International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 7s, 2025
https://www.theaspd.com/ijes.php

Climate Change And Medicinal Plant Resources: Implications For Human Health And Ecosystem Services

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Abstract
Climate change is becoming one of the biggest problems that threatens our planet, its living creatures and the well-being of humans involved. Medicinal plants are especially at risk because of higher temperatures, unusual rainfall, damage to habitat and the decline in pollinators. This review paper explores connections between climate change and the biodiversity of medicinal plants, especially in the Eastern Ghats of India. Many medicinal plants used by tribal communities are found in the region, but as the climate changes and plants are taken without care, some of these plants are about to become extinct. This paper highlights that ecological niche modeling studies, recent ethnobotanical surveys and gene analyses reveal the urgent need to use essential climate-related strategies in conserving our plants. This effort to protect these plants is both needed for the environment and for the health, traditions, careers and science of people.

Keywords *Climate change, Eastern Ghats, medicinal plants, ethnobotany, ecosystem services, bioprospecting, conservation genetics, traditional knowledge, phytochemistry, adaptive strategies.*

1. INTRODUCTION

Health systems everywhere view medicinal plants as essential parts of healthcare, especially since not all regions have well-developed hospitals or clinics. World Health Organization reports (2020) that about 70% of the world's population includes herbal remedies as their primary or secondary source of healthcare. In rural and tribal areas of India, the need for traditional healers is clear since their knowledge is shared orally and plays an important role in local culture and religions. The existence and easy availability of medicinal plants in forests and certain terrains are important for Ayurveda, Siddha and tribal medicine.

The Eastern Ghats which are a series of disconnected hills, stretch through Odisha, Andhra Pradesh and Tamil Nadu. There are over 3,200 flowering plant species in this region and based on information found in traditional medicinal books (indigenous pharmacopeias), more than 400 are known to have therapeutic properties (Reddy et al., 2008; Kamila, 2020). They serve both the environment by supporting nutrient sampling and humans through using them in health care and traditions. Over the years, this rare biotic wealth has been deeply threatened because of many human pressures and the quick changes in climate.

Changes in the climate are causing major disturbance to the environment in the Indian subcontinent by raising temperatures, disrupting rainfall, leading to prolonged droughts and bringing extreme weather events (Kattel, 2022). Not only do such disturbances affect countries as a whole, but they can also damage the local environments where lots of medicinal plants live and grow. The works of Sudhakar Reddy et al. (2001) and Singh et al. (2010) reveal that there are smaller areas of vegetation, less fertile soil and reduced moisture in the forest patches of the Eastern Ghats which concerns the growth of medicinal plants.

Lately, research on their niches, surveys in the field and genetic examinations have pointed out that certain medicinal species are vulnerable to climate impacts such as heat, reduced moisture, intrusion by harmful species and a lack of pollinators (Kamila, 2020). Cycas sphaerica and Hypericum gaitii which are both native and threatened, are seeing serious reductions in their usual habitats./ Research conducted in the field shows that their species are rarely found together but mainly on isolated hillsides and in cleared forests with less ability to reproduce (Mishra et al., 2001; Sahu et al., 2009). The same thing happened to Hemidesmus indicus which is valued in traditional medicine for cleansing the body and boosting the immune system. However, its abundance has significantly dropped because of changes and damage to its habitats.

In addition, changes in the environment are made worse by people's activities such as overharvesting, clearing land, using a type of farming called shifting cultivation and taking too many natural resources from forests. This combination causes medicinal plants to become less available and also puts the indigenous knowledge related to them at risk (Kamila, 2020; Reddy et al., 2012). The problem goes further than nature, affecting the health, support for sickness and financial status of people in tribal and forest areas.

Because of these challenges, it is important to use a way of thinking that connects ecological science, climate modeling, ethnobotany and public health to assess the future of medicinal plants. The review will investigate how climate change affects many aspects of medicinal plant biodiversity, mainly focusing on the Eastern Ghats. This paper carefully looks at the impacts of climate-related changes on ecology, the diversity of natural resources and how humans use traditional therapies by gathering recent research.

The report points out that it is urgent for societies to blend age-old experience with advanced knowledge of conservation to look after medicine-derived plants as the climate continues to change.

2. CLIMATE CHANGE AND ECOSYSTEM SERVICES

Things like nutrient recycling, cleaning the water and pollinating crops depend on the wide variety of plants. As a result of climate change, the timings of important events, where species live and their connections with other organisms are disturbed (Singh et al., 2010; Bakure et al., 2022). For example, in the Eastern Ghats, some important medicinal plants such as Justicia adhatoda and Wrightia tinctoria are now threatened because both their climate and the species that help in pollination are no longer stable (Kamila, 2020).

Kattel (2022) argues that the gradual increase in global warming has caused the movement of animals to higher altitudes in the Himalayas which is also being found in the Eastern Ghats. Due to a lack of pollinators and drier soil, the amount of seeds and fruit formed in many medicinal plants has decreased which means there are fewer plants available and their components are less effective (Theodoridis et al., 2023). The changes lessen the usefulness of medications and also damage the ecological associations needed for forests, wetlands and grasslands to be strong.

Since people in local communities use these ecosystems for medicine as well as food, firewood and fodder, major reductions in them can greatly affect those communities. So, the loss of medicinal plants because of climate change makes societies and ecosystems more susceptible to challenges (Steiner et al., 2021).

3. MEDICINAL PLANTS AND HUMAN HEALTH

Medicinal plants are consistently used in India's primary health system. Ayurveda, Siddha and tribal ethnomedicine make great use of herbs and other plants from their region. The same trends are reported by Eshete and Molla (2021) in Ethiopia, where medicinal plants have culturally important roles as well as being used for medicine. Among the Eastern Ghats, Kamila's (2020) study found more than 150 species used by Kondh and Saura tribes for treating problems with the digestive system and reproductive health.

As Theodoridis et al. (2023) observe, changes in the natural environment are becoming more of a challenge to medicinal resources. A good example is Andrographis paniculata, a plant for treating infections and inflammation, that is getting harder to find due to overexploitation by the industry and drier soil in its habitat (Kamila, 2020; Mishra et al., 2012). In addition, the wild population of Lasiococca comberi which is full of tocopherols and bioactive lipids, has seen a decrease of more than 50% in Andhra Pradesh (Reddy et al., 2012).

Medicinal plants could lose their usefulness if they are not treated properly. If the plant experiences stress, its composition of alkaloids, flavonoids and tannins is likely to be differently affected (Singh et al., 2010; Kamila, 2020). The result is clear effects on the correct use of drugs, their standard daily amounts and well-known medical approaches. All in all, these plants' protection is important for supplying both healthcare and drugs in the future.

4. VULNERABILITY OF EASTERN GHATS FLORA

Because of people's activities and the effects of climate change, the wide range of plants found in the Eastern Ghats is at greater risk. The MaxEnt analysis by Kamila displayed that Cycas sphaerica and Hypericum gaitii are likely to lose their suitable habitats with both RCP 4.5 and RCP 8.5 climate changes. Experts predict that, depending on today's trends, these animals will lose 40% of their homes in the next few decades because they are already categorized as threatened.

According to studies by Sahu et al. (2009) and Reddy et al. (2008), the survival of medicinal plants is not high as seedlings. Kamila (2020) showed that the presence of things like invasive weeds and grazing also leads to less successful recruitment of lizards. In both Rayagada and Gajapati districts, official surveys found those two species almost vanished from areas where they used to be plentiful.

Also, ISSR marker tests revealed that Cycas sphaerica and Wrightia tinctoria are seriously losing their genes which means they may not be able to adapt well to environmental changes (Mishra et al., 2012). If strategies for conservation do not address climate and gene health, they usually won't last a long time.

5. CULTURAL AND ETHNOBOTANICAL DIMENSIONS

Using plants for medicine in the Eastern Ghats matters not only to health care but also to cultural traditions. This research (Kamila, 2020) shows many examples of how plant species are linked to tribal rituals, customs and traditions. Wrightia tinctoria plays a role in postnatal care and Cycas sphaerica is traditionally shown in marriage ceremonies.

The parts of intangible heritage that matter are being lost due to the decrease in biodiversity and changes in cultural life. Migration away, cutting down of forests and little care for tradition among young people are breaking the links of knowledge passed through stories (Kamila, 2020; Reddy et al., 2008). Eshete and Molla (2021) argue that medical knowledge systems could disappear completely even before any of the plants vanish, unless they are recorded and taught from one generation to another.

Herbal gardens that are supported by the community and educational programs in schools have done well in Odisha and Andhra Pradesh. Nevertheless, unless these efforts are connected to climate policy and receive official backing, they stay isolated (Kamila, 2020).

6. RISK MANAGEMENT AND ADAPTIVE STRATEGIES

It takes both traditional and scientific methods to conserve nature. Cycas sphaerica and Hypericum gaitii were successfully propagated for two growing seasons when Kamila tested nursery-based interventions and direct in-situ methods. Other studies analyzed genes to single out populations with the highest number of alleles which increased the chances of finding compatible donors (Mishra et al., 2012).

In Lasiococca comberi researches by Kamila and co-workers, potential compounds were found to be helpful in skin care and food conservation. It appears that linking conservation incentives with the use and sharing of benefits would help protect nature.

It is important to develop ecological models, interact with local communities and introduce agroforestry that is able to withstand climate changes. Integrating medicinal plant conservation with watershed and livelihood efforts might bring about extra benefits, according to Kumar & Choudhary (2016) and Sudhakar Reddy et al. (2001).

7. SYNTHESIS OF CLIMATE IMPACT ON MEDICINAL PLANTS IN THE EASTERN GHATS

The table below gives an organized review of medicinal plants native to the Eastern Ghats, including their traditional uses, ecology and possible climate changes that threaten them, their conservation status and possible steps that can help conserve them. The table helps us visualize, at a broad level which species are very sensitive to environmental harm and human actions. It serves as a base for deeper analysis of ecological risks and ways to protect the environment considered in the next sections.

Table 1 Review of Climate-Vulnerable Medicinal Plants in the Eastern Ghats

Species Name	Therapeutic Uses	Ecological Role	Observed Climatic Threats	Conservation Status	Suggested Interventions	Sources
Cycas sphaerica	Neuroprotective, antioxidant, and used in traditional fertility treatments	Soil binding, shade provider	Habitat loss, fragmentation, poor regeneration under moisture stress	Endangered	In situ protection, seed banking, assisted regeneration	Mishra et al. (2001); Kamila (2020)
Hypericum gaitii	Antidepressant and anti-	Understory shrub	Narrow niche range, drought	Critically Endangered	Micropropagation, niche modeling for	Sahu et al. (2009);

	inflammatory properties	in hill slopes	intolerance, seed desiccation		assisted relocation	Kamila (2020)
Hemidesmus indicus	Blood purification, immune support, antipyretic	Ground cover, contributes to soil microbial health	Overharvesting, changing soil moisture, climate-driven flowering shifts	Vulnerable	Sustainable harvesting guidelines, herbal garden cultivation	Reddy et al. (2008); WHO (2020)
Asparagus racemosus	Adaptogen, lactation aid, GI treatment	Forest edge climber, pollinator attractor	Increasing temperature, reduced pollinator activity, fire-prone habitats	Near Threatened	Community-led seedling plantation, reforestation in degraded forest edges	Reddy et al. (2012); Sudhakar Reddy et al. (2001)
Lasiococca comberi	Rarely used traditionally, high phytochemical potential	Part of canopy ecosystem	Climate-driven contraction of range, low natural regeneration	Data Deficient / Rare	Ex-situ propagation, reintroduction into fenced plots, biocultural mapping	Panda et al. (2018); Reddy et al. (2012)
Gymnema sylvestre	Antidiabetic herb ("sugar destroyer"), antioxidant	Climbs over dry deciduous forest trees	Drying streambeds, deforestation, reduced viable seed dispersal	Declining	Rainwater harvesting, seedling transplantation, inclusion in agroforestry models	Kamila (2020); WHO (2020)
Rauvolfia serpentina	Source of reserpine; antihypertensive and tranquilizer	Grows in semi-shaded deciduous forests	Soil degradation, loss of shade cover, high harvesting pressure	Endangered	Strict ban on wild collection, large-scale cultivation, farmer-subsidy models	Mishra et al. (2001); Kumar & Choudhary (2016)
Terminalia chebula	Digestive tonic, antimicrobial, anti-aging	Keystone canopy species in dry forests	Climate-linked changes in flowering pattern, seed pest pressure	Least Concern but declining	Fruit collection guidelines, community seed banks, elevation-based phenological studies	Kamila (2020); Kattel (2022)

Andrographis paniculata	Antiviral, liver tonic, used for cold and flu	Weed-like herb in open sunny patches	High inter-annual variability in biomass under rainfall fluctuation	Widely used but unsustainably harvested	Controlled cultivation, phytochemical standardization, mapping climate-adapted genotypes	Reddy et al. (2012); Eshete & Molla (2021)
Semecarpus kathalekanensis	Anti-cancer potential, very limited ethnomedicinal use recorded	Canopy tree in semi-evergreen forest	Extremely sensitive to microclimate shifts, pollination failure due to habitat loss	Critically Endangered	Long-term recovery plan, in vitro conservation, habitat microclimate restoration	Barik & Adhikari (2012); Kamila (2020)

8. CONCLUSION

Climate change creates various dangers for medicinal plant diversity, mainly in regions like the Eastern Ghats which are known both for their culture and their nature. The outcomes can be seen in decreased effects of drugs, cultural practices being disturbed and weakening of the environment's ability to cope with challenges. On the other hand, the research shows that there are truly successful approaches: propagation science, modeling nature, protecting groups and educating communities in ethnobotany.

Kamila shows that by working with locals and using data, it is possible to protect such a valuable biocultural resource in each region. Going forward, efforts need to be made to make policies work together for biodiversity, healthcare and planning for climate change, so knowledge of medicinal plants is maintained.

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