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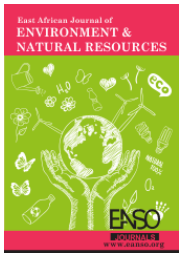

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Original Article

Review of Deforestation in Ugandan Tropical Rainforest Reserves: A Threat to Natural Medicine

Upton Nuwagira[1*], *Igga Yasin*[1] & *Hilda Ikiriza*[1]

[1] Mbarara University of Science and Technology, P. O. Box 1410, Mbarara, Uganda.
*Correspondence ORCID ID: https://orcid.org/0000-0001-6200-522; email: unuwagira@must.ac.ug.

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ABSTRACT

Deforestation in Ugandan Tropical Rainforest Reserves as threat to natural medicine is still undocumented. In this study, we reviewed literature on deforestation most especially from 1990-2020 in the Tropical Rainforest Reserves. We examine the trend of deforestation, impact of deforestation on medicinal plant species' and threatened medicinal plant species in the Tropical Rainforest Reserves in Uganda. Secondary data from National Forestry Authority on deforestation (1990-2020) was analysed to determine the trend of forest deforestation while PubMed®, Google Scholar, and SCOPUS databases were also used to provide information on the threatened medicinal plants. Our results show that there has been an annual incredible decline of 17% in the trend of deforestation both in Tropical Rainforest Reserves (low-stocked and well-stocked). The results of the review also noticed a 0.86 strong positive correlation in the decline of both Tropical Rainforest Reserves. This review also documented 13 medicinal plants as the most threatened in the Ugandan Tropical Rainforest Reserves. The medicinal plants in Uganda include *Dioscorea bulbifera, Cytropsis articulata, Prunus africana, Warburgia ugandensis, Entandrophragma utile, Irvingia gabonensis, Spathodea campanulate, Aloe ferox, Vernonia amygdalina, Erythrina abyssinica, Moringa oleifera, Hoslundia opposita Vahl* and *Milicia excelsa*. Our study articulates human activities that are affecting medicinal plants include agricultural expansion, timber harvesting, charcoal burning, firewood harvesting, weak forest policies and laws, un clear forest boundaries infrastructure development e.g., roads.

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INTRODUCTION

Deforestation at a global scale is overwhelming and accounts for eighty million hectares since the 1990s with a 40 percent decline attributable to agriculture (FAO, 2020). In addition, forest clearance reduces the biodiversity in tropical rainforests (Achard *et al.,* 2014; Galabuzi *et al.*, 2015; Call *et al.,* 2017). In the Sub-Saharan African region, deforestation accounts for 8% annually, which is linked to poor governance (Assa, 2018). For instance, in East Africa, the average deforestation rate is approximately 1.53% annually, with Uganda being the first having a 0.4 to 3% annual forest decline (Mwangi *et al.*, 2018).

However, reports on serious deforestation in Uganda started way back 1980s, 1990s, and the early 2000s when many researchers had started to document the terrifying challenges associated with deforestation (Hamilton, 1987; Kayanja & Byarugaba 2001; Banana *et al.,* 2007). Currently, in Uganda, deforestation is escalated by the increased population (3.4% per annum), which demands more fuel wood that acts as a source of energy for cooking in many homes (Jagger & Kittner, 2017; Josephat, 2018).

Other studies have articulated that deforestation in Uganda is due to poor implementation of the policies and laws, socio-economic factors, technological vagaries, lack of clear boundaries between the forest reserves and nearby communities, flux in agriculture and infrastructure development (Naughton-Trevesa et al., 2011; Twongyirwe *et al.,* 2015; Petursson *et al.*, 2013; Waiswa *et al.*, 2015; Twongyirwe *et al.*, 2018).

Uganda lost 30% of its tree cover between 2001 to 2020 through an uncontrolled rate of deforestation (Mongabay, 2020). According to (UBOS, 2020), Uganda's well-stocked Tropical Rainforests lost 227 hectares while low-stocked Tropical Rainforest lost 235 hectares in 2015. Tropical rainforests are sources of medicinal plant species that are used in day-to-day life for both people and animals when curing diseases. The tropical rainforest Reserves in Uganda include Mabira, Budongo, Bugoma, Bwindi, Kalinzu, Mghahinga, Kibale, Maramagambo, Echuya, and Katsyoha-Kitomi (Wronski & Hausdorf, 2010).

Most of these forests are located along the equator and are at times known as equatorial forests, because of the heavy rainfall and cool temperatures and biodiversity (Obua *et al.*, 2010). People around and within the proximity of tropical rainforests have used them for a couple of years to cure diseases (Baranga, 2007). Furthermore, tropical rainforest medicinal plant species have shown evidence to be of great importance in the modern world (Shrestha & Dhillion, 2003). According to Namukobe *et al.,* (2011), over one hundred plants have been evidenced to be used, for instance, by the people living in the proximity of Kibale National Park which is a Tropical Rainforest.

The medicinal plant species from Tropical Rainforests include *Vernonia amygdalina* for curing malaria, *Erythrina abyssinica* for prevention of vomiting, *Prunus Africana* for curing prostate cancer in men, *Cytropsis articulata* (locally known as Katimboro) for curing male erectile disfunction, *Dioscorea bulbifera* for the treatment of cancer, leprosy, and

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ulcers, *Allophylus abyssinicus and Symphonia globulifera* species are vital in curing malaria and skin diseases in humans (Tugume *et al.,* 2016; MWE, 2016; Ikiriza *et al.,* 2019; Wangalwa *et al.,* 2021; Lukubye *et al.,* 2022).

However, these medicinal plants of great importance are getting depleted from their natural habitat in Ugandan forests (Maundu *et al.,* 2006; Ii & Order, 2006; Namukobe *et al.,* 2011; Amujoyegbe *et al.,* 2012; Galabuzi *et al.,* 2015b; Ikiriza *et al.,* 2019; Wangalwa *et al.,* 2021). The documentation of the threats to medicinal plant species has been given a deaf ear yet medicinal plant species are evidenced to be vital in the treatment of several diseases. For example, during the COVID 19 pandemic, *Zanthoxylum gilletii, and Warburgia ugandensis* tropical rainforest trees were used to make COVIDEX 100% natural herb that treated COVID-19 pandemic in Uganda. Several ethno botanical studies conducted in Uganda only focus on the identification of medicinal plant species and their use (Asiimwe *et al.,* 2013; Mugisha *et al.,* 2014; Baana *et al.,* 2018; Schultz *et al.,* 2020).

Thus, it is very key to put more emphasis on studying the threatened medicinal plant species in the Tropical Rainforests in Uganda to better understand strategies for In-situ or Ex-situ conservation. More so, attempts by the ethno botanical studies have not put in place sensitization workshops and community programs emphasising the importance of conserving medicinal plants in Uganda most especially in areas surrounding the Tropical Rainforests which are termed niches for medicinal plant species.

Whereas, other scholars have focused on the phytochemistry and extraction of important compounds from the medicinal plants (Omara *et al.,* 2020; Beressa, *et al.,* 2021; Lukubye *et al.,* 2022), thus they have left the important part of the conservation of threatened medicinal plant species and their distribution within the Tropical Rainforest Reserves in Uganda. However, this review has helped in documenting the impact of deforestation on the medicinal plant species in Uganda. In this review, we seek to answer the following research questions 1) what is the trend of deforestation in Tropical Rainforest Reserves in Uganda? 2) What is the impact of deforestation on medicinal plant species' existence in Tropical Rainforests in Uganda? And 3) what are the threatened medicinal plant species in the Tropical Rainforest Reserves in Uganda?

MATERIALS AND METHODS

Study Area

Uganda is a landlocked state situated in East Africa (Nuwagira & Yasin, 2022). It lies between 27'0'0" E-35'0'0" E and 1'0'0" N-4'0'0" N (Figure 1). The country is also situated along the equator line that divides it into the Northern and the Southern hemispheres with a variety of Tropical Rainforest Reserves like Mabira, Kalinzu, Budongo, Bugoma, Bwindi, and Kibale. The country has a flat area and gentle slopes of 1,500 m.a.s.l in southern Uganda and 3000 m.a.s.l in northern Uganda. It receives rainfall between 500 – 2000 mm and temperatures between 20^0C - 25^0C (Kiwanuka et al., 2021). The country depends on subsistence farming as the main source of income (CEPA, 2019). Agriculture is supported by deep fertile soils and therefore, highly productive (Minai, 2015). The country also has several open waters such as Lakes Victoria, Edward, Kyoga, George, and Albert with rivers like the Nile, Kafu, Kagera, and Rwizi (Ngoma *et al.,* 2021).

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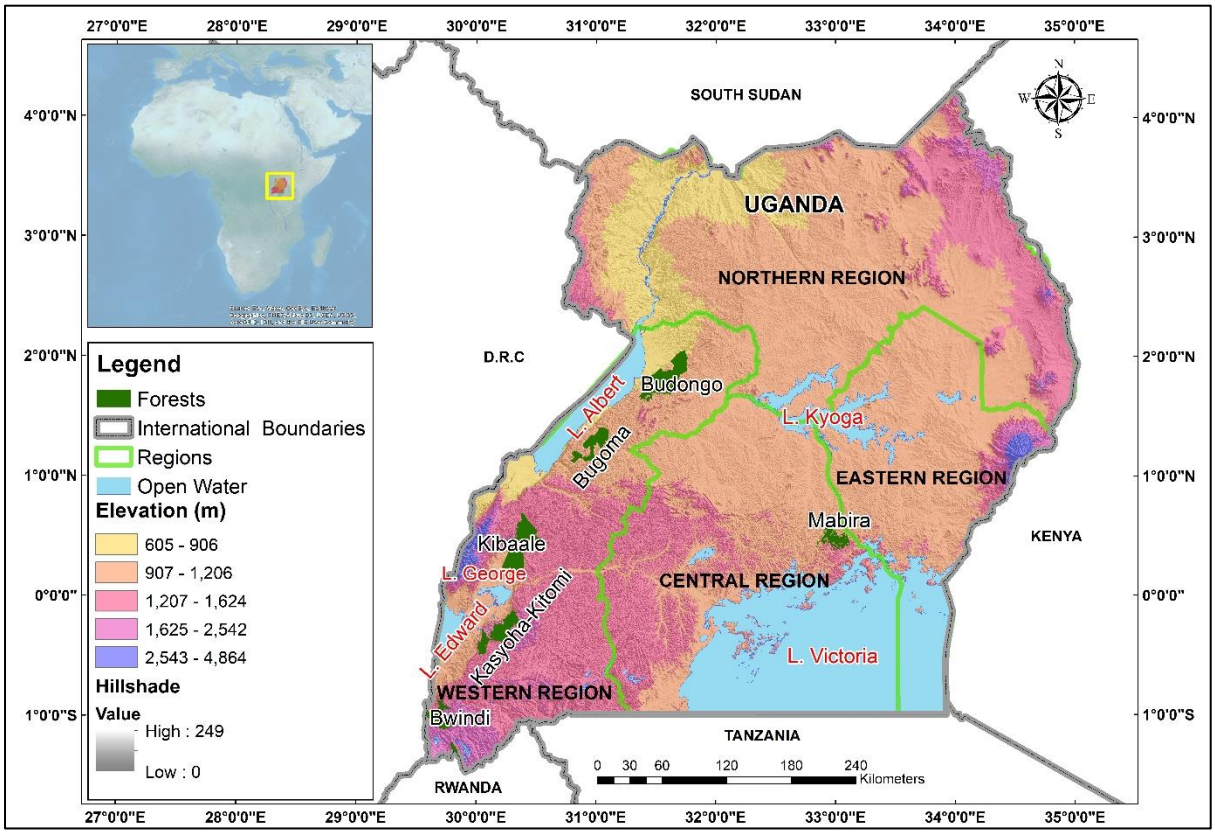
Figure 1: Map of Uganda showing major Tropical Rainforest Reserves



Data Collection

Data collection is a fundamental aspect of the course of any scientific research because it's the best choice of methods that give you better results and vice-versa (Rutten, 2015). We involved the use of secondary data including scholarly articles from peer-reviewed journals and published reports such as PubMed®, Google Scholar and SCOPUS databases. The scholarly articles we used in the review of this work are cited. In addition, the reports that were used in the review included the Uganda Bureau of Statistics (UBOS) and the National Forestry Authority (NFA) of Uganda where statistics were obtained. The selection of the study areas was because Tropical Rainforest Reserves in Uganda are endemic sources of medicinal plants used for the treatment of human diseases and these plants are threatened (Ikiriza *et al.*, 2019; Wangalwa *et al.*, 2021; Lukubye *et al.*, 2022).

Data Analysis

The data on the trend of deforestation in the Tropical Rainforest Reserves in Uganda such as descriptive (mean and standard deviation) and correlation statistics were analysed using SPSS software version 25. The data was later presented in form of graphs using Microsoft Excel.

RESULTS

The Trend of Deforestation in Tropical Rainforest Reserves in Uganda

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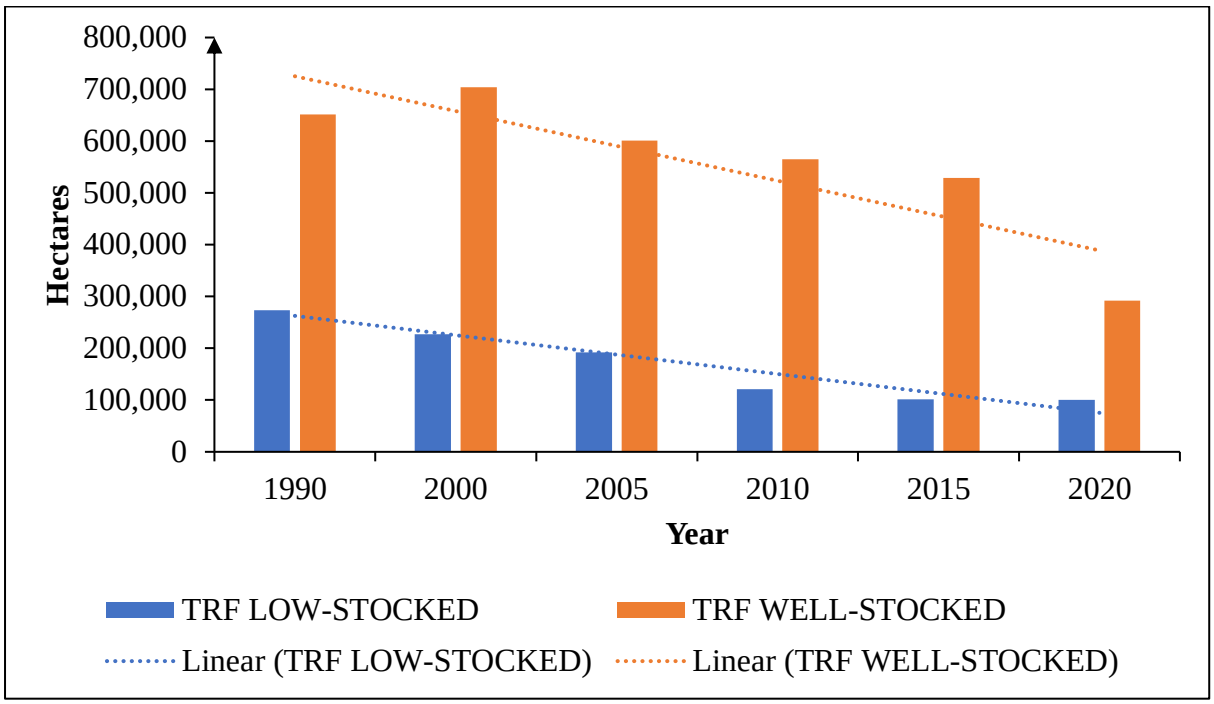
Figure 2: Trend of deforestation in Tropical Rainforest Reserves in Uganda (Source: NFA,2015; FAO, 2020)



Both the TRFR (Low and well stocked) showed a linear decline in the number of hectares per year. However, in 2000 the Tropical Rainforest Reserve well-stocked recorded an increment in the number of hectares. TRFR = Tropical Rainforest Reserve whereas the dotted lines (blue and red) show the linear trend line within the number of hectares per year. Tropical Rainforest Reserve (low-stocked) recorded an exponential decline in 2015 as compared to 1990. In 1990 the Tropical Rainforest Reserve low-stocked was at 30% and the declined to 10% in 2020 meaning that the percentage decline is 20% from 1990-2020. Tropical Rainforest Reserve well-stocked in 1990 was 21% and declined to 9% in 2020, the recorded percentage decline is 12%.

Table 1: Decline in the number of hectares between years in the Tropical Rainforest Reserves (TRF*R*s) in Uganda Source: (NFA, 2015; FAO, 2020)

Year	TRFR LOW- STOCKED	TRFR WELL-STOCKED
1990-2000	46,511	(52,819)
2000-2005	34,857	102,971
2005-2010	70,938	36,008
2010-2015	18,892	35,827
2015-2020	1,864	236,812

The results in *Table 1* show that between 1990-2000 Tropical Rainforest Reserves well-stocked had a negative decline in the number of hectares (52,819). The brackets mean a negative decline while values without brackets mean that there was a decline but the decline was positive.

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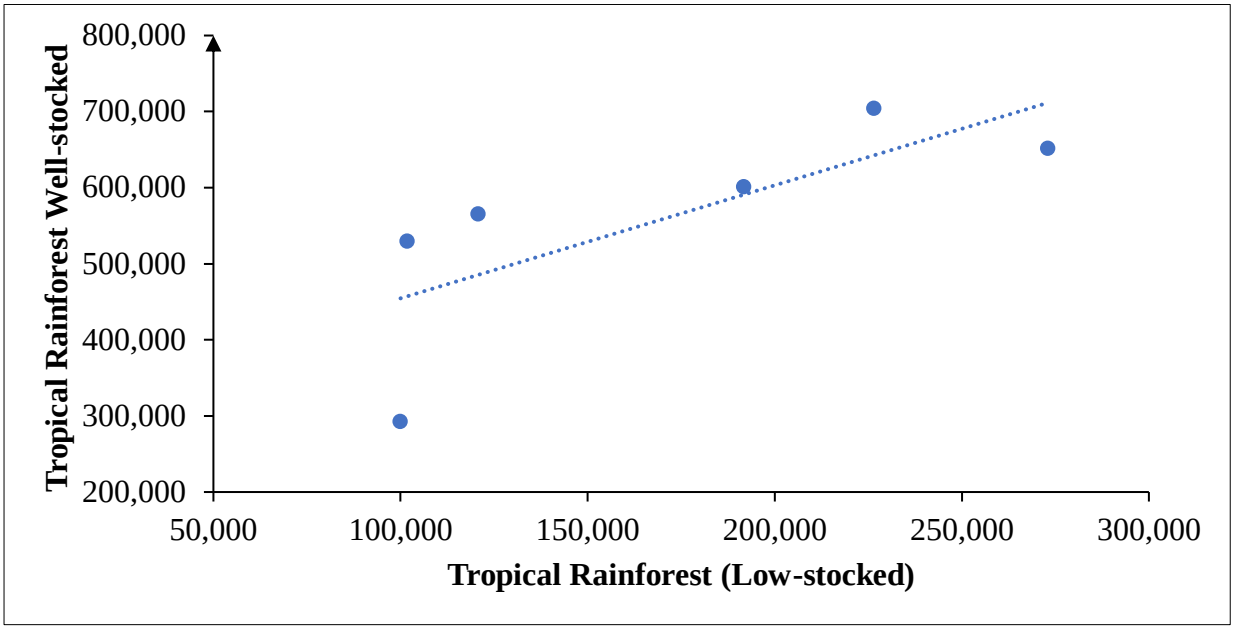
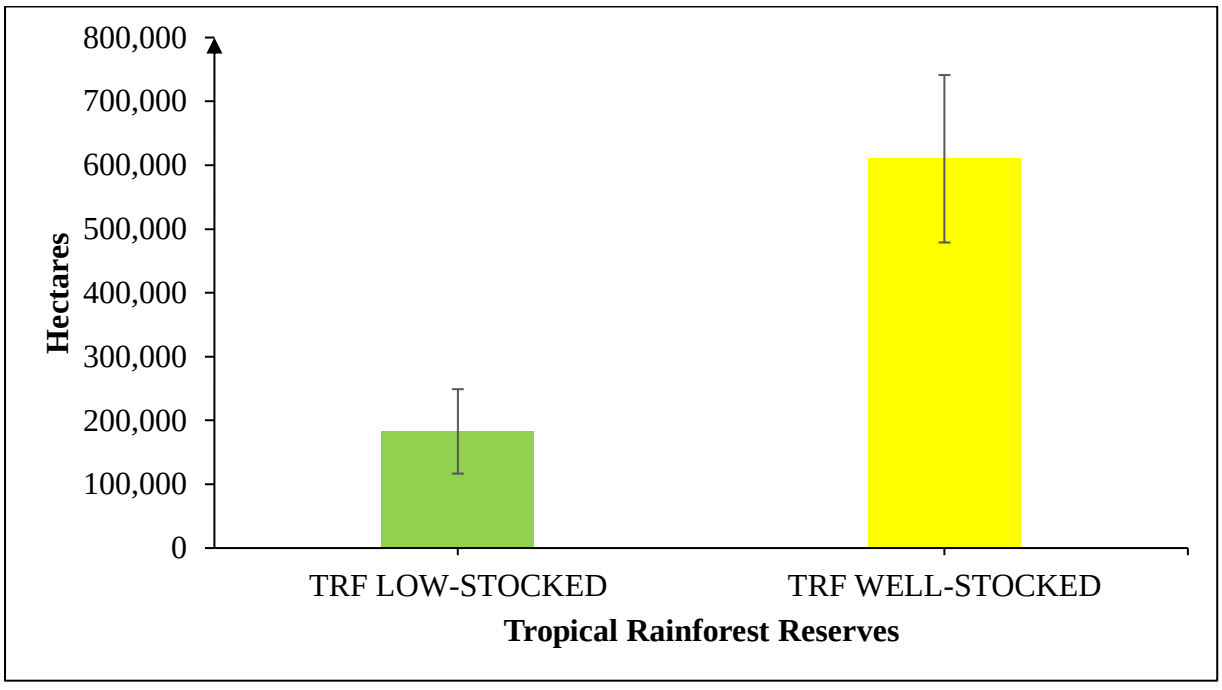
Figure 3: Correlation between the decline in the *Tropical Rainforest Reserves* well-stocked and low-stocked Source: (NFA, 2015; FAO, 2020)



The correlation between the Tropical Rainforest Reserves (well and *low-stocked*) shows that the two *forests* are strongly correlated r = 0.86. However, the p = 0.06 *means* that the decline in the number of hectares from 1990-2020 is not significant. The decline in the forest coverage in hectares showed a very strong positive correlation *with* the decline of the Tropical Rainforest Reserves from 1990-2015 (*Figure 4*).

Figure 4: Mean ± SD (Hectares) in Tropical Rainforest Reserves (TRF*R*) low and well-stocked from 1990-2020. Source: (NFA, 2015; FAO, 2020)



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Impact of Deforestation on Medicinal Plants' Existence in Tropical Rainforests

Deforestation in Tropical Rainforest Reserves in Uganda has a devastating impact on medicinal plant species because it reduces the diversity and existence of various species in their natural niche. Most medicinal plant species are herbs (*Table 2).* Therefore, they require a lot of shade that protects them from direct light which is provided by the closed canopy of the Tropical Rainforest Reserves. However, when the Tropical Rainforest Reserves are cleared, the medicinal plant species are exposed to direct sunlight energy which leads to the disappearance of the shade-tolerant species most especially the medicinal plants. The impact of deforestation is presented in the plate below.

Plate 1: Deforestation in Uganda's Tropical Rainforest Reserves a & b is Bugoma), c and d) is Mabira

(a)

Source: (Twongyirwe *et al.,* 2015)

(b)

Source: (Mangusho, 2019)

(c)

Source: (Monitor, 2017)

(d)

Source: (MWE, 2016)

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Table 2: Major threatened medicinal plant *species* in the Tropical Rainforest Reserves s in Uganda

English name	Scientific name	Treatment	Occurrence	Reference
Air potato/air yam/ bitter yam	*Dioscorea bulbifera*	Cancer, leprosy, and ulcers in humans	Mabira, Bugoma, Kasyoha-Kitomi and Bwindi	(Ikiriza *et al.*, 2019)
African cherry orange	*Cytropsis articulata*	Human male erectile disfunction	Mabira, Budongo, and Kibale	(Wangalwa *et al.*, 2021)
African cherry	*Prunus africana*	Prostate cancer in male humans		(Cunningham *et al.*, 1997; Galabuzi *et al.*, 2015)
Ugandan greenheart	*Warburgia ugandensis*	Malaria	Mabira	(Tugume *et al.*, 2016a)
Sipo Mahogany	*Entandrophragma utile*	Ulcers	Mabira	(Baranga, 2007)
African mango/wild	*Irvingia gabonensis*	Removal of cholesterol from the body	Mabira	(Baranga, 2007)
African tulip tree	*Spathodea campanulata*	Kidney diseases and removal of animal poison	Kalinzu	(Musinguzi *et al.*, 2017)
Bitter aloe	*Aloe ferox*	Reduction of pain due to gastrointestinal parasite infections	Kalinzu	(Musinguzi *et al.*, 2017)
Bitter leaf	*Vernonia amygdalina*	Dysentery and gastrointestinal disorders	Kalinzu	(Musinguzi *et al.*, 2017)
Red hot poker tree	*Erythrina abyssinica*	Malaria, snakebites, cough, and stomach-ache	Kalinzu	(Musinguzi *et al.*, 2017)
Drumstick tree	*Moringa oleifera*	Body healing and development of muscles	Kalinzu	(Musinguzi *et al.*, 2017)
Kamyuye	*Hoslundia opposita Vahl*	Malaria and stomach aliments	Mabira	(Asiimwe *et al.*, 2021)
African teak	*Milicia excelsa*	Diarrhea and dysentery	Mabira	(Asiimwe *et al.*, 2021)

The threatened species in the Tropical Rainforest Reserves of Uganda are presented in *Table 2*. The same table outlines the treatment for each medicinal plant. Mainly the threatened species are located in Mabira, Kalinzu, Budongo, Kibale, Kasyoha-Kitomi, and Bwindi.

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DISCUSSION

The Trend of Deforestation in Tropical Rainforest Reserves in Uganda

Our review articulates that both Tropical Rainforest Reserves (Low and well-stocked) showed a linear significant decline in the number of hectares between 1990-2020 with 10% being Tropical Rainforest Reserves Reserve low-stocked and 12% as Tropical Rainforest Reserves Reserve well-stocked which has an impact on the occurrence and diversity of medicinal plant species. The reason for such a drastic decrease in the forest cover could be a due increase in population which leads to the demand for forest products such as hardwood timber and fuel wood that provides a source of energy for cooking (Turyahabwe *et al.,* 2015; UBOS, 2020). In addition, other scholars have indicated that the decline in the forest cover is attributable to the conversion of more forest land to crop farming and animal rearing which corroborate with our findings of the review (Waiswa *et al.,* 2015; Josephat, 2018; Mwangi *et al.,* 2018; Twongyirwe *et al.,* 2018). Similarly, our review shows evidence of failure to have a proper land-use plan and failure to implement and enforce laws have a big impact on the escalated trend of deforestation in Uganda which coincides with findings of a similar study on deforestation (Ordway *et al.,* 2017). According to Hosonuma *et al.* (2012), the availability of international markets and high demand for hardwood from the Tropical Rainforest Reserves remain a big indicator of the increased deforestation in Uganda. Nabukalu & Gieré (2019) also evidences that charcoal burning also is a big contributor to the decline in the forest in Uganda. Therefore, in the long run, this can also lead to the decline in the medicinal plants in these forests. However, such activities can lead to the disappearance of the forest cover as well as a decline in existence of the medicinal plants.

Impact of Deforestation on Medicinal Plants' Existence in Tropical Rainforest Reserves

Our review explains that most of the medicinal herbs in Tropical Rainforest Reserves are shade-tolerant species as shown in *Table* 2 and hence require closed canopies. However, deforestation leads to the opening of the Tropical Rainforest Reserves Reserve canopies which exposes the medicinal plants under them to the direct sunlight and therefore, leads to their death as evidenced in deforestation studies (Mesfin *et al.,* 2013; Garbarino *et al.,* 2012; Hosonuma *et al.,* 2012; Muscolo *et al.,* 2014; Tefera & Kim, 2019; Peñuelas & Sardans, 2021). In addition, our review also articulates that deforestation also contributes to the disappearance of medicinal plant species through the use of poor harvesting methods which corroborates with evidence of the use of poor timber harvesting methods in the disappearance of medicinal plants (Shinwari, 2010; Akhtar *et al.,* 2013). This review evidences that the major cause of medicinal plant disappearance is deforestation coupled with agricultural expansion majorly near the Tropical Rainforest Reserves in Uganda. Similarly, other studies conducted in the Sub-Saharan African region also pronounce that deforestation geared by the expansion of agricultural land remains a big threat to the existence of medicinal plant species (Dambatta & Aliyu, 2011; Birhanu, Hong *et al.,* 2015)

Threatened Medicinal Plants in the Tropical Rainforest Reserves in Uganda

Grounded on the evidence of our review paper, we found out that the most threatened medicinal plant species in Uganda are 13 in number and include *Dioscorea bulbifera, Cytropsis articulata, Prunus africana, Warburgia ugandensis, Entandrophragma utile, Irvingia gabonensis, Spathodea campanulate, Aloe ferox, Vernonia amygdalina, Erythrina abyssinica, Moringa oleifera, Hoslundia opposita Vahl* and *Milicia excelsa.* The reason for threatening such plants is that they have a significant role in the treatment of enormous diseases indicated in *Table 2* and therefore, overharvesting and poor methods of collection may bring about their depletion.

Nevertheless, not the foremost part of our review, some indicated medicinal plants in *Table 2* such as *Prunus africana* and *Milicia excelsa* are also

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known as sources of hardwood timber which is used for the construction and making of furniture locally, nationally, and on a global scale and evidence to such is explained by several scholars (Stewart, 2003; Jimu, 2011; A. Cunningham *et al.*, 2016; Grace, 2019; Gachie *et al.*, 2020; Galabuzi *et al.*, 2021). Moreover, since *Prunus africana* and *Milicia excelsa* are well known for providing good hardwood timber globally, they also provide medicinal treatment *Table 2* therefore, such evidences are a big reason why the two species are highly threatened mostly in Uganda as well as within other Sub-Saharan African regions.

CONCLUSIONS

This paper reviews deforestation in Ugandan Tropical Rainforest Reserves, a threat to natural medicine. Deforestation has continued to increase in Uganda due to increased demand for timber, fuel wood, charcoal, and agricultural expansion. More so, this has impacted on the occurrence of medicinal plants in the Tropical Rainforest Reserves.

The study also noted a linear and an exponential decline in both Tropical Rainforest Reserves (low-stocked and well-stocked) from 1990-2020.

Recommendations

We recommend that the National Forestry Authority of Uganda should regularly monitor the trend of deforestation in Tropical Rainforest Reserves. We recommend that government of Uganda through the National Forestry Authority should put up strict laws and regulation regarding the impact of deforestation on medicinal plants in Tropical Rainforest Reserves. We recommend that ethnobotanical studies should be conducted to determine the medicinal plant species occurrence, abundance, distribution, diversity, and richness in the Tropical Rainforest Reserves.

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