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**Human-Woodland interactions during the Pre-Aksumite and Aksumite periods in NE Tigray, Ethiopia: insights from the wood charcoal analyses of Mezber and Ona Adi.**

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**ABSTRACT:**

The Tigray region witnessed the rise and fall of the Pre-Aksumite and Aksumite polities between the mid-2nd millennium BCE and the late-1st millennium CE. Despite the importance of these entities in recent African prehistory, the issue of how they interacted with their surrounding environment has only been addressed very recently. Here, we present the first systematic anthracological analysis in the region. Wood charcoal samples from two archaeological sites were analyzed: the Pre-Aksumite rural site of Mezber (c. 1600 BCE – 1 CE) and Ona Adi (c. 600 BCE – 700 CE), an urban center occupied continuously from the Late Pre-Aksumite period to the fall of the Aksumite kingdom. A total of 2708 charcoal fragments from 25 samples and 9 archaeological phases were analyzed, and 19 plant taxa associated with at least 3 different vegetation types were identified. The results demonstrate rather continuous environmental conditions at a local level, with no major or abrupt environmental changes. They also evidence a process of landscape degradation as a result of human activity during the early-to-mid 1st millennium BCE, as well as a subsequent recovery that occurred gradually throughout the next c. 1,500 years. Finally, differences in firewood exploitation were identified in relation to the rural/urban nature of each settlement, showing an evolution in wood selection, management and exploitation strategies which indicates that both Pre-Aksumite and Aksumite populations featured a significant degree of resilience and adaptation capacity.

**KEYWORDS:**

Archaeobotany; Charcoal analysis; Pre-Aksumite period; Kingdom of Aksum; Tigray; Ethiopia.

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**CONFLICTS OF INTEREST**

The authors declare that they have no conflict of interest.

**AVAILABILITY OF DATA AND MATERIAL**

Reference collection is available at https://repositori.upf.edu/handle/10230/43106

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## Introduction

Pre-Aksumite and Aksumite communities, which flourished in the Tigray region of Ethiopia between the mid-2nd millennium BCE and the late-1st millennium CE (Harrower and D'Andrea 2014; D'Andrea et al. 2018; Taddesse 2019) represent two of the most notable ancient cultural horizons of recent African prehistory. During this period, these communities transformed from farming communities into a complex literate civilization spanning across the Ethiopian/Eritrean Highlands (Fattovich 2012). Nonetheless, these ancient polities of the Horn are still incompletely known, as archaeological research there has been overshadowed by other contemporaneous civilizations such as ancient Egypt, Meröe, and the Greco-Roman world. Recent research in Tigray has provided important insights to our understanding of human-environment relationships during these millennia (Boardman 1999, 2000; D'Andrea et al. 1999, 2008a, b, 2011, 2018; Cain 2000; D'Andrea 2003, 2008; Lyons and D'Andrea 2003; Sernicola 2008; French et al. 2009, 2014; Terwilliger et al. 2011; Harrower and D'Andrea 2014; Sulas 2014; Graniglia et al. 2015; Woldekiros and D'Andrea 2017; Harrower et al. 2020). However, the issue of woodland exploitation remains largely unexplored, as no anthracological analyses from anthropic deposits have been published so far (but see Gebru et al. 2009). This paper presents the results of anthracological analyses from two archaeological sites in the Gulo Makeda district in the eastern Tigray (Fig. 1): the Pre-Aksumite rural site of Mezber and the Aksumite urban center of Ona Adi, both excavated in the frame of the Eastern Tigray Archaeological Project (ETAP) (D'Andrea et al. 2008a). As such, this work constitutes pioneer research in defining human-woodland interactions using archaeobotanical data by reconstructing how people exploited woodlands and exploring the socio-ecological behaviors that underlie the gathering and use of wood resources during the Pre-Aksumite and Aksumite periods.

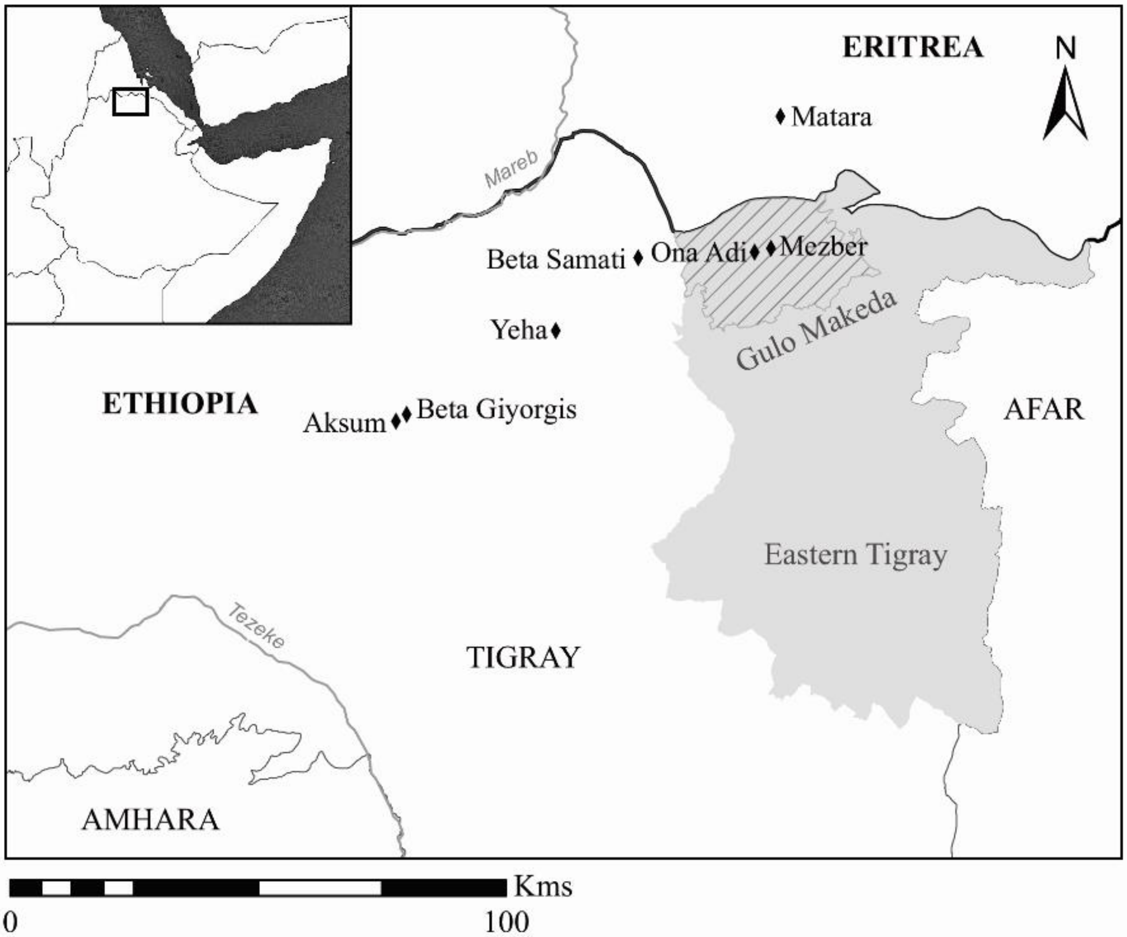


**Fig. 1** Map of the study area with the location of Mezber (14.417167º N, 39.40781079º E), Ona Adi (14.28583067º N, 39.01690588º E) and other archaeological sites mentioned in the text.

**Cultural background**

*The Pre-Aksumite period* (>800 - 50 BCE)

The term Pre-Aksumite refers to human occupations in the northern Highlands between the 1st millennium BCE and the rise of the Aksumite civilization (c. 50 BCE). During these centuries, the region experienced a substantial increase in settlement density, accompanied by the appearance of diverse agropastoral economies and social differentiation (Phillipson 2009). Based on ceramic traditions, this horizon is usually divided in three subphases –Early, Middle and Late Pre-Aksumite– with radiocarbon dates that vary significantly between subregions (Fattovich 2004; Michels 2005; Bard et al. 2014). Recently chronologies older than 800 cal. BCE have been obtained at the site of Mezber (Harrower and D'Andrea 2014), hence introducing a fourth subphase named Initial Pre-Aksumite (1600-800 BCE).

Excluding the Initial phase at Mezber, two types of settlements have been documented in the northern Highlands during the Pre-Aksumite period: (a) elite settlements such as Yeha (see Fattovich 2009, Phillipson 2012: 24-32), which contained elaborate monumental architecture and dedicatory inscriptions – both considered symbols of power; and (b) non-elite villages built of undressed dry-stone (Phillipson 2012) that seem to represent the majority of occupations in Tigray (D'Andrea et al. 2008a; Sernicola 2008). Settlement pattern analysis shows associations between sites and their surrounding environment –including preferential selection for agriculturally more productive and water outflow areas (Sernicola and Sulas 2012; Harrower and D'Andrea 2014). Cultivated crops are well attested as both African C4 cereals and Near Eastern C3 crops have been documented throughout the region (Boardman 1999, 2000; D'Andrea et al. 2008b, 2011; Schmidt 2009; Beldados et al. 2015) along with zooarchaeological evidence of domesticated species such as cattle, caprines, chicken, dog and donkey (Cain 2000; Shoshani et al. 2008; Lesur et al. 2014; Woldekiros and D'Andrea 2017).

*The Aksumite Kingdom* (50 BCE - 700 CE)

The emergence and development of the Aksumite civilization was a gradual process. Its origins can be traced back to the last centuries of the 1st millennium BCE, specifically in the Aksum area, where a polity centered on Beta Giyorgis has been identified as "Proto-Aksumite" (c. 400 – 50 BCE). This phase has been called "Pre-Aksumite to Aksumite Transition" (PA-A Transition) elsewhere in Tigray (see Taddesse 2019: 339). From Beta Giyorgis, Aksumite regional and interregional influences rapidly consolidated during the Early/Classic Aksumite period (c. 50 BCE – 350 CE) (Bard et al. 2014; Taddesse 2019), allowing this new polity to extend its political and economic control over the previously distinct Pre-Aksumite populations (Phillipson 2012). Settlement patterns show a general continuity in occupation from previous Pre-Aksumite sites (e.g. Anfray 2012; Taddesse 2019), as does subsistence economies (Bard et al. 2000; Boardman 2000; Cain 2000; D'Andrea et al. 2008b, 2011).

According to exogenous historical sources (see Kobishchanov 1979; Munro-Hay 1991; Phillipson 1998), the 3rd century CE witnessed an important territorial expansion, with various kings of Aksum incorporating new territories into a centralized state, which adopted Christianity in the 4th century CE, marking the beginning of the Middle Aksumite phase (c. 350-500 CE) (Bard et al. 2014; Taddesse 2019). This polity featured a stratified society with urban centers such as Matara (Anfray 2012) or Beta Samati (Harrower et al. 2019) –organized by complex political, administrative and military structures– which minted its own official currency and maintained varying degrees of contact with foreign populations, both adjacent and distant (see Phillipson 2012: 71-106, 181-208; Fattovich 2019 for details). Nonetheless most Aksumite sites were rural, food-producing settlements; the number in mid-sized urban centers registered a steady increase until the 6th century CE. Available information points to differences in productive activities between urban and rural areas: the former featuring industrial activities which included metalworking and the manufacture of glass and ivory artifacts (Phillipson 2012), although the division was rarely rigid and available archaeological data is still incomplete.

The Late Aksumite period (c. 500-700 CE) marked the beginning of the Aksumite decline (Bard et al. 2014; Taddesse 2019). Archaeological evidence attests a social and economic crisis at Aksum during the 6th and 7th centuries CE, as reflected by the gradual reduction of the metropolis occupation and economic wealth (Fattovich 2010; Phillipson 2012). Nonetheless, a considerable number of rural compounds persisted (Sernicola and Sulas 2012) not only around Aksum, but also in other areas of the kingdom where population is believed to have only slightly decreased (Sernicola 2008; Philipson 2012; Harrower and D'Andrea 2014).

**Environment and vegetation**

The Tigray plateau extends over a total area of circa 50,000 square kilometers along the northern Ethiopian Highlands and is drained by the Tezeke and Mareb rivers. The geology of the area is mainly shaped by the volcanic activity associated with the East African Rift system, which has resulted in a landscape dominated by an irregular plateau ranging from 1,000 to 3,500 m.a.s.l. (Machado et al. 1998; Bard et al. 2000; Hagos et al. 2002; Gebru et al. 2009). Current Tigray shows a semi-arid, subtropical climate, characterized by a strong seasonality (Machado et al. 1998) with a main rainy season from June to mid-September (Araya et al. 2010). The marked variations in topography and altitude greatly influence environmental conditions, producing different microclimates within short distances (Hagos et al. 2002): mean annual temperatures range from 15º to 25ºC while mean annual rainfall ranges between 500 and 750 mm (Hadgu et al. 2013).

The region is highly sensitive to environmental changes due to its geographical position and mountainous terrain (Machado et al. 1998). As shown by paleoclimatic records from fluvio-lacustrine sediments (see Trauth et al. 2007; Lanckriet et al. 2015 for further explanation), marked environmental variation has characterized the Tigray Plateau since at least the Early Pleistocene (c. 2.5 mya), with a general tendency towards aridification, alternating with relatively humid periods until the beginning of the Holocene when the East African Humid Period begun (c. 9000 – 3600 BCE) (Nyssen et al. 2004; Tierney et al. 2011). Nonetheless, dry events have been documented during these moister millennia (Marshall et al. 2009, 2011), which finally gave place to a period of landscape destabilization and reduced precipitation, reaching its minimum level from 2200 BCE onwards (Lanckriet et al. 2017) –when present-day climatic conditions were established (Bard et al. 2000). The subsequent centuries featured a significant increase in sediment supply (Machado et al. 1998) and colluvial activity (Moeyersons et al. 2006), while C4 plants became increasingly abundant (Gebru et al. 2009). Such a tendency would have reached its peak between 800-500 BCE, when there was a rapid decline of Afromontane forests, substituted by Afromontane woodlands and grasslands that persisted until the beginning of the 2nd millennium CE (Bard et al. 2000; Darbyshire et al. 2003; Sulas et al. 2009). The shift to a relatively wetter climate between 450 BCE and 500 CE, along with decreased soil erosion rate (Ciampalini et al. 2008) and diminished sediment supply (Machado et al. 1998) allowed landscape stabilization (French et al. 2009). At this period, palynological analyses indicate a predominance of grasses together with some arboreal plants and scrubs related to wooded grassland environments, as well as Afromontane forests (see Bard et al. 2000; Darbyshire et al. 2003; Sulas et al. 2009). After 500 CE, the landscape in the highlands started to degrade once again. Geoarchaeological research has shown that deforestation and intensification of land-use related to the Aksumite kingdom led to erosion and soil degradation (French et al. 2014). This tendency would have lasted for at least 300 years, until the beginning of the 9th century CE –coinciding with the decline of the Aksumite Kingdom– when geoarchaelogists have identified the last major period of landscape recovery (Machado et al. 1998; Bard et al. 2000).

Presently the area is largely devoid of forest vegetation, with almost all available land under cultivation or pasture. Nonetheless, based on colonial sources most scholars agree that a large area of the northern Highlands of Ethiopia was forested in earlier times (see references in Bard et al. 2000). Due to the lack of paleobotanical research, scholars have used ecological and bioclimatic data to reconstruct the distribution of past vegetation communities. According to Bard et al. (2000: 67-69) the Tigray region featured great floristic complexity, especially in relation to altitude: the primary vegetation of Tigray was dry evergreen montane forest dominated by *Juniperus procera* and *Olea europaea* subsp. *cuspidata* at altitudes above 2,200 meters, mixed *Podocarpus-Juniperus* forest on more humid areas between 1,400-2,200 meters and *Acacia* wooded grassland at altitudes below 2,200 meters. Available pedo-anthracological data confirms the presence of both *Juniperus-Olea* forests and *Acacia* wooded grasslands in the Tigray Plateau from 7,800 years ago until today (Gebru et al. 2009; Terwilliger et al. 2011). How such natural woodland landscape evolved into the current vegetation patterns has yet to be resolved. Most explanations coincide in the double effect of climate change and human activities (Butzer 1981; Bonnefille and Mohammed 1994; Machado et al. 1998; Bard et al. 2000; Darbyshire et al. 2003; Gebru et al. 2009) though the details about their relative significance remain unknown. Modern botanical surveys (Friis 1992; Friis et al. 2010; Kindt et al. 2011a, b, c; van Breugel et al. 2015) over the past 30 years have added further complexity to the current vegetational landscape of Tigray (Table 1). According to van Breugel et al. (2015), the Northeastern regions of modern Tigray are covered by a combination of predominant undifferentiated (DAF/U) and dry-single dominant (DAF/SD) Afromontane forests, along with significant areas of Afromontane woodlands, wooded grasslands and grasslands (DAF/WG). Friis et al. (2010) notes that Afromontane forests (DAF) can be understood as a gradient from wetter (DAF/U) to drier (DAF/SD and DAF/WG) types. More importantly, DAF/WG represents a degradation type of DAF, sharing an increasing number of taxa with more arid vegetation units from lower altitudes such as *Acacia-Commiphora* woodlands and bushlands proper (ACB), *Acacia* wooded grasslands of the Rift Valley (ACB/RV) or desert and semi-desert scrublands (DSS) (Friis et al. 2010). ACB and ACB/RV are recorded in the lower margins of the Tigrinya Highlands, especially in the eastern escarpment leading to the lowlands of the Afar region, mostly characterized by DSS (Friis et al. 2010; Breugal et al. 2015). The rest of the province is dominated by *Combretum-Terminalia* woodlands and wooded grasslands (CTW) (van Breugel et al. 2015). Finally, small patches of vegetation associated with the Ericaceous (EB) and Afroalpine (AA) belts can be found throughout the entire Tigrinya Highlands at altitudes above 3,000 m.a.s.l. (Friis et al. 2010; van Breugel et al. 2015).

**Table 1** Main vegetation units in modern Tigray with their dominant woody genera (adapted from Friis et al. 2010, van Breugel et al. 2015)

| **Vegetational unit** | **Altitude (m.a.s.l.)** | **Main genera** | **Secondary genera** |
|---|---|---|---|
| Undifferentiated Afromontane forests (DAF/U) | 1,500 - 2,700 | *Juniperus, Podocarpus, Olea, Croton, Ficus* | *Allophylus, Apodytes, Bersama, Carissa, Celtis, Discopodium, Dombeya, Dovyalis, Dracaena, Ekebergia, Erythrina, Hagenia, Halleria, Millettia, Lepidotrichilia, Lobelia, Maytenus, Myrsine, Olinia, Pittosporum, Prunus, Teclea, Vepris* |
| Dry single-dominant Afromontane forest (DAF/SD) | (1,600 -) 2,200 - 3,200 | *Juniperus, Olea* | *Carissa, Calpurnia, Clausena, Clutia, Discopodium, Euclea, Grewia, Hagenia, Maesa, Morella, Psydrax, Teclea, Rhus* |
| Afromontane woodlands, wooded grasslands and grasslands (DAF/WG) | 1,400 - 2,200 | *Acacia, Euclea, Dodonaea, Maytenus, Rhus* | *Acanthus, Buddleja, Grewia, Heteromorpha, Myrsine, Nuxia, Osyris, Podocarpus, Protea* |
| *Combretum-Terminalia* woodland and wooded grassland (CTW) | 400 - 1,900 | *Combretum, Terminalia* | *Acacia, Anogeissus, Balanites, Boswellia, Cussonia, Dalbergia, Grewia, Lanea, Lonchocarpus, Piliostigma, Pterocarpus, Vitex* |
| *Acacia-Commiphora* woodland and bushland proper (ACB) | 400 - 1,900 | *Acacia, Commiphora* | *Boswellia, Balanites, Boscia, Cadaba, Combretum, Terminalia* |
| *Acacia* wooded grassland of the Rift Valley (ACB/RV) | 400 - 1,800 | *Acacia* | *Capparis, Carissa, Croton, Dodonaea, Euphorbia, Grewia, Rhus, Scutia, Tarenna* |
| Desert and semi-desert scrublands (DSS) | 0-400 | *Acacia, Boswellia, Commiphora, Gyrocarpus, Kissenia, Ochradenus, Diceratella, Cadaba, Ziziphus* | |
| Ericaceous belt (EB) | > 3,000 | *Erica, Hypericum, Myrsine* | |
| Afroalpine belt (AA) | > 3,000 | *Erica, Hypericum* | |

## Study area

Located 15 kilometers north of Adigrat, the Gulo Makeda region was recognized as a part of the Pre-Aksumite and Aksumite territories long ago (Anfray 1973; Michels 1988; Munro-Hay 1991). Available archaeological evidence indicates that people have occupied Gulo Makeda for at least 3000 years (Harrower and D'Andrea 2014) and several archaeological sites have been described (Rossini 1928; Coulbeaux 1929; Mordini 1941; Caquot and Drewes 1955; Anfray 1966, 1972, 1973, 1974; D'Andrea et al. 2008a; Sernicola 2012; Harrower and D'Andrea 2014). Although numerous, these sites are generally smaller than those in western Tigray (Harrower and D'Andrea 2014).

The Eastern Tigray Archaeological Project (ETAP) is currently carrying out interdisciplinary studies with the aim to better understand how Pre-Aksumite and Aksumite populations interact with the surrounding environment. The present paper explores the cultural and socio-ecological behaviors that underlie the gathering, management and utilization of wood resources as fuel, analyzing charcoal samples from Mezber and Ona Adi. Both sites were inhabited during times of critical cultural developments, and together they provide a unique occasion to question the differences between rural and urban, and domestic and elite status in terms of wood availability and use, but also to investigate human-environmental interactions, and their evolution between the mid-2$^{nd}$ millennium BCE and the late-1$^{st}$ millennium CE.

### *Mezber*

The site of Mezber (Aby Adi, Tabia Addis Alem) covers approximately 0.83 ha and lies on a slightly raised hillside situated in a valley bottom adjacent to an intermittent stream at 2,242 m.a.s.l. (Woldekiros and D'Andrea 2017). Archaeological work has documented an extended occupational sequence dated from 1600 cal. BCE to 1 cal. CE. No other site in the region has recorded such an early occupation with associated Pre-Aksumite cultural materials. Based on ceramics, stratigraphy and radiocarbon dating, four pre-Aksumite horizons with at least two building construction phases have been described. The earliest occupation of the site dates to the Initial phase (c. 1600-900 BCE) and is followed by Early (c. 850–750 BCE), Middle (c. 600–400 BCE) and Late (c. 400 BCE–1 CE) pre-Aksumite phases. The site is one of only a few known Pre-Aksumite sites that have been undisturbed by later settlement. Archaeobotanical, zooarchaeological and isotopic evidence at Mezber document a fully developed agropastoral economy (Woldekiros and D'Andrea 2017; Beldados pers. comm.). The site has produced large-scale domestic architecture, suggesting the presence of wealthy or elite individuals in the Early phase, as well as evidence of specialized hide-working craft production in the Middle phase (Peterson 2017). The site was abandoned at the beginning of the 1$^{st}$ century CE for unknown reasons.

### *Ona Adi*

Ona Adi is located near the villages of Menabeity and Etchmare (Tabia Shewit Lemlem) at 2,452 m.a.s.l. The site is estimated to cover around 10 ha (Harrower and D'Andrea 2014) and was occupied between c. 750 BCE – 700 CE (Taddesse 2019). The ceramic sequence demonstrates that the site was occupied during the Pre-Aksumite to Aksumite (PA-A) transition, documenting 5 occupational phases: Mid/Late Pre-Aksumite (c. 750-400 BCE), PA-A Transition (c. 400 BCE – 1 CE), Early Aksumite (c. 1 – 330 CE), Middle Aksumite (c. 330 – 500 CE) and Late Aksumite (c. 500 – 700 CE) (Taddese 2019: 339). Noteworthy, it is the only systematically investigated site that has a record of occupation during the PA-A Transition, a period of cultural transformation which involved changes in leadership and settlement abandonment in the regional centers of Yeha and Aksum (D'Andrea et al. 2008a). Further analyses of lithics, animal bone, phytoliths and radiocarbon dating are currently ongoing.

## Materials and methods

### *Sampling*

Bulk soils samples were recovered between 2007 and 2015 at both sites, following a systematic sampling strategy. They were then floated using a recirculating bucket flotation system. Screens of both 1 mm and 0.25 mm mesh size were used in order to separate heavy and light fractions, which were subsequently air dried. Charcoal remains were sorted from the light fraction samples using a stereo microscope Leica EZ4 (7x-30x). Anthracological samples for analysis were selected according to stratigraphical criteria in order to represent the complete chrono-cultural sequence of both sites. They were all recovered from non-specialized long-term deposits to get a reliable environmental signature. A total of 25 samples from 9 different archaeological phases were weighted and separated for analysis (Table 2).

**Table 2** Mezber (MBR) and Ona Adi (OA) charcoal samples by phase

| Site | Phase | Field:Locus | Pail | Archaeological context | Sample number | Flotation volume (L) | Charcoal remains (g) | Analyzed fragments |
|---|---|---|---|---|---|---|---|---|
| MBR | Initial Pre-Aksumite | A1:54 | 108 | Living surface | 1126 | 0.2 | 0.28 | 232 |
| | | A1:54 | 109 | Living surface | 1337 | 5 | 1.55 | |
| | | A1:55 | 110 | Living surface | 1345 | 3.25 | 0.61 | |
| | Early Pre-Aksumite | A1:61 | 114 | Midden | 1585 | 9 | 7.88 | 315 |
| | | A1:67 | 146 | Infill | 1908 | 10 | 6.86 | |
| | | A1:74 | 156 | Infill | 2106 | 10 | 5.40 | |
| | Middle Pre-Aksumite | A1:72 | 154 | Infill | 2096 | 8 | 2.87 | 310 |
| | | A1:73 | 155 | Living surface | 2102 | 7.25 | 3.59 | |
| | | A1:73 | 155 | Living surface | 2110 | 4 | 7.55 | |
| | Late Pre-Aksumite | A1:10 | 42 | Infill | 18 | 0.3 | 0.58 | 306 |
| | | A1:10 | 45 | Infill | 20 | 0.55 | 8.06 | |
| OA | Late Pre-Aksumite | D1:13 | 23 | Infill | 1127 | 5 | 0.55 | 305 |
| | | D1:13 | 26 | Infill | 1139 | 7 | 0.89 | |
| | | D1:16 | 30 | Infill | 1163 | 4.5 | 7.35 | |
| | PA-A Transition | D1:13 | 22 | Living surface | 769 | 6 | 4.26 | 310 |
| | | D1:14 | 24 | Infill | 1131 | 4 | 8.05 | |
| | | D1:15 | 29 | Infill | 1157 | 2.5 | 3.04 | |
| | Early Aksumite | D1:10 | 18 | Infill | 1106 | 4 | 5.19 | 319 |
| | | D1:10 | 19 | Infill | 1110 | 6 | 24.95 | |
| | | D1:10 | 20 | Infill | 1118 | 5 | 3.26 | |
| | Middle Aksumite | D1:7 | 13 | Infill | 811 | 7 | 2.56 | 305 |
| | | D1:9 | 14 | Infill | 818 | 4 | 5.50 | |
| | | D1:10 | 17 | Infill | 843 | 4 | 5.85 | |
| | Late Aksumite | D1:3 | 5 | Living surface | 711 | 7 | 8.18 | 306 |
| | | D1:6 | 7 | Infill | 722 | 8 | 9.70 | |

*Identification, reference collection and data analysis*

Microscopic identification of charcoal fragments was routinely carried out at the archaeobotanical laboratories of the National Museum of Natural History, Paris (MNHN), and Pompeu Fàbra University, Barcelona (UPF), using a reflected light microscope with incident light and magnifications between 50x and 1000x. Botanical taxa were described following the codes proposed in the International Association of Wood Anatomists (IAWA) list of microscopic features for both hardwood (Wheeler et al. 1989) and softwood (Richter et al. 2004) identification. Taphonomic features such as charcoal size (<5 mm/5-10 mm/<10 mm), and the presence of natural (wood compression, tree ring alteration), biological (collapsed cells, xylophage activity, fungi alterations), combustion (radial cracks, vitrification), and diagenetic (post-depositional alterations, cell structure deformation) alterations (Fig. 2) were recorded as proposed by Allue et al. (2009).

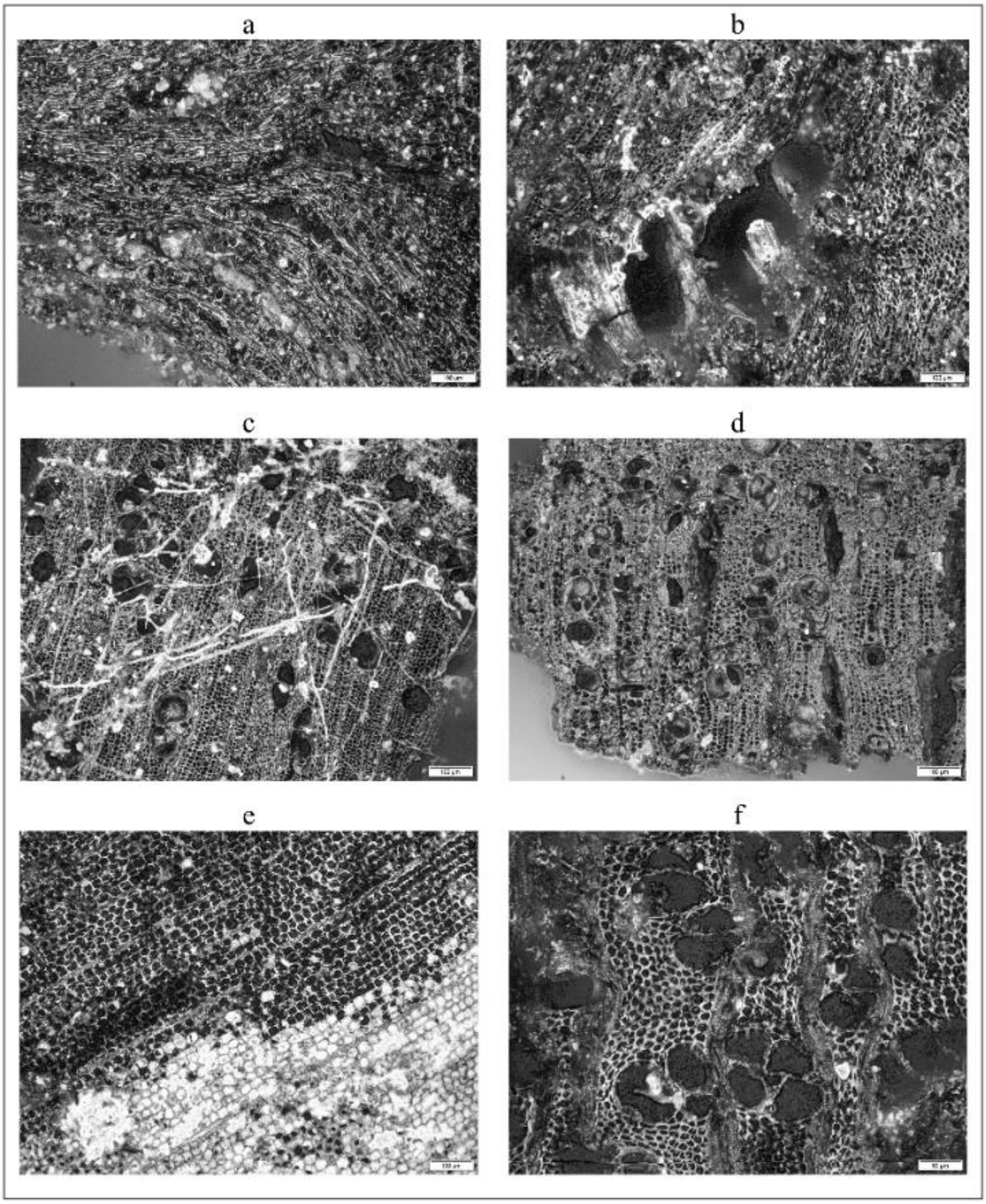

**Fig. 2** Microscopic photos showing examples of different alterations observed on Mezber and Ona Adi charcoal assemblages: a) Wood compression, b) Cell collapse due to xylophage activity, c) Fungi hyphae infestation, d) Radial cracks and vitrification, e) Post-depositional alteration, f) Cell-structure deformation

Taxonomic identification was achieved following the methodology proposed by Höhn and Neumann (2018) for charcoal identification in species-rich environments and comparing with modern reference material produced specifically for this study with samples obtained from the wood collections of the MNHN in Paris, and charcoal reference collection of the AASPE unit (UMR 7209, CNRS-MNHN). Plant taxa for this reference material were selected according to their importance amongst the vegetation units published by Friis et al. (2010) and their availability in the collections. The unburned wood samples were prepared for microscopic observation at the MNHN, following an adaptation of the procedure described by Orvis et al. (2005). Anatomical descriptions and images of all reference materials are available at the UPF e-Repository (https://repositori.upf.edu/handle/10230/43106). Online databases (InsideWood 2004-onwards) and published atlases were used to help and refine the identifications (e.g. Fasolo et al. 1939; Metcalfe and Chalk 1950a, b; Neumann et al. 2001; but see references in Supplementary Materials 1).

Data analysis was performed using relative frequencies of number of remains by charcoal type but also according to the vegetational units proposed by Friis et al. (2010), associating each taxa to the ecological groups in which they are common or predominant (Table 3) following previous research (Friis et al. 2010; Kindt et al. 2011a, b, c; van Breugel et al. 2015). The main vegetational units present in modern Northeastern Tigray were included (van Breugel et al. 2015). The frequencies of the vegetational units were calculated by summing the frequencies of the taxa associated with them. Undeterminable fragments were excluded from the data analysis. Various indexes and ratios were employed in order to assess taphonomic processes –Fragmentation/Preservation index (Lancelotti 2010), Density index (Asouti 2003)– as well as assemblage biodiversity and taxa distribution –Simpson's Diversity Index (Branch et al. 2005), Pielou's evenness index (Pielou 1966), and the Ubiquity rate (Miller 1988; Popper 1988) (see Supplementary Materials 2 for further explanations). In order to evaluate assemblage representativeness of the original deposits, we used effort curves, both qualitative and quantitative (Chabal et al. 1999; Asouti and Austin 2005). The Gini-Lorenz Index (Scheel-Ybert 2005; Dotte-Sarout et al. 2015) was applied to measure the ecological representativity of the assemblage. Statistical analyses were performed using PAST (Hammer et al. 2001), whereas graphic representations of the results were constructed using Microsoft Excel (2013) and Tilia (Grimm 1992) software.

## Results

### *Taphonomy*

Taphonomical alterations are presented in Fig. 3. No phase overcomes 60% of taphonomically affected charcoal fragments and accumulated means by site for Mezber and Ona Adi are 38% and 48% respectively. Alteration ratios are rather similar throughout the sequence of both sites. The most common alterations are associated with combustion (X=27%) and diagenetic processes (X=18%), whereas natural and biological agents show very low impact degrees in all phases (<4%). Despite such a degree of alteration, the Fragmentation/Preservation index (F/P) remains low (X=10%), meaning the general state of preservation allowed proposed taxonomic identifications for 90% of the charcoal fragments. Density, Simpson's diversity and Pielou's evenness indexes were calculated and compared against the taphonomical data by phase and type of context. The results show no correlation, indicating that taphonomy did not severely impact charcoal density nor plant biodiversity hence suggesting the studied assemblage was well preserved. Raw data is available electronically as supplementary material (Supplementary Materials 3).

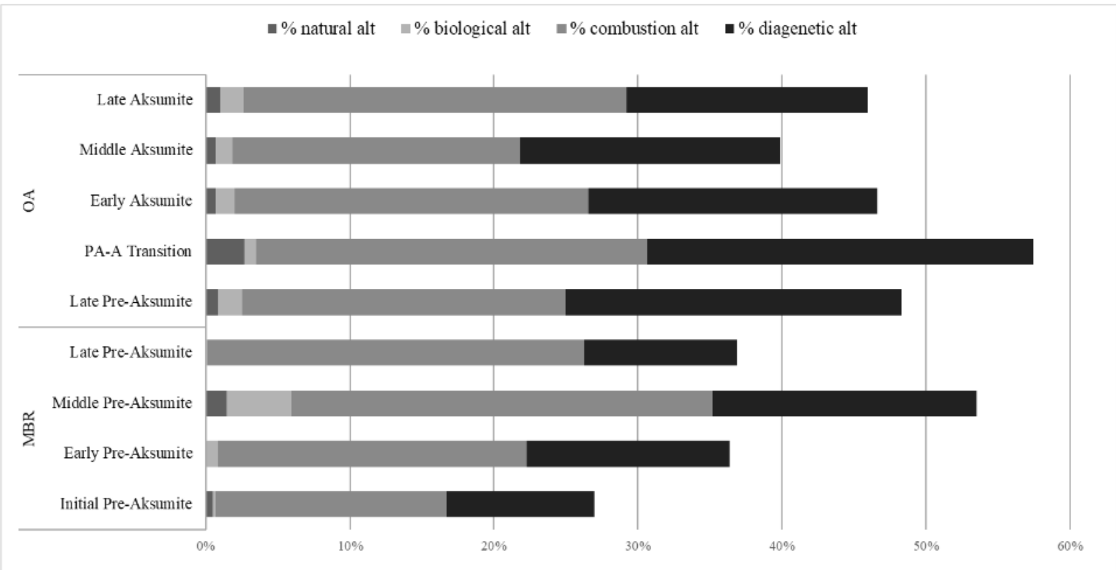


**Fig. 3** Summary of taphonomical alterations by phase (including all analyzed fragments)

Quantitative and taxonomic curves (Supplementary Materials 4) from all phases are recognized as saturation curves, showing a clear stabilization tendency after 200 fragments analyzed hence indicating that species frequencies by phase are a fair representation of the originally deposited assemblage and that every significant taxon is represented. Finally, Gini-Lorenz index results (Supplementary Materials 4) vary between 30:70 and 23:77, with a rounded media of 26:74 for Mezber and 29:71 for Ona Adi. As such, both assemblages can be considered as representative of the past vegetation and no taxa appears to be significantly overrepresented.

*Taxonomic results*

A total of 2,708 charcoal fragments were studied, of which 2,428 were identified at different taxonomic levels. Raw data is available electronically as supplementary material (Supplementary Materials 5). 23 different plant types were documented, both angiosperms (21) and gymnosperms (2). Taxonomic identifications were proposed for all types except 3 angiosperms which remain unidentified. We found 4 distinct *Acacia* types, although their identification to species level was not possible and therefore, they were grouped and listed as *Acacia* spp. Detailed anatomic descriptions and images of the 17 identified charcoal types, as well as a discussion of each taxonomic classification can be found as supplementary materials (Supplementary Materials 1). Tables 3 and 4 synthesize both ecological distribution and wood features of the identified taxa.

**Table 3** Summary of the identified taxa ecological distribution after Friis et al. (2010), Kindt et al. (2011a, b, c) and van Breugel et al. (2015): 0 = absent or not recorded; * = present, but minoritary, ** = common, *** = predominant; Grey = included in analysis as a part of the vegetational unit.

| Identified taxa | Altitude (m.a.s.l.) | DAF/U | DAF/SD | DAF/WG |
|---|---|---|---|---|
| *Acacia* spp. | 0 - 3,100 | 0 | 0 | *** |
| *Carissa* spp. | 550 - 2,500 | * | *** | * |
| cf. *Boscia* spp. | 50 - 1,900 | 0 | 0 | ** |
| *Croton* spp. | 500 - 2,350 | ** | 0 | *** |
| *Dodonaea angustifolia* | 500 - 2,900 | * | ** | *** |
| *Hagenia abyssinica* | 2,450 - 3,250 | ** | ** | * |
| *Juniperus procera* | 1,100 - 3,500 | *** | *** | 0 |
| *Maerua* spp. | 0 - 2,100 | 0 | 0 | ** |
| *Maytenus* spp. | 380 - 3,500 | ** | * | *** |
| *Nuxia* spp. | 800 - 3,800 | * | ** | ** |
| *Olea* spp. | 1,250 - 3,200 | *** | *** | * |
| *Pittosporum* spp. | 1,400 - 3,200 | ** | * | * |
| *Podocarpus falcatus* | 1,350 - 2,900 | *** | 0 | 0 |
| *Rhamnus* spp. | 1,175 - 3,200 | ** | *** | * |
| *Rhus* spp. | 700 - 2,800 | 0 | * | *** |
| Rubiaceae cf. Ixoroideae | 400 - 3,000 | ** | ** | ** |
| *Ziziphus* spp. | 0 - 2,400 | 0 | 0 | ** |

**Table 4** Summary of the identified taxa wood features and uses (von Maydell 1990; Ruffo et al. 2002; Bekele-Tesemma 2007; Louppe et al. 2008; Gebreselassie et al. 2014)

| Identified taxa | Hardness | Quality as fuel | Resistance to pests | Durability | Other uses than fuel |
|---|---|---|---|---|---|
| *Acacia* spp. | Hard | Good | Variable | Durable | Instruments |
| *Carissa* spp. | Hard | Good | Medium | Durable | Instruments |
| cf. *Boscia* spp. | Hard | Good | High | Durable | Instruments |
| *Croton* spp. | Soft | Good | Low | Perishable | Construction, instruments |
| *Dodonaea angustifolia* | Hard | Good | High | Durable | Instruments |
| *Hagenia abyssinica* | Soft | Good | Low | Perishable | Construction, instruments |
| *Juniperus procera* | Medium | Good | High | Durable | Construction |
| *Maerua* spp. | Hard | Good | Variable | Durable | Instruments |
| *Maytenus* spp. | Hard | Good | Variable | Durable | Construction |
| *Nuxia* spp. | Hard | Good | Variable | Durable | Construction |
| *Olea* spp. | Hard | Good | High | Durable | Construction, instruments |
| *Pittosporum* spp. | Soft | Bad | Low | Perishable | Instruments |
| *Podocarpus falcatus* | Soft | Good | Low | Durable | Construction |
| *Rhamnus* spp. | Hard | Good | Variable | Durable | Instruments |
| *Rhus* spp. | Soft | Good | Low | Perishable | Construction, instruments |
| Rubiaceae cf. Ixoroideae | Variable | Variable | Variable | Variable | Variable |
| *Ziziphus* spp. | Hard | Good | High | Durable | Construction, instruments |

*Descriptive and quantitative results of Mezber.*

A total of 19 taxa - 3 of which remain unidentified - were recorded amongst the 1,163 charcoal fragments analyzed from Mezber samples. Angiosperms account for 98% of the total assemblage, which is dominated by the Afromontane woodlands, wooded grasslands and grasslands (DAF/WG) genus *Rhus* spp. (27%) and the undifferentiated (DAF/U) and dry-single dominant (DAF/SD) Afromontane forests genus *Olea* spp. (24%). Despite the plant diversity and the *Rhus-Olea* predominance, the assemblage shows a rather high species evenness: 79% of the taxa range between 1 and 7% of the identified charcoal fragments. Indeed, results by phase reveal a rather stable degree of biodiversity, as 13 taxa have been found to be present at all phases. Still, diachronic variation is evident in plant distribution (Fig. 4).

The Initial pre-Aksumite phase features a weaker dominance of *Rhus-Olea* than the site average. *Olea* and *Rhus* spp. are accompanied by the DAF/WG genus *Acacia* spp. and the DAF/SD genus *Carissa* spp. Unlike the following occupations of Mezber, during this phase the exploitation of wood appears undifferentiated, with all vegetational groups exploited similarly and a more even distribution of species (see Figure 4). The subsequent Early Pre-Aksumite phase indicates a higher rate of DAF/U and DAF/SD exploitation, whereas DAF/WG percentage is reduced. This occupation' assemblage is widely dominated by *Olea* spp., accompanied by *Rhus* spp., *Dodonaea angustifolia* and *Croton* spp. The DAF/U and DAF/SD gymnosperm species *Juniperus procera* and DAF/U *Podocarpus falcatus* both score under 3% - despite their potential dominance in the DAF/U and DAF/SD vegetational units, both taxa reach their highest values of the site sequence in this phase. This situation changes during the Middle Pre-Aksumite phase, when *Olea* spp. presents its lowest occurrence values in favor of *Rhus* sp. During this phase, DAF/U and DAF/WG are significantly reduced, whereas DAF/WG significantly rises: its presence is well attested by lower-storey taxa such as cf. *Boscia* sp. and *Dodonaea angustifolia,* even though the DAF/WG emblematic taxon, *Acacia* spp., scores under 1%. Lastly, the Late Pre-Aksumite phase at Mezber shows a relative recovery of the *Olea* spp. exploitation versus *Rhus* spp., while the rest of the taxa remains relatively stable. As a result, DAF/U and DAF/SD feature a meaningful increase though DAF/WG maintains its predominance.

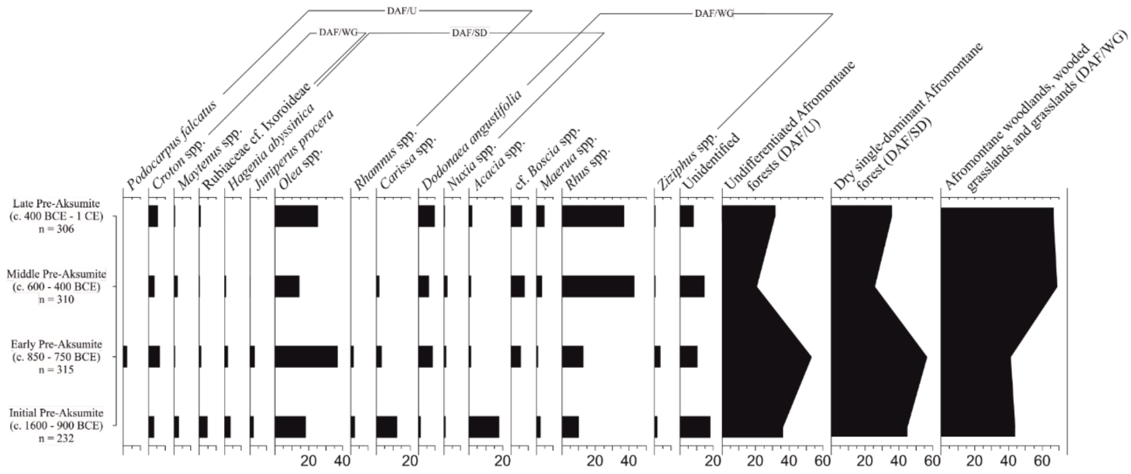


**Fig. 4** Anthracological diagram of Mezber by chronocultural phase

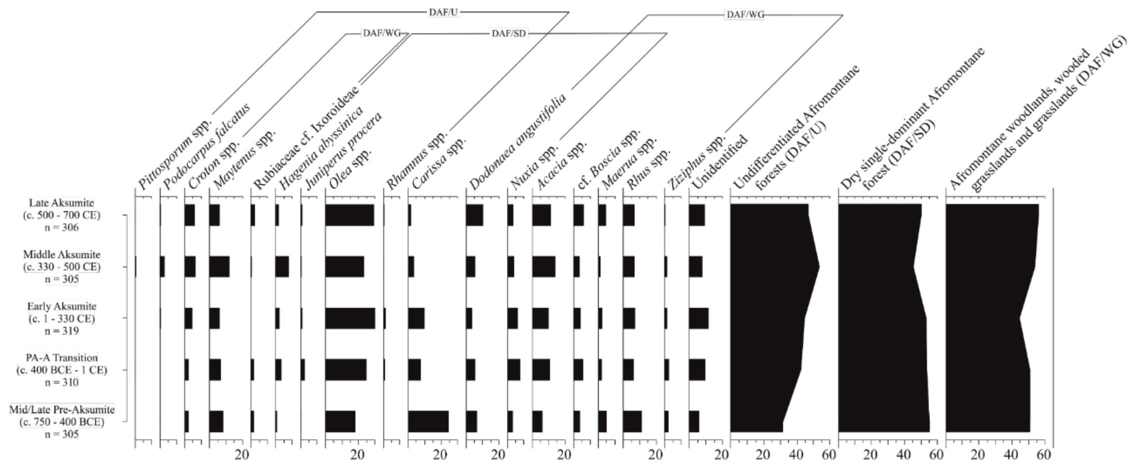


**Fig. 5** Anthracological diagram of Ona Adi by chronocultural phase

*Descriptive and quantitative results of Ona Adi.*

As for Ona Adi, 1,545 charcoal fragments were studied and a total of 20 plant types were identified, including 3 unidentified angiosperms. Angiosperms account for 98% of the total assemblage. The assemblage is dominated by DAF/U and DAF/SD genus *Olea* spp. (25%) along with the DAF/WG genus *Acacia* spp. (10%), and the DAF/SD genus *Carissa* spp. (9%). Ona Adi assemblage features high biodiversity in all phases: 80% of the taxa are present in all phases. Fig. 5 presents taxa distribution and its variation throughout occupational phases.

Late Pre-Aksumite samples are dominated by *Carissa* spp. followed by *Olea* and *Rhus* spp. This phase features the lowest occurrence of the main DAF/WG genus *Acacia* spp. During the Pre-Aksumite to Aksumite Transition phase, the assemblage primarily features *Olea* and *Acacia* spp. The main secondary taxa are from the DAF/WG vegetational unit namely *Rhus* and cf. *Boscia* spp., as well as *Dodonaea angustifolia*, *Nuxia* spp. (both also present in DAF/SD), and *Maytenus* spp. (also in DAF/U) showing values between 5 and 8%. The DAF/U and DAF/SD gymnosperm *Juniperus procera* scores 3%. During this phase, there is a rather even distribution between the three vegetational units that will continue during the Early Aksumite phase, with mild differences on the most common taxa: whereas *Olea* spp. and *Carissa* spp. slightly increase during this phase, the presence of *Acacia* spp., as well as other secondary taxa from the DAF/WG (e.g. cf. *Boscia*, *Ziziphus* spp.) is similarly reduced. This continuity extends to the Middle

Aksumite occupation even though some differences are recorded as *Olea* spp. dominance decreases in favor of *Acacia* spp. At the same time, however, other DAF/U and DAF/SD taxa such as *Hagenia abyssinica* and *Podocarpus falcatus*, as well as the DAF/U and DAF/WG *Maytenus* and *Croton* spp. respectively feature their highest occurrence. Some of the secondary species exclusively associated with the DAF/WG formations (e.g. cf. *Boscia, Maerua* spp.) score their lowest values. Finally, even though the Late Aksumite phase witnesses a relative recovery of the *Olea* spp., the overall distribution of the vegetational units maintained its stability: the small decrease of *Acacia* spp. is balanced by relatively higher scores of the secondary taxa from the DAF/WG unit (e.g. cf. *Boscia, Maerua* spp.), while the secondary species of DAF/U and DAF/SD (e.g. *Hagenia abyssinica*, *Podocarpus falcatus*) appear slightly reduced.

**Discussion**

*Landscapes and woodland vegetation*

Despite the well-known problems with paleoenvironmental interpretations derived from anthropic anthracological assemblages (see Chabal et al. 1999; Asouti and Austin 2005; Dotte-Sarout et al. 2015), the general homogeneity of plant taxa distribution through the archaeological sequence of both Mezber and Ona Adi suggests that no major climate changes took place in Northeastern Tigray during the Pre-Aksumite and Aksumite periods, in accordance with pedo-anthracological and isotope geochemical analyses developed in the region (Gebru et al. 2009; Terwilliger et al. 2011). The anthracological data from Mezber and Ona Adi show that people were exploiting taxa originating from at least three separate vegetation units –both Undifferentiated (DAF/U) and dry single-dominant (DAF/SD) Afromontane forests, as well as Afromontane woodlands, wooded grasslands and grasslands (DAF/WG)– throughout the entire sequence of occupation at both sites. This is consistent with the current vegetational landscape as described by van Breugel et al. (2015), and it is also in accordance with present vegetation distribution by altitude: Friis et al. (2010) records the presence of DAF/U, DAF/SD and DAF/WG between 1,400 and 3,200 m.a.s.l., concurring with the locations of both Mezber (2,242 m.a.s.l.) and Ona Adi (2,452 m.a.s.l.).

Previous palynological studies in more southern areas of the northern Ethiopian Highlands have suggested a significant decline of Afromontane forests (DAF/U and DAF/SD) between 800 and 500 BCE in the Tigray province, and their almost complete substitution by afromontane wooded grasslands (DAF/WG) by the 2$^{nd}$ millennium CE. (Bard et al. 2000; Darbyshire et al. 2003). According to these studies, this deforestation process was the combined result of drier environmental conditions and anthropic activity (Bard et al. 2000; Darbyshire et al. 2003). However, the present study indicates that even if the use of wood from taxa associated with the DAF/U and DAF/WG units declined after the Early Pre-Aksumite phase (c. 750 BCE), they continued to be consistently exploited after 400 BCE at both Mezber and Ona Adi sites. On the one hand, this supports the argument of anthropogenic deforestation - as DAF/WG represent a degraded type of Afromontane vegetation, mainly through human impact (Friis et al. 2010). On the other hand, it indicates that such inflection was not as widespread in space and time as previously suggested by the palynological record (Bard et al. 2000; Darbyshire et al. 2003). This discrepancy could be attributed to intra-regional heterogeneous environmental conditions, similar to what has been described for modern Tigray (Hagos et al. 2002), where a wide array of microclimates within very short distances are recorded. In this sense, changes at regional-scale level might have affected the studied area differently than other areas, hence explaining contradictions with the palaeoecological studies from southernmost regions (e.g. Bard et al. 2000; Darbyshire et al. 2003; Sulas et al. 2009).

The rapid reestablishment of the exploitation of Afromontane forests species after the Late Pre-Aksumite phase overlaps with a shift to a relatively wetter climate and landscape stabilization documented at c. 450 BCE by several authors (Machado et al. 1998; Ciampalini et al. 2008; French et al. 2009). The use as fuel of species associated with the DAG/WG formation such as *Acacia* spp. increases by 10% from the PA-A Transition (400 BCE - 1 CE) onwards at Ona Adi. This could be associated with the aforementioned expansion of DAF/WG. Recent studies have shown no evidence of general changes in climate and suggested that land-clearing practices played a more meaningful role in shaping the surrounding landscape (Terwilliger et al. 2011). The results presented in this study support the hypothesis that such increase is the product of anthropic selection and may not be related to environmental shifts. A comparable situation can be observed between c. 500-800 CE, when a period of environmental degradation has been documented (Marshall et al. 2009; French et al. 2014). During these centuries, Middle and Late Aksumite phases at Ona Adi show continuity in woodland exploitation as no significant changes are identified. This indicates that the abandonment of Ona Adi after c. 700 CE - which coincides in time with the disappearance of the Aksumite Kingdom - was not related to an extreme anthropogenic deforestation process resulted from intense land-clearing activities.

*Firewood selection and management strategies at Mezber and Ona Adi*.

The anthracological data from both Mezber and Ona Adi show that a high variety of woody species was exploited. 23 plant types have been identified in the anthracological record, associated with at least 3 vegetational types. The exploited taxa mostly featured hard and durable wood, performing well as fuel. Notable exceptions, characterized by soft and easily perishable wood, include *Rhus* spp., *Hagenia abyssinica* and *Croton* spp. (von Maydell 1990; Ruffo et al. 2002; Bekele-Tesemma 2007; Louppe et al. 2008). Preferences and selection criteria are evident in both assemblages: favored species include *Rhus* and *Olea* spp. at Mezber, representing more than half of the assemblage whereas at Ona Adi the most common taxa are *Olea, Acacia,* and *Carissa* spp., composing almost half of the total analyzed charcoal fragments. The presence in the record of lower quality firewood can be related to the accidental or deliberate burning of woody construction elements and instruments at the end of their life cycles. For example, *Pittosporum* spp. is known to be employed in basketry production. The use of taxa featuring bad-smelling wood at firing, such as *Dodonaea angustifolia* or *Hagenia abyssinica* (Liu and Noshiro 2003; Gebreselassie et al. 2014) could be associated with a similar phenomenon, since the wood of both species is known to be suitable for construction and instrument manufacture (Ruffo et al. 2002). Finally, Afromontane forest gymnosperms such as *Juniperus procera* or *Podocarpus falcatus* were rarely exploited, although their presence in the studied region is well attested by pedo-anthracological analyses, constituting up to 50% of the past woodland vegetation during Pre-Aksumite and Aksumite times (see Gebru et al. 2009: 76). While the latter does not perform well as fuel and it is not a durable wood, the former features a high-quality firewood (Chudnoff 2007). They both produce high quantities of dead biomass and are thornless. The virtual absence of *Juniperus procera* could be explained by both functionalist or symbolic reasons: even though a cultural taboo is possible –as it has been documented amongst the Konzo of southwestern Ethiopia (Amborn 2002)– we argue that its low occurrence was probably due to the fact that these species grow in closed forest. By examining the anthracological records from Mezber and Ona Adi it would seem that both Pre-Aksumite and Aksumite people did not enter closed forests to recover wood, but they rather gathered firewood from open forests and forest margins instead, as they were more accessible.

Despite the high degree of homogeneity in both assemblages, we argue that selection strategies may have changed through time based on the distinctive characteristics of the wood used. First, during the Initial Pre-Aksumite phase at Mezber, a generalist approach is observed: main and secondary taxa from all vegetation types are used in similar proportions. According to Asouti and Austin (2005), this type of strategy is characteristic of mobile hunter-gatherers and nomadic pastoralists. The presence of nomadic and semi-nomadic cattle herders in Eastern Tigray since at least the 2$^{nd}$ millennium BCE is attested by the rock art (see Fattovich 2019: 254-255). The Initial Pre-Aksumite phase at Mezber thus represents one of the oldest Pre-Aksumite occupations of the Ethiopian highlands (c. 1600-900 BCE), which origin has been linked to previous seasonal movements of pastoral communities from the Sudanese lowlands, as suggested by their ceramicware and lithic equipment, both associated with an agro-pastoral economy (see Fattovich 2012; Phillipson 2017).

The Early Pre-Aksumite phase shows signs of selection criteria and specialization. From this phase onwards, Afromontane forests (DAF/U and DAF/SD) taxa, and especially *Olea* spp., were preferred over other taxa at Mezber: availability, caliber and state of the firewood were surely crucial factors, but its high quality as fuel, along with its hardness, durability and resistance to pests cannot be overlooked (Bekele-Tesemma 2007; Gebreslassie et al. 2014). As very few Pre-Aksumite settlements have shown an occupation as ancient as Mezber, the importance of the presence of specific desirable resources such as high-performance firewood could have played a vital role in the prolonged occupation of the site. However, the overexploitation of *Olea* spp. - along with the mentioned period of forest degradation between 800 and 500

BCE (Darbyshire et al. 2003) - would have rendered *Olea* spp. wood less easily accessible, hence forcing a change in the main source of firewood. As so, the Middle and Late Pre-Aksumite phases at Mezber witnessed the substitution of *Olea* for *Rhus* spp. as the principal focus of wood exploitation. During these phases, *Rhus* spp. exploitation was as predominant as *Olea* spp. was during the previous phases, hence indicating that there was not a change in the firewood selection strategy, but merely the election of a newly preferred taxon based on its availability and performance as fuel. The choice of *Rhus* spp. as the *Olea* substitute can be understood if we consider that both species share a similar ecological niche in their respective vegetational units - occurring in well-drained soils with good access to sunlight (Ruffo et al. 2002; Bekele-Tessema 2007) - hence after DAF/U and DAF/SD degraded into DAF/WG, *Olea* spp. would have retreated in favor of *Rhus* spp. Despite the presence of a new focused taxon, *Olea* spp. was still collected and used as firewood during Middle and Late Pre-Aksumite times, indicating how valued its wood was.

A different situation can be observed at Ona Adi during the Late Pre-Aksumite phase, when the exploitation of *Olea* spp. seems to have been complemented mainly with *Carissa* spp. –a DAF/SD genus which also grows in well drained soils requiring sunlight access. The wood selection pattern at Ona Adi remained fairly steady throughout the entire occupation of this Aksumite site, featuring a more generalized wood selection strategy than the community at Mezber. Although the recovery of the DAF/U and DAF/SD units re-established *Olea* spp. hegemony as the preferred taxon, the exploitation of DAF/WG taxa such as *Acacia* spp. remained fairly constant –even increasing through time in detriment to *Carissa* spp. We argue that this trend is associated with the introduction of new selection criteria. These taxa provide not only excellent firewood, but also are highly resistant to pest attack (von Maydell 1990; Ruffo et al. 2002). This would have been fundamental for an urban site such as Ona Adi, where most of the inhabitants –and especially the elites– were unlikely to gather firewood themselves. Instead, they would have acquired and stored it, as suggested by the presence of fungi infested wood in the Ona Adi charcoal assemblage –absent at Mezber. The recorded taxa at Ona Adi are mainly local, so the acquired wood was not from external tradesmen as suggested by Phillipson (2012). Another possible explanation is related to the introduction of industrial production activities at Ona Adi by its Aksumite inhabitants (see Phillipson 2012 for a review of industrial production during Aksumite times). The wood requirements of a manufacturing community such as Ona Adi are different from those of rural settlements such as Mezber, and differences in wood selection can also be produced by the quality for charcoal production - e.g. *Acacia* spp. is commonly preferred for charcoal production in modern Ethiopia (Bahru et al. 2012; Bekele and Girmay 2014). High quantities of fuel are needed to carry out industrial activities such as pottery or metal production, for which storage suitability is again a crucial factor. Since all analyzed samples were retrieved from generalized contexts, and no differences by type of contexts have been documented, this question remains unsolved.

**Conclusion**

The anthracological study performed on Mezber and Ona Adi charcoal assemblages has revealed insights into the past socio-ecological systems and human-woodland relationships in northeastern Tigray during Pre-Aksumite and Aksumite times. The analyses have recorded the presence of plant taxa related to undifferentiated (DAF/U) and dry-single dominant (DAF/SD) Afromontane forests as well as Afromontane woodlands, wooded grasslands and grasslands (DAF/WG) at both Mezber and Ona Adi. Furthermore, our results show coherence and consistency at both intra- and inter-site levels. This continuity of plant diversity points to rather stable environmental conditions at a local level, with no major climatic or environmental changes. Our data also shows an important process of anthropogenic deforestation during the early-to-mid 1st millennium BCE. However, this process of landscape degradation does not appear to be as dramatic as previously suggested by the palynological record. As so, we suggest that the current mosaic of microclimates and short distance environmental variation was in existence during the mid-2nd BCE to late-1st millennium CE. Further palaeoecological analyses are needed, in order to build a data corpus that allows palaeoenvironmental reconstruction at both local and regional levels.

Our results also suggest that both Mezber and Ona Adi populations exploited most of the surrounding habitats as a wide variety of woody plants were used as fuel. There are, however, some points to be emphasized. On the one hand, the ecological features of the identified taxa suggest that wood collection was mostly carried out in open forests and forests margins. On the other hand, the economical features of the wood exploited point to the existence of selection criteria employed at both sites. In this sense, at least 3 different approaches to the use of firewood resources, as well as a diachronic evolution through time, were identified: a generalist strategy; a burning quality-oriented selection criterion; and a storage-oriented strategy. The differences between strategies seem to respond to a functionalistic cause, mainly related to the type of occupation by ancient settlers at Mezber and Ona Adi. The generalist approach has been identified at the earliest occupation of Mezber, the Initial Pre-Aksumite phase. We argue that this first occupation could have been started by a small group of people featuring low intensity agro-pastoral activities. The burning-quality oriented strategy developed at Mezber from the Early Pre-Aksumite phase onwards would be consistent with an established self-sufficient non-elite rural community. Finally, an elite urban center such as Ona Adi would have employed diverse selection criteria in order to be able to secure the proper storage of the wood resources and perhaps support industrial activities. At any rate, new anthracological analyses of specialized contexts related to both domestic and industrial activities are needed in order to further test these hypotheses. Nonetheless, we reckon that wood exploitation strategies were an important aspect of both Pre-Aksumite and Aksumite cultures and that they evolved accordingly to both human necessities and woodland availability, hence playing a significant role in the development of ancient complex societies in the northeastern Ethiopian highlands.

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