

The Future Alert of Research on Medicinal Plants and Climate Change

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Abstract:

This review highlights the crucial role of medicinal plants and their secondary metabolites in treating various health issues. However, **rapid climate change** is a major threat to these plants, contributing to the decline of wild medicinal species. The review examines how climate change affects the distribution and life cycles of these plants, including the impact of **high CO₂ and ozone levels, temperature changes, and drought** on **secondary metabolite synthesis**. These environmental factors can have both positive and negative effects on the yield and quality of medicinal plant products. Given the complexity of these impacts, the review calls for further research into the interactions of climate change and its effects on medicinal plants to better understand and mitigate potential risks. The effect on medicinal plants, which are crucial to human health, is one area of worry, especially in areas where access to Western medicine is limited. Climate change poses several dangers to these plants, including changes in temperature and precipitation patterns, strained ecological interactions, an increase in pests and diseases, and fragmentation of their habitat, all of which can make it more difficult for them to move and thrive. Furthermore, these difficulties are made worse by unsustainable harvesting methods, which may lead to the loss of several species of medicinal plants. Additionally, the quality and safety of medical goods may be impacted by climate change since it may modify the chemical makeup of medicinal plants in addition to reducing plant biomass. The report suggests the following measures to resolve these issues: 1) Preservation and regional production of important medicinal herbs. 2) Harvesters' certification and training in sustainability

Keywords: Harvesters, Carbon dioxide, Ozone, Secondary Metabolite

INTRODUCTION

Many secondary metabolites that are essential for daily life and treatment are produced by plants. However, the physiology of plants is impacted by climate change, which has an effect on the manufacturing of significant medicinal chemicals. The impact of fast climate change on the global loss of wild medicinal plant species is highlighted in this review. Though the precise effects on species distribution and secondary metabolite production vary among species, it is anticipated that medicinal plant species would suffer as a result of the upcoming climate change. Thus, after carefully reviewing previous publications and journals, as well as taking into account firsthand observations, this review has suggested adaption strategies for climatic change and described plans for the future to guarantee the survival of species of medicinal plants for use and additional study Future researchers should also

extensively examine how different direct and indirect sources of climate fluctuation interact and how this affects medicinal plants. Medicinal plant secondary metabolites are presently utilized as a safe alternative to allopathic treatment's negative effects and multidrug resistance. Since ancient times, herbal plants and their products have been widely utilized to cure common illnesses including diabetes, cancer, cholera, diarrhea, asthma, and pyrexia. Over the past 20 years, one of the most significant scientific issues in the world has been climate change [1]. More and more people are realizing that climate change poses a serious threat to all life on Earth, including humans. A plant that contains substances with therapeutic qualities or that serve as building blocks for the production of beneficial medications in one or more of its components is referred to as a medicinal or Pharmacopeia plant [2]. The life of humans depends critically on medicinal plants [3]. Changing climatic conditions have an adverse effect on biodiversity, agriculture, forestry, ecosystem function, and the normal course of human existence [4]. Climate change has negative consequences on a number of areas, including food security, microbial ecosystems, plants and their medicinal components, soil integrity, individual well-being, water and air quality, and secondary metabolites. The world's population explosion, fast industrialization, and extensive use of chemical pesticides are the main causes of climate change. agricultural fertilizers [1]. Changing weather patterns include rising temperatures, periods of cold, changes in rainfall patterns and drought. There are numerous distinct plant species that fall under the umbrella of medicinal and aromatic plants (MAPs), including annuals, biennials, perennials, and more. All of these plants' components are valuable, and they usually grow in a variety of temperatures and settings. Shrestha et al. claim that aromatic and medicinal plants play a key role in enhancing human well-being by providing both financial and health benefits [5]. Put another way, the acknowledgment of different plant types throughout the evolution of human civilization is ascribed to their important sustenance-contributing, therapeutic, restorative, and nutritional qualities that are necessary for daily life. The medical plant group is the most significant of these plant categories because of its secondary metabolites and pharmacological qualities [4,6], which are widely used in pharmaceutical, fields of nutrition, medicine, and cosmetics [7]. Mohammadhosseini et al. [8] state that a large number of reviews have highlighted the medicinal plants' promising biological and pharmacological qualities, ethnobotany, conventional and traditional medicine, advantageous bioactive compounds, and other relevant characteristics in the literature and scientific databases to support their extraordinary effects.

Modifications to Plant Productivity or Quality

Even if a species' range is unaffected by climate change, it may have a good or negative impact on its quality or production, particularly its potency or chemical makeup in the case of medicinal plants. The whole goal of using medical plants for consumption or other purposes is to obtain health advantages from their bioactivities, even if variations in the chemical composition of food plants may also be more pertinent to human health than is often recognized (e.g., [9–13]). The primary source of the bioactivities is the secondary metabolites that the plant produces, whether they are endophytic symbiont-produced or autogenous. Therefore, if a plant's composition altered in a negative or unforeseen way, those who are benefiting from its use would suffer if its makeup unexpectedly or negatively changed. This is especially true for less affluent and traditional society users, who lack the means to conduct complex chemical testing to detect such changes and modify dosages to make up for them. A new generation of customers may overlook or misunderstand a plant medicine's diminished potency as an innate lack of effectiveness, which might result in the abandoning of beneficial plants. As previously mentioned, montane habitats

are expected to experience the largest biological consequences of climate change (e.g., [12, 11, 13]), and plants that live at the highest elevations are thought to be more vulnerable to extinction (e.g., [15]). People who live in many high-altitude areas have little access to Western treatment, thus botanicals are very crucial to them. Numerous It has long been thought that medicinal species are more effective when gathered at higher elevations (e.g., [14]) and this has been verified for a few significant plants, such as arnica (*Arnica montana* L. [16]), chamomile (*Matricaria chamomilla* L. [17]), and bush tea (*Athrixiphylicoides* DC. [19]). Usually, it is uncertain what causes are to blame. In contrast to bush tea, where the relationship between altitude and chemical content does not seem to be connected to temperature [19], an experimental research of arnica revealed that temperature had a significant impact on chemical content [20]. In contrast, it appears that temperature has little bearing on the relationship between altitude and chemical content for bush tea [19]. The medicinal quality of montane species whose chemical composition is temperature-dependent may not necessarily increase if they migrate to higher elevations and stay in the same temperature range, while populations that stay at their original elevations may see a reduction in quality. To fully comprehend the connections between therapeutic potency and elevation in certain species, further data is obviously required. In many regions of the world, harsher weather extremes such as more severe droughts, torrential rain falls, heat waves, and cold snaps are anticipated as a result of climate change [22]. All of these extremes have the potential to reduce sustainable harvest levels by hindering the development and reproductive performance of plants that are not suited to such circumstances. Nevertheless, the concentrations of active metabolites are not consistently impacted by these conditions. By either reducing biomass or boosting the metabolites' actual synthesis, drought stress that is not severe enough to kill plants frequently raises the concentration of bioactive secondary metabolites. The content of bioactive chemicals in a range of species is increased by drought stress, according to two recent reviews of the literature [21,22]. Compound groups that may be impacted include alkaloids, glucosinolates, essential oils and terpenes, and simple and complex phenolic compounds. In drier regions, active metabolites are more prevalent in certain wild plant products, including shea butter (derived from *Vitellaria paradoxa* Gaertn.) [20]. The potency of some medicinal plants from such places may thus rise as a result of increasing drought stress in those areas. Uncontrolled natural drought, however, would often result in a drop in biomass that would offset any increases in the concentration of active metabolites, even if customers were aware of those increases and the dose was lowered to make up for them. Second, there are instances when the chemical content is reduced at high temperatures but higher under water stress, such as in di huang (*Rehmannia glutinosa* (Gaertn.) Steud. [23]). Any positive effects of drought on the chemical composition of these species may be offset by the opposite if drought is accompanied by rising temperatures. Similar to drought stress, high temperatures can also cause a dramatic reduction in biomass, which can result in an increase in secondary metabolite concentrations, as seen for American ginseng [24]. People who are used to collecting a specific amount of material for their own use or to sell for financial subsistence would suffer significant economic losses and harvest levels would become more unsustainable if biomass output significantly declined as a result of drought and high temperatures.

Possible effects of climate change on plant species' life cycles and distribution: Studies have been conducted in Thailand [25], China [26], Indonesia [27], Pakistan [28], and Africa [30-31] to investigate the ways in which the changing climate is affecting the geographic range of medicinal plants. The life cycles and dispersion of the global The impact of climate change on vegetation, especially wild medicinal plants, is substantial [32]. soils as well as The fact that plants alter soil properties, which in

turn impact plant performance and have a variety of interactions, makes plants intimately linked. When plants interact with abiotic soil conditions and soil organisms, they can have an impact on other plant species, themselves, and their offspring. This phenomenon is known as "plant-soil feedbacks" (PSFs) [33]. Given that temperature has a significant influence on both organism growth and species distribution, a changing climate may have an effect on plant dispersion and interactions with other soil communities [34]. As a result, it is predicted that climate change will have a variety of impacts on plants and soil organisms, including both direct and indirect effects that are both important and arise from modifications to the physiological processes of plants as well as the amount and makeup of resources added to the soil. As a result, PSFs, vegetation patterns, and feedback mechanisms affecting local, regional, or even global climatic conditions may all experience notable consequences [32]. For instance, research employing the Maximum Entropy Model (MaxEnt) modeling was done to evaluate the effects of global climate change on the regional distribution of *Gentiana rigescens*. Previous studies indicate that this species prefers the warm, humid temperatures seen in subtropical areas. However, Shen et al.'s study showed that the mean temperature of the driest quarter, temperature seasonality, elevation, year precipitation, hottest quarter precipitation, and yearly range this species prefers the warm, humid temperatures *rigescens* [33]. Furthermore, it is anticipated that future climatic scenarios may cause many plant species to move from their original locations to new ones. At the expense of other species, climate change may benefit some and give them a suitable home. For example, the study included Huang et al.'s study on the regional distribution of *Glycyrrhiza* species in China and the impact of climate change showed that a few *Glycyrrhiza* species will find their habitats more suitable in the upcoming years due to changing climatic circumstances, as follows: 34.0% for *Glycyrrhiza pallidiflora*, 49.0% for *Glycyrrhiza yunnanensis*, 51.7% for *Glycyrrhiza glabra*, 65.9% for *Glycyrrhiza aspera*, 61.6% for *Glycyrrhiza inflata*, and 47.5% for *Glycyrrhiza squamulosa* [36]. However according to a recent study by Cahyaningsih et al., in the upcoming years, it is expected that eleven medicinal plants from Indonesia will have the most limited distribution regions [22]. Furthermore, by analyzing the present and anticipated distributions of areas that are suitable for the cultivation of *Camellia sinensis* (L.) O. Kuntze in Sri Lanka, Jayasinghe and Kumar projected that the aggregate areas classified as "optimal," "medium," and "marginal" suitability would decline by roughly 10.5%, 17%, and 8%, respectively, by 2050 and 2070 [35]. This shows that climate change may create favorable conditions for certain species, which would significantly reduce the number of vulnerable species overall. Chronic disregard of the species or population characteristics and their interactions with the ecosystem may lead to an overestimation of the impact of climate change on plant species. Despite the possibility that certain species might expand their range a number of variables, including altitude [37] and human activities in the surrounding area, may make it more difficult for them to move. According to Harnik et al.'s results, local abundance, habitat breadth, and regional range all affect the determination of extinction [38]. Notably, the loss of geographic range is predicted to cause the extinction levels to grow even in areas where the population is now numerous.

Medicinal Plants in Modern Era

In the present day, medicinal plants are still very important since they have many uses and advantages in research, healthcare, and sustainability. With natural, sustainable, and efficient substitutes for manufactured medications, medicinal plants are a priceless healthcare resource in the current day. Their incorporation into modern medicine, in conjunction with conventional wisdom and cutting-edge

scientific discoveries, demonstrates their ongoing significance in tackling issues related to global health, fostering cultural diversity, and encouraging environmental sustainability.

Traditional Wisdom and Current Studies:

Historical Use: Due to their healing qualities, medicinal plants have been utilized by many societies for ages. The efficacy of natural remedies is currently being verified and enhanced by combining this ancient knowledge with contemporary scientific study. The identification of bioactive molecules in plants that have demonstrated effectiveness in treating a variety of illnesses, from infections to cancer, is the result of recent study. Numerous pharmacological medications have been made from plant-based ingredients, such as morphine from opium poppies or aspirin from willow bark

Alternative Medicine and Natural Treatments:

Alternative Medical Treatments: Medicinal plants are being utilized more often as natural treatments for a range of illnesses as a result of the growing interest in complementary and holistic medicine. The anti-inflammatory, antibacterial, and antioxidant qualities of herbs like garlic, ginger, and turmeric have made them well-liked. Patients looking for more natural options may find many medicinal plants intriguing since they are thought to have fewer adverse effects than manufactured medications.

Challenges in Global Health

Antibiotic Resistance: Medicinal plants provide encouraging alternatives as antibiotic resistance becomes a more significant worldwide issue. Some plants have shown antibacterial qualities, and they may play a key role in the fight against viruses and bacteria that are resistant to treatment. **Chronic Illnesses:** Plants that boost the immune system and help treat ailments including diabetes, high blood pressure, and stress include ginseng, ashwagandha, and echinacea. They are a useful tool in the management of chronic illnesses, which are becoming more and more common in contemporary culture, because of their adaptogenic qualities.

Environmental Impact and Sustainability

Sustainable & Eco-friendly: Medicinal plants offer a sustainable alternative to synthetic medications, which are increasingly being criticized for their negative effects on the environment and their excessive dependence on chemical processes. The environmental impact of growing medicinal plants may be less than that of making drugs in an industrial setting. **Biodiversity conservation:** Overharvesting and habitat loss are threats to many therapeutic plants. These plants must be cultivated and conserved sustainably in order to maintain biodiversity and guarantee their availability for future generations.

Economic Significance

Global Market: The market for herbal goods, such as teas, supplements, and essential oils, is expanding quickly on a global scale. For farmers, companies, and communities involved in the production and distribution of therapeutic plants, this opens up financial prospects.

Employment Creation: The desire for medicinal plants has boosted local economies, particularly in rural regions, by generating jobs in marketing, processing, research, and agriculture.

Cultural Importance

Cultural legacy: For many indigenous and local cultures, medicinal plants are an essential part of their cultural legacy. Respect for traditional knowledge is fostered and cultural identity is preserved via the preservation of these plants and their usage.

Spiritual and Emotional Health: In many cultures, plants are employed for their spiritual and emotional properties in addition to their ability to treat physical illnesses. For example, aromatherapy uses essential oils derived from plants to support mental and emotional health.

Drug Development and Innovation

Plant-based medications: Compounds produced from plants are still used in modern medicine development. The Pacific yew tree, for instance, is the source of the anticancer medication paclitaxel (Taxol). Potential novel treatments and cures are the result of ongoing research into plant chemicals. **Biotechnology:** Developments in biotechnology enable the improved synthesis and genetic alteration of therapeutic molecules from plants, boosting their effectiveness and accessibility.

Future challenges of climate change and medicinal plants

Climate change and the future of medicinal plants

Numerous obstacles that medicinal plants must overcome as the consequences of climate change become more apparent may have an influence on their accessibility, effectiveness, and cultivation. Preserving these priceless resources and making sure they remain essential parts of both contemporary and traditional medicine require an understanding of these difficulties.

Modified Growing Environments

Temperature Shifts: For optimum growth, a number of medicinal plants require particular temperatures and environments. Climate change may cause temperature variations that impact the quality of medicinal substances found in these plants in addition to lowering yields. Certain plants, for instance, can need colder climates, and rising temperatures may force them outside of their ideal growth regions.

Variations in Rainfall Patterns: The water supply for plants might be drastically changed by droughts or heavy rains, which would affect their development cycles. In example, drought stress may lessen a plant's capacity to generate medicinally useful bioactive chemicals or possibly cause crop failure. **Changing Habitats and Ecosystems.**

Loss of Habitat: As a result of ecological changes brought about by climate change, medicinal plants are being forced from their natural habitats. Climate-related changes including deforestation, increasing sea levels, and habitat fragmentation are having an influence on forests, marshes, and mountain ranges—all of which are home to a variety of medicinal plants. Numerous species of medicinal plants may become endangered or become extinct as a result of the disruption of these ecosystems.

New illnesses and Pests: As a result of warming temperatures and shifting weather patterns, invasive species, illnesses, and pests may appear that might endanger medicinal plants. Without adaptation to these new dangers, plants may grow less or lose their therapeutic qualities.

Impact of Changes in Chemical Composition on Active Compounds: The chemical makeup of medicinal plants can be changed by climate-related stressors such variations in temperature, light, and humidity. The concentration of advantageous molecules may be lowered by certain environmental variables, making them less useful as medications or natural cures.

Loss of Potency: For instance, plants' secondary metabolites—such as terpenes, flavonoids, and alkaloids—that give them their therapeutic qualities can be changed by extreme heat and water stress. This may lessen the therapeutic efficacy and potency of several plant-based medications.

Extinction Risks: A lot of medicinal plants are extremely susceptible to going extinct as a result of climate change, especially those that live in isolated or specialized environments. The loss of uncommon and endemic species that may have potential medical uses is made worse by climate change, which already threatens biodiversity.

Genetic variety: In order to develop and maintain robust crops, medicinal plants' genetic variety is essential. The gene pool of medicinal plants may be reduced by climate change, which would further restrict their availability and lessen their capacity to adapt to changing climatic conditions.

The Effect on Indigenous Knowledge

Loss of Traditional Knowledge: Medicinal herbs have long been used by local and indigenous cultures to promote health and healing. However, customs and knowledge that have been passed down through the years may disappear when these plants' environments are destroyed or changed. This can result in the loss of knowledge that has been applied to the sustainable management and cultivation of these plants, as well as the degradation of priceless cultural property. **Cultural Practice Disruption:** Numerous indigenous groups have accumulated complex knowledge about the area flora and fauna. A collapse in the link between these people and their natural resources might result from climate change upsetting the customs of agriculture, harvesting, and conservation.

Economic Repercussions

Worldwide Supply Chain Upheavals: The world economy depends heavily on the medicinal plant sector, which supplies raw materials for pharmaceutical, cosmetic, essential oil, and herbal medicine goods. Price volatility, supply shortages, and economic instability in the businesses that rely on medicinal plants might result from climate change-related disturbances in their availability and cultivation.

Employment Losses in Herbal Medicine and Agriculture: Due to the detrimental effects of changing climate conditions on crop yields, farmers who depend on farming medicinal plants may have financial difficulties. Small-scale manufacturers and practitioners of herbal medicine may also find it difficult to sustain their enterprises, which might result in job losses and financial displacement.

Concerns for Conservation and Sustainability

Overharvesting and Unsustainable Practices: The urge to overharvest medicinal plants in order to satisfy the rising demand for herbal goods worldwide may result in unsustainable practices, as climate change is already putting stress on plant populations. Without effective conservation measures, these plants' populations may decline and their long-term supply may be threatened if they are harvested at an unsustainable pace.

Conservation Initiatives: Strategies for medicinal plant conservation are made more difficult by climate change. As plant species' native habitats change, protected places could no longer be appropriate for them. It could be necessary to modify preservation efforts for these plants to take into consideration the altered environmental conditions.

Climate Change Adaptation: Approaches and Remedies

Biotechnology and Breeding: Utilizing biotechnology and plant breeding is one possible way to overcome these obstacles. Researchers may concentrate on creating therapeutic plant cultivars that are more adaptable to pests, droughts, and harsh temperatures. Furthermore, under shifting climatic conditions, biotechnology developments may improve the synthesis of therapeutic .

Sustainable Methods of Cultivation: The effects of climate change on medicinal plants can be lessened by promoting sustainable agricultural methods including organic, permaculture, and agroforestry. These techniques help increase biodiversity, conserve water, and maintain soil health. Conservation and Seed Banking: In situ conservation efforts and seed banking are crucial tools for preserving genetic variety. This guarantees the preservation of therapeutic plant species so they can be grown or reintroduced into the wild in the future. To successfully execute these initiatives, cooperation between local communities, NGOs, and governments is essential.

Conclusion

In many regions of the world, public health is predicted to suffer from increased climatic extremes and economic losses brought on by climate change, while at the same time, the resilience offered by access to helpful medicinal plants is predicted to deteriorate. If action is not taken immediately, it may be anticipated that this may lead to more avoidable fatalities and human misery. Reversing the current trends would be ideal, and we naturally support vigorous efforts to ameliorate climate change in order to lessen its detrimental consequences on human societies and the ecosystem globally. Yet, as mitigation isn't likely to be vigorous and quick enough to completely stop disruptive climate change, adaptation actions are also crucial to lessen the harm that will be experienced, and they may frequently be carried out locally. We implore the national and local governments, nongovernmental organizations, and the public health and ethno botanical communities to take steps to ensure that all communities, especially those that rely on medicinal plants for their income or medical care, continue to have access to high-quality traditional medicines. Promoting the growth of medicinal plants in community gardens to preserve local access, protecting and honoring the significance of traditional knowledge about plants and their sustainable use, and educating harvesters in sustainable methods are some actions that could support medicinal plant populations. Promoting or mandating the use of certification schemes for materials gathered from the wild, particularly in global trade, and putting in place immediate, extensive conservation initiatives, such as habitat preservation. In the event that use patterns need to be adjusted, consumers and product manufacturers could be informed by regional Phytochemical research or quality control programs that track the biomarker content of economically significant medicinal plants, particularly alpine species, and identify changes in their content and quality brought on by climate change. Although ex situ seed banking and aided migration may be necessary as last choices to stop the permanent worldwide extinction of valuable species, we stress that these actions will not lessen the impact to modern human populations.

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