

Forest and Woodland Vegetation in the Highlands of Dogu'a Tembien

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Raf Aerts

Much of the available land in Dogu'a Tembien is under cultivation or is used as grazing land. Open woodland of small shrub and tree species has regenerated during the past decades in exclosures (see Chap. 18), but semi-natural forest vegetation remains largely restricted to small, isolated patches. These patches are most often church yards and other sacred sites. In this chapter, the historical forest vegetation of the Ethiopian highlands and how this vegetation changed are briefly described, an overview of the different Afromontane forest types of the Ethiopian highlands is given and the present vegetation of church forests in the dry Afromontane forest zone is described. Against this broad ecological background of the dry Afromontane forests, the forest and woodland vegetation of Dogu'a Tembien is discussed.

15.1 Historical Forest Vegetation, Clearance and Regrowth

Pollen records from Ashenge and Hayk lakes indicate that the natural vegetation of the northern Ethiopian highlands, before the large scale human transformation of the landscape, was Afromontane *Afrocarpus-Juniperus* forest, with *Afrocarpus falcatus* (yellowwood, previously known as *Podocarpus falcatus*), *Juniperus procera* (African cedar) and other high-elevation species. This primary mixed forest was cleared and, presumably under the influence of heavy livestock grazing, replaced by a secondary vegetation shrub and grassland at about 500 BCE,

R. Aerts (✉)

Department of Earth and Environmental Sciences, KU Leuven,
Celestijnenlaan 200E-2411, 3001 Leuven, Belgium
e-mail: raf.aerts@kuleuven.be

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J. Nyssen et al. (eds.), *Geo-trekking in Ethiopia's Tropical Mountains*,
GeoGuide, https://doi.org/10.1007/978-3-030-04955-3_15

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with *Dodonaea* and *Rumex* as disturbance indicators in the pollen record. Interestingly, dry Afromontane *Juniperus* forest with secondary or intermediate species such as *Olea europaea* ssp. *cuspidata* (African wild olive) and *Celtis africana* (white stinkwood) expanded in the northern highlands from 1400 to 1700 CE, potentially a result of accelerated secondary succession following increased rainfall, reduced human impact, or a combination of both. Clearing of these forests, excessive harvesting of high-quality timber, increased livestock grazing and subsequent land degradation throughout the past three centuries have led to the present dominance of drought-resistant and often thorny savanna tree and shrub species in the uncultivated parts of the landscape. In Dogu'a Tembien, these species include *Acacia etbaica*, *A. abyssinica*, *Euclea racemosa*, *Senna (Cassia) singueana*, *Dodonaea angustifolia* and *Dichrostachys cinerea*. Despite the high demand for wood and grazing land, isolated patches of dry Afromontane forest vegetation have persisted throughout the northern highlands for centuries as a result of the traditional protection of vegetation near churches and other sacred sites (Photo 15.1). A study that compared historical aerial photographs to present-day satellite imagery of 37 of such church forests in the hills east of Lake Tana demonstrated that, at least over the past 80 years, church forests have hardly changed in size. Conversely, trees and natural vegetation in the landscape surrounding the church forest disappeared. In the forest, species composition, structure and tree population dynamics may have been affected by these changes in the surrounding matrix and by forest management, but at least the shape and thus the extent of the church forests remained largely the same. A comparison between an oblique aerial photograph of 1936 and a satellite image of 2016 demonstrates that the extent of the eastern part of Chege forest, a large forest just west of Dogu'a Tembien, also has not changed since at least 1936 (Photo 15.2).

15.2 Afromontane Forest and Woodland Vegetation

Different types of Afromontane forest vegetation occur in the Ethiopian highlands. According to the most recent classification of vegetation in Ethiopia by Ib Friis and colleagues, the potential natural vegetation of the Ethiopian highlands between 1800 and 3000 m altitude is “dry evergreen montane forest and grassland complex” in areas with rainfall below 1700 mm per year (northern and central highlands), and “moist evergreen Afromontane forest” in areas where rainfall exceeds 1700 mm per year (southern and southwestern highlands; this forest type does not occur in Dogu'a Tembien).



Photo 15.1 May Be'ati church forest and its surroundings. The forest (6 ha) is located at the base of a limestone cliff and has a perennial spring. A large grazing enclosure (13 ha), dominated by shrubs, extends this patch of semi-natural vegetation to the west. Hedgerows and isolated trees dot the village and the homestead fields south of the forest. There are no trees in the grazing land and the arable land on the plateau. Photo Raf Aerts/Eva November, 2001

The dry evergreen montane forest is not one well defined forest type, but a collective designation for a landscape mosaic of different dry forest and woodland types varying from grasslands with shrubs and trees to closed-canopy forest. It is nevertheless possible to define several dry evergreen montane forest subtypes based on differences in the dominance of the indigenous coniferous species *A. falcatus* and *J. procera* and in the relative abundances of grass, shrubs or broadleaved trees present in the forest.

A first subtype of the dry evergreen montane forest is the “undifferentiated Afromontane forest”, a forest type that is presumably similar to the historical *Afrocarpus-Juniperus* forest mixed with broadleaved species such as *Croton macrostachyus*, *Ficus* species and *O. europaea*. The two indigenous conifers can be equally important or one of the two species can be dominant in the undifferentiated Afromontane forest. A second, drier, subtype of the dry evergreen



Photo 15.2 Chege forest (1936–2016), in a cove that is difficult to access. A comparison between an oblique aerial photograph of 1936 (see Chap. 31) and a satellite image of 2016 demonstrates that the extent of the eastern part of Chege forest has not changed since at least 1936. The base of the forest (line A–B) is 1 km wide. Open *Olea-Acacia* woodland has expanded into the present-day northwestern extension of the forest. Oblique VHR satellite imagery over global DTM © 2018 CNES/Airbus by way of Google Earth; eye altitude 3.6 km; view towards the east

montane forest is the “dry single-species dominant Afromontane forest of the Ethiopian highlands” with *Juniperus* the dominant species in the upper storey and *Olea* as well as other species in the middle and under storey.

In Dogu’a Tembien, and in the northern highlands in general, the dry evergreen montane forest transitions into *Combretum-Terminalia* woodland and wooded grassland below 1800 m, with (sometimes very locally) very interesting species such as *Adansonia digitata* (baobab, e.g. near Agbe) and *Boswellia papyrifera* (frankincense tree, in the Giba gorge, see Chap. 19). Above 3000 m, the dry evergreen forest is flanked by the ericaceous belt (3000–3200 m) with *Erica arborea* (tree heath); this belt gradually changes into the afro-alpine belt on higher mountains (>3200 m). The Dogu’a Tembien massif peaks at 2845 m and the area is therefore too low to sustain afro-alpine or even ericaceous vegetation. In the dry evergreen montane forest zone, *Erica arborea* may be present as an understory shrub and some small pockets of this species occur in the area, for instance on the northern slopes of the Dabba Selama peak (13.72351°N, 39.2013°E) (Photo 38.22).

15.3 Church Forests as Islands of Forest Biodiversity

A study of satellite images of 394 church forests within the dry evergreen montane forest zone of the Ethiopian highlands showed that church forests are consistently small with a remarkably similar surface area (average size 2.5 ha) and on average separated by ~ 2 km from the nearest neighbouring church forest (Photo 15.3). There is approximately only one church forest per 10 km^2 . In the northern highlands, church forests tend to have a more complex shape and are located on steeper slopes than in the southwest, where church forests are often perfectly circular, with a sharp boundary and with the church in the center of the forest. The sizes of 38 church forests in Dogu'a Tembien identified on satellite images ranged between



Photo 15.3 Addi Geza'iti church forest. Church forests in the dry evergreen montane forest zone of Ethiopia are typically isolated and small, on average 2.5 ha in size and separated by ~ 2 km from the nearest forest patch. With an area of only 1.4 ha, this church forest is even smaller than the average, yet it is rich in tall, old trees including olive and fig trees. Harehuwa church forest (Photo 15.9) is located exactly 2 km north of this forest patch. The tree line on the horizon are exotic *Eucalyptus* trees, planted throughout the higher range of Dogu'a Tembien to produce timber. Photo Raf Aerts (2003)

0.36 and 63 ha, with a total surface area of 330 ha. By size, church forests were distributed over 5 size classes: less than 2 ha (N = 11 forests; mean 1 ha; total area \sum 11 ha); 2–5 ha (N = 10; mean 3.5 ha; \sum 35.4 ha); 5–10 ha (N = 9; mean 6 ha; \sum 53.7 ha); 10–30 ha (N = 5; mean 16.9 ha; \sum 84.5 ha); and more than 30 ha (Abiy Dur—“large forest” in Waseya, 48 ha; May Mirara, 63 ha; and a forest without a church located in between those two forests, 34 ha). The church forests of Dogu’a Tembien usually have a very diffuse edge and many of the forests in the larger size classes are rather open woodlands that transition into shrubland.

A ground survey of 78 church forests within the dry evergreen montane forest zone of the Ethiopian highlands showed that *O. europaea* (present in 71% of the surveyed forests), *Juniperus procera* (67%) and *Croton macrostachyus* (54%) (and not *Afrocarpus*, 19.2%) are the most prevalent tree species in church forests. In the understorey, *Calpurnia aurea* and *Carissa spinarum* (both 74%) are the most common shrub species. Also in and around Dogu’a Tembien *O. europaea* is indeed the keystone tree species of most church forests (Photo 15.4). Across the surveyed forests, a total of 148 indigenous tree, shrub and liana species were recorded, but, on average, there were only 25 woody species recorded per forest patch. The number of species per forest patch increased from northeast to southwest with increasing mean annual precipitation; this means that the church forests in Dogu’a Tembien belong to the drier and relatively species-poor church forests of the Ethiopian highlands. Common secondary and intermediate species of the church forests of Dogu’a Tembien include *Acacia etbaica*, *A. abyssinica*, *A. seyal*, *Acokanthera schimperi*, *Aloe macrocarpa*, *Celtis africana*, *Calpurnia aurea*, *Combretum collinum*, *Cordia africana*, *Cassia singueana*, *Euphorbia abyssinica*, *Euclea racemosa*, *Faidherbia albida*, *Ficus vasta*, *Maytenus senegalensis* and *Rhus natalensis*. Exotic timber (e.g. *Eucalyptus spp.*, *Cupressus lusitanica*, *Grevillea robusta*) and fruit tree species (e.g. *Psidium guajava*, common guava) are often planted in or near the church forests.

The vegetation of the 78 ground-surveyed church forests (across the dry evergreen montane forest zone) could be classified into four plant communities. Two communities belonged to the dry single-species-dominant Afromontane forest and the other two to the undifferentiated Afromontane forest. The plant communities of the undifferentiated Afromontane forest type were predominantly found in the central highlands and were mixed conifer forest with *Juniperus* or with *Juniperus* and *Afrocarpus* as dominant species, both mixed with broadleaved species. The plant communities of the dry single-species-dominant Afromontane forest type were degraded *Olea-Acacia* woodland and typical dry Afromontane forest dominated by *Juniperus* with *Olea* and other secondary species.



Photo 15.4 Abune Aregawi Minta church forest. African wild olive (*Olea europaea* ssp. *cuspidata*) is the keystone tree species of the church forests in and around Dogu'a Tembien. The tree in the foreground and the trees with round, grey-green crowns in the forest are olive trees. The trees with flat-topped crowns are *Acacia* species. The church is located at the base of the cliff in the foreground (see also Photo 17.1). Photo Raf Aerts (2004)

The church forests of Dogu'a Tembien are predominantly remnants of *Olea-Acacia* woodland and *Juniperus-Olea* forest. The nearest remnant population of *Afrocarpus* trees is found in the National Forest Priority Area Hugumburda, a relatively well-conserved dry Afromontane forest located in a secluded, relatively moist valley next to the parallel rift of Lake Ashenge.

The *Olea-Acacia* woodland is an open woodland with relatively few tree species and a low, single-storied, discontinuous canopy. In the rainy season, grasses and herbaceous vegetation, including *Bidens prestinaria*, emerge under this open canopy (Photo 15.5). Natural tree regeneration is very poor or entirely lacking, because very few seedlings are able to survive the dry season in these open woodlands. This has resulted in skewed tree diameter distributions and threatens these church forests in the long term. Near the lower ranges of the dry evergreen



Photo 15.5 Indagabr Miheni church forest. The church forest of Miheni is a mosaic of open *Olea-Acacia* and open *Acacia* woodland. In the rainy season, grasses and herbaceous species, including the conspicuous yellow meskel flower, cover the soil. In the dry season, the soil is barren and dry, which impedes regeneration of trees. Photo Raf Aerts (2004)

montane forest zone, the *Olea-Acacia* woodland may contain elements of the *Combretum-Terminalia* woodland and wooded grassland, such as *Combretum collinum*. This forest type attracts biota from habitats of lower altitudes, including birds from the Sahel and Northern Africa (Chap. 17).

The *Juniperus-Olea* forest usually has a two-storied canopy, with *Olea* trees underneath a tall overstorey of *Juniperus* trees, but in Dogu'a Tembien *Juniperus* is very rare and small or entirely lacking and because of internal degradation this canopy is very often open and patchy. This phase of the dry evergreen montane forest may be defined as dry Afromontane forest dominated by *Olea* (Photo 15.6). In more closed canopy *Juniperus-Olea* forests, especially in the higher ranges, epiphytic lichens and orchids can form an important component of the forest ecosystem. Beard lichens and orchids intercept water from clouds and contribute to



Photo 15.6 Chege forest occupies a steep, bowl-shaped slope between 2100 and 2300 m and is one of the few large forests in and near Dogu'a Tembien (75 ha; Chege is located just to the west of the administrative boundary of Dogu'a Tembien; see also Photo 15.2). The emerging round, grey-green crowns are *Olea* trees. This forest is much denser than the typical open *Olea-Acacia* woodlands of Dogu'a Tembien and may be defined as dry Afromontane forest dominated by *Olea*. Photo Jan Nyssen (2017)

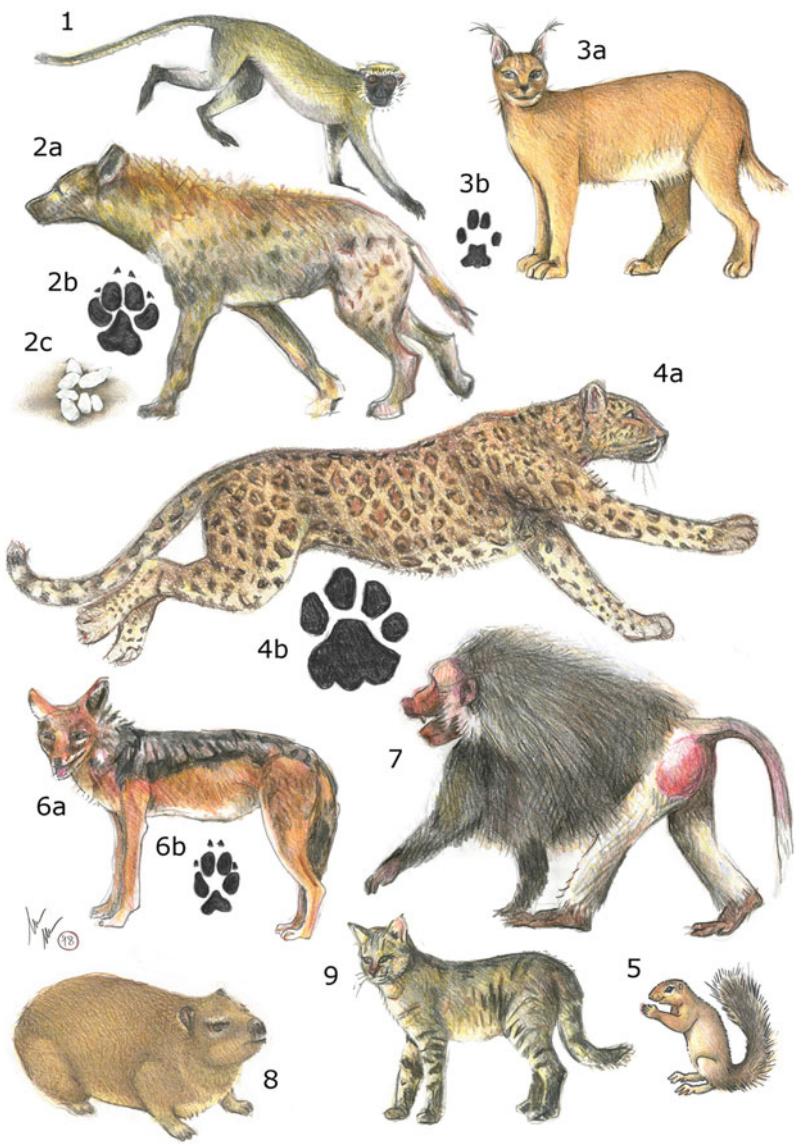
the local hydrological cycle. In Dogu'a Tembien, epiphytic orchids and lichens have become very rare. Even the once widespread orchid *Polystachya bennettiana* with its light greenish yellow or cream flowers has disappeared from many church forests, presumably following unfavourable changes in the forest microclimate. Even in the National Forest Priority Area Dessa'a, a large but degraded dry Afromontane forest dominated by stunted *Juniperus* with *Olea* on the western Great Rift escarpment, lichens and orchids are becoming increasingly rare. In most church forests, however, patches with nearly complete crown closure and dense undergrowth remain (Photo 15.7), for instance where woody climbers such as *Pterolobium stellatum* have overgrown the canopy, or near large fig trees (e.g. *Ficus vasta*) (Photo 15.8). These pockets of dense vegetation act as surrogate



Photo 15.7 Interior of Abiy Dur forest near Waseya. The steep banks of ephemeral streams running through church forests are often covered by dense thickets of understory trees and shrubs, and act as surrogate forest 'core' area for understory bird species and other forest specialists. Abiy Dur (49 ha) is large enough to have a proper forest core area in addition to these ephemeral river habitats. The stream running through the forest is an interesting route to explore the entire elevation gradient of the forest. The cacti on the right are *Opuntia ficus-indica*, an alien invasive species common in Dogu'a Tembien that is appreciated for its fruits, cactus-figs (*beles* in Tigrinya). Photo Raf Aerts (2003)



Photo 15.8 Massive fig tree trunk in Abiy Dur. Impressive fig trees growing on and over boulders and large woody climbers make the interior of some church forests in Dogu'a Tembien resemble tropical forests. Photo Raf Aerts (2004)



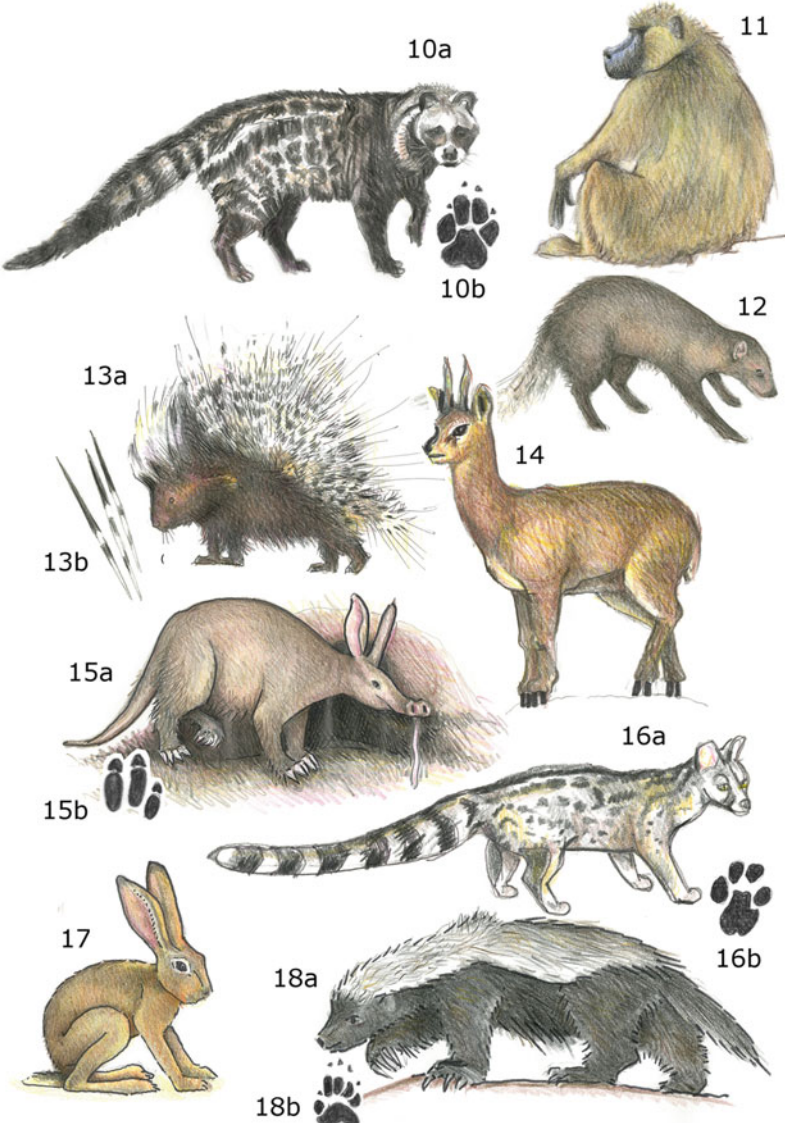


Plate 15.1 (continued)

◀ **Plate 15.1** Large mammals of Dogu'a Tembien, with scientific (*italics*), English and Tigrinya names. Some striking characteristics are outlined: (1) *Cercopithecus aethiops*; grivet monkey, ወዓግ (wi'ag); (2a) *Crocuta crocuta*, spotted hyena, ዝብኢ (zibi), with (2b) paw print and (2c) typical white excrements; (3a) *Caracal caracal*, caracal, ጭክ አንበሳ (ch'ok anbessa), with (3b) paw print—as it is a cat, nails are retracted; (4) *Panthera pardus*, leopard, ነብሪ (nebri)—rare and alternatively in black coat, with (4b) paw print; (5) *Xerus rutilus*, unstriped ground squirrel, ምጹጽላይ or ጨጨራ (mitsutsilay, chechera); (6a) *Canis mesomelas*, black-backed jackal, ቡካርያ (bukharya), with (6b) paw print—closely related *C. anthus*, golden jackal, occurs also; (7) *Papio hamadryas*, hamadryas baboon, ጋውና (gawina); (8) *Procavia capensis*, rock hyrax, ጊሐ (gihè); (9) *Felis silvestris*, African wildcat, ሓክሊ ድሙ (hakili dummu); (10a) *Civettictis civetta*, African civet, ዝባድ (zibad), with (10b) paw print; (11) *Papio anubis*, olive baboon, ህበይ (hibey); (12) *Ichneumia albicauda*, white-tailed mongoose, ጊሒራ (tsihira)—not pictured and similar in shape at night is *Herpestes ichneumon*, large grey mongoose; (13a) *Hystrix cristata*, crested porcupine, ቅንፈዝ (qinfiz), with (13b) released quills; (14) *Oreotragus oreotragus*; klipspringer, ሰስሓ (sesiha); (15a) *Orycteropus afer*, aardvark, ፍሒራ (fihira), with (15b) footprint; (16a) *Genetta genetta*, common genet, ሰልሕልሕት (silihlihot), with (16b) paw print; (17) *Lepus capensis*, cape hare, ማንቲለ (mantile); (18a) *Mellivora capensis*, honey badger, ትትጊ (titigi), with (18b) paw print. Artwork by Mieke Nyssen (2018)

forest 'core' area and are important for understorey bird species (Chap. 17), as well as for large mammals that hide in these almost impenetrable thickets during the day—most notably the spotted hyena (Plate 15.1). Other mammals that have been observed in or near the church forests and other more or less woody habitats of Dogu'a Tembien include hamadryas, olive baboon, grivet (also known as African green or Savannah monkey; the most common primate in the area), klipspringer, black-backed jackal, honey badger, African civet, common genet (often under church roofs and in large trees, including *Euphorbia*), large grey and white-tailed mongoose, African wild cat, caracal, (occasionally) leopard, rock hyrax (on steep cliffs and in large trees), cape hare, unstriped ground squirrel and crested porcupine (Plate 15.1).

A number of relatively large church forests has been conserved along the Tsaliet River to the west of Tinsehe waterfall—Harehuwa (~13 ha; Photo 15.9) and Abiy Dur in Waseya (~49 ha; Photo 15.10)—and in the Tanqwa valley—May Mirara (~63 ha; Photo 15.11), a forest without church, and Chege (~75 ha; Photo 15.6)



Photo 15.9 Harehuwa church forest. This large church forest (13 ha) is located at the base of a limestone cliff and ranges between 2229 and 1973 m, near the lower limit of the dry evergreen montane forest and grassland zone. The protection of trees near churches often extends into grazed land adjacent to the church forest, as seen here on the grassy plateau on the left. Photo Raf Aerts (2002)



Photo 15.10 Abiy Dur (48 ha) is one of the largest church forests in Dogu'a Tembien. There is a narrow belt of tall trees in the immediate vicinity of the church and a second, wider belt of *Olea* woodland. The tallest and presumably oldest trees do not necessarily represent the natural vegetation as trees may have been planted near the church. Photo Raf Aerts (2003)

(Chege lies just west of the administrative boundary of Dogu'a Tembien). These forests cover steep west-facing slopes and extend from the edge of the plateau towards the lower limit of the dry evergreen montane forest and grassland zone. A favourable rainfall regime during the main *kremti* rainy season (Fig. 3.3) may explain why these forests are larger and less degraded than other forests in Dogu'a Tembien. These forests are the most intact dry evergreen montane forests in Dogu'a Tembien. Relic populations of *Juniperus* are conserved in the forests of May Mirara and especially Abiy Dur. These forests also contain Afromontane highland biome bird species that were not recorded in the smaller, more degraded forests of Dogu'a Tembien, such as white-cheeked turaco or Abyssinian oriole (Chap. 17). Satellite imagery provides evidence that these large forests have not changed in size since at least 1984.



Photo 15.11 May Mirara forest (63 ha). This is open *Olea-Acacia* woodland with some *Juniperus* and most likely represents the intermediate stage between vegetation that can be observed in exclosures today and the vegetation of dry Afromontane forest. Photo Jan Nyssen (2017)

Church forests in northern Ethiopia have been quite literally islands of forest biodiversity for centuries and are likely to remain isolated patches for many more years because of the slow pace of natural regeneration of forest microclimate and structure in exclosures (Chap. 16). In Dogu'a Tembien, church forests and some large, well-developed exclosures are the most important forests and woodlands of the area. These forests have an important conservation value for plants, birds and mammals and are vital seed sources of indigenous tree species for natural and assisted regeneration in exclosures and for the production of tree seedlings in nurseries. In Chap. 17, we suggest a few sites that are interesting for birdwatching but we do stress that it is important to seek prior informed consent to visit forests in the vicinity of churches and other sacred sites including woodlots around “holy waters” (see also Chap. 37).

Field observation sites: natural vegetation can be observed as small patches near churches all over Dogu'a Tembien—see the dark green coloured areas on the geo-trekking map, as well as church symbols. Treks #3, #4, #5, #6, #22 and #25 allow to visit some of the larger areas with natural vegetation.

Further Reading

- Aerts R, Van Overtveld K, Haile M, Hermy M, Deckers J, Muys B (2006) Species composition and diversity of small Afromontane forest fragments in northern Ethiopia. *Plant Ecology* 187:127–142.
- Aerts R, Van Overtveld K, November E, Wassie A, Abiyu A, Demissew S, Daye DD, Giday K, Haile M, TewoldeBerhan S, Teketay D, Teklehaimanot Z, Binggeli P, Deckers J, Friis I, Gratzner G, Hermy M, Heyn M, Honnay O, Paris M, Sterck FJ, Muys B, Bongers F, Healey JR (2016) Conservation of the Ethiopian church forests: threats, opportunities and implications for their management. *Science of the Total Environment* 551–552:404–414.
- Aynekulu E, Aerts R, Moonen P, Denich M, Gebrehiwot K, Vagen TG, Mekuria W, Boehmer HJ (2012) Altitudinal variation and conservation priorities of vegetation along the Great Rift Valley escarpment, northern Ethiopia. *Biodiversity and Conservation* 21:2691–2707.
- Aynekulu E, Aerts R, Denich M, Negussie A, Friis I, Demissew S, Boehmer HJ (2016) Plant diversity and regeneration in a disturbed isolated dry Afromontane forest in northern Ethiopia. *Folia Geobotanica* 51:115–127.
- Darbyshire I, Lamb H, Umer M (2003) Forest clearance and regrowth in Northern Ethiopia during the last 3000 years. *The Holocene* 13:537–546.
- Friis I, Demissew S, van Breugel P (2010) Atlas of the potential vegetation of Ethiopia. *Biol. Skr. Dan. Vid. Selsk.* 58:1–307.
- Klepeis P, Orłowska IA, Kent EF, Cardelús CL, Scull P, Eshete AW, Woods C (2016) Ethiopian church forests: a hybrid model of protection. *Human Ecology* 44:715–730.
- Scull P, Cardelús CL, Klepeis P, Woods CL, Frankl A, Nyssen J (2017) The resilience of Ethiopian church forests: interpreting aerial photographs, 1938–2015. *Land Degradation and Development* 28: 450–458.
- Woods CL, Cardelús CL, Scull P, Wassie A, Baez M, Klepeis P (2017) Stone walls and sacred forest conservation in Ethiopia. *Biodiversity and Conservation* 26: 209–221.