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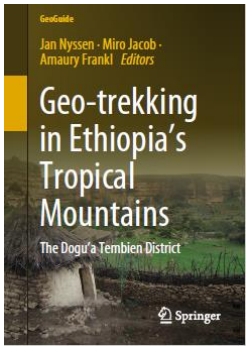

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Forest and woodland vegetation in the highlands of Dogu'a Tembien

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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 Chapter 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.

16.1 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, 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 16.1). 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 church forest, a large forest just west of Dogu'a Tembien, also has not changed since at least 1936 (Photo 16.2)

16.2 Afromontane forest and woodland vegetation

A number of different types of Afromontane forest vegetation occur in the Ethiopian highlands. According to the most recent classification of vegetation in Ethiopia by Friis et al., 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).

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 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 Chapter 22). 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 plateau of Dogu'a Tembien peaks at 2845 m and the area is therefore too low to sustain ericaceous or afro-alpine vegetation.

16.3 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 16.3). There is approximately only one church forest per 10 km². 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 0.36 and 63 ha, with a total surface area of 330 ha. By size, church forests were distributed over 5 size classes: ≤ 2 ha (N = 11; mean 1.03 ha; SD 0.51 ha; ∑ 11.32 ha); 2-5 ha (N = 10; mean 3.54 ha; SD 0.86 ha; ∑ 35.40 ha); 5-10 ha (N = 9; mean 5.96 ha; SD 1.46 ha; ∑ 53.65 ha); 10-30 ha (N = 5; mean 16.90 ha; SD 5.32 ha; ∑ 84.52 ha); and >30 ha (Waseya, 48.29 ha; May Mirara, 63.06 ha; and a forest

without a church located in between those two forests, 34.11 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 16.4). 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

142 Afromontane forest. The plant communities of the undifferentiated Afromontane forest type
143 were predominantly found in the central highlands and were mixed conifer forest with *Juniperus*
144 or with *Juniperus* and *Afrocarpus* as dominant species, both mixed with broadleaved species.
145 The plant communities of the dry single-species-dominant Afromontane forest type were
146 degraded *Olea-Acacia* woodland and typical dry Afromontane forest dominated by *Juniperus*
147 with *Olea* and other secondary species.

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

152 The *Olea-Acacia* woodland is an open woodland with relatively few tree species and a low,
153 single-storied, discontinuous canopyIn the rainy season, grasses and herbaceous vegetation,
154 including *Bidens prestinaria*, emerge under this open canopy (Photo 16.5). Natural tree
155 regeneration is very poor or entirely lacking, because very few seedlings are able to survive the
156 dry season in these open woodlands. This has resulted in skewed tree diameter distributions and
157 threatens these church forests in the long term. Near the lower ranges of the dry evergreen
158 montane forest zone, the *Olea-Acacia* woodland may contain elements of the *Combretum-*
159 *Terminalia* woodland and wooded grassland, such as *Combretum collinum*. This forest type
160 attracts biota from habitats of lower altitudes, including birds from the Sahel and Northern Africa
161 (Chapter 20).

162 The *Juniperus-Olea* forest usually has a two-storied canopy, with *Olea* trees underneath a tall
163 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 16.6). In more or less 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 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 16.7), for instance where woody climbers such as *Pterolobium stellatum* have overgrown the canopy, or near large fig trees (e.g. *Ficus vasta*) (Photo 16.8). These pockets of dense vegetation act as surrogate forest 'core' area and are important for understorey bird species (Chapter 20), as well as for large mammals that hide in these almost impenetrable thickets during the day – most notably the spotted hyena (Plate XX). 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 (near Waseya forest), 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, small-spotted 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 XX).

A number of relatively large church forests has been conserved along the Tsaliet River to the west of Tinsehe waterfall – Haragua (~13 ha; Photo 16.9) and *Abiy Dur* ('Large Forest') in Waseya (~48 ha; Photo 16.10) – and in the Tanqwa valley – May Mirara (~63 ha; Photo 16.11), a forest without church, and Chege (~75 ha; Photo 16.6) (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 favorable rainfall regime during the main Kremt rainy season (Figure 3.3) may explain why these forests are larger and less degraded that 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 church forests of May Mirara and especially Waseya. 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 (Chapter 20). Satellite imagery provides evidence that these large forests have not changed in size since at least 1984.

Church forests in northern Ethiopia have been quite literally islands of forest biodiversity for decades 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 (Chapter 18). 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

209 Chapter 20, we suggest a few sites that are interesting for birdwatching but we do stress that it is
210 important to seek prior informed consent to visit church forests and other sacred sites including
211 woodlots around “holy waters”.

212

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