletters 2003).

## 7.3 Forest Cover and Soil Erosion

Unfortunately, little information exists on the Eritrean landscape before the Italian colonization in 1890. Available information suggests that forest resources were already scarce before the Italian colonization (Boerma 2005b). While the vegetation of the Eastern Escarpment of the Central Highlands was rather rich, richer than today, the plateau hosted very little woodlands of any kind (Boerma 2005b). In 1941, Eritrea went under the stewardship of the British Military Administration (BMA) and the British, like the Italians, were greatly concerned about paucity of wood resources in the country. In an initial estimate of tree cover in 1945, it was calculated that roughly 5% of the entire country was wooded. However, this estimate was revised two years later, after a more comprehensive survey, which indicated that 10% of the three Central Highland provinces included wooded areas (Boerma 2005b). This estimate was similar to that inferred by Fiori in 1912. On the base of archival material, oral testimonies and photos, it was possible to confirm that, in the past, woodlands and forests covered not more than 7.5% of Eritrea land (7575 km$^2$). In the 1970s, approximately 2966 km$^2$ of Eritrea was covered by forests. This area declined to 1401 km$^2$ in 2014 (Ghebrezgabher et al. 2016). Over a period of 44 years, Eritrea lost approximately 1565 km$^2$ of forestland, thereby attaining a maximum rate of deforestation during the 1980–2014 period, with an annual rate of 28.30 km$^2$ per year (Ghebrezgabher et al. 2016). This phenomenon may appear recent, but, on the contrary, it is the result of very ancient exploitation of forested lands. The United Nations Food and Agriculture Organization (FAO 1997) reported that the total forest area including woodland forests was approximately 15,276 km$^2$. In 2014, the forest and the woodland were 15,078 km$^2$ (Ghebrezgabher et al. 2016). These data highlight an important contradiction between the documental evidence, which indicates that already by the first decade of the twentieth century forests were scarce and limited to the Eastern Escarpment and some valleys, and the population belief that in the recent past large forests existed. This convincement is also fostered by the Eritrean government which, in the National Environmental Management Plan of 1995, states that at the beginning of the twentieth century 30% of Eritrea was covered with forests, but then this percentage was reduced to the 1% of today (Boerma 2005b). Nyssen et al. (2004) confirmed that there is no evidence of a supposed 30–40% of forest cover in Eritrea in 1900. Instead, the relationship between deforestation and erosion remains a valid assumption.

In 1995, a team of agronomists and pedologists of the former IAO carried out a phyto-sociological survey in the upper Mareb river basin, located 20 km south of Asmara and with a catchment area of 535 km$^2$ (15°00′ and 15°15′ N–38°40′ and 38°55′ E). The upper Mareb basin, upstream of the town of Debarwa, is located in the southern region, administrative subzone of Debarwa. The drainage area is about 200 km$^2$ with elevation varying between 2550 and 1905 m asl (Gehbrehiwot et al. 2019). The main aim of this work was to evaluate the possibility of estimating the *Acacia etbanica* woody biomass available as fuel wood. The calculated productivity of this tree species (0.2 m$^3$/ha/year of wood) could sustain 10,000 people (Viti et al. 2001).

When comparing the estimates of the Agricultural Ministry of Eritrea for 48,000 people living in the area, a marked disequilibrium between offer and demand emerged (Viti et al. 2001). About 70% of the basin is cultivated, while the remaining part is used for extensive grazing (Colombo and Sarfatti 2001). These data are confirmed by the historical map of the Mareb basin (Fig. 7.8).

Two sub-catchments of the same upper Mareb river basin (the Shiketi, located at 15°10′ N and 38°51′ E, and the Emni Tselim, located at 15°02′ N and 38°44′ E l) were selected in order to calculate the rates of soil erosion by the Universal Soil Loss Equation (Colombo et al. 2001). The area of the Shiketi sub-basin is 585 ha, and denudation processes are very active, with hill slopes affected by mass movements, gully and ravine erosion. The lateritic formation gives rise to structural terraces due to differential erosion which uncovers the surface of the old buried peneplain. This flat surface represents the local base level for the deposition of colluvial sediments and talus slope coming from the weathering of above-lying volcanic rocks. The valley bottom is covered by ancient alluvial sediments and by recent colluvial and fan debris (Colombo et al. 2001). The Emni Tselim sub-basin is 1172 ha. Here, volcanic rock outcrops prevail and slope erosion processes produce large accumulation landforms (glacis) that are periodically eroded by deep, linear gullies and progressively destroyed by lateral fluvial erosion. In the Tselim plain, portions of ancient terraces, buried by a colluvial layer variable in depth, are also found (Colombo et al. 2001). This layer is also eroded, and screen deposits accumulate at the footslopes.

The rates of soil erosion are controlled by three principle factors: geomorphological setting, soil type and land use.


**Fig. 7.8** The Mareb basin in an Italian historical map 1:550,000. Cultivated areas in dark green, non-cultivated areas in light green and no-cultivable areas in ochre colour (Checchi et al. 1907) (Photographic Archive of the former Istituto Agronomico per l'Oltremare)

The geomorphological units include alluvial plains, alluvial terraces, recent upper and lower accumulation glacis, plateaus with sheet flood cover, concave-shaped valleys, a volcanic fault escarpment, residual volcanic hills, volcanic structural terraces and recent lower buried glacis. The FAO soil types are eutric cambisol, eutric vertisol, ass. eutric fluvisol–calcaric cambisol–regosol, ass. eutric vertisol–eutric cambisol, gleyic cambisol, ass. eutric leptosol–eutric regosol and ass. eutric regosol–eutric cambisol. In the same river basin, Micconi (1998a, b) classified six land units: seepage slope (Unit 2), convex creep slope (Unit 3), fall face (Unit 4), transportation mild slope (Unit 5), colluvial footslope (Unit 6) and alluvial toeslope (Unit 7) (Fig. 7.9). Land use consists of controlled grazing, no grazing, improved agricultural techniques and degraded land.

In both sub-basins, the largest soil loss, calculated with the USLE, was found to occur in degraded lands with 255 and 129 t $ha^{-1}$ $yr^{-1}$ in the Shiketi and the Emni Tselim, respectively. In the degraded land of the Shiketi, conservation practices such as terracing of hillslopes underlain by volcanic deposits and cultivated colluvial deposits could lead to a 1/3 reduction of erosion and to a 50% reduction for the whole basin (Colombo et al. 2001). Soil loss resulted to be lower in non-grazing land than in controlled grazing areas, 60 and 15% less in the Shikeli and Emni Tselim, respectively. A SCS-CN method was also applied to the two sub-basins to calculate the annual runoff which resulted in 95 mm $yr^{-1}$in the Shikeli and 84 mm $yr^{-1}$ in the Emni Tselim. In Eritrea, it is estimated that 35–70$\times 10^6$ t of fertile soil is eroded annually from an area of 2240,000 ha (MLWE 2012). Figure 7.10 shows the soil map of Eritrea and indicates the prevalence of leptosols (FAO-UNESCO soil classification1998) in the Central Highlands.

Yet in 1995, a more specific research on gully erosion was carried out in Halhale Experimental Station of the Eritrean Ministry of Agriculture, near Debarwa. This study was carried out in a small (about 260 ha) sub-basin of the upper Mareb river, ranging in elevation between 1910 and 2020 m asl (Rodolfi et al. 1998). The entire Halhale watershed is included in the region defined as "basaltic plateau" by Abul-Haggag (1961). The study site was subdivided in four land units (Table 7.2).

This study pointed out susceptibility to gully erosion by applying De Ploey's Es Model (Rodolfi et al. 1998). The

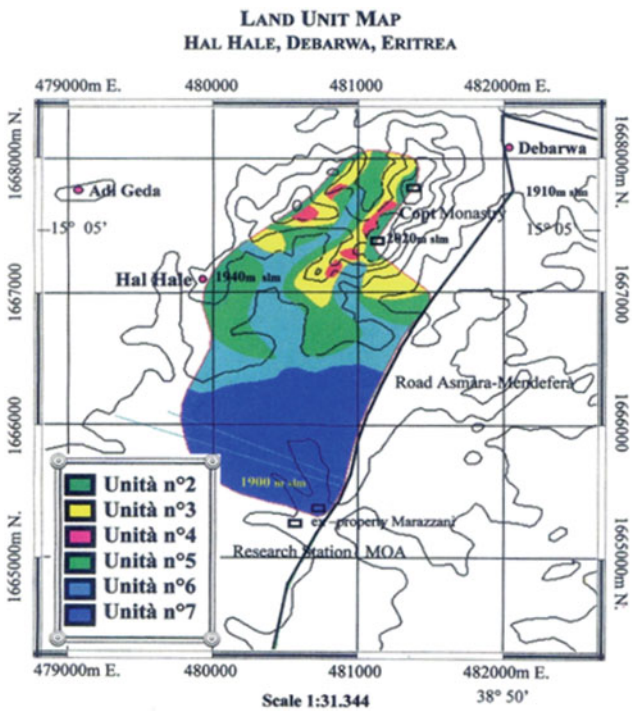


**Fig. 7.9** Land Unit Map in the upper Mareb river basin in the area between Debarwa and Halhale localities. In this map is also indicated as an important site the Coptic Monastery Modified from Micconi (1998a, b)

amount of eroded soil volumes during the great rainy season of 1995 (260.2 mm rainfall) was calculated for two gullies (G1 with a drainage area of 145,854 $m^2$ and G2 with a drainage area of 157,018 $m^2$) as 42.05 $m^3$ (G1) and 13.61 $m^3$ (G2). This level of susceptibility is worrying. The highest values of soil loss are reached at the beginning of the rainy season, while they tend to decrease with the progress of the rainy season. This is probably due to the increase in the protective effect of vegetation cover, as it keeps on growing during the rainy season. Careful observations of the two representative gullies allowed one to obtain objective, though approximate, information regarding the magnitude of soil and gully erosion within a very short time interval (Rodolfi et al. 1998). Figures 7.11 and 7.12 show two typical aspects of Eritrean landscape linked to water erosion.

## 7.4 Discussion

### 7.4.1 The Consequences of Colonialism on the Forest Land

Although during the Italian colonial period much work was made on the classification of vegetation, ironically, this period posed a threat to the forests. The main threats were

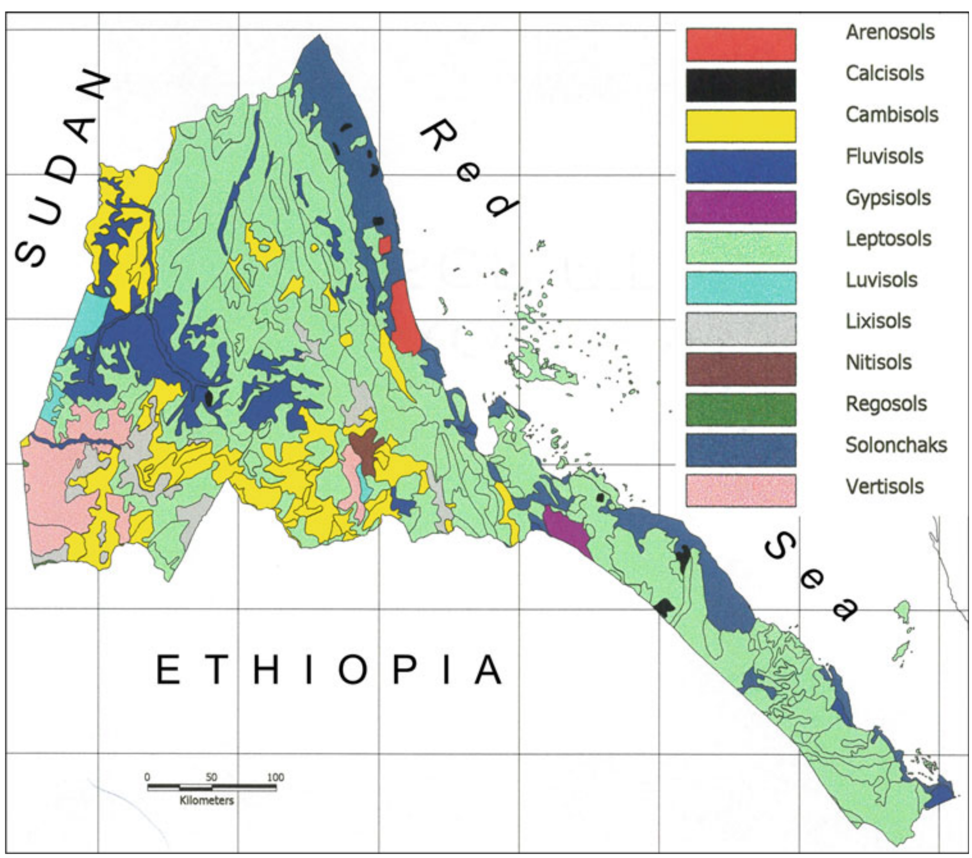


**Fig. 7.10** Soil map of Eritrea 1:4,000,000 based on the FAO-UNESCO soil classification (Photographic Archive of the former Istituto Agronomico per l'Oltremare Archive 1998)

**Table 7.2** The Land Unit subdivision in the Halhale experimental catchment (modified from Rodolfi et al. 1998)

| Land unit | Soil type (FAO-UNESCO) | (ha) | Main description |
|---|---|---|---|
| Convex interfluves | Rock outcrops | 70.1 | Vegetation cover is an open shrub, dominated by *Acacia etbaica*. This unit is considered as "marginal land" by the local communities (villages) and utilized as common grassland and for wood collection. Vegetation cover never exceeds 60%, even during the rainy season; water erosion has no obstacle at all |
| Seepage and creep slopes | Mollic-eutric leptosols | 125.5 | |
| Transportational midslope | Mollic-eutric leptosols, eutric cambisols | 62.5 | Utilization pressure is heavier, and this causes clear erosional features: many rills and sporadic but deeper channels (gullies) can be observed near clear effects of sheet erosion |
| Colluvial footslope | Eutric vertisols | 25.6 | Soils can present drainage problems and a high shrink coefficient; however, they are deep and fertile. The main land utilization type is the cultivation of cereals and other annual rainfed crops. In some places, cultivation is hindered because of the development of deep gullies |
| Alluvial toeslope | Fluvic-eutric cambisols | 38.8 | These areas can become prone to sheet erosion hazards, where cultivation is extensive and mechanized: the use of a disc plough can lead to the crushing of the soil structure and the formation of surface crusts during successive rains, so that the erosion hazard is increased. Along the riverbanks, basal undercutting can be very active, especially where banks exceed 3 m in height |

**Fig. 7.11** Eritrean landscape: contour bounds on bare slopes (photo by Rodolfi 1995)

economic, through the expansion of coffee plantations, and the resultant impact on the local population that, in turn, threatened the forests. The main causes of deforestation included traditional and colonial agricultural practices, overgrazing and tree felling for new pastures, the use of trees for firewood, house construction (the traditional Abyssinian *hedmò)* and railway construction (Massawa-Biscia in 1930s). Senni (1915) reported that in 1905 the livestock carrying capacity of Eritrean pastureland was 0.03 big head per hectare and, as a whole, the animal population amounted to 1,063,665 heads, the larger part of which was represented by goats and sheep (69.2%). Furthermore, an important

**Fig. 7.12** Eritrean landscape: typical gully erosion within a flat plain (photo by Rodolfi 1995)

factor contributing to the loss of forested land was the use of wood for military purposes in the form of mobile garrisons. According to Senni (1915), during the 1898–1901 interval, a company of indigenous soldiers consumed about 14,000 trunks of acacia species and about 38,000 poles of junipers and other tree species for the construction of traditional dwellings. The industrial activity consumed more than 1800 $m^3$ of firewood per year. Vegetation was destroyed in periods of both war and peace, with demographic growth as the principal reason for deforestation. Yet, the colonial government favoured deforestation for agricultural settlements by the concessional land system. In 1933, comprehensive legislation was introduced, which laid down which type of wood could be cut by the Italian and native population, respectively, in which areas and under which circumstances, and specified the conditions of allocation of concessions (Lätt 2004). Fifty years of Italian colonial dominion in Eritrea resulted in the systematic degradation of its forest assets. In this regard, it is interesting to report here a short description of the vegetal landscape by Guidotti (1934) before the massive forest degradation: "Along the border of the Setit river there are incense plants (Fig. 7.13) and *Acacia gummifera* trees, which are intercalated with small ebony plants, covering sets of ten square kilometres of land. Along the rivers of the Sudanian lowland, it is possible to encounter palms, tamarind, mahogany and sycamore trees, and on the top hills, there are spiny bushes without any importance. From Akordat to Cheren, tamarisk, baobab (Fig. 7.14), poinciana flame trees and many types of Acacia provide the landscape with a particular physiognomy. On the slopes and highlands, wild olive, *Euphorbia candelabrum, Combretum* plants, terminalia trees, *Anogeissus and Junipers* trees such as *Juniperus procera* (Fig. 7.15) are prevailing on different zones as a consequence of soil characteristics and water content, rainfall distribution and general climatic conditions".

A typical example of deforestation in Eritrea was provided by the Metaten Forest case. This area is in the Woina-Degà zone on a high mountain (2727 m asl), where evergreen rain forest with coniferous plants prevailed. In the 1920s, this forest consisted of 100,000 adult trees with a diameter exceeding 25 cm and approximately 100,000 $m^3$ of wood were calculated to be present in the region. In that time, however, about 30% of the trees were either already dead or dying. A further 30% were deformed trunks, with the remaining 40% being represented by trees still standing (Mangano 1920). Thus, the Metaten Forest seemed like an ecological island surrounded by a territory with scarce vegetation cover. This forest was the most expansive juniper woodland in Eritrea but, like the other forests, it was rapidly deteriorating. The disproportionately high percentage of dead trees and trees with rotted inner wood compared to the low percentage of young trees required for the forest renewal was impressive. The causes of the forest fatal decline are manifold, including the lack of a rational forest management system (Mangano 1920). At that time, there was no efficient forest service at the national level. Incorrect utilization of adult trees, the fires set by indigenous people to extend their small cereal crops, local practices of felling medium-size trees and parasitic phyto-patologies were among important causes leading to the degradation of the Metaten Forest. The colonial administration of Eritrea attempted to reduce the loss of forest cover. In Fig. 7.16, the forest zones existing during the Italian occupation of Eritrea are shown in green

**Fig. 7.13** *Boswellia papyrifera* trees along the Tekezé-Setit River. This is a small tree well known for its frankincense. It is a multipurpose deciduous species (photo by Maugini 1933) (Photographic Archive of the former Istituto Agronomico per l'Oltremare)

**Fig. 7.14** Western lowlands of Eritrea are rich in baobab trees (Photographic Archive of the former Istituto Agronomico per l'Oltremare 1937)

on the map drawn by the *Milizia Forestale* (Italian forest rangers) in 1930s.

In 1890, the first governmental ban prohibited fires next to woodlots and the felling of large trees, particularly tamarind and ebony trees. Other bans followed in 1898, 1907, 1927 and 1932–1933. In the last period, the Forest Rule was set up and woods were classified into three types: open access woods, reserved woods and reserved woods where grazing was forbidden. In the 1910s, assignments were carried out by Bartolommei Gioli (1903), Senni (1915), Baldrati (1907) and Fiori (1908–1909), with the predominant objective to solve the problem of incipient deforestation and soil degradation. Proposals of reforestation and re-afforestation measures were reiterated by these authors. Fiori (1912) reported that some tree species were already experimented in situ giving good results in terms of forestry. These tree species were *Cupressus sempervirens* and *Cupressus macrocarpa* in the highlands (Fig. 7.19). In 1911, the first tree plantation site for *Schinus molle*, eucalyptus and acacia species, along with species of pines, *Angophera sub-velutina*

**Fig. 7.15** *Juniperus procera* trees (Photographic Archive of the former Istituto Agronomico per l'Oltremare Archive 1927)

and casuarina trees was setup in the Asmara Region (Fig. 7.18).

Between 1922 and 1931, new tree nurseries were setup by the colonial forest service, involving participation of both indigenous people and colonialist farmers. As a result, over a period of twelve years, 1,998,700 trees were planted (Guidotti 1934). This venture consisted of 22 indigenous tree nurseries, distributed over three different altitudinal levels (lowlands, highlands and intermediate altitude plains), in sites most suitable for cultivation (Fig. 7.17). Exotic seeds, derived from America (Tecoma Spp, *Ipomea arborea, Acacia picnanta, Acacia tabehnia, Acacia leucaena*), Ethiopia and Kenya (*Acacia australiana*) and Italy (many coniferous, eucalyptus and robinia tree species), were introduced in 1932–1933 for experimentation. Moreover, seeds of the spontaneous Eritrean flora (*Eritrina* spp., *Euphorbia* spp., *Eugenia* spp. and *Juniperus procera*) were also used (Guidotti 1934).

Though traditional agriculture and goat, sheep, cattle and camel breeding were in part banned in order to protect natural forestlands, the colonial administration not only agreed but also favoured the expansion of cotton and coffee plantations. This fact represented an anomaly. The first attempt to introduce the Arabica coffee on the highlands (>1400 m asl) was done directly by Yemenite growers invited by the colonial administration. The Italian forestry inspector Senni, who periodically visited the Eritrean Colony, identified the northern and eastern mountain slopes (from 1100 to 1900 m asl) as the preferred sites for the extension of coffee plantations, though Brizioli (1930) reported: "In the recent past, this sufficiently wide region was covered by a massive dense tree vegetation and in some sites, it was similar to the forest in the moist tropical regions". Nevertheless, after preliminary forest cleaning and terracing, coffee was cultivated over an area of about 25,000 ha, under both the former natural forest canopy and in artificial plantations of *Poinciana regia* and *Melia azedarach.* In 1923, the coffee farming system was formally initiated, and seven years later, more than 350,000 young coffee plants were planted, approximately 233,000 of which were already producing (Senni 1930). Exotic coffee species such as *Coffea excelsa*, *Coffea robusta* and *Coffea canephora* were also introduced. In 1923–1934, the coffee yield increased from 6.5 to 120 t (Brizioli 1936). In order to protect coffee plantations at higher altitudes, the Italian foresters proposed to plant tree lines of eucalyptus species, namely *Eucalyptus globulus* and *E. corynocalix.* These species were planted along with *E. mollissima*, a well-adapted species able to grow on the slopes of the Eastern Escarpment, and *Leucaena glauca,* a useful tree able to grow on the *bahari* land (Brizioli1930). Other eucalyptus species such as *E. resinifera, E. rostrata, E. robusta, E. citriodora, E. cornuta, E. amygdalina, E. dives, E. piperita* and *E. macarthuri* were introduced for phyto-therapeutic purposes and for the oil extraction industry (Rovesti 1928). Larger eucalyptus plantations still exist on the land of former Italian concessionaires and in the vicinity of towns (Boerma 2005b) (Fig. 7.20).

Undoubtedly, eucalyptus represented a valid alternative in response to the domestic firewood demand, which was increasing by both demographic and industrial growth. In recent years, the wood collecting continues to be a traditional women task (Fig. 7.21).

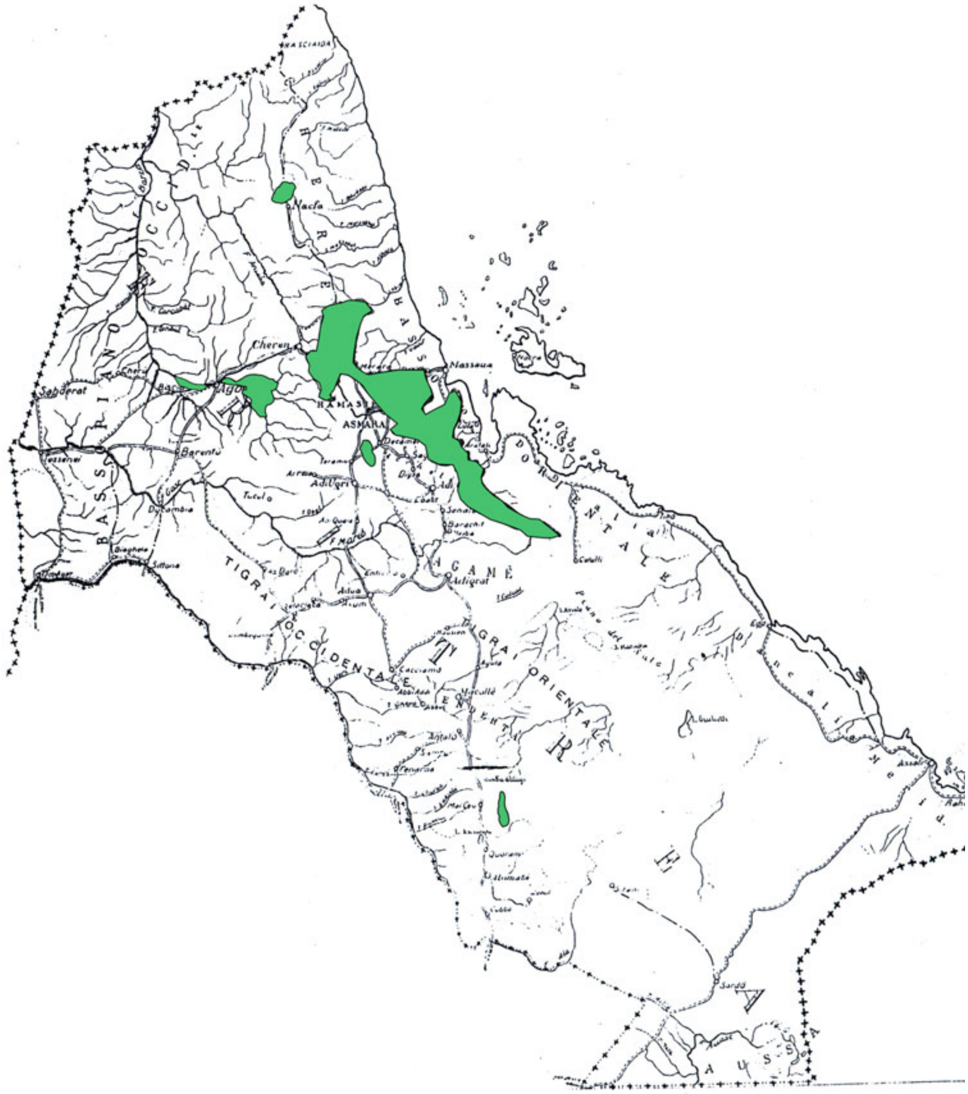


**Fig. 7.16** Forested areas (green colour) in Eritrea Italian Colony Map 1:2,000,000 (unpublished, Documentation Centre of the former Istituto Agronomico per l'Oltremare, undated)

### 7.4.2 Reforestation and Landscape Protection

The rapid demographic increase that occurred on the highlands after the Italian occupation not only created the conditions for the displacement of local people towards zones characterized by a double rainfall regime in search of better crop lands with higher productivity, but also left the forestland subject to plundering and grabbing (Brizioli 1930). According to Boerma (2005b), on the eastern side of the Eritrean highland, "trees are often grown in household compounds, while many villages also have small eucalyptus plantations". During the Eritrean Civil Wars, many former, large Italian plantations and local community plantations were plundered, leading the vegetation landscape back to the situation before the 1920s and 1930s (Boerma 2005b). A large proportion of the old eucalyptus plantations, completed before the liberation, was reduced to degraded lots because of expansion of agricultural fields and soil erosion (Micconi 1998b). According to recent statistics (FAO 2010), from 1990 to 2010, there was a 240% increase in planted forests in Eritrea to attain 34,000 ha by the year 2010. Nevertheless, deforestation is still identified as one of the most serious threats to the indigenous forests of Eritrea. According to MLWE (2014), most of the Eritrean land, originally covered by *Juniperus* forest, has been extensively harvested, mostly for fuel wood and traditional housing construction.

In areas suitable for cultivation, forestlands were replaced by croplands (FAO 1997). Since 80% of the Eritrean population is dependent on farming, the negative impact of subsistence cultivation and overgrazing on forest cover is significant. The dependence on firewood and traditional housing are also factors contributing to excessive deforestation of the country (Ghebrezgabher et al. 2016). Approximately 63 km$^2$ of forestland and woodland were lost annually in the 1970–2014 interval (Ghebrezgabher et al.

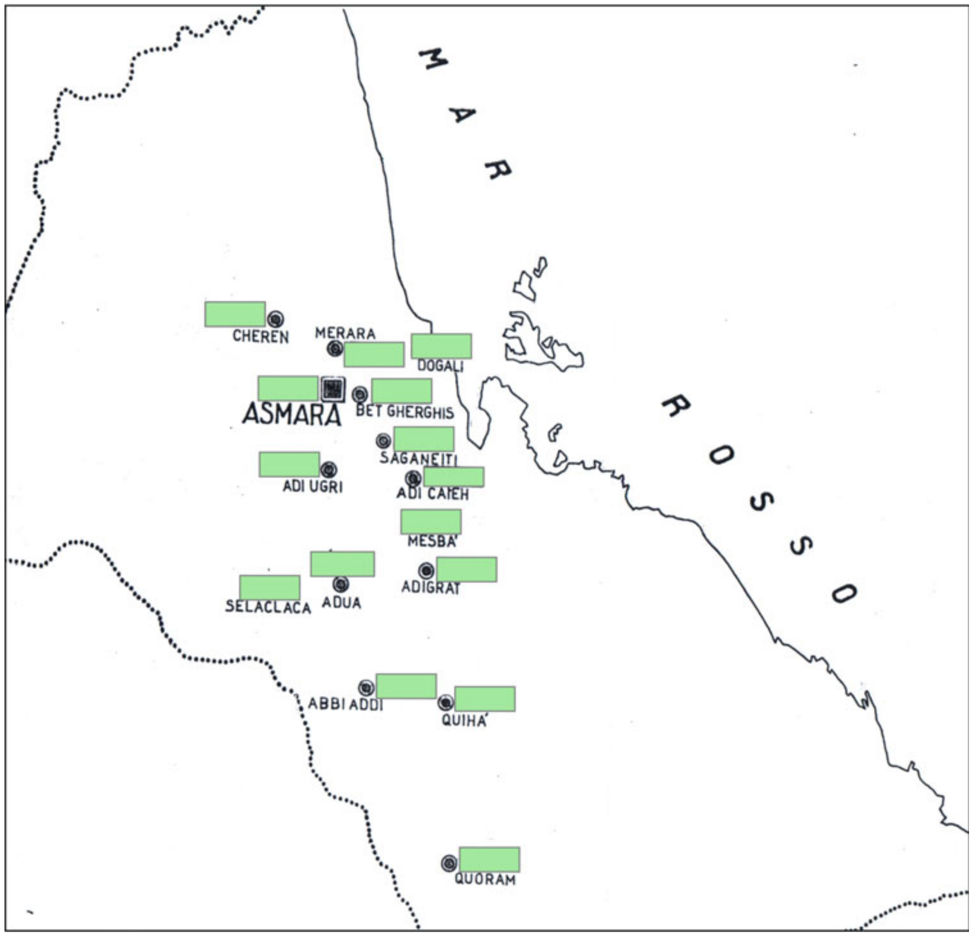


**Fig. 7.17** Forest nurseries location in Eritrea in the 1930s on a 1:2,000,000 map (unpublished, Documentation Centre of the former Istituto Agronomico per l'Oltremare, undated)

**Fig. 7.18** Reforestation area near Asmara (Photographic Archive of the former Istituto Agronomico per l'Oltremare 1937)

2016), and it has been estimated a devastation of about 70% of woodland during the conflict between Eritrea and Ethiopia (1961–1991). Forests, in fact, were not considered by armies as a mere livelihood resource, but they also were used as shelters, and for this reason, they had to be completely destroyed (usually using fires) (Micconi 1998b).

During warfare periods, in the Eritrean Highlands, the ratio between the number of people living within an area and

**Fig. 7.19** Reforestation area with *Cupressus* spp. in Bet-Ghirghis at 2400 m asl (Photographic Archive of the former Istituto Agronomico per l'Oltremare 1937)

the number of people that actually could be sustained based on the available wood resources was calculated to be 4:1, which implied wood consumption four times larger than what the environment could normally sustain (Micconi 1998b). In recent years, invasive alien species (such as *Opuntia ficus indica* in the highland forests and *Prosopis juliflora* in the riverine forests), excessive pollarding of multipurpose trees (such as *Balanites aegyptiaca*, *Faidherbia albida* and for dry season fodder *Terminalia brownii)*, desert locusts and the excessive use of pesticide sprays are reported to affect forest resources (MLWE 2012, 2014). Grazing pressure is also common throughout the country, and it is particularly severe during the dry season. There are no systematic data on the effect of livestock population size on the forest cover. However, diffuse degradation and the lack of regeneration of many tree species due to overgrazing are ubiquitously evident throughout the country. In the highlands, the growth rate of herbaceous species is extremely low; therefore, the foliage of shrubby and arboreous species (mainly *Acacia* spp.) constitutes the primary food source for pasture. This implies that pastures represent the main cause of the decrease in the number of healthy trees and the decreased opportunity of both regrowth and new seedling birth. All that leads to a vicious circle, in which, as the pasture resources decrease, the potential of rearing resources is also destined to decrease, thereby obliging the farmers to increase the number of animals to satisfy their needs with unpredictable consequences for the environment (Micconi 1998b). Where natural woods were felled and the land degraded, relatively aggressive pioneer species (e.g.

**Fig. 7.20** Reforestation plan by eucalyptus trees and anti-erosion techniques on a mountain slope at the Asmara—Nefarit road (photo by Pollera 1961) (Photographic Archive of the former Istituto Agronomico per l'Oltremare)

**Fig. 7.21** In Eritrea, wood collection is yet a traditional woman task (photo by Rodolfi 1995)

*Opuntia vulgaris, Dodonea viscosa, Carissa spinarum, Euclea schimperi* and *Nicotiana* spp,) started to invade the most compromised territories in the upland and at intermediate altitudes (Micconi 1998a), giving way to an ecological succession. In 1994, FAO proposed a reforestation programme to combat the incipient deforestation. It was proposed to create closed areas, inaccessible to both people and farm animals for at least 7–8 years to permit a sort of rotation among many wood lots within the territory. The success of such measures would inevitably depend on the extent to which the local community is involved (Micconi 1998b). The Eritrean government made many efforts and deployed many initiatives for environmental and soil conservation over a 10-year period in the 2000s. In that period, 206,000 ha of permanent forest were closed, more than 90 million tree seedlings were planted, more than 300 dams and millions of kilometres of hillside terracing were constructed, and, since 1995, five sites were proposed as protected areas (MLWE 2012). Moreover, it is interesting to note that the areas surrounding the local Copt Monastery, found for example in the upper Mareb basin (Fig. 7.8), represent an environmental exception because of the presence of plants, including, *Olea* spp, *Euphorbia candelabrum*, and *Prunus* spp. growing on mollisols, which constitute a kind of secondary forest, still very disturbed, but potentially extensible (Micconi 1998a). This secondary forest, if not disturbed, was envisaged to lead to the return of the original vegetation (Micconi 1998b). Figure 7.22 shows a Copt Monastery surrounded by tree vegetation such as an acacia woodlot that creates an ecological island on the Mandefera Plain. Knowledge about forested areas developed around churches and monasteries is yet scarce in Eritrea. During the Italian occupation, the colonial government confiscated the land of one of the most famous monastery of Eritrea, the Dabra Bizen, located in Hamasièn, about 25 km east of Asmara. The surrounding forest was destroyed by the colonialists (Breton 2009). Traditionally, the land tenure system in Eritrea was distinguished according to highlands and lowlands, respectively. On the plateau, the Eritrean Orthodox Tewahido Church was the main owner of a considerable amount of land (Houtart 1980).

In the neighbouring Ethiopia, researches on the church-forests are more advanced. The only areas where one can yet observe natural forests, in northern highlands of Ethiopia, for example, are concentrated in the surroundings of churches. These patches of natural forest have survived as a result of traditional conservation effort of the Ethiopian Orthodox Tewahido Churches (EOTC) (Mekonen et al. 2019). Pilot studies suggest that church-forests might be relics of ancient and largely lost forest ecosystems. They are hotspots of biodiversity for indigenous species, and therefore, they might serve as priority areas for in situ conservation (Wessie Eshete 2007). The effectiveness of these church-forests to provide ecosystem services for the landscape and serve as "stepping stones" for restoration will depend on their long-term sustainability (Wessie Eshete 2007). *Juniperus procera*, *Podocarpus falcatus*, *Olea europaea* L., *Ficus vasta* Forssk, *Ficus sur* Forssk, *Hagenia abyssinica* and *Dovyalis abyssinica* are common native trees grown in church-forests (Endalew et al. 2020). In general, sacred groves are the ideal sites for species afforestation programmes in their specific localities (in situ) and could serve as models of sustainable forest management and biodiversity conservation (Mekonen et al. 2019). The benefits of church-forests are categorized under non-market goods because the market has no bid to estimate the monetary value of these goods and services (Endalew et al. 2020).

**Fig. 7.22** Coptic Monastery localized in the Mandefera Plain. The woodlot developed around the church is like an ecological island (photo by Billi 2011)

In Eritrea, the indirect economic values of Eritrean forests include catchment protection (57%), carbon sequestration (41%) and erosion control (2%). Emerton and Asrat (1998) estimated these indirect benefits to be nearly 29.8 million euro at the current value (2020) in total. Most recently, a study carried out on the change of ecosystem service monetary values in response to the shift in Eritrea's forest cover during the period 1970–2020 has estimated these losses: "from US$ 5.05 billion in 1970 to US$ 4.75 billion, US$ 3.74 billion and US$ 3.57 billion in 1980, 2014 and 2020, respectively. The overall ecosystem service value in the study period decreased by US$ 1.48 billion due to a decline in woodland and forest land cover 1341 and 1785 km$^2$, respectively, resulting from deforestation and desertification" (Gebremariam et al. 2021).

The economic loss due to the soil erosion was estimated, in terms of crop losses, as about 46,500 euro per year at the current value (2020). The cost for water supply micro-dams maintenance, in the presence of on-farm soil erosion, was calculated to be around 516,000 euros per year at current value (2020). This amount is equivalent to the value of natural vegetation in mitigating local soil erosion (Emerton and Asrat 1998). The economic value of carbon sequestration by forests, woodlands and grasslands as a whole was estimated to be about 11.8 million euro per year at the current value (2020). The cost to the Eritrean economy of replacing the catchment protection services provided naturally by plant resources would require expenditures of nearly 17.89 million euro per year at the current value (2020).

The direct economic value of biological resources expressed in term of forest products utilization has been calculated to be about 46.6 million euro per year at the current value (2020). This budget does not include local non-timber forest products utilization (fruits, fibres, roots, bark, leaves, seeds, fodder) and the potential income from terrestrial protected areas (Emerton and Asrat 1998).

## 7.5 Conclusion

In 1998, Micconi stated that "significant data on forest resources in Eritrea are nearly non-existent especially because of the former occupation of Ethiopian armed forces, the consequent situation of compromised safety and finally due to the remarkable lack of interest by the Ethiopian Regime during the last decades". It is worth recalling that in that same year, in June, a new conflict between Eritrea and Ethiopia exploded. This event could explain the existence of two particularities characterizing the environmental history of Eritrea. The first is that the actual knowledge on forest patrimony is linked to the military occupation during the Italian colonial period. The second is that an endogenous process of scientific improvement was never carried out by national institutions. Sometimes, the knowledge about the Highlands, for example, is deduced from parallel studies carried out in an analogous environmental context in Ethiopia. In this *excursus* on the woodlands in Eritrea, we have through necessity followed the *fil rouge* of history because of the scarcity of detailed data and information available today. As historical environmental background, this article referred to the so-called narrative of reforestation that is an expression coined by McCann (1997) and recalled by Lätt (2004), who stated: "There is a widespread belief in Eritrea, that the woodland cover has decreased significantly during last century and that the Highlands were covered with dense forests before or even during Italian colonization" (Lätt 2004). As such, we have outlined the contradictory nature of recent data sources and the difficulty in attaining a comprehensive description of the state of art of the Eritrean forests. We recall here the fact that the prevailing belief about 30% of wood cover in Eritrea just before the Italian colonization would go back to Andrea Branca, leader of the Forest and Wildlife department under the British Administration in Eritrea, who published this figure in a report in 1947 (Lätt 2004).

Surely, Eritrean forests necessitate serious conservation attention. Documented findings from previous studies, presented in this article, have shown that the country has been losing its floristic wealth over a long period. Anthropogenic activities are noted as the principal factors resulting in deforestation. Forest resources are utilized for subsistence cultivation, firewood, timber, urbanization and road construction. Overgrazing, population growth and climate changes are also noted as additional factors aggravating deforestation in the country, and deforestation in turn can exacerbate the effects of climate change; in fact, a quite recent study on the spatio-temporal dynamics of vegetation cover in Eritrea in response to climate (precipitation and temperature) and drought from 2000 to 2017 confirms that "low precipitation was mainly attributed to the slowly declining vegetation trends and increased drought conditions in the semi-arid region of the country" (Measho et al 2019).

Besides boosting the existing reforestation effort by the government, conservation attention should be currently given to the few remaining forest patches in the country. According to the FAO's country programme in Eritrea (2017–2021), the management of natural resources, including soil conservation measures, water harvesting and afforestation, represents "areas that the government of Eritrea wishes to explore in the next phase with FAO" (FAO 2021).

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