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Challenges and Prospects of Medicinal Plant Sustainability in Ethiopia

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Abstract

The use of plants, mostly wild plants, for medicinal purposes in Ethiopia, a practice relied upon by an estimated 80% of the population, may not be sustainable. The decline in the supply of indigenous medicinal plants, both in Ethiopia and world-wide, has prompted research into the threats to their sustainability and measures that might reverse this trend. This review of literature from 2000 to 2023 identifies threats to medicinal plants in Ethiopia. Overharvesting of medicinal plants around population centers and habitat destruction are the major threats to medicinal plant sustainability. These threats are exacerbated by the country's large human and livestock populations, which are causing land degradation and habitat destruction through deforestation, and intensive cultivation and grazing of the erosion prone mountainous landscape. This study also assesses interventions at the household, community, and government levels aimed at conservation, habitat maintenance and restoration, and biotechnology applications. These interventions need to be strengthened through greater awareness of the threats to medicinal plants, longitudinal studies that include pre- and post-intervention assessments, and enforcement of environmental and conservation policies. The most promising interventions are plant cultivation in home gardens and the conservation of natural vegetation in biospheres, coffee forests, and church forests.

Keywords: Medicinal plants, overharvesting, environmental degradation, climate change, conservation, cultivation, government policies, Ethiopia

Introduction

Ethiopia has a long history of traditional medicine that goes back hundreds of years [1]. About 70% of Ethiopia's human population and 90% of its livestock population depend to varying degrees on traditional medicine for their primary healthcare [2]. Ethiopians treat human and livestock diseases either with plants obtained from nature, markets, or home gardens or by using traditional healers [3-5]. More than 7,000 vascular plants have been identified in Ethiopia, including nearly 300 species used for medicinal purposes [6, 7]. The value of medicinal plants used in Ethiopia has been estimated at $74 million and in Sub-Saharan Africa at $1.4 billion [8]. However, wild medicinal plant species are increasingly subject to overharvesting, habitat destruction, and the risk of extinction, a problem reported from many developing countries. An estimated 15,000 of the 50,000 to 80,000 medicinal plants species world-wide may become extinct; 20% are already extremely rare [9].

The study and use of indigenous medicines are encouraged by the World Health Organization (WHO) and the Ethiopian government. WHO [10] promotes and supports research on traditional plant medicines for the prevention, treatment, and management of endemic and epidemic diseases and

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illnesses in Africa. The affordability, accessibility, and cultural acceptability of these medicines are major factors encouraging their utilization, especially in developing countries [10]. The health and drug policies of the Ethiopian Ministry of Health recognize the need for traditional medicine in preventing and treating diseases, but little progress has been made in incorporating indigenous healing systems into public health programs [11]. Further progress will require research focused on ensuring the sustainability of medicinal plant species, most of which are wild [3]. Awulachew [13] recommended that community- and research-based interventions be employed towards sustaining medicinal plants and protecting their habitats. Numerous studies in Ethiopia have noted declines in the distribution of medicinal plants and made suggestions how to reverse that trend [14-16] without examining in depth underlying impediments and possible interventions. Two plant species, *Hagenia abyssinica* and *Withania somnifera*, have reportedly become extinct around a southern Ethiopian community [17]. The objective of this study is to review the literature regarding threats and opportunities to the sustainability of medicinal plants in Ethiopia with a focus on overharvesting, land and vegetation degradation, and climate change, and also to explore potential interventions.

Methods

Online searches were carried out to examine the risk of non-sustainability of medicinal plants and to identify possible interventions to their decline. The following search terms were used to identify pertinent publications covering the period 2000 to 2023 on Google Scholar and the Ethiopian Ministry of Health website: "overharvesting of medicinal plants in Ethiopia," "land degradation," "deforestation and traditional medicines in Ethiopia," "conservation of medicinal plants in Ethiopia," "cultivation of medicinal plants in Ethiopia," "church forests, sacred forests and medicinal plants in Ethiopia," "coffee forests and medicinal plants in Ethiopia," and "traditional medicine and climate change." We reviewed the abstracts of all articles and reports to select publications relevant for the objectives of the study.

Results and Discussion

Threats to the sustainability of traditional medicinal plants

Overharvesting

Overexploitation of medicinal plants and other biotic resources is closely related to increasing demands linked to population growth and associated expansion of agricultural land into forests and woodlands, land degradation, and habitat destruction [9]. The population of Ethiopia is estimated to have grown from 21 million in 1958 to 127 million in 2023 and is projected to grow to 182 million by 2040 [18]. The continuing high population growth rate is largely due to the persisting high birth rate. The country's fertility rate decreased by less than one child (5.5 to 4.6) per women between 2000 and 2016, significantly lower than in most other developing countries such as Kenya and Vietnam, whose populations have stabilized [19]. The rapid growth of Ethiopia's large rural population, which constitutes more than 80% of the country's total population, has resulted in the persistent decrease of the land holdings of subsistence farmers; the extension of farmland into forests, woodlands, and shrub lands; and increasing exploitation of medicinal plants by poor peasants seeking supplemental income [20]. Plant species gathered for their roots, stems, and bark, including *Dracaena steudneri* and *Securidaca longepedunculata*, are particularly vulnerable to extinction [21], although a wide range of other anthropogenic as well as natural threats affects all medicinal plants, as detailed below.

One plant frequently mentioned in the literature as being at risk of extinction is the climber *Zehneria scabra,* a popular folk medicine in Ethiopia and several other African countries for the management of rabies, fever, headache, and other conditions [22-24]. Giday [25] reported that this species is becoming increasingly rare in the Lake Tana basin due to overharvesting [25] attributed. The scarcity *of Zeheneria scabra and Verbena officinalis* in northern Ethiopia with their intense exploitation in highland forests. A longitudinal study in the Merkato market in Addis Ababa found that traders of traditional medicines, especially resins, must travel greater distances from source areas due to overharvesting in nearby locales [5]. The plant *Taverniera abyssinica* has also become highly vulnerable due to overharvesting, and *Hagenia abyssinica* and *Prunus africanus* have become rare throughout Ethiopia, largely because of their multi-use for fuel, house construction, and other purposes [22, 26].

Habitat destruction and land degradation

Although no reliable data are available in the absence of comprehensive surveys on the decline of forests in Ethiopia during the last century, estimates of 30% to 40% forest, woodland, and shrub cover in the late twentieth century are often used [27, 28]. Several studies in the western highland forests and in the Rift Valley indicate that natural high forests covered less than 3.0% of Ethiopia's land surface in 2020 and annual deforestation rates varied from 2.5% to 3.5% between 1957 and 2005 [29]. Similarly, according to [30], total tree cover in areas with more than 30% of the land covered with trees, which described 11% of Ethiopia in 2000, decreased 3.9% between 2001 and 2022. This tree loss could not be offset by the 1.5 square mile of forest cover added during that period [30]. Forests, woodlands, shrubs, and grasslands have been destroyed by the encroachment of agriculture and livestock grazing into wooded areas, a result of rapid population increase in rural areas associated with land degradation and decreasing crop yields on increasingly smaller farm plots as

Kloos H., J Pharm Pharmacol Res 2023
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well as drought, climate change, and tree cutting [31]. The total dependence of most communities on wood and charcoal is a key contributor to the loss of forests and woodlands [32].

Land degradation, habitat destruction, and soil erosion are most severe in the humid highlands, where the great majority of the Ethiopian population lives and agriculture is most intense [20]. Cultivation of seeds crops, including *teff*, wheat, barley, and millet, on steep slopes using the plow; the use of dung and crop residues for fuel; and overgrazing are also degrading the land [33, 34]. Water-related soil erosion rates range from 3.4 to 84.5 tons per hectare per year, leaving many mountainous landscapes with little or no soil cover [35].

Climate change

Developing countries, including Ethiopia, are disproportionately affected by climate change. An increase in global warming to the 1.5°C threshold is expected to pose a high risk of species extinction, especially in developing countries and in dry areas [36]. Mean temperatures in Ethiopia increased by about 0.2°C and minimum temperatures by 0.4°C each decade between 1920 and 2020 while annual rainfall changed little. However, variations in rainfall increased [3]. interfering with seasonal germination, blossoming, and fruiting cycles of vascular plants. Zegeye [37] analyzed the spatial and temporal distribution of rainfall, associating the decline in wetlands, increasing desertification, and loss of biodiversity with climate change. No empirical research has been carried out about the impact of climate change and climate variations on the distribution and ecology of medicinal plants in Ethiopia. However, the fact that these two climatic parameters contribute to reducing agricultural production [20] suggests they may similarly affect medicinal plants.

Climate change may impact medicinal plants in at least five ways. First, the growth and survival of medicinal plants may be curtailed by drought and higher temperature conditions. Second, subsistence farmers affected by climate change and drought have been collecting and selling medicinal plants to supplement their income. Third, climate change affects the pharmaceutical properties of medicinal plants because species may change their secondary metabolites, the basis for their medicinal activity, under changing climatic conditions [38, 39] and thus may become less safe and effective [40]. Fourth, pests, diseases, and invasive species emerging in response to climate change may adversely affect plant habitats. And fifth, medicinal plants may migrate to higher elevations to find suitable habitats in a warming environment [3, 39, 40]. Upward altitudinal migration of medicinal plants into cooler, more humid areas could become an adaptive mechanism in Ethiopia with its highly dissected mountain topography.

While the impact of these factors on medicinal plant growth and survival in Ethiopia has not been studied, indirect evidence of the negative effect of climate change comes from Ethiopian crop plants. Simulation modeling by Soloman [41] indicates that production of the staple crops *teff (Eragrostis tef),* maize, and sorghum will decline between 21% and 25% by 2050 due to climate change [41]. Even higher declines are predicted for wheat by 2050 [42]. We therefore recommend that carefully designed longitudinal studies of in-situ and/or ex-situ medicinal plants protected from anthropogenic activities be carried out that may facilitate the measurement of climate change effects.

Ethiopia's contribution to the global increase in greenhouse gases is small, with CO_2-equivalent emissions per capita being one-tenth of those in Europe and one-twentieth of those in the USA. In 2022, the car/population ratio in Ethiopia was about 1 per 100 [43], a miniscule ratio compared to the United States, where every family owns, on average, about two cars [44]. As a predominantly agricultural country, Ethiopia emits mostly methane from livestock and CO_2 from burning forests and grasslands. In 2010, 51% of all greenhouse gases in Ethiopia came from agriculture and 37% from forestry [37].

According to recent estimates, methane produced worldwide by livestock constitutes about 35% of total anthropogenic methane emissions [45]. This proportion is probably much higher in Ethiopia, where agriculture, particularly livestock husbandry, is the major contributor to climate change. [46], studying greenhouse gas emissions on 180 farms in mixed cropping/animal husbandry, pastoral and urban settings in northern Ethiopia, estimated that 82.8% of all emissions came from methane emitted by livestock, mostly cattle; 13.3% from CO_2; and 3.8% from nitrous oxide. Methane, a greenhouse gas with a global warming potential up to 80 times greater than CO_2 [47] is being emitted in large quantities by the country's large cattle population. Ethiopia had 61.5 million cattle in 2019 [48], more than twice as many as in the second- and third-ranking African countries (Chad and Sudan) [49]. No data are available on the impact of methane on climate change in Africa, but it is generally accepted that CO_2 must be reduced to net zero emission levels and significant methane missions must be achieved by mid-century to avoid breaching the 1.5°C warming limit agreed on in the 2017 Paris Agreement on Climate Change [50]. In addition to producing methane, cattle cause much overgrazing and land degradation (of both soil and vegetation), further contributing to climate change by reducing the capacity of rangelands as carbon sinks [51], emphasizing the need for mitigation practices.

Interventions

Environmental policies

The Ethiopian government implemented several policies, strategies, and plans with the overarching objective of

supporting sustainable development; these may enhance the survival of medicinal plants. After the failure of the Derg socialist regime's top-down approach to sustainably managing natural resources [52], the government developed an Environmental Policy of Ethiopia in 1997, which is based on environmental sustainable development principles [53]. The subsequent National Adaptation Plan aims at developing a climate resilient economy; the framework of the "Climate Resilient Green Economy" is focused on building a sustainable, environmentally adaptive economy [48]. The Plan for Accelerated and Sustained Development to End Poverty, the Growth and Transformation Plan, and the Sustainable Development Poverty Reduction Program were aimed at economic growth and reducing poverty with an environmental component. The impact of these programs and initiatives on the economy were considerable but unsatisfactory in solving environmental problems, largely due to institutional shortcomings, the politization of environmental issues, political instability, military conflict and failure to carry out pre- and post-environmental impacts equitably [54, 55].

Conservation

Conservation of medicinal plants can significantly reduce the harvesting of vulnerable plant species toward levels at which they can meet demands and retain biodiversity. Careful management of three ecosystems and preserves—namely the five biospheres established by the Ethiopian government's National Biodiversity Strategy and Action Plan (NBSAP), the coffee forests in southwestern Ethiopia, and sacred forests—may be able to conserve medicinal plants because of the ecosystems' status as natural preserves and the sacredness of the ladder. The biosphere initiative developed five conservation sites in areas with high biodiversity, including the Lake Tana, Sheka, Majang, Yayo, and Kafa biospheres, with the objectives of reducing deforestation and biodiversity loss of endemic flora and fauna; promoting sustainable livelihoods, and supporting research, monitoring, and the provision of information and training [56]. All biospheres contain many medicinal plants. In Sheka Biosphere, for example, Kassa [57] found 266 medicinal plant species, a larger number than reported by any other survey in Ethiopia. Nevertheless, the joint management of these cloud montane forest ecosystems by the local people and management of the biospheres require continuing vigilance and conservation to minimize overgrazing, deforestation, and unsustainable utilization of resources associate with agricultural expansion, overgrazing, logging, charcoal production, and cutting trees for firewood [56].

Coffee forests and sacred forests also provide higher protection against overuse of medicinal plants than surrounding landscapes because of their well-recognized economic and religious values, respectively. Traditional coffee cultivation in Ethiopia involves harvesting the berries from wild trees and maintaining shade trees instead of removing trees as in other agricultural systems. The high genetic diversity of *Coffea arabica* and the biodiversity of the coffee forests, which includes many medicinal and other useful plants, have been instrumental in preserving them. However, the trend towards higher intensity cultivation, characterized by thinning of tree cover in the quest for higher coffee yields, has resulted in vegetation degradation and declining biodiversity [58], although the impact on medicinal plants has not been studied.

Non-coffee producing agroforestry has also been practiced in Ethiopia for hundreds of years, with the objective of preserving multipurpose trees on cultivated land. The predominant tree species are managed and used by farmers for multiple purposes, including fodder, charcoal, timber, fuel-wood, farm implements, medicines, and income generation. In addition, indigenous trees are more effective in maintaining ecosystems, soil conservation, and soil fertility than eucalyptus, the dominant and widespread exotic species in Ethiopia. The predominant agroforestry trees are *Cordia africana, Millettia ferruginea, Erythrina brucei, Olea capensis, Croton macrostachys, Vernonia amygdalina, Albicia gummifera, Acacia nilotica, Faidherbia albida,* and *Albizia nilótica*. All of these are multi-purpose plants that are also used for medicinal purposes by the Ethiopian population. Because of their numerous uses they have been rapidly declining in recent decades [59]. The chances of their survival may be increased by official recognition and scientific study of their numerous benefits and the threats they are facing [60]. In an effort to conserve plant material, the Ethiopian Biodiversity Institute is conserving 260 species of forest plants in gene banks [24].

Forests around Orthodox Tewahido Christian churches in the central and northern Ethiopian highlands have been conserved by local communities for centuries. These small forests are characterized by high biodiversity similar to natural Afromontane forests and contain various medicinal plants, mostly indigenous trees [60, 63]. The church forests are increasingly affected by human and livestock disturbance. Wolde [60] recommended that forest be consolidated to increase plant dispersal and human and livestock incursions into the trees be prevented. The Gurage ethnic group in central Ethiopia maintain sacred forests for spiritual, cultural and ecological purposes [61]. The indigenous trees dominating these forests, including *Podocarpus spp., Ficus sycamorus, Croton macrostachys, Cordia africana, Juniperus procera,* and *Hagenia abyssinica* trees, are well known in Ethiopia for their medicinal properties [64, 65]. The old ages and large sizes of the trees in these sacred forests render them effective carbon sinks. Sacred forests have also been reported from

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the Konso ethnic group in southern Ethiopia which have been traced to the pre-Christian era [66].

Cultivation of medicinal plants

Cultivating medicinal plants in home gardens is an effective form of conservation. Whereas gathering of wild medicinal plants may lead to increased scarcity and the extinction of species, cultivation of plants may help meet the growing demand for plant medicines [14]. Agize [67] described home gardens as "living gene banks" that preserve indigenous plant varieties, landraces, and rare species over generations. One review of home gardens throughout Ethiopia [4] identified 539 plant species, including 137 food plants and 81 medicinal plants, which represent about 80% of all food plants and 9% of the medicinal plants in Ethiopia. These data reveal the high biodiversity of home gardens, which is being maintained by well-tried managerial and experimental practices that can strengthen their resilience against and adaptation to climate change [4]. Most medicinal plants used for human and livestock purposes in Ethiopia are wild [26], putting them at high risk of species loss because the threats to forest, woodland, and rangeland vegetation also affect medicinal plants.

Another challenge to conserving wild medicinal plants is that although some species have been successfully domesticated, difficulties of domesticating and managing certain medicinal plants requires that they be conserved *in-situ* [17]. Mesfin et al. [21] reported from one *wereda* (district) in southern Ethiopia that local healers have started to cultivate some herbaceous medicinal plants but not others in their gardens because they consider wild species to be more effective. Several communities in the humid southwestern highlands recently started to cultivate medicinal plants from seeds they collected in forests to ensure the availability and sustainability of species being threatened by overharvesting [25]. The various management practices for medicinal plants in gardens also include intercropping of different plant species and crop rotation [68].

Biotechnology may facilitate the production of endangered wild plants in home gardens or in horticultural stations through micropropagation, plant breeding, and hybridization. In one experimental study, the use of micropropagation increased the germination rate and growth of *Securidaca longipedunculata* and the propagation rate of *Aloe vera* [69]. The Ethiopian government established five field gene banks for in-situ conservation of herbal and tree medicinal plants [3, 6]. These biotechnological approaches to increasing the conservation of medicinal plants constitute encouraging prospects for their phytochemical and hybridization experiments and cultivation towards meeting the increasing demand for these plants, although the application of these techniques requires training and technical guidance at the household and community levels. [14] suggested the use of biotechnological techniques may permit the cultivation of wild plants on a large scale and increase their yields to ensure their year-round availability and sustainability. That approach includes new production techniques that can boost the yield of active compounds and control toxic components [9].

Moreover, farmers/plant gatherers can increase their profit margins and diversify their income by cultivating instead of collecting medicinal plants; this practice would also reduce ecological pressure on wild plants caused by overharvesting [70]. Whereas more home-grown medicinal plants than wild plants have reportedly been used in several urban communities [71], rural communities located in highly productive and diverse plant communities in southwestern Ethiopia rely mostly on wild plants [72]. In rural communities in the southern Ethiopian semi-arid lowlands, where indigenous medicinal plants are threatened by environmental change, deforestation, and overharvesting. Regassa et al. [73] found that half of 58 plant species were cultivated in gardens and half gathered as wild plants. [14] recommended that the number and volume of medicinal plants cultivated in home gardens in sub-Saharan Africa may be increased by addressing the prejudice against this practice through educational campaigns in an effort to meet the sharply increasing pharmaceutical demand. This discussion indicates that the popularity and advantages of cultivating medicinal plants in home gardens will most likely promote their sustainability in Ethiopia.

Afforestation, reforestation, and land rehabilitation

High rates of land and forest degradation world-wide are costing $6.3 trillion. Many of the community-based land and forest conservation practices developed in Ethiopia did not survive the political and social changes ushered in by the 1975 revolution, which nationalized all land and impeded the conservation of natural resources [29]. During the four subsequent decades several large-scale government-controlled interventions failed to control the deepening degradation crisis. The goal of the new forest law of 2018 is to restore the right of communities to manage natural forests with government guidelines and restore 2,200 km^2 of natural forest through afforestation and reforestation to increase cover and improve rural livelihoods as part of making Ethiopia a middle-income country by 2025, with a carbon-neutral economy by 2030 [74]. The optimal way to reach this goal is to select multi-use tree species. Reubens et al. [75] identified seven indigenous multi-use tree species that have traditionally been used for construction, fuel, agricultural, and medicinal purposes and are known ecologically and preferred by local populations. They are *Cordia africana, Dodonaea angustifolia, Eucalytus spp, Acacia abyssinica, A. saligna, Olea europea,* and *Faidherbia albida*. All these trees are used for medicinal purposes in Ethiopia [66, 76, 77]. Besides the selection of appropriate tree compositions, a sense of pride

Kloos H., J Pharm Pharmacol Res 2023
DOI:10.26502/fjppr.088

in resource ownership in communities will be required for the success of afforestation and reforestation programs using community participation approaches [72].

The Ministry of Environment, Forest, and Climate Change has prepared national maps with the objectives of identifying landscapes that could benefit from more trees, evaluating which tree-based options may be implemented, and determining where intervention should be implemented [78]. The spatial patterns presented by these maps may guide decision makers as to where more selected trees could best restore forests and woodlands. [79] developed a spatial model to enhance the conservation of endangered plants. By modeling the potential spatial distribution of *Echinops kebericho* using the maximum entropy model (MaxEnt) they identified many local areas totaling nearly 138,000km^2, mainly in the western mountains, where the species could be introduced or cultivated to promote its conservation. This technique may be used to determine the potential distribution of other medicinal plants that have become confined and threatened.

Climate change mitigation

In addressing the world-wide problem of climate change, Ethiopia became a signatory to several international environmental protocols, including the United Nations Convention on Biological Diversity, the UN Framework Convention on Climate Change, and the Kyoto and Paris protocols. The government also implemented mitigation and adaptation responses in 2007 and 2011, respectively. The Climate Resilient Green Economy policy, developed in 2011, is expected to play a major role in developing a resilient economy with net-zero national greenhouse gas emissions by 2030. The Ministry of Environment, Forest, and Climate Change was recently established to address deforestation and reforestation; 2 million hectares of pastureland are to be afforested and 1 million hectares of degraded forest to be reforested by 2030 [37]. These and other national policies are also focused on achieving sustainable economic development, environmental sustainability, poverty reduction, and food security and can foster mitigation and adaptation to climate change in an integrated manner. Achieving these various objectives will require environmental awareness creation and training in the population to change exploitive attitudes and behaviors of poor rural people lacking renewable energy sources, in addition to overcoming the institutional and political impediments discussed above [80].

Reductions in greenhouse gas emissions by agriculture and forests in Ethiopia may be possible and are necessary to achieve climate mitigation and adaption objectives. Although reducing the number of cattle in order to lower methane emissions would be a highly contentious issue due to the dependence of a large proportion of the Ethiopian population on milk, meat, and other products of cattle and their cultural importance among pastoralists [82, 83], significant reductions in methane emissions may be achieved. Berhe et al. [46] reported that improvement of feed, herd management, and manure management reduced manure emissions by 30, 21, and 29%, respectively. Reductions in methane and other greenhouse gas emissions may also be achieved in forestry. Berhanu et al. [83] found that the emissions of all three major greenhouse gases--methane, CO_2 and nitrous oxide-- were significantly lower in closed canopy coffee forests than in open-shade coffee forests, thus contributing more to mitigating climate change than disturbed forests. A study of smallholder agriculture in three districts in southern Ethiopia estimated that trees were the component with the highest greenhouse gas mitigation potential in various land use systems [84].

Conclusions

This article indicates that overharvesting of medicinal plants, deforestation, land degradation, overgrazing by large cattle populations, and poverty are major factors in the decline of medicinal plants in Ethiopia. Overharvesting of multipurpose plants, particularly the regenerative parts of wild plants growing near population centers, pose a particularly serious threat to the survival of medicinal plants**.** The dynamics and interactive nature of these relationships requires that interventions by the federal government, administrative regions, communities and households be carried out longitudinally in an integrated manner, that pre- and post-intervention evaluations be employed, and that traditional plant knowledge of rural people be preserved. Promising interventions include cultivation of medicinal plants in home gardens, which benefit from accumulated horticultural and conservation knowledge of rural households. The maintenance and replanting of natural vegetation in biospheres and in sacred forests and the management of coffee forests also contribute to the survival and biodiversity of medicinal plants. Other interventions that need to be carried out include application of various biotechnological techniques that can increase the productivity and adaptability of plants to climate change and environmental degradation. Future activities also need to examine environmental impacts, and enforce the Ethiopian government's environmental and conservation policies and strategies. Although the impact of Ethiopia's greenhouse gas emissions from agriculture, forestry, industries and automobiles on climate change and plant communities is currently comparatively small and requires less mitigation than the main drivers of environmental degradation and ecosystem changes, this issue will require more attention in the future with further industrialization and urbanization.

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