Climate Change Impacts on Traditional Medicine in Meru County, Kenya

Cleophas Ondieki[1]*, Justus Makori[2] & Evance Mbao[3]*

[1]Department of Psychology and Human Development, The Technical University of Kenya

[2]Department of Science, Njuri Secondary School, Kenya

[3]Department of Geosciences and The Environment, The Technical University of Kenya

**Corresponding authors: (cleophas.ondieki@tukenya.ac.ke, embao@tukenya.ac.ke)*

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Abstract

Climate change is increasingly recognized as a global phenomenon with multifaceted impacts, affecting various aspects of human life including traditional medicine practices. Currently there seems to be minimal studies that have been conducted regarding the negative effects of climate change on herbal medicine in Meru County. It is against this background that this study was carried out with an aim that it may fill this gap to make a difference. The objectives of the study included to: (i) determine the negative impact of climate change on herbal medicine (ii) find out the influence of climate change on herbal profession and (iii) determine climate change mitigation measures for herbal medicine in Meru County, Kenya. The present study was carried out between April and September 2023 to investigate the effects of climate change on traditional medicine in Meru County, focusing on shifts in medicinal plant availability, efficacy, and access. A survey research design was applied using semi-structured and structured questionnaires. Mixed-methods approach was used, including surveys, field observations, and interviews. Data was collected from traditional healers, community members, and local authorities. The study showed that over 50% of the Meru County residents rely heavily on traditional medicine for healthcare delivery, making it susceptible to the impacts of climate change. Additionally, the study revealed that climate change has resulted to alterations in the availability and distribution of medicinal plants (85%), disrupting the traditional healing practices deeply rooted in the region's cultural heritage. Further, the results indicated that changing precipitation patterns, temperature fluctuations, and habitat destruction have contributed to the decline of several medicinal plant types. Moreover, Herbalists reported that they experience greater difficulties accessing the medicinal plants, often missing them out or travelling over huge destinations. This loss of biodiversity has not only affected the abundance of medicinal resources but has also compromised the effectiveness of traditional remedies. The increased frequency of extreme weather events, such as extended dry or wet weather conditions have hindered access to remote areas where medicinal plants are typically harvested, further exacerbating the challenges faced by traditional healers. Therefore, this study underscores the urgent need for climate change adaptation strategies that integrate classical knowledge systems with modern approaches to safeguard the rich cultural heritage and ensure the sustainability of healthcare practices in Meru County.

Keywords: Adaptation; Efficacy; Biodiversity; Medicinal Plants; Climate Change; Cultural Heritage; Traditional Healers

Introduction

Globally climate change has had a negative and wholesale impact on both human and wildlife including flora. Its catastrophic features are worldwide warming and related higher temperatures together with drought and floods. These cause, individually or in combination, destruction of flora and fauna including humankind. A review study demonstrated that both climate change and habitat loss were major threatening factors that contributed to the biodiversity loss transcontinentally (Turyasingural et al., 2022). Another research indicated that the major three climate change variables, that is; precipitation, temperature, and a number of natural disasters occurrences generally increased biodiversity loss (Habibullah et al., 2022). Various regions have also attested to the adverse impacts of climate change on herbal vegetation. Explorations in India revealed how global warming caused noticeable impacts on the distributions and lifecycles of vegetation, covering also wild medicinal and aromatic plants (Das et al., 2016). In Guatemala and Honduras heightened amounts and power of storms, floods and droughts mainly due to changed and more volatile climate natural disasters created serious consequences for the two nations. Natural space diminished. There was loss of infrastructure due to landslides and floods, and inadequate harvest led to food shortages (Waddick 2017). A renowned enterprise in the USA, Gaia Herbs of Western North Carolina, and with international linkages in Europe and Central America, described the catastrophic impact of climate variabilities in its medicinal herb growing and sourcing (Gaia Herbs Farm 2019). In Africa climate change continues to ravage biodiversity and biodiversity-based ecosystem services that people rely on (Sintayehu, 2018). Declining agricultural production and food security are cases in point.

Recent years have witnessed an increasing corpus of research publications worldwide on the impact of climate change in multifaceted subjects including traditional medicine. Studies on health effects of climate change are among the commonest (Rocque et al., 2021). Other frequent investigations are on environmental and health impacts which are led by the Environment Protection Agency of the United States of America under its branch of the National Service Center for Environmental Publications. A limited rise in exploration of impacts of climate change on medicinal plants has been revealed over the past decade (Hounsou et al., 2024). Investigations have been conducted in Indonesia (Ria et al., 2021) China (Yi et al., 2016; Wei et al., 2018), Thailand (Tangjitman et al., 2015), and Pakistan (Khanum et al., 2013) among a few other countries. An example from Africa came from West and Central African countries where *Alstonia boonei* is used to treat malaria, ulcers sores, snakebites, and toothaches (Asase et al., 2019). The United Nations Framework Convention on Climate Change also published Climate-Impacted Loss and Damage in Kenya (Climate Refugees 2023). From the World Bank (2021) came Climate Risk Country Profile which had summaries on adaptation, climatology, climate change impacts and climate related natural hazards to key sectors. A report entitled "From Climate Risk to Resilience: Unpacking the Economic Impacts of Climate Change in Kenya" came from the International Food Policy Research Institute (2023). All these documents examined how the changing climate is impacting the geographic range of medicinal plants. A problem therefore is the paucity of scholarly work concerning climate change and the wider impact on herbal medicine.

In Kenya, a challenge highlighted is the apparent lack of political goodwill. Several legal instruments describe the significance of herbs and the traditional medical profession in Kenya. In Article 69 of the "*Constitution of Kenya*" explores obligations in respect of the environment. Among its provisions is that the Government of Kenya shall ensure sustainable utilization, exploitation, conservation, and management

of the environment and natural resources, as well as ensuring the equitable sharing of the accumulated benefits. Another requirement is to enhance and protect intellectual property including indigenous knowledge of biodiversity resources of the communities. Article 185(2), 186(1) and 187(2), which are detailed as the Forth Schedule in the Constitution, specifies the powers and functions of the County. One of these relates to the environment which expounds on the implementation of national government policies on environmental and natural resources conservation, including water, forestry and soil conservation. Forestry is promoted largely through "*The Forest Conservation and Management Act, 2016*". Counties are also responsible for cultural activities which though not exemplified to encompass herbalists, are covered by implication of traditional practices. The Constitution itself lays emphasis on this under Article 11, which emphasizes on the promotion of all forms of cultural and national expression through literature, traditional celebrations, science, arts, communication, mass media, publications, information, libraries as well as other cultural heritage "*The National Museums and Heritage Act, 2006*", accomplishes the endeavor on behalf of the Government. Among the functions of the museums in this context is the identification, protection, conservation and transmission of the natural and cultural heritage of Kenya. Promoting the herbal profession even more directly is the "*Protection of Traditional Knowledge and Cultural Expressions Act, No. 33 of 2016*". The act emphasizes the protection of traditional medicine knowledge, biological diversity, genetic resources and practitioners. Moreover, both counties and the National Government are designated responsibilities for the enhancement of indigenous therapeutical information and herbalists. Recognition of traditional medicine as a health product became legal by the "*Health Laws Act No. 5 of 2019*" and herbalists, by implication, were accorded further official status. Despite the foregoing legal instruments, the situation on the ground was quite different. Current research identified major gaps in climate change mitigation/adaptation measures for traditional medicine in Meru County. Recommendations were also put forward to address challenges.

Provision of healthcare in Kenya and other sub-Saharan African countries greatly recognizes the role of traditional healers. The World Health Organization (WHO) attributes this to unavailability of health care facilities and affordability (WHO 2008; 2002). The practice of herbal medicine in Kenya has been largely considered primitive by the elite unlike in other parts of the world like Asia. In addition, available legislation is scattered and fragmented without coordination and harmonization Sifuna (2022). For quite a number of years the utilization of herbal medicine for treatment of ailments has been downgraded, especially at a time when the usage of conventional medicine is available in formulations that are friendly to the patients. Herbal medicine on the other hand comes in form of organs of plants such as barks and leaves. These organs are often bitter to taste by the intended patients. Again, there is a feeling among the majority of the population that the practice is no longer an income generating activity as it was previously regarded. For this reason, it has been downgraded to poor and illiterate people (Thairu 1975). Additionally, currently there is serious threat to the existence of herbal medicine in many parts of the world Meru County included. This could be attributed to the negative effects of climate change. Climate change was a dominant factor habitat destruction through land degradation, bush fires, deforestation, overgrazing and fragmentation. (Gakuya et al., 2020). Other inquiries in Kenya have focused on agriculture. One of those pertaining to Meru County concentrated on smallholder farming communities in which the necessity of integrating farmers' and scientific approaches in mitigation against effects of climate variability was emphasized (Muthee et al., 2016). Another examination was on the interplay between land use changes and climate variability which

were proven to be potential causes for the declining agricultural productivity in Meru County (Muthee et al., 2015)

According to Owour and Kisangau (2006) many localities are finding it increasingly difficult to find some species of medicinal plants. Currently there seems to be minimal studies that have been conducted regarding the negative effects of climate change on herbal medicine in Meru County. It is against this background that this study was carried out with an aim that it may fill this gap to make a difference. Therefore, the specific objectives of the study included to: (i) find out the negative impact of climate change on herbal medicine (ii) find out the influence of climate change on herbal profession and (iii) determine climate change mitigation measures for herbal medicine in Meru County, Kenya.

Methodology

Study Area

The study was conducted in Meru County which lies a portion of Mount Kenya Forest. The Meru County Culture Officer provided the researcher with contact details of two groups: Meru County Herbalists Association and Tecocider Herbalists Group. Their combined membership totaled 105. Due to practical considerations such as time, cost and accessibility of respondents a sample size of 45 was evaluated to be acceptable. Interviewees were then invited by chairpersons of the two groups to a facility in the Meru Museum on diverse dates. Questionnaires were subsequently served to them.

Research Design

A survey research design was adopted from where participants responded to questionnaires. A survey research design, a quantitative research method used to collect data from a large population or sample in a systematic and structured way was employed in this study. It gathered information about attitudes, opinions, behaviours, experiences, and the characteristics of the target group. Before the exercise those involved consented orally. For non-traditional medicine practitioners, a flexible semi-structured questionnaire was applied.

Sampling Frame and Target Population

Since available traditional medicine practitioners comprised a manageable number their entire population of 45 individuals was drawn in. For others a relevant sampling frame was put in place. It covered professionals from the National Museums of Kenya (headquarters in Nairobi and Meru branch), culture officials (Directorate of Culture in Nairobi and Meru County), environmentalist (Meru County), pharmacognosy experts (Technical University of Kenya). Both professional experts and traditional medicine practitioners were interviewed for the purpose of acquiring a holistic picture.

Data Collection

We used a semi-structured questionnaire as the primary data collection tool. This approach combines both structured and unstructured elements, providing a framework of pre-determined questions to ensure consistency across interviews while allowing flexibility to probe deeper into relevant topics that emerge during the conversation. The technique facilitated gathering detailed and comparable data across participants while leaving room for spontaneous insights. Additionally, an open-ended questionnaire was employed to complement the semi-structured approach. Unlike closed-ended questions that restrict

responses to specific options, open-ended questions encouraged participants to elaborate on their thoughts freely. This method was particularly useful for exploring and accumulating nuanced data on the thematic categories under investigation, as it allowed respondents to share detailed perspectives, experiences, and ideas that might not have been captured through the semi-structured format alone. Jointly, these techniques created a comprehensive and dynamic data collection process, balancing the need for systematic inquiry with the flexibility to capture rich, in-depth information.

Data Analysis

The collected data was entered in Microsoft Excel where descriptive statistics such as frequencies, means, and percentages were performed. Chi- square was performed to establish whether there was any association between the years of practice of herbal medicine and gender as well as climate change variation. The data analysis was stepwise, starting with data preparation: The data on years of practice and gender were tabulated into a contingency table, showing the frequency of participants in each category combination. The Chi-square test compared the observed frequencies in the contingency table with the frequencies expected if there were no association between the variables. Interpretation of results was based on p-value < 0.05. This analysis was crucial in understanding demographic patterns and potential gender-related trends within the practice of herbal medicine, providing insights that could inform further studies or policy development. STATA software version 13.0 was used to analyze the data. Tables, column graphs, bar charts, and a pie chart were used to present the data.

Results

Gender

The investigation comprised both male and female traditional medicine practitioners. The total number of participants by gender was determined and their proportions with male showing greater frequency of 30% and proportion of 66% as shown in Figure 1. The data implied that more males practiced herbal medicine than females.

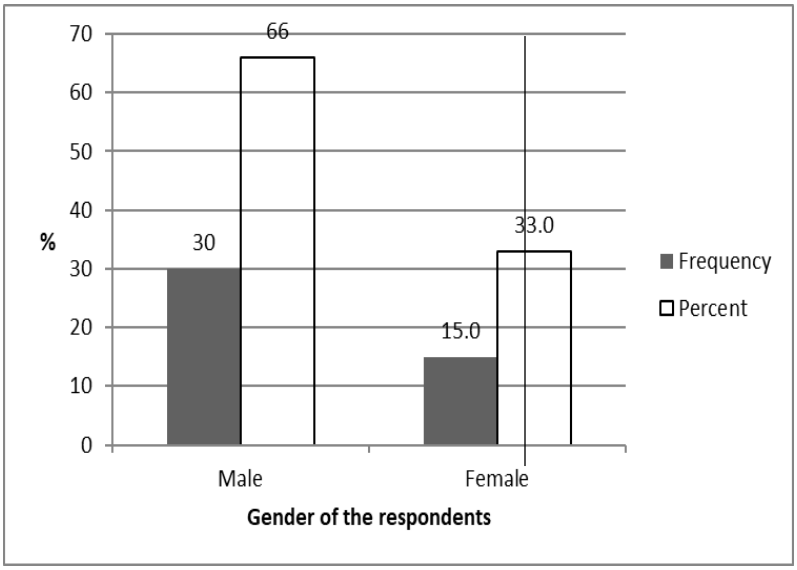

Figure 1: Percentage of Participants Gender

The second aspect of the study that was collected and analyzed was the level of education of the herbalists. With regard to the level of education of the participants in the study, Figure 2 showed the numbers.

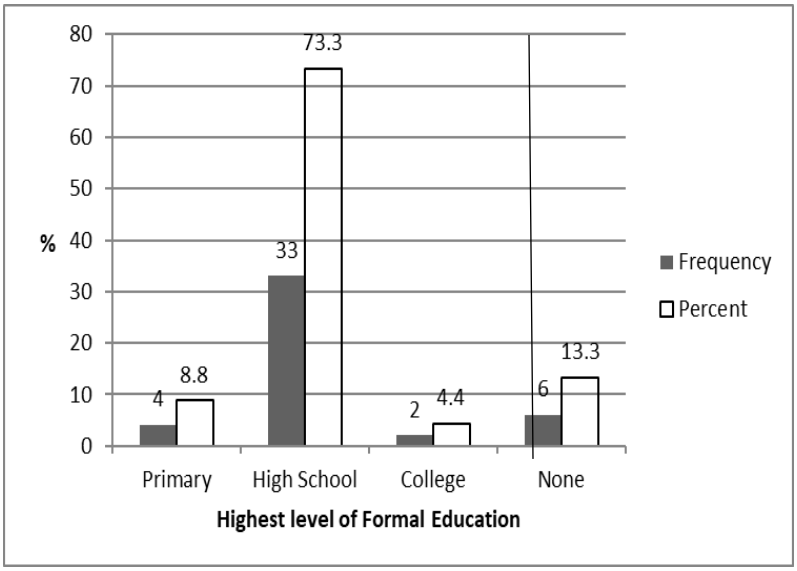

Figure 2: Level of Education of the Participants

Figure 2 indicated that the highest level of formal education of the participants was high school (73.3%). Traditional medicine practitioners with primary level of education stood at 8.8% while those with college education were at 4.4 %. From the foregoing, the figures indicate that herbal medicine in Meru County is mostly practiced by individuals with high school education. Table 1 reveals the various ways in which participants learnt the skills of treatment.

Table 1: Learning about Treatment

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How Participants Learnt to Treat using Herbs	Frequency	Percent
Learnt from parent	10	22.2
Learnt from relatives other than parent	6	13.3
Learnt from another herbalist	28	62.2
No response	1	2.2
Total	45	100.0

Table 1 disclosed that a majority (62.2 %) of the respondents sampled acquired the profession from other herbalists. Traditional medicine practitioners who learnt from relatives who were not their parents and those who learnt from their parents stood at 13.3 % and 22.2 % respectively.

Additionally, the research sought to investigate the experience of herbalists in the traditional medicine profession. In this regard, the respondents were asked to indicate how long they had practiced herbal medicine. The information in Table 2.0 gives the study findings.

Table 2: Duration of Herbal Medicine Practice

How long participants have practiced herbal medicine profession	Frequency	Percent
1 - 5 years	15	33.3
6 - 10 years	19	42.2
More than 10 years	11	24.4
Total	45	100.0

Table 2 showed that the majority (42.2%) of the herbalists have practiced herbal medicine in the study location for between 6-10 years. The table further reveals that those who practiced between 1-5 years stood at 33.3% while those who had practiced more than ten years was 24.4%. In order to establish whether there was any association between the years of practice of herbal medicine and gender, a chi-square was computed. The result for the chi-square is shown in table 3

Table 3: Chi-Square Values for Years of Herbal Practice and Gender

Gender	1-5 years	6-10 years	More than 10 Years	$\chi 2$	df	P value
Male	10	14	11	4.398	95	0.111
Female	5	5	0			

Table 3 revealed that the chi-square calculated was, $\chi 2$ (95) = 4.395, p = 0.111, α = 0. 005.The p value obtained is greater than the critical alpha (α = 0.005). This implies that there was no association between the number of years of practice of herbal medicine and the gender of the herbalist.

The other aspect of interest for the study was the parameters that were used to determine the cost of treatment of the patients in herbal medicine. The respondents were asked to select from any of the following options: the nature of the illness, period of treatment, cost of herbal medicine or others where they were required to specify. The results are provided in Figure 3.

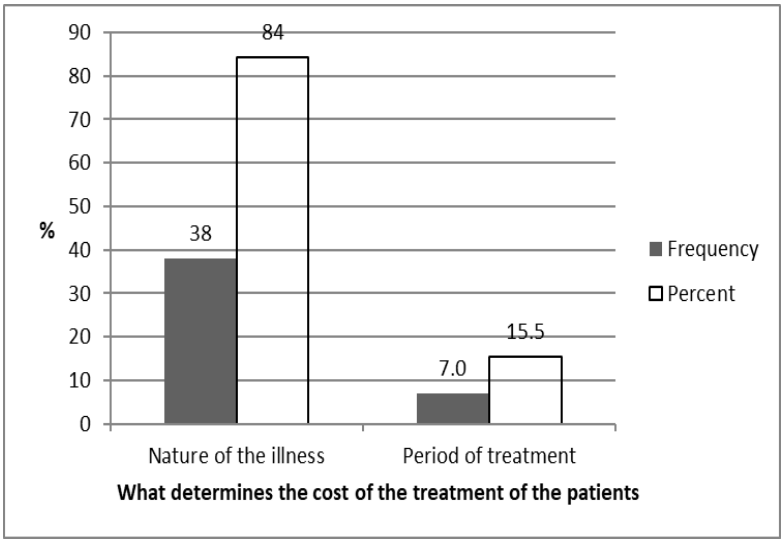

Figure 3: Determinants of Cost of Treatment

The observation made from Figure 3 is that the nature of the illness as a factor that determines the cost of treatment in herbal medicine in Meru County is higher (84%) than the period of treatment whose figure stood at 15.5%. An inference of this is that herbalists interviewed reverted to the nature of illness as a parameter to determine the cost of medicine.

Documentation of administration of herbal medicine or any other medicine for that matter is a critical aspect of the treatment process. Through a questionnaire, the respondents were required to indicate whether they kept records of medicine prescribed to their patients. Table 4 shows the results obtained.

Table 4: Documentation of Herbal Medicine Administration

		Frequency	**Percent (%)**
Gender	Male	30	66.6
	Female	15	33.3
Total		45	100

It is evident from Table 4 that majority (66.6%) of the male respondents sampled indicated that they documented the administration of herbal medicine. The female respondents who kept records represented 33.3% of the total population sampled in the survey. Besides documentation of administration of medicine, the sampled respondents indicated whether they usually monitored the usage of herbal medicine among the patients. The findings are shown in Figure 4.

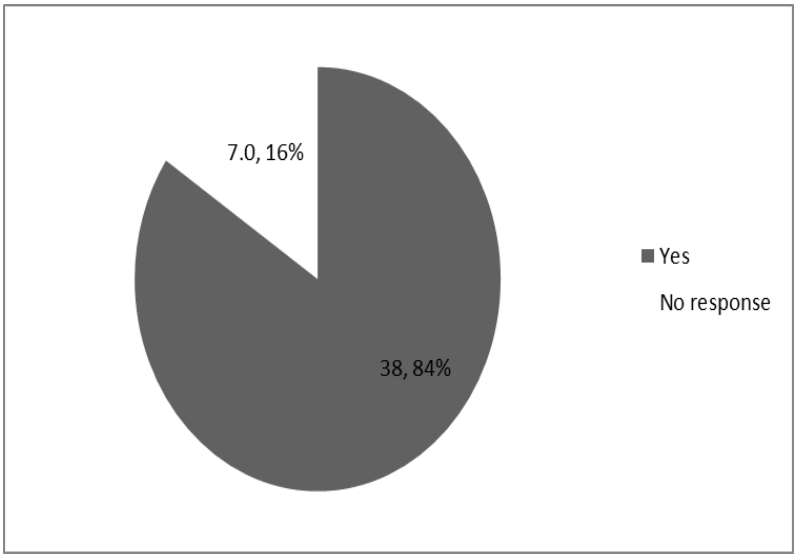

Figure 4: Monitoring of Usage of Herbal Medicine

The observation made from the pie chart in Figure 4 is that majority (84%) of the sampled respondents demonstrated that they monitored the usage of the herbal medicine while 16% of the participants in the study did not monitor the usage. The observation emphasizes the importance of closely monitoring the usage of herbal medicine.

The study also sought to find out the main source of herbal medicine raw materials in Meru County. The respondents were asked to indicate whether they obtained their herbal medicine from: Ngare Ndare,

Kibithewa, Nthunguru, Upper Imenti, Lower Imenti Forest or any other. The study findings are shown in Figure 5.

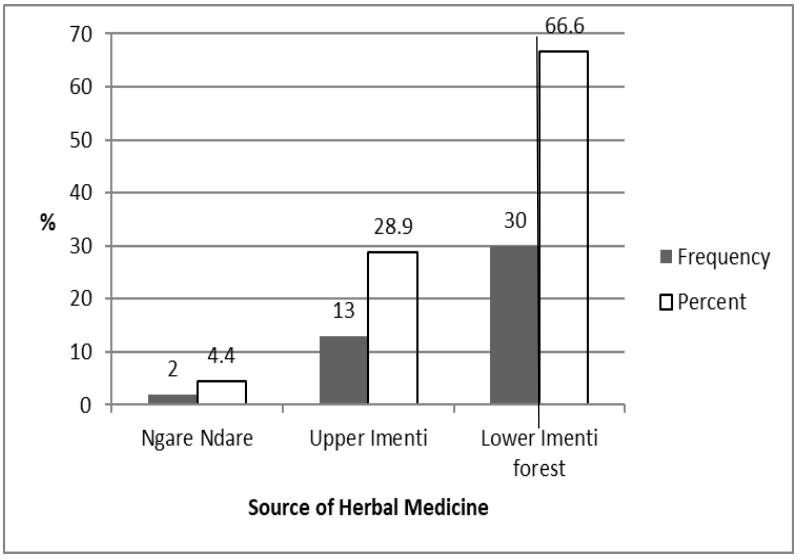

Figure 5: Source of Herbal Medicine in Meru County

The study finding in Figure 5 revealed that most (66.6%) of the herbal medicine in Meru County, Kenya is sourced from the Lower Imenti forest while Ngare Ndare provides the least (4.4%) source of herbal medicine. Slightly more than a quarter (28.9%) of the total herbal medicine is obtained from Upper Imenti Forest by herbalists. These study findings imply that traditional medicine sources have continued to decline in most of the forests within Meru County.

Negative Impacts of Climate Change on Herbal Vegetation in Meru County

The first objective of the study sought to find out the negative impact of climate change on herbal medicine in Meru County, Kenya. With the questionnaire as the research instrument, the respondents were asked to indicate whether they understood what climate change means. The study findings are shown in Figure 6.

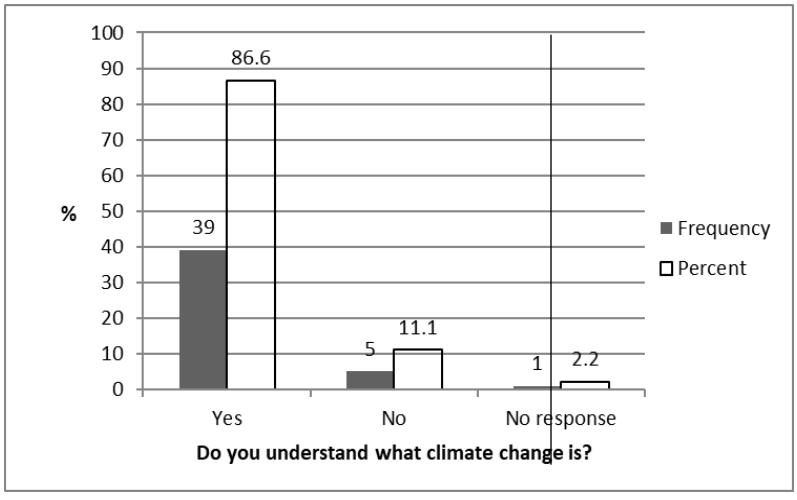

Figure 6: Understanding of climate change

The bar graph in Figure 6 indicated that majority (86.6 %) of the respondents understood what climate change means. The figure further shows that a very small percentage (11.1%) of the participants in the study did not understand the meaning of climate change. The implication of this study finding was critical to the study because it shows that the respondents would easily relate the negative impacts of climate change on availability of herbal medicine in the study location. The other aspect that was of great interest to the study was the relationship between negative impact and availability of herbal medicine. The respondents were asked to indicate their own assessment on whether there were some medicinal plants that were previously easy to find in the forests but over the past few years, they are now not easy to obtain. The results are shown in the Figure 7.

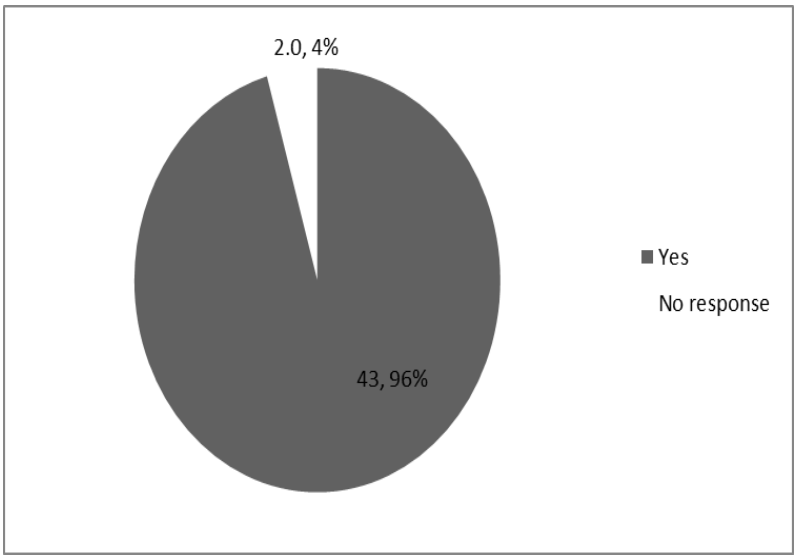

Figure 7: Percentage Ease of finding Herbal Medicine in Some Forests in Meru

The pie chart in Figure 7 revealed most of the medicine (96%) were easy to find previously but currently they have become difficult to find. The extreme weather conditions that range from soaring temperatures to excessive flooding has caused flora and fauna to diminish hence some of the herbal medicine is not easy to find. Therefore, the study notes that climate change has greatly contributed to the scarcity of herbal medicine in Meru County. This study finding is in tandem with the study findings on impact of climate change on biodiversity loss (Habibullah et al., 2022). The study found out that climate change and habitat loss were the major threatening factors to biodiversity. Studies in other parts of the world also concur on the negative effects of climate change on herbal vegetation. A good example is the exploration in India that demonstrated that negative effects of climate had a noticeable effect on the lifecycle and distribution of vegetation including medicinal and aromatic plants (Das et al., 2016),)

Influence of Climate Change on Herbal Profession in Meru County

The second objective of the study sought to find out the influence of climate change on herbal profession in Meru County. With the questionnaire as the research instrument, the respondents were asked to indicate on a Likert scale the impact of climate change on herbal medicine profession. Key: 1-Never impacts 2-Rarely impacts 3- Occasionally impacts 4- Greatly impacts.

Table 5: Influence of Climate Change on Herbal Medicine

Item	1	2	3	4
	Never impacts	**Rarely impacts**	**Occasionally impacts**	**Greatly impacts**
Lessening availability	2 (4.4%)			43 (95.5%)
Declining number of customers	2 (4.4%)			43 (95.5%)
Reduced income	2 (4.4%)			43 (95.5%)

Table 5 showed that a majority (95.5%) of the respondents sampled agreed that climate change has greatly negatively affected the herbal medicine profession in Meru. In contrast, 4.4 % of the participants in the study felt that climate change had neither resulted to decrease in availability of herbal medicine nor led to decline in the number of customer and income of the herbalists.

This study finding is in agreement with assertions in the USA, Central America and Europe Gaia Herbs (2021) which noted that continuous medicinal crop loss and decreasing profits from growing herbs was due to unpredictable weather, which forced some farmers to abandon their vocation. Additionally, it concurs with the analysis in South Africa that displayed how a combination of water scarcity, poor soil conditions, pest infestations and disease infections gave rise to a threat of unsustainable agricultural production and increased poverty levels among the smallholder farmers (Popoola et al., 2017)

Climate Change Mitigation/Adaptation Measures for Herbal Medicine

The third objective of the study sought to find out the climate change mitigation/adaptation measures for herbal medicine in Meru County, Kenya. With the questionnaire as the research instrument, the respondents were asked to indicate on a Likert scale climate change mitigation/adaptation measure for herbal medicine in Meru County, Kenya. The results are shown in Table 6.

Table 6: Climate Change Mitigation/Adaptation Measures on Herbal Medicine

	Poor	**Average**	**Good**	**Very Good**
Item	1	2	3	4
Improved conservation of herbs in forests		2(4.4%)		43 (95.5%)
Exhibitions and marketing of herbs in Meru County and beyond		2(4.4%)		43 (95.5%)
Establishment of herbal gardens at county and sub-county levels				42 (93.3%)
Facilitation of village herbal gardens.				42 (93.3%)
Training of herbalists				42 (93.3%)

Table 6 revealed that most (95.5%) of the respondents rate the conservation of herbal medicine, exhibitions and marketing of herbalists in Meru County and beyond as a very good intervention measure. Again, with regard to establishment of herbal gardens at County and sub-county level, facilitation of village herbal gardens and training of herbalists was rated unanimously (93.3%) by the respondents as being a very good measure. Based on the second objective, the study notes that the climate change mitigation measures on

herbal medicine in Meru County is generally rated as acritical intervention measure. The current study findings concur with a scrutiny conducted in Tharaka Nithi County which endorsed awareness campaigns on the importance of cultivating medicinal plants as part of mitigation measures (Kaigongi and Musila 2015). From the literature reviewed again, a corresponding message was conveyed through an inspection conducted in Baringo County. It was demonstrated how animal grazing, firewood collection, herbs collection, placing beehives and gathering fruits were affected in the conservation areas which were the natural habitats of the indigenous medicinal plants practices which led to destruction (Rotich, 2016). The study opines that there was need for pertinent education to create awareness on conservation so as to ensure sustainable use and conservation of the unique flora.

Discussion

Impact Of Climate Change on Herbal Medicine

Herbal medicine relies heavily on the availability of specific plants and natural resources, which are directly influenced by environmental conditions. Climate change, characterized by shifting weather patterns, rising temperatures, prolonged droughts, and erratic rainfall, can significantly affect the growth, distribution, and quality of medicinal plants. The study revealed that climate change has significantly contributed to the scarcity of herbal medicine in Meru County, this is in agreement with previous study by Kito (2015) who revealed that prolonged droughts, erratic rainfall, and changes in temperature can lead to the loss of habitats for many medicinal plants, reducing their populations or driving some species to extinction. Additionally, the extreme weather conditions associated with climate change can hinder the growth and reproductive cycles of medicinal plants, resulting in lower yields and diminished potency of herbal remedies. Further, Kito (2015) demonstrated that climate-induced issues such as erosion, loss of soil fertility, and desertification can further threaten the natural habitats of these plants, making it harder for them to thrive.

Principally conserving herbs means conserving natural habitats and ecosystems and all other taxa that co-occur with them, that are suited to in situ conservation (Ria et al., 2021). The present study is in agreement with a previous study in the USA about sustainable forest agriculture which described Black Cohosh (*Cimicifuga racemosa*) and Goldenseal (*Hydrastis canadensis*) as examples of wild herbs, of economic importance, that may be readily cultivated (Cech 2002). The economic value of medicinal plants in the Kakamega Forest Ecosystem provided another testimony which underscored the critical role of conservation of herbs (Ojunga et al., 2023)

Impact of Climate Change on Herbal Medicine Profession

The present study has demonstrated that herbal medicine profession face challenges in sourcing essential plants, increasing the time and cost of obtaining raw materials as exacerbated by climate change, which is in agreement by Dunn (2017) who demonstrated the challenges and benefits of herbal medicine in Tanzania. This scarcity not only threatens their livelihood but also limits the availability of traditional remedies for the community. Economic and Livelihood Challenges. The scarcity of medicinal plants due to climate change directly impacts the income and sustainability of herbalists' practices. In Meru County, many herbalists depend on the trade of these remedies as their primary source of income. The increased cost for scarce plants has resulted into reduced profit margins, thus reduced client base consequently the inability to meet demand or maintain the quality of remedies which has led to a decline in customer trust and patronage. This has resulted to herbal profession in Meru County to shift to alternative sources, by

purchasing plants from other regions or grow them domestically, requiring significant investments in time and resources.

Facilitating the participation of traditional medical practitioners in exhibitions and marketing can increase their revenue besides offering educational opportunities. In Ganjam District, Orissa, India, exhibitions were proved to be an effective promotion of local products from rural cultivators who had also formed self-help groups (Mohanty and Tripathy 2012). A corresponding evaluation of the Agricultural Society of Kenya Mombasa Show attested to the role of such functions. Shows provided a special environment where a wide range of sales and marketing objectives were pursued (Situma 2012). Some of the limitations noted in the exhibition included continued over-harvesting from wild populations, inadequate domestication of valuable plants species, poor knowledge of required agronomic practices, and low efficacy perception regarding derivatives from cultivated plants

Climate Change Mitigation Measures

This study demonstrated that sustainable harvesting practices is one of the key mitigation measures of climate change in Meru, a finding that is in agreement with previous studies Shisanya et al (2022). Overharvesting of medicinal plants exacerbates the effects of climate change on plant populations. Sustainable harvesting ensures that plants are collected responsibly without depleting their natural supply. Measures include educating herbalists and communities about ethical harvesting techniques, such as collecting only mature plants or parts of plants (e.g., leaves instead of uprooting entire plants). Additionally, encouraging rotational harvesting to allow plant populations to regenerate. Secondly, conservation and reforestation efforts mitigate the impact of climate change (Shisanya et al., 2022). The destruction of forests and natural habitats has significantly reduced the availability of medicinal plants in Meru County. Reforestation and conservation initiatives can restore these critical ecosystems. Here, the measures include establishing protected areas for medicinal plants, such as herbal sanctuaries or reserves. Moreover, planting native and endangered medicinal species in degraded lands and community spaces as well as collaborating with environmental organizations and government agencies to implement reforestation programs is crucial for the mitigation efforts. Thirdly, conservation and reforestation efforts is important. This is because the destruction of forests and natural habitats as a consequence of climate variability has significantly reduced the availability of medicinal plants in Meru County. Reforestation and conservation initiatives can restore these critical ecosystems. Measures to abate the trend would be establishing protected areas for medicinal plants, such as herbal sanctuaries or reserves. Fourthly, climate change has led to erratic rainfall patterns and prolonged droughts in Meru County, affecting plant growth, therefore, effective water management can help mitigate these effects. Measures include construction of rainwater harvesting systems to ensure a steady water supply for cultivating medicinal plants, encouraging the utilization of drip irrigation and other efficient water-use technologies, as well as restoring wetlands and riparian zones to maintain local water cycles. Lastly, there is need of promoting Climate-resilient plant Species. This is because some medicinal plants may be more resilient to climate change than others. Identifying and prioritizing these species can help sustain the herbal profession. Measures would be conducting research to identify plants that can thrive in changing climatic conditions. Additionally, encouraging the use of alternative species with similar medicinal properties to reduce reliance on vulnerable plants.

Meru County could also draw from the experience of several countries which have set up herbal gardens. India is an example whereby the national government, private agencies, non-government organization are

involved in the creation and maintenance of common, rare and endangered medicinal plant species. Moreover, State Medicinal Plant Boards with funding from the National Medicinal Plants Board promote home herbal gardens, Institutional herbal gardens and school herbal gardens. In the process an awareness is generated among local people about the rich diverse indigenous knowledge on medicinal plants and their benefits (Kumar 2020). In South Africa cultivation of medicinal plant is largely a mitigated measure geared towards biodiversity conservation. In addition, it is contemplated as a feasible choice to overcome challenges that are inherent to medicinal plant materials availability for commercialization and for quality assurance (Tanga et al., 2018). A lesson to be learnt as well, through another research in South Africa, is referred to as Constraints to Cultivation of Medicinal Plants by small-scale farmers in South Africa (Nwafor et al., 2021). Insufficient domestication of valuable plants species continued over-harvesting from wild populations, dismal knowledge of required agronomic practices, poor efficacy perception regarding derivatives from cultivated plants were the main challenges cited. Potential solutions included improvement of smallholder participation in the cultivation of medicinal plants to encompass support to research and extension, focused inducement to smallholders. Others were contracting and off-take agreements, for promotion of an alternative poverty-alleviation-aimed at economic development strategy. Much can also be learnt from an arboretum in Tigoni, Limuru, Kiambu County, which has a herbal garden (Nicholson 2001) If Meru County establishes herbal gardens, particularly at institutional levels, more benefits will accrue. Among these are biodiversity conservation, soil and water conservation, awareness, utilization of wasteland and unfertile land, as well as research and development (Pandey et al., 2021)

Training of Herbalists

Since traditional Chinese medicine is an important component of China's medical system the training of herbalists is considered critical. Curriculum implementation usually occurs at college or university level (Nzeng et al., 2019). Core to pedagogy is the teacher–apprentice style (Liu et al., 2016). Recent discourse in Kenya including Meru County, has also underlined the essence of training (Kimondo et al., 2023). One of the observations is that practitioners require education and support in the different levels from cultivation stage, to the processing and storage of the herbal product. Training should also encapsulate identification of the plant species, use of fertilizers, pesticides, herbicides, proper harvesting, storage and prescription practices. Training harvesters in sustainable practices is also critical (Applequist et al., 2020).

Invaluable as the training of herbalists is a paradigm shift in the human resource portfolio of the Meru County Government is prerequisite. Since the dawn of the devolved government system in 2013 recruitment has only been at the County Culture Officer level. Indeed, the major preoccupation of the culture docket has been the construction and equipping of cultural centers (Meru County, 2013; 2016; 2018; 2022; and 2023). No explanation has ever been availed for the long-standing evasion of prioritizing the crucial aspect of climate change impact upon herbs and traditional medical practitioners.

The National Museum of Kenya among whose portfolio, as earlier indicated, identification, protection, conservation and transmission of the cultural and natural heritage of Kenya has had very limited showcases. The Meru branch maintains a few herbs. Inadequacy of funds is cited as *rai·son d'être* for the apparent minor execution of its mandate. The challenge is perennial and cascades down from the national headquarters. Another obstacle is retaining skilled manpower (National Museums of Kenya, 2009; 2020; and 2023)

Training and Support of Herbal Medicine in Good Practices

To harmonize herbal medicine practice across Meru County, practitioners need support and training in the different levels from cultivation stage to the processing and storage of the herbal product (Chebii et al., 2020). Accurate identification, and confirmation, of the species of plant is the first stage towards making sure that, at the tail end of the cycle, the correct plant is dealt with. Misidentification may be unnoticed specifically in a self-regulated practice like the herbal medicine sector. There is need of collaboration with research institutions as well as the National Museum of Kenya for specimen preservation and authentication. The archiving of such information together with the indigenous names of the plant will provide useful references for future investigators. Farmers need to be supported with high quality seeds to ensure maximum yield, with special attention given to the use of herbicides, pesticides, fertilizers and other chemicals that may affect the quality of the herbal plant and subsequently human safety (Nguetti et al., 2018).

Good harvesting practices need to be observed to ensure that the timing is accurate when the secondary metabolites linked with therapeutic activity are at peak concentration (WHO 2003). Further, postharvest, appropriate packaging as well as storage are essential to minimize the risks of contamination by the microbes (Pandey et al., 2021).

Conclusion

The first objective of the research study was to find out the negative impact of climate change on herbal medicine in Meru County, Kenya. The key finding based on this objective is that climate change has greatly contributed to the scarcity of herbal medicine in Meru County. Kenya.The study concludes that the negative effects of climate change greatly contributes to scarcity of herbal medicine

With regard to the second objective which was to find out the influence of climate change on herbal profession in Meru County, Kenya. The key study finding based on this objective is that climate change negatively affected herbal profession in Meru County. According to the study finding, it has become increasingly difficult to find herbal medicine, which has in turn reduced the number of clients and income of the herbalist. This not only threatens the livelihood of the herbalists but also the culture of the people in this part of the country.

The third objective of the research study sought to determine climate change mitigation measures for herbal medicine in Meru County, Kenya. The key finding based on this objective is that the climate change mitigation measures on herbal medicine in Meru County is generally rated poor. The study concludes that there is need to put in place mitigation measures.

Recommendation to the County Government of Meru

Supplementary Table 3 reveals that all the respondents unanimously agreed that there is a need for the county Government to first develop and implement a county policy on indigenous medicine. The government must start by mapping indigenous knowledge involving documenting the traditional medical practices, remedies, and practitioners within the county; assessing the current state by evaluating how indigenous medicine is practiced, its impact on community health, and its economic and cultural

significance; and engaging stakeholders through collaborating with traditional healers and community leaders among others.

Secondly, the government needs to promote climate-resilient cultivation practices. This may include research on resilient varieties involving investing in research to identify and develop climate-resilient species of medicinal plants; encourage sustainable farming practices that promote organic farming, water conservation, and crop rotation techniques to enhance soil health and protect plant growth; and provide climate information involving educating herbal professionals on weather patterns, drought-resistant plants, and suitable planting seasons using localized data

Thirdly, there is need for conservation of medicinal plant resources as a mitigation measure. This may include protecting natural habitats through the implementation of community-based conservation projects in Meru County to safeguard forests, wetlands, and grasslands where medicinal plants grow; creation of Seed Banks and Herbariums facilities to preserve seeds and specimens of medicinal plants to ensure their availability for future generations; and develop Botanical Sanctuaries in protected areas for the cultivation and regeneration of medicinal plants in climate-resilient zones.

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Supplementary Tables

Table 1: Unpredictable rainfall patterns with remarkable decline in the years 2017 and 2020 adopted from Muthee et al. (2015

Year	Rainfall (mm)
2010	7.73
2011	14.06
2012	8.89
2013	10.62
2014	9.07
2015	3.36
2016	3.42
2017	2.90
2018	4.12
2019	3.24

2020	1.90

Table 2: Recommendation to the County Government of Meru

	Poor	**Average**	**Good**	**Very good**
Item	**1**	**2**	**3**	**4**
Develop and implement a county policy on indigenous medicine				45 (100%
Regulate and protect herbalists				45 (100%)
Train herbalists on herbal conservation				45 (100%)
Establish Sub-County herbal nurseries				45 (100%)
Map herbal resources				45 (100%)
Patent indigenous medicine				45 (100%)
Promote indigenous medicine as county cultural heritage				45 (100%)
Facilitate participation of herbalists in county, national and international cultural festivals				45 (100%)

Table 2: Professional Experts

Professional Expert/Herbal Medicine Practitioners	**Institution**	**Number of Respondents**
Herbal Medicine Practitioners	Meru County/Meru Herbalist Association	45
Cultural officer	Meru County	1
Environmentalist	Meru County	1
Conservation expert	National Museums of Kenya (Nairobi, Meru)	2
Pharmacist	Technical University of Kenya	1