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(RESEARCH ARTICLE)

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Assessment of the threat status of *Boswellia dalzielii* Hutch (Burseraceae) in Togo, according to the IUCN Red List Categories and Criteria (Version 3.1)

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Abstract

The African frankincense tree (*Boswellia dalzielii* Hutch.) is a species that occurs in Togo, specifically in the village of Tami in northern Togo. The current number of mature individuals of B. dalzielii is estimated to be 202. Its EOO is estimated to be 1293 km2, and its AOO is 4 km2. Currently, the species is known in only one location. The number of mature individuals qualifies B. dalzielii for criteria D in the Endangered category. Its EOO qualifies the species for criteria B in the Endangered category and with its AOO qualifies the species for B in the Critically Endangered (CR) category. However, the following risks have been identified: overgazing, insect infestation, fire, and a continuing decline in the quality and extent of the habitat, as well as the number of mature individuals. Therefore, the highest category of threat the species meets is B (CR B2ab (iii, iv).

Keywords: African Frankincense Tree; AOO; Biodiversity; Conservation; Critically Endangered; EOO; Harvesting Practices; Relist; Single Occurrence; Tami

1. Introduction

Togo's flora is estimated at around 4002 plant species, according to inventories that have begun since the colonial era (MERF 2014). Understanding ecological phenomena and developing strategies for biodiversity conservation at regional, national or local scales requires a better knowledge of biological diversity (Bazin & Barnaud, 2002; Oyono, 2002; Davies et al., 2012). However, updating the list of species through ongoing inventory efforts must be improved by assessing the conservation status of these species. Data on the conservation status of species can contribute to decision-making around the world.

Since established in 1964, the International Union for the Conservation of Nature (IUCN) has aimed to create a comprehensive global inventory of the conservation status of plant and animal species. The IUCN Red List Categories and Criteria is now widely regarded as one of the most effective scientific decision-making tools for environmentalists worldwide (Ginsburg 2001; Callmander et al. 2005; IUCN, 2012). In the 1970s, Europe witnessed the establishment of several Red Lists, which aimed to assess and document the conservation status of various species (Fenu et al., 2018; Orsenigo et al., 2018; UICN France, 2011; Véla et al. 2008). These lists focused mainly on species that were endemic or had a restricted range. This emphasis on endemic and restricted range species was justified by the fact that they are

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particularly vulnerable to the risk of extinction (Véla et al. 2008). By prioritizing these species, conservation efforts could be directed toward protecting their unique habitats and addressing the specific threats they faced.

In Africa, there has been a scarcity of efforts to classify species. This may be due to the fact that researchers focus more on habitat description than on the autoecological aspect. In Togo, some lists of threatened or endangered species have been published, if we skim through the reports on the issue; unfortunately, *Boswellia dalzielii* Hutch. is not included in any of these lists. *B. dalzielii* can be regarded as a new species for the vascular floristic of Togo. The species is missing from the list of species described in the analytical flora of Togo (Brunel et al., 1984). It was recorded in June 2007 in the Nakpadjoack community forest in Tami village, west of Dapaong town. It is also the only credible occurrence to date, despite several surveys in its range.

The aim of this study is to understand the current conservation status of *B. dalzielii* and to assign it to one of the IUCN Red List categories by reviewing all available data in its native range in Africa.

2. Materials and Methods

2.1. Plant

Boswellia dalzielii Hutch, also known as the African frankincense tree, is a species belonging to the genus Boswellia. Its main centre of endemism in Africa is found in the Sudanian and Sahelian zones of Benin, Burkina Faso, Cameroon, Central Africa, Chad, Côte d'Ivoire, Ghana, Niger, Nigeria and Togo (Sabo, 2023; Atato, 2022; Kemeuzé et al., 2012; Ouédraogo et al., 2006; Akoègninou et al., 2006).

2.2. Databases and Search Terms

Other authors' approaches were used (Atato, 2022; Sabo et al, 2022; Akindele et al., 2020). Relevant literature was reviewed by searching through scientific databases such as Scopus, PubMed, Science Direct, Google Scholar, African Journals OnLine (AJOL), Web of Science, African, Plant Database, GBIF, World Flora Online (WFO), Plants Of the World Online Portal (POWO). This review of the literature has made possible to provide information for each of the countries in the centre of endemism of the species, under headings such as : Distribution, population information, AOO, EOO, status of conservation etc. The search was carried out using the following keywords: Bowellia dalzielii Hutch and country **''*Bowellia dalzielii* Hutch, Togo''**

2.3. Categorization of *B. dalzielii* according to iucn criteria

The approach and methodology proposed by the IUCN and drawn from two reference documents were used, with one setting the international rules of the method (IUCN 2001) and the other dealing with regional adaptations of the method (IUCN 2012). This methodology consists in applying the criteria of the Red List to the population of *B. dalzielii* to determine a preliminary assessment that enables the classification of the species in the following categories.

To obtain a more accurate evaluation, it is crucial to gather additional data. In the absence of comprehensive data, the assessment has relied on Criteria B (geographical distribution) and D (very small or restricted population) using measures such as Area of Occupancy (AOO), Extent of Occurrence (EOO) and the number of mature individuals. These criteria provide valuable information on the conservation needs of the species based on the available information.

3. Results

3.1. Species range in Africa

After consulting four major databases, three on a global scale (Plants of the World Online (POWO), 2024; World Flora Online (WFO), 2024 and GBIF, 2024) and one on an African scale (African Plant Database, 2024), Figures 1, 2 and 3 show the countries where B. dalzielii has been recorded.

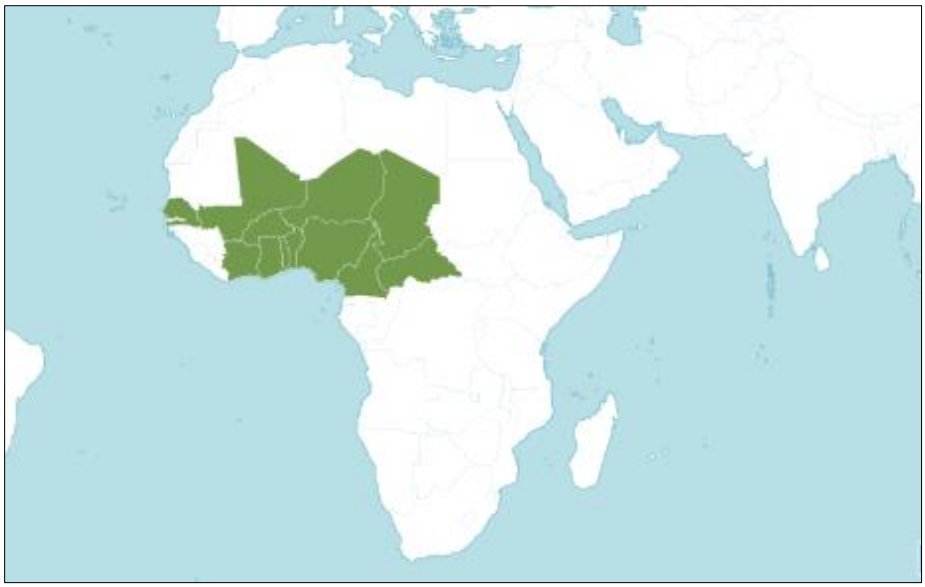


Figure 1 Native range of the species according POWO and WFO (2024)

Figure 2 Native range of the species according GBIF (2024)

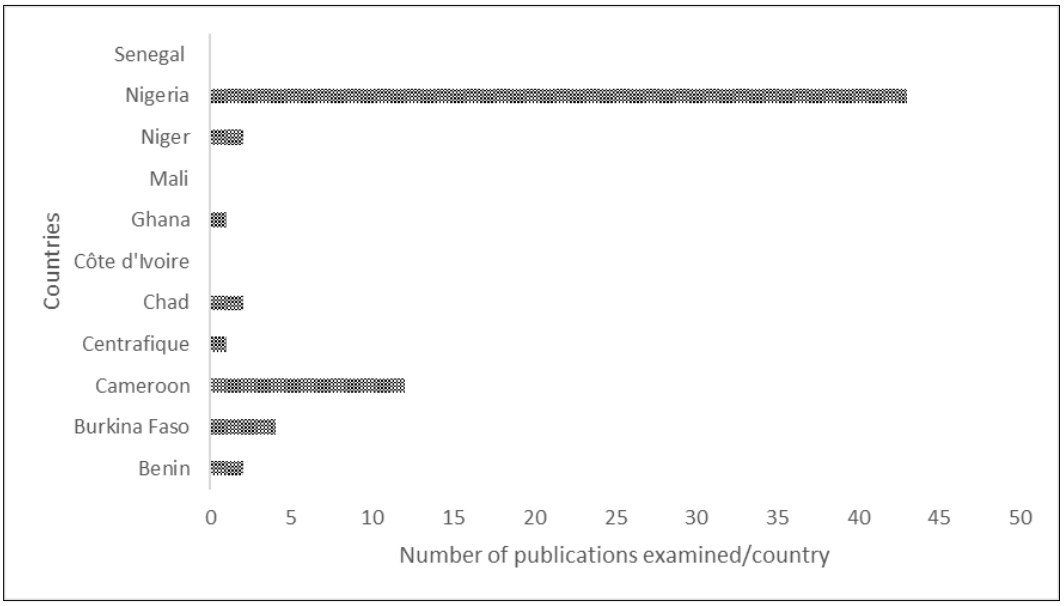
Figure 3 Native range of the species according African Plant Database (2024)

3.2. Species details for each country in its range

Figure 4 presents the results of the analysis of the relevant publications and indicates that Nigeria is the country with the highest number with 43 publications (64%) followed by Cameroon. In terms of the number of occurrence records, Benin is in the lead (Figure 5), as the data come from three independent sources.

By analysing relevant publications and consulting appropriate databases, the geographical distribution of the species has been defined for each country, except for Senegal, where there is no published information on the distribution of the species. However, there is a lack of published data on the extent of occurrence (EOO), area of occupancy (AOO) and conservation status of the species within each country.

The conservation status of the species' populations has only been addressed in five of the 11 countries in the species' range in Africa.



Be: Benin; BF: Burkina Faso; Cm: Cameroon; CA Central Africa republic; Ch: Chad; CI: Côte d'Ivoire; Gh: Ghana ; Ma: Mali; Ni: Niger; Na: Nigeria

Figure 4 Number of relevant publications per country in native range of the species

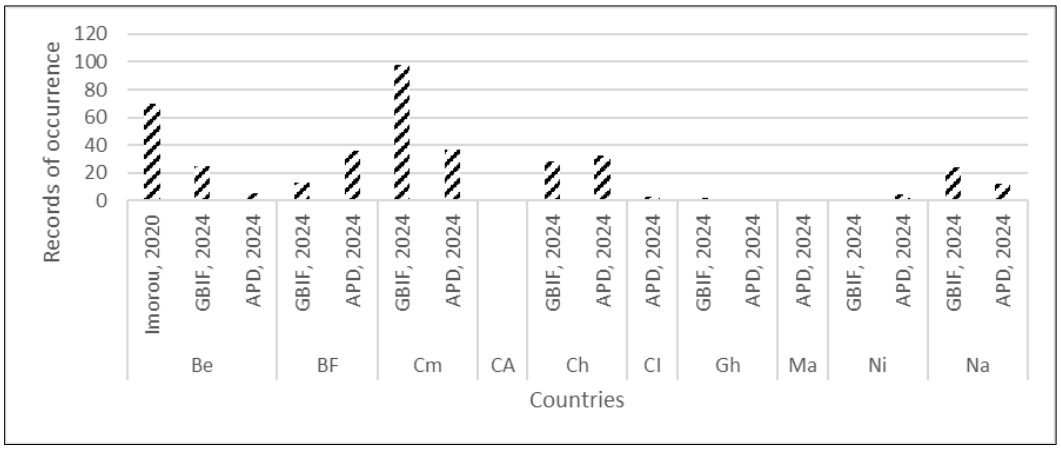


Figure 5 Records of occurrence per country in native range of the species

3.3. Occurrence, distribution and demographic data

The species was discovered during a survey in June 2007 within the Nakpadjoak Community Forest (NCF) in a village called Tami. The village is located about twenty kilometres west of the regional capital, Dapaong, in northern Togo. It

was identified using the analytical flora of Benin (Akégninou et al., 2006). This was because the species was not listed in the analytical flora of Togo (Brunel et al., 1984). From 2007 to date, active surveys have been carried out to find the species at other sites in the region, but these have not been successful.

Within the NCF, *B. dalzielii* forms a population consisting of individuals of approximately the same age, with an average diameter of approximately thirty centimetres and a height of approximately ten centimetres. Two hundred and two (202) mature individuals (IUCN, 2001) were counted within the forest in June 2019 (Fig. 6). The ecological niche of B. dalzielii is characterised by the notable absence of seedlings within the NCF. The few rare young plants observed are suckers.

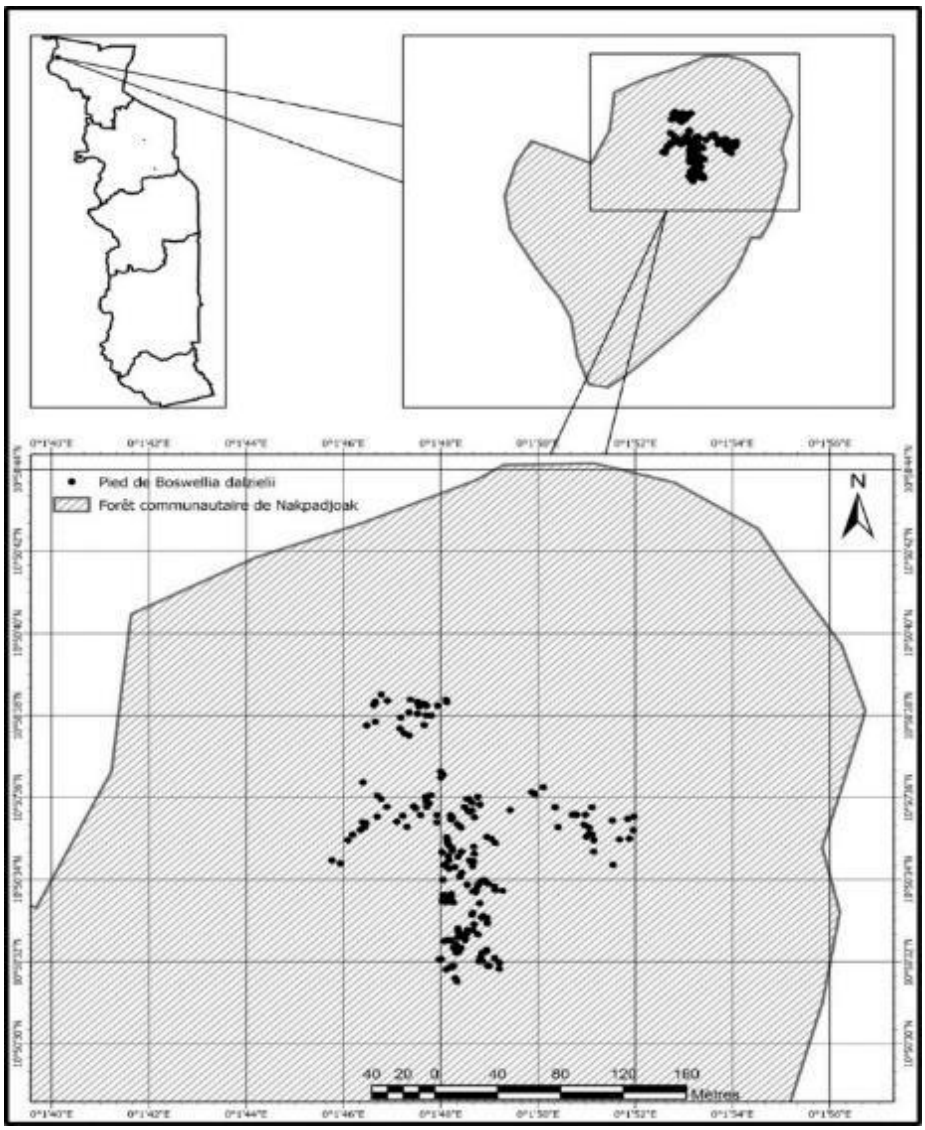


Figure 6 Area of occupancy (hatched perimeter) and mature individuals (point) of *Boswellia dalzielii* Hutch

3.4. Habitat ecology, distribution and current conservation status of B. dalzielii in Togo

This species is specifically restricted to the NCF (Photo 1). This is a community-managed forest of 45 ha, located on a 280 m high inselberg of granitic scree (Photo 2). The distribution of B. dalzielii ranges from 210 metres above sea level (ASL) to the top of the inselberg. At this altitude, *B. dalzielii* forms a cohesive population (Photo 2) and shows sociable behaviour (Photo 3)

Figure 7 NCF landscape view from villagers' settlement (September 2018)

Figure 8 Granite blocks in Nakpadjoak community forest (March 2019)

Figure 9 B. dalzielii stand in the Nakpadjoak community forest (March 2019

The EOO of the species is estimated to be approximately 1,293 km2, calculated using a minimum convex hull polygon in ArcGIS (Sambiani et al., 2023). As the species is restricted to a community forest of 45 ha, its AOO according to IUCN guidelines (2012) is estimated to be under 4 km^2 calculated with a fixed grid of 2×2 km cells. The search for other habitats to support the species has been unsuccessful. It is believed that the ecological conditions necessary for the species to thrive are only found in the Nakpadjoak Community Forest (NCF) in Togo. The Nakpadjoak forest has community status due to its sacred nature. The only permitted activity is grazing. Potential threats to B dalzielii include trampling of suckers, insect infestation (dead individuals with perforations have been found during surveys) and, most importantly, accidental or criminal fires.

3.5. Threat status of the species according to IUCN criteria

Based on the data in Tables 1 and 2; the number of mature individuals is estimated at 202, the extent of occurrence (EOO) is estimated at 1293 km^2, and the area of occupancy (AOO) is estimated at 0.5 km^2, and the species is currently known from only one site. Active searches for the species at a large number of additional sites have been unsuccessful, indicating a rather small range of uncertainty in the measured parameters (e.g. AOO, EOO). The above data indicate that the species meets Criterion B in both the Critically Endangered and Endangered categories, and only Criterion D in the Endangered category, in which case only Criterion B is listed in the Critically Endangered category (the highest category of threat). Due to gazing, insect infestation, and a risk of fire, a continuing decline in the quality, extent of the habitat, and number of mature individuals is expected. *B. dalzielii* is assessed as a critically endangered species in accordance with criterion **B (CR B2ab (iii, v))** of the IUCN Red List criteria.

Table 1 Summary of quantitative or qualitative data necessary for the use of the assessment criteria.

	scientific name	***Boswellia dalzielii* Hutch.**
Raw data (current and past)	Number of mature individuals	202 mature individuals
	Regional range of the species, accompanied, if possible, by mapping	Nakpadjoak Community Forest
	Number of localities where the species is present	1
Data processed for assessment	Extent of occurrence estimated	1293 km^2 .
	Area of occupancy estimated	4 km^2
	Number of localities identified	1
	Continuing decline of the species	Any recent or historical data to confirm whether there is a continuing decline in the species or not.
	Population size reduction (estimated on 10 years or three generations)	Any recent or historical data to confirm whether there is a reduction or not.
others information's	Severely fragmentation	The fragmentation is significant compared to the populations of Benin and Burkina Faso (closest countries of occurrence)
	Extreme fluctuations	Any recent or historical data to confirm whether there are extreme fluctuations or not.
	Habitat evolution trend	More or less stable. No agricultural activities other than grazing. The 45 ha were closed with the support of the Global Environment Fund (GEF) association.
	Threats to the species	Species confined to Nakpadjoak Community Forest. Potential threats: overgrazing and accidental or criminal fires.

Table 2 Summary of quantitative or qualitative geographic data necessary for the use of the evaluation criteria.

Nature of criteria	**Criteria**	***B. dalzielii* data**	**Categories**		
		Exact value	Critically endangered Critique (CR)	Endangered (EN)	Vulnerable (VU)
			Threshold value		
Extent of occurrence (EOO)	Current surface	1293 km²	< 100 km²	< 5000 km²	< 20000 km²
	Extreme fluctuations	Not applicable			
	Continuing decline (10 years)	Not applicable			
Area of occupancy (AOO)	Current surface	4 km²	< 10 km²	< 500 km²	< 2000 km²
	Extreme fluctuations	Not applicable			
	Continuing decline (10 years)	Not applicable			
Habitat (area, extension, quality)	Continuing decline (10 years)	Not applicable			
Locality	Current number	1			
	Extremes fluctuations	Not applicable			
	Continuing decline (10 years)	Unknown			
	Severely fragmentation	Not applicable			
Matures individuals	Current number	202			
	Extreme fluctuations Continuing decline (10 years)	Not applicable Unknown			
Population size	Reduction Causes of reduction	Unknown Unknown			
Quantitative analysis Indicating the probability of extinction in the wild to be		Not done			

4. Discussion

4.1. Habitat ecology, distribution range of the species

The habitat of *B. dalzielii* in Togo is a granitic chaos. Sabo et al. (2023) and Ouédraogo et al. (2006) in Burkina Faso and Kameuzé et al. (2012) in Cameroon have reported this type of habitat. The species occurs in the NCF as a gregarious species. This gregariousness has been documented by Ouédraogo et al. (2006) in eastern Burkina Faso and by Kameuzé

et al. (2012) in Cameroon. The B. dalzielii stand studied in the Nakpadjock community forest has no seedlings and the only young plants observed are suckers. This is also reported by Ouédraogo et al. (2006) in eastern Burkina Faso and Kameuzé (2012) in Cameroon.

Within NCF, B. dalzielii occupies the top of the Inselberg. Sabo et al. (2023) showed that in Burkina Faso, stands of the species are found on variable topography (top, slope and plain).

The geological substratum where the species occurs, is the Birimian basement. This basement is also the geological substratum of eastern Burkina Faso, called socle Mossi (Petit, 1994), where Ouédraogo et al. (2006) and Hahn and Thiombiano have described populations of *B. dalzielii*. The area of this basement in Togo is about 1293 km2 and can be considered as the extent of occurrence (EOO) of the species. Toko Imorou (2020), in Benin, estimated the area of habitats more favourable to the distribution of the species under current climatic conditions at 29022 km^2 of the study area.

However, this area of favourable habitat cannot be considered as the EOO of the species in Benin, as this estimate does not correspond to the IUCN (2012) definition.

4.2. Threat status of species

According to Mengistu (2011), it has been highlighted that the range of these species is under threat due to various factors. Habitat destruction (caused by human activities), insect infestation and overexploitation for national and international purposes.

In terms of habitat destruction, the main threats are agriculture, overgrazing, fires. According to Ogbazghi et al. (2006), species of the Boswellia genus are vulnerable to attack by various species of beetles that penetrate living trees.

In Africa, the native range of *Boswellia dalzielii* covers Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Côte d'Ivoire, Ghana, Niger, Nigeria, Senegal, and Togo.

Investigations undetaken in Benin (Toko Imorou, 2020); in Burkina Faso (Sabo, 2023; Sabo et al., 2023; Sabo et al., 2022; Sabo et al., 2021; Ouédraogo et al., 2006; Ouédraogo et al., 2006; Hahn and Thiombiano, 2000) in Cameroon (Froumsia, 2019; Kémeuzé et al.,2012) in Chad (Todou et al., 2018) and in Niger; Mahamane et al, 2009) reported that the main threats to species is intensive debarking. Those authors have adressed stand dynamic of the species in the locations investigated. However, the available data on the current conservation status of populations, on EOO, AOO, and threats facing the species in other countries within the species'range are severely limited. The only known and documented occurrence of *B. dalzielii* in Togo is in the Tami locality. Tami is located 172 km from the nearest known occurrence of *B. dalzielii* in eastern Burkina Faso (Ouédraogo et al., 2006), 252 km from the nearest occurrences in the Savelugu/Nanton district, northern region of Ghana (African Plant Database, 2024) and 400 km from the nearest occurrence in the Borgou department of Benin (Toko Imorou, 2020). In eastern Burkina Faso, Ouédraogo et al. (2006, 2006) described declining stands of *Boswellia dalzielii* under to intense bark removal. In Ghana, there is no information on the species and in Benin, according to Toko Imorou (2020), *B. dalzielii* has a low stem density in its range and under anthropogenic stress. Therefore, there is no need to consider adjusting the preliminary assessment of *B. dalzielii* which is **B (CR B2ab (iii, v)).** Because there is uncertainty about a rescue effect from outside currently.

Of the 21 species of the genus Boswellia, thirteen (13) have been globally assessed by IUCN (Oldfield et al. 1998; Thulin 1998; Walter et Gillett 1998; Miller 2004a,b,c,d,e,f; Vivero et al. 2005; MOE 2012; Saha et al. 2015; Modi & Mathad 2016; Alemu et al. 2018a,b; Awas et al. 2018;). Nine (8) are Vulnerable (VU); two (2) are Critically Endangered (CR); two (2) are Near Threatened ; and one (1) is Least Concern.

Threatened species reassessments are a crucial aspect of conservation efforts, as they allow for the accurate assessment of species' vulnerability and the implementation of appropriate conservation measures. These reassessments are usually prompted by revisions to the International Union for Conservation of Nature (IUCN) Red List categories and criteria, as well as advances in species data. Many researchers have contributed to these reassessments, providing valuable insight into the conservation status of various species. For example, the work of Walter & Gillett (1998), Oldfield et al. (1998), Miller (2004g), Vivero et al. (2005), Véla et al. (2008), and Alemu et al. (2018a) has been instrumental in informing the reassessment process. Their studies have shed light on population trends, the loss of habitat and other factors that affect the conservation status of a wide range of species. By applying robust criteria and relying on reliable data sources, researchers can make an objective assessment of the threatened status of a species.

This approach helps maintain the integrity of the reassessment process and ensures that conservation efforts are effectively targeted.

There have been further updates on the threat status of certain species within the genus Boswellia. For example, *B. pirottae* Chiov. and *B. ogadensis* Vollesen (Walter & Gillett 1998; Oldfield et al. 1998; Vivero et al. 2005; Véla et al., 2008; Alemu et al. 2018a) and *B. nana* Hepper have had their threat status reassessed. Revisions have also been proposed for species in other families, namely *Arenaria provincialis* Chater & Halliday (Véla et al. 2005).

These revisions in threat status highlight the dynamic nature of conservation assessments and the importance of ongoing research and monitoring to accurately assess the vulnerability of plant species.

This will be the case for *B. dalzielii* once additional research data on its conservation status are available from other countries within its range.

5. Conclusion

After this preliminary assessment, *Boswellia dalzielii*, is a critically endangered species in Togo. This highlights the urgent need for immediate action to improve preservation efforts and ensure the survival of this species.

B. dalzielii is highly valued for its bark, which have been used for centuries in traditional medicine. These uses led to unsustainable harvesting practices. Fortunately, this use is not yet common in its area of occurrence in Togo. This indicates that there is a need to take measures to safeguard the species before these practices become widespread among the local population.

The community status of the Nakpadjoak forest plays a crucial role in ensuring the preservation of the species. However, to effectively conserve *B. dalzielii*, it would be essential to raise awareness of its significance and the potential consequences of its overuse or exploitation.

Compliance with ethical standards

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Disclosure of conflict of interest

We, authors, declare that there is no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Statement of authorship

Abalo ATATO collected data, performed modeling work, analyzed output data, and performed the meta-analysis. He wrote the first draft of the manuscript and all authors contributed substantially to revisions.

Data accessibility statement

Raw data analysed in data that support the findings of this paper are available online library of the University of Kara : https://univ-kara/bibliothèque-virtuelle/

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