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A Review on Benefits, Distribution and Threat of Combretum-Terminalia Woodland Ecosystem in Ethiopia Biodiversity

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***Abstract*: *The Combretum-Terminalia Woodland Ecosystem is one of the ecosystems with the highest biodiversity in Ethiopia, ranking among the top ten ecosystems. The ecosystem comprises a diverse array of fauna and flora species. Ethiopia is a land of geographical contrasts, with elevations that range from 125 m below sea level in the Danakil Depression to 4533 m above sea level in the Semien Mountains, a UNESCO World Heritage Site. The objective of this article review is to describe the distribution, threats and benefits of the Combretum -Terminalia Woodland Ecosystem in Ethiopia. This review article was written using secondary sources of data, primarily from internet databases. We used Google Scholar, Science Direct, and Scopus to look for online reports, book chapters, theses, and scholarly papers. This ecosystem occurs in the northwestern, western, and southwestern parts of Ethiopia. The existence of this ecosystem has the potential to provide significant socioeconomic benefits and several critical ecological services, including the accumulation of carbon stock, provision of regulatory services, and rural livelihood diversification. Currently, rapid population growth, agricultural expansion, forest fires, and overgrazing are severely threatening the biodiversity of the Combretum-Terminalia Woodland Ecosystem in Ethiopia. Various efforts, including the protection of the Combretum terminalia ecosystem in Ethiopia, are being implemented to safeguard this ecosystem from degradation. These efforts include plantation, the implantation of PFM, awareness raising, improving the effectiveness of policies, regulations, and agreements, as well as the demarcation and designation of protected areas, such as Alotishe, Qaftashiraro, Anbesa Chaka, and Gambella national parks.*

Keywords*: *Ethiopia, Ecosystem Combretum- Terminalia, Woodland

Abbreviations:
CTWE: Combretum Terminalia Woodland Ecosystem
NGO: Non-Governmental Organisation
PFM: Participatory Forest Management
SNNPR: South Nation Nationality People Region

I. INTRODUCTION

Ethiopia has the fifth-highest biodiversity in Africa [1]. This biodiversity in flora and fauna is strongly linked to the region's geomorphological history.

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The country is characterized by a dramatic geological history and a broad range of elevations, from the Afar Depression (~125 m below sea level) in the east to the incredible World Heritage Mountains of Ras Dashen (4533 m above sea level) in the north [11].

The Combretum-Terminalia woodland ecosystem in Ethiopia occurs between 500 and 1,900 m above sea level (masl). It is found in different parts of all regions of the country. The soils are mainly Chromic and Pellic Vertisols, with Eutric Glysols and Eutric Histosols in areas that experience extreme seasonal flooding [14]. This biodiversity in flora and fauna is strongly linked to the region's geomorphological history.

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This ecosystem generally occurs on rockier, sandy soils. The second highest mean maximum temperature for the country was recorded in the western lowlands of Ethiopia (35-40ºC °C), an area where the Combretum- Terminalia ecosystem occurs, next only to that of the Afar Depression (40 °C), an area where the Woodland forests cover a larger proportion of the total land areas of Ethiopia (49%) [26].

Combretum-Terminalia woodland vegetation is found in the western escarpment of Ethiopia, where the Gambella and Alatish national parks are located. It consists of widely distributed small to moderate-sized trees that are adapted to fire [11]. The characteristic plant species in this vegetation type include small trees with fairly large deciduous leaves, often featuring commonly observed species such as lowland bamboo (Oxythea abyssinica), species of Combretum and Terminalia, Boswellia papyrifera, Lannea schimperi, Anogeissus leiocarpa, and Stereospermum lanthanum, among others. The understory is a combination of herbs and grasses. In some shallow valleys, extensive areas of very tall grasses, dominated by species such as Cymbopogon, Hyparrhenia, Echinochloa, Sorghum, and Pennisetum, are found. Commonly observed wild animal species include elephants, buffalo, eland, greater and lesser kudu, hartebeest, gazelle, and DeBrazza's monkey [20].

The grass stratum of Combretum-Terminalia woodland is well-developed and frequently burned during the dry season [7]. Thus, this vegetation type is especially vulnerable to fire during the dry season [8]. Taxonomy of Ethiopia's vegetation zones refers to the research region as the Combretum-Terminalia Woodland Ecosystem. The primary dangers to this kind of vegetation are wildfire, invasion, unrestricted grazing, and agricultural investment [12].

The Combretum-Terminalia woodland ecosystem plays a crucial

ecological and socioeconomic role in conservation, recreation, ecotourism, and employment. Combretum-Terminalia vegetation accumulates more carbon stocks in the soil than the biomass along the elevation ranges of dry land ecosystems. However, these forest types, including Combretum-Terminalia, have been given less attention from policy and development perspectives. This review aims to describe the benefits, distribution, threats, and potential of the Combretum-Terminalia Woodland Ecosystem in Ethiopia.

II. THE PURPOSE OF THE REVIEW

The overall objective of this review paper is to compile information on Ethiopia's forest resources, with particular emphasis.

- To review the benefits of the Combretum-Terminalia woodland ecosystem in Ethiopia.
- To review the geographical distribution and ecological attributes of the Combretum-Terminalia Woodland ecosystem in Ethiopia.
- To review the threat encountered towards the Combretum-Terminalia Woodland ecosystem in Ethiopia and thereby indicate a future direction for promoting the sustainability of this ecosystem in the country.

A. Reviewing Methodology

This review article was written using secondary sources of data, primarily from internet databases. We used Google Scholar, Science Direct, and Scopus to look for online reports, book chapters, theses, and scholarly papers. In Ethiopia, we conducted a critical evaluation of the relevant literature, focusing on the biodiversity, threats, importance, and distribution of the Combretum-Terminalia woodland ecosystem.

B. Types of ecosystems in Ethiopia

The ecosystem of Ethiopia has been described in several reports, indicating that there are 10 distinct ecosystems [10]. Therefore, here we present 10 ecosystem types: Afroalpine and sub-Afroalpine ecosystems, montane grassland ecosystems, dry evergreen montane forest and evergreen scrub ecosystems, moist montane forest ecosystems, Acacia-camphor woodland ecosystems, Combretum-Terminalia woodland ecosystems, lowland tropical forest, desert and semi-desert scrubland, and wetland and aquatic ecosystems.

[Fig.1: Partial view of Combretum -Terminalia Woodland Obtained with Permission From [8]]

III. BIODIVERSITY OF COMBRETUM-TERMINALIA WOODLAND ECOSYSTEM

A. Flora Biodiversity

The Combretum-Terminalia Woodland Ecosystem is one of the ecosystems with the highest biodiversity in Ethiopia, ranking among the top ten. The ecosystem comprises a diverse array of fauna and flora species. The characteristics of woody trees and shrub species of this ecosystem include *Combretum* spp., *Terminalia spp., Lannea spp., Boswellia papyrifera, Anogeissus leiocarpa, Sterospermum kuntianum, Combretum molle, Lonchocarpus laniferus, Pterocarpus lucens, Terminalia laxiflora, and Combretum collum. Oxytenanthera abyssinica, Combretum harotomannianum, Osteospermum kunthinanum, Albizia malacophylla and Enatada africana.* These are small trees with large deciduous leaves, which often occur with the lowland bamboo (*Oxytenanthera abyssinica*) [6].

Combretum-Terminalia woodland also occurs as a comparatively narrow zone in central and eastern Ethiopia, between the Acacia-Commiphora woodland and bushland, and the vegetation on the plateau [3].

Herbaceous species of genus *Justicia spp., Barleria spp., Eulophia spp., Chlorophytum spp., Hossolunda opposita and Ledeburia spp.* It exists in this ecosystem. The grass includes *Cymbopogon, Hyparrhenia, Echinochloa, Sorghum, and Pennisetum* [1]. The unique plants, such as Vetellaria paradox and Oxynothera abyssinica, form an understory of herbs and grasses.

The grasses include *Cymbopogon, Hyparrhenia, Echinochla, Sorghum, Pennisetum,* etc. Typically, herbs dominate the ground layer at the beginning of the rainy season, while grasses predominate toward the end of the rainy season. *Oxytheca abyssinica and Boswellia papyrifera* are threats [5]. Common grasses in the Combretum terminal ecosystem are Andropogon chinensis, A. gayanus, A. schirensis, Hyparrhenia anemopaegma, H. filipendula, Hyperthelia dissoluta, *and Tristachya superba*.

B. Fauna Biodiversity

Wild mammals such as Swaynes, hartebeest (Alcelaphus busselaphus swine), Tiang (Damalisus korrigum), Grant's gazelle (*Gazella granti*), Greater kudu (*Tragelaphus strepsicerose*), lesser kudu (*Tragelaphus imberbis*), Gerenuk (*Liocranids walleri*), lion (*Panthera leo*), leopard (*Panthera pardus*), Giraffe (*Giraffa camelopardalis*), African bush elephant (*Loxodonta africana*), African buffalo (*Syncerus caffer*), Cheetah (*Acinonyx jubatus*) and Oryx species are found in this ecosystem.

Characteristics of bird species of this ecosystem include fox kestrel (Falco Alopex), Ostrich (*Struthio camelus),* red pate cisticola (*Cisticola ruficeps*), Green-backed robin (Eremomela caesia), Bush petronia data) and Black-rumped waxbill (*Estrilda troglodytes*).

Different birds, such as the Red-throated Serin, Fox Kestrel, Red-pate Cisticola, Green-backed Eremomela, Bush Petronia, and Black-rumped Waxbill, are found [8]. Wild animals include elephants, buffalo, eland, greater and lesser kudu, hartebeest,

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gazelle, and De Brazza's monkey [20].

C. Combretum-Terminalia Forest Possesses the Following Typical Characteristics

i. Small to medium tree with large deciduous leaves (often occurs with lowland bamboo).
ii. The understories is a combination of herbs and grass- usually herbs dominate the ground layer at the beginning of the rainy season. In contrast, grasses dominate towards the end of the rainy season. and
iii. The vegetation has developed under the influence of fire. Thus, trees have very thick bark to cope with fire, while most herbs have perennial bulbs (they are geophytes) [14].

Wild mammals such as Swaynes, hartebeest *(Alcelaphus busselaphus swine*), Tiang (*Damalisus korrigum*), Grant's gazella (*Gazella granti*), Greater kudu (*Tragelaphus strepsicerose)*, and lesser kudu (*Tragelaphus imberbis*), Gerenuk (*Liocranids walleri*), lion (*Panthera leo*), leopard (*Panthera pardus*), Giraffe (*Giraffa camelopardalis*), African bush elephant (*Loxodonta africana*), African buffalo (*Syncerus caffer*), Cheetah (*Acinonyx jubatus*) and Oryx species are found in this ecosystem.

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IV. THREAT OF COMBRETUM-TERMINALIA WOODLAND ECOSYSTEM (CTWE)

The Combretum-Terminalia woodland ecosystem is highly threatened by rapid population growth, forest fires, shifting cultivation, overgrazing, encroachment, and agricultural expansion, including small- and large-scale agrarian operations for crops such as sugar cane, cotton, sesame, rice, and biofuel plantations, which are aggressively undertaken in these ecosystems [5]. Fire and agricultural settlement are the main threats to this ecosystem in Ethiopia [1].

A. Rapid Population Growth

One of the significant challenges to CTWE's efforts to mitigate forest degradation in Ethiopia is the country's rapid population growth.

Despite this biodiversity, Ethiopia's biological resources are currently under critical threat, primarily due to rapid population growth. The livelihood of the population mainly depends on natural resources and land, and the demand for these is consistently increasing. This substantially drives the rapid decline of natural vegetation in Ethiopia [24]. The population's increasing rate of deforestation is also exacerbated by the high demand for raw materials for construction, charcoal, and firewood.

B. Overgrazing

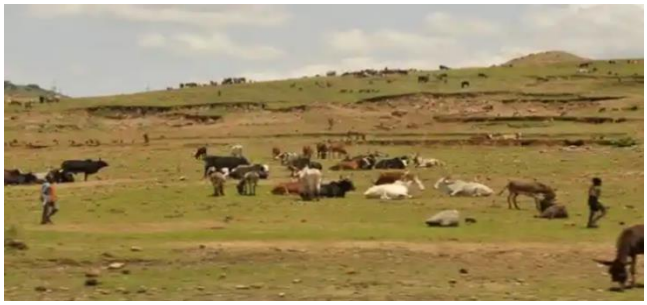
Despite the marginal environmental conditions for living and farming in semi-arid and arid lowlands, where oleo gum resin-producing plants dominate, these areas are under increasing human pressure in Ethiopia. The lowlands, above all, offer high livestock production potential due to their lush grass resources. The Combretum-Terminalia woodland ecosystem is primarily suited to agro-pastoral and pastoral systems, where it supports large livestock populations. The animals were allowed to graze freely in all the forest without restriction on the number or season.

Overgrazing can reduce ground cover, enabling erosion and compaction of the land by wind and rain. This reduces the ability of plants to grow and water to penetrate, which harms soil microbes and leads to severe land erosion [15].

Continued overgrazing reduces inputs of soil organic matter because less plant biomass is available as litter, which in turn reduces soil organic matter, nutrients, and biotic activity. This leads to a deteriorated soil structure, which increases the potential for erosion and reduces the soil's ability to hold water. Among other factors, overgrazing by livestock has been identified as a primary cause of soil erosion and nutrient loss in Ethiopia [22].

Agricultural expansion refers to the conversion of uncultivated land, including natural forests, woodlands, grasslands and wetlands into crop or grazing land. Smallholders or large-scale farmers may undertake it. The north-western parts of the country, categorised under a specific vegetation type, have traditionally grown sorghum, sesame, and cotton. Here, the population is increasing, leading to the intensification of agriculture [14].

As a result of the intensification of agriculture and the demand for wood for fuel, charcoal production, and other purposes, deforestation is increasing. However, it has been indicated that the vegetation type is perhaps the least affected of the wooded vegetation types [20]. The factors that affect the Combretum terminalia woodland ecosystem in Ethiopia, including the expansion of small and large-scale crops such as sugarcane, cotton, sesame, rice, and biofuel plantations, as well as shifting cultivation, are detrimental to the ecosystem. In the case of agricultural expansion, many wild animals (including lions, cheetahs, giraffes, and buffalo) and unique plants such as Vetellaria paradox, Oxyanthemum abyssinicum, and Boswellia papyrifera are threatened [5].



[Fig.2: Partial View of Overgrazing]

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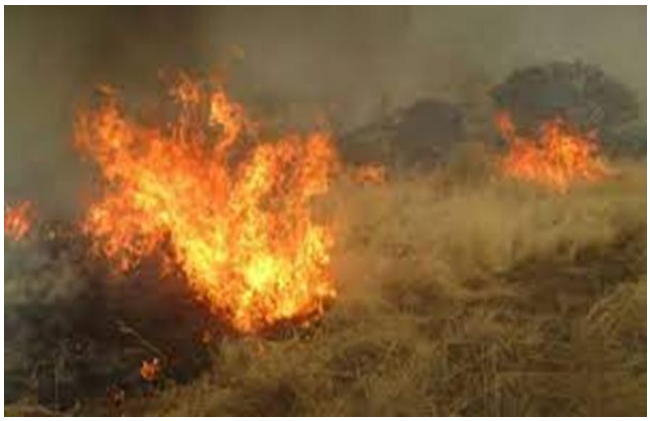
C. Forest Fire

Forest fires are a global phenomenon that involve grave consequences for ecology, the environment, population, and property [18].

Traditional combretum-terminal board-leaved deciduous forest vegetation management involves fire, particularly by cattle herders and pastoralists. Wildfires have a complex impact on forests, including changes in vegetation, threats to biodiversity, and the emission of greenhouse gases like carbon dioxide, which exacerbates climate change. More than 90% of forest fires are caused by human activity. A major fire has burned more than 1,000 hectares, or nearly 2,500 acres, of grassland in the Guassa Community Conservation Area of Ethiopia. The grass stratum of Combretum-Terminalia woodland is well-developed and frequently burned during the dry season. Thus, this vegetation type is especially vulnerable to fire during the dry season [8].



[Fig.3: Partial View of Wildfire]

D. Agricultural Expansion

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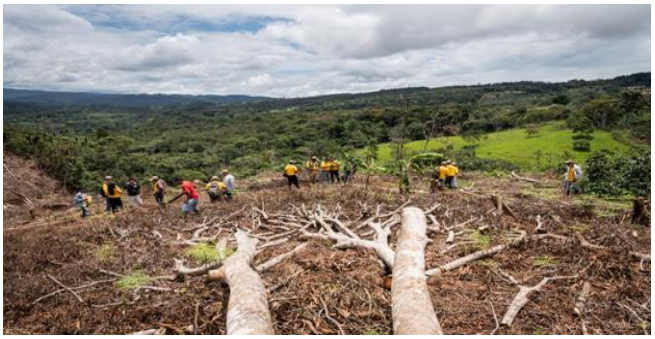

[Fig. 4: Partial View of Agricultural Expansion]

V. EFFORTS OF COMBRETUM -TERMINALIA WOODLAND ECOSYSTEM

Different efforts, including the Combertum-termilania ecosystem in Ethiopia, are being made to plant, implement PFM, raise awareness, demarcate, and designate protected areas such as Alatish, Qafta Sheraro in the Tigera region, Anbesa Chaka in the Benshangule Gumez region, and Gambella National Parks in the Gambella region [5]. Area closure and afforestation, along with integrated watershed management, are also necessary to restore ecosystem resources in different niches. Integrated land-use planning with environmental conservation activities at the landscape level is needed for sustainable and healthy ecosystem management and utilisation [10].

VI. BENEFITS OF COMBRETUM-TERMINALIA WOODLAND ECOSYSTEM

Woodland forests cover a larger proportion of Ethiopia's total land area (49%) [26]. They play important ecological and socioeconomic roles [10]. Dry land ecosystems, including Combretum-Terminalia vegetation, cover a broader area in the tropics. These resources are believed to make a significant contribution to climate change mitigation in dryland ecosystems [3].

Combretum-Terminalia vegetation accumulates more carbon stocks in the soil than the biomass along the elevation ranges of the dry land ecosystem in Southern Ethiopia [16]. The studied Combretum-Terminalia woodland ecosystem sinks higher carbon stocks, both in biomass and soil, than some other dry land vegetation reported in Ethiopia and elsewhere in the tropics.

The existing ecosystem has the potential to provide significant socioeconomic benefits and several critical ecological services. From a local livelihood perspective, the Ethiopian forest ecosystem offers a range of ecosystem services, including food, water, energy, and shelter, in both rural and urban areas [4]. As a regulating service, flood and disease control serve as a shelter and play a crucial role in mitigating climate variability [3].

Diversified trees, shrubs, and grasses serve as sources of medicinal substances, while also providing recreational and cultural benefits [2]. According to studies from various countries in the tropics, including Ethiopia, overall forest incomes from timber and non-timber forest products contribute substantially to household annual income [21].

Forest resources are also an essential component of rural livelihood diversification, providing safety nets during income crises for many households and supporting poverty alleviation [9]. Protected Ecosystems are also used to purify the air and water, generate oxygen, and stabilize the climate. [23]. The creation of the air we breathe and the supply and distribution of the water we drink are essential components of healthy ecosystems. Tree species in the Combretum-Terminalia woodland broad-leaved deciduous forest provided a diverse range of products, including fodder, apiculture, fuel, timber, tannin or dye-stuffs, medicine, and soil improvement [17].

A. Geographical Distribution of Combretum-Terminalia Woodland Ecosystem

The Combretum-Terminalia woodlands and wooded grasslands (CTW) are a widely distributed ecosystem

in East Africa, including Ethiopia [13].

The CTW of Ethiopia comprises 199 woody species, of which nearly 41% are endemic [8], thus having a high potential for local biodiversity conservation [19]. Additionally, it is one of the four major biomes that sequester carbon in dryland ecosystems [25]. This ecosystem occurs in the northwestern, western, and southwestern parts of Ethiopia. Regionally, it exists in Tigray, Amhara, Benishangul Gumuz, Gambella, Oromiya and SNNPR in (Bench Maji, Gamo Gofa and Sidamo). It penetrates the plateau along the large river valleys, such as the Dedessa, Omo, Abay, Baro, Tekeze, Anger, and others.

The Combretum- Terminalia board-leaved deciduous forest is also recognised in the rocky slopes of the Dakota Valley, between Babile and Jijiga, in Harer, and South of Lake Langano, on the hills east of the Acacia woodlands [14].

B. Ecological Attributes of Combretum-Terminalia Woodland Ecosystem

The Combretum terminalia board-leaved deciduous forest occupies the altitudinal range between 400-500 and 1,900 m asl [10]. The environment of the ecosystem is characterized by high temperatures and relatively good rain rainfall. The second-highest maximum temperature of the country was recorded in the western lowlands in Ethiopia (30-40^{0}C °C).

The soils are mainly Chromic and Pellic Vertisols, with Eutric Glysols and Eutric Histosols in areas that experience extreme seasonal flooding. Shallow-type lithosols, Cambi soils, and Regosols characterise mountain sides. In some areas with high rainfall, such as the slow land of Disdessa, and regions with highly weathered soils, including Feralsoil, or their associated predominant types [14].

VII. CONCLUSION AND FUTURE DIRECTIONS

Ethiopia covers a total land area of 1.12 million km2, with diverse geophysical features. It spans a wide range of altitudes, varying from 126 meters below sea level to 4,620 meters above sea level, resulting in diverse climatic conditions and numerous agro-ecological zones. Ethiopia is rich in biodiversity, topographical complexity, and climate variability, which jointly result in different vegetation types. The Combretum-Terminalia Woodland Ecosystem is of great importance for both socioeconomic and ecological reasons, and it also plays a crucial role in purifying the air and water, generating oxygen, and stabilising the climate. The common threats to the Combretum-Terminalia woodland ecosystem include rapid population growth, forest fires, shifting cultivation, overgrazing, encroachment, and agricultural expansion, both small-scale and large-scale, for crop production.

A. Future Directions

The following future strategic directions are proposed for overcoming the challenges and addressing the identified issues for the proper conservation and management of the CTWE of Ethiopia:

i. Establishing demarcation and designation of protected areas, such as national parks, is being made in the ecosystem.
ii. Area closure and restoration with integrated watershed management are also necessary to restore the ecosystem resources in different regional states.
iii. Improving the effectiveness of policies, regulations and agreements that are important for the development and conservation of the ecosystem,
iv. Rehabilitating and restoring degraded ecosystems and promoting the recovery of threatened species by scaling up best area enclosure practices, agroforestry, afforestation, and reforestation programs.
v. Giving awareness-raising training and promoting forest education for the local communities on the value of forest resources and the ecological consequences of deforestation.
vi. Implementation of PFM with the collaborative effort of the government, NGO, and the local community for the reduction of forests in the ecosystem.
vii. Sustainable protection and management of the existing natural forests is needed through the collaborative effort of integrated land-use planning with environmental conservation activities at the landscape level, which is necessary for sustainable, healthy ecosystem management and utilisation.

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