Eco-Friendly Farming of Medicinal Herbs for Pharmaceuticals in Australasia and Asia

Mohamed Khadeer Ahamed Basheer [1]

Abstract

The increasing demand for medicinal herbs in Australasia and Asia highlights the need for sustainable cultivation practices. Unregulated harvesting of valuable botanical resources has raised environmental concerns, emphasizing the urgency of eco-friendly approaches. Traditional medicine systems have long valued medicinal herbs, but overexploitation poses a threat. Sustainable cultivation, employing techniques like organic farming and agroforestry, is crucial to protect biodiversity and ensure a stable herb supply. Integrating traditional knowledge into modern practices, fostering collaborations, and establishing fair value chains contribute to the sustainability of medicinal herb production. Certification systems like FairWild and organic certifications guide consumers toward ecologically responsible choices. Sustainable methods benefit the environment, local communities, the pharmaceutical industry, and overall human well-being. So, growing medicinal herbs sustainably across Australasia and Asia is crucial to meet rising demand and preserving ecosystems and cultural traditions. This review emphasizes the importance of supporting ethical supply chains, preserving traditional knowledge, and adopting modern farming techniques for a reliable and environmentally friendly supply of medicinal herbs, benefiting local communities, the global pharmaceutical industry, and human welfare.

Keywords: Sustainable Cultivation, Medicinal Herbs, Traditional Knowledge, Pharmaceutical Supply

Significance | The increasing demand for medicinal herbs in Australasia and Asia underscores the necessity for sustainable cultivation, preserving ecosystems and cultural traditions.

*Correspondence: Mohamed Khadeer Ahamed Basheer, CTI Research institute, Level 21/207 Kent St, Sydney NSW 2000, Australia,
E-mail: khadeermanuscript@gmail.com

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Introduction

Farming has a big impact on everyone, with both good and bad effects. From 1950 to 1980, more land was turned into farms to feed the growing population. However, this intensive farming caused significant environmental issues, as shown in Figure 1.

Between 1990 and 2015, agriculture had the most significant impact on global growth, leading to a 3% decrease in total forest area, cutting down trees from 4,128 million hectares to 3,999 million hectares (FAO 2016). Deforestation, especially between 1980 and 2000, resulted in a 28% loss of primary forests to secondary woods, affecting biodiversity. It's predicted that about 1 million species, including animals, plants, and insects, may go extinct in the coming decades (Almond et al. 2020). This has both positive and negative effects on herbal medicine.

Throughout history, medicinal plants have been crucial in Australasia and Asia's healthcare systems, contributing to their traditional medical practices. With unique medicinal properties and cultural significance, these plants are part of the rich biodiversity found across continents (Yan et al., 2018). However, the increasing demand for natural medicines and pharmaceutical components globally raises concerns about the future of these valuable herbal resources.

Author Affiliation:
[1] CTI Research institute, Level 21/207 Kent St, Sydney NSW 2000, Australia

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In ancient Australasia and Asia, a holistic approach to treatment emerged by blending indigenous knowledge and traditions with the surrounding environment (Kongkiatpaiboon et al., 2019). This approach, rooted in the belief that the medicinal value of plants extended beyond physical recovery to include spiritual and cultural aspects, has been passed down through generations, shaping the healing systems of the region.

In the 21st century, there's a rising global demand for natural treatments and herbal medicines due to their perceived benefits and the search for sustainable healthcare solutions (Tugizimana et al., 2018). However, this increased demand has put traditional medicinal plant resources at risk of exploitation, overharvesting, and habitat damage, threatening the foundations of these ancient systems. Globalization and the growing popularity of natural medicines, particularly in Australasia and Asia, have led to a surge in demand for medicinal herbs, causing overuse and unsustainable collection practices (Zhu et al., 2019). This has resulted in a significant decline in plant populations, with some species now facing endangerment. Indigenous and local populations possess valuable traditional knowledge about cultivating and using therapeutic plants. To effectively conserve these resources, it's essential to integrate this knowledge into sustainable farming practices (Barstow et al., 2019). Additionally, involving these communities in the herb-growing industry could create new economic opportunities and promote conservation.

Promoting the sustainable cultivation of medicinal plants in Asia and Australia is crucial for preserving biodiversity. These practices protect the targeted herbs and contribute to the overall ecosystems' well-being, relieving pressure on wild populations and ensuring the survival of various plant and animal species (Jain et al., 2019). Governments and international organizations should establish regulatory frameworks supporting sustainable agriculture to achieve this. These rules can address challenges such as incentives for adopting sustainable methods, setting wild harvesting quotas, and certifying responsibly supplied herbs (Ghorbani et al., 2018). This paper addresses the issue of overharvesting medicinal herbs in Australasia and Asia and advocates for the proactive implementation of sustainable cultivation practices. The goal is to balance meeting the global demand for natural remedies and preserving the invaluable heritage of medicinal herbs in this culturally and ecologically diverse region. A Sustainable Cultivation Practices shows in Figure 2.

Ethnobotanical Research

Before embarking on the path toward sustainable production, it is essential to consult with indigenous populations and traditional herbalists (Berkes, F., et al., 2000). Ethnobotanical studies are vital in identifying indigenous medicinal plants, understanding their traditional uses, and cultivating methods that align with regional customs and ecosystems (Cotton, C. M., 1996; Hunn, E. S., 2007). This systematic study of human-plant interactions, focused on the historical use of plants for medical, dietary, and cultural purposes across various cultures, aims to document and preserve traditional plant knowledge (Prance, G. T., 1993; Posey, D. A., 1999).

Indigenous groups and traditional herbalists hold valuable information about local flora, including recognizing, preparing, and using medicinal plants to cure different illnesses (Albuquerque, U. P., et al., 2005). This orally transmitted knowledge may be lost without proper documentation, representing a priceless cultural treasure (Phillips, O., & Gentry, A. H., 1993). Ethnobotanical research is crucial for sustainable agriculture due to several reasons. Firstly, it aids in plant identification, as indigenous groups possess extensive knowledge of native plant species, their medicinal properties, and distribution, guiding focused cultivation efforts (Bye, R. A., 1986). Secondly, traditional knowledge illuminates plants' therapeutic, gastronomic, and cultural uses, contributing to the sustainable preservation of their benefits (Voeks, R. A., & Leony, 2004).

Ethnobotanical studies often reveal the adaptation of traditional farming techniques to regional habitats, guiding environmentally friendly farming practices and promoting environmental preservation (Saslis-Lagoudakis, C. H., et al., 2011). In summary, many academics emphasize the crucial role of ethnobotanical research as a tool for sustainable agricultural practices (Pieroni, A., et al., 2004; Vandebroek, I., et al., 2010). It preserves cultural heritage and facilitates the integration of ancient knowledge into contemporary agriculture, fostering a harmonious interaction between people and their natural environment.

Organic Framing

Organic farming prioritizes environmental protection, animal welfare, food quality, safety, resource sustainability, and social justice. It operates within a market framework to support these goals and cover internalized costs (Müller et al., 2009). According to the International Federation of Organic Agriculture Movements (IFOAM), organic farming is a production system that sustains ecosystems, soils, and people. It emphasizes ecological processes, biodiversity, and cycles adapted to the environment, avoiding inputs with negative consequences. Organic agriculture combines tradition, innovation, and science to provide high-quality food, benefit the environment, and promote equitable relationships and a good quality of life for all involved (Miniakiewicz et al., 2021).

Organic agriculture has five key features, including respect for the environment and animals, promotion of sustainable cropping methods, use of non-chemical fertilizers and pest control, production of high-quality food, and avoiding genetically modified crops (Lairon et al., 2010). Eco-friendly methods and minimal external inputs ensure food security (Zundel et al., 2007). Organic

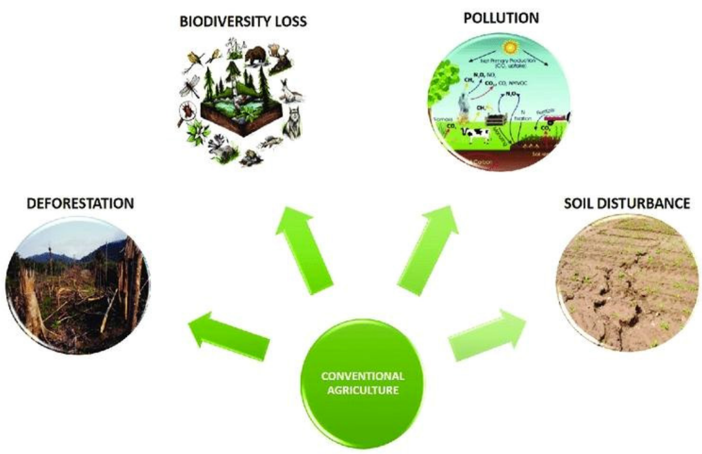

Figure 1. Some environmental problems of conventional agriculture

Figure 2. Sustainable Cultivation

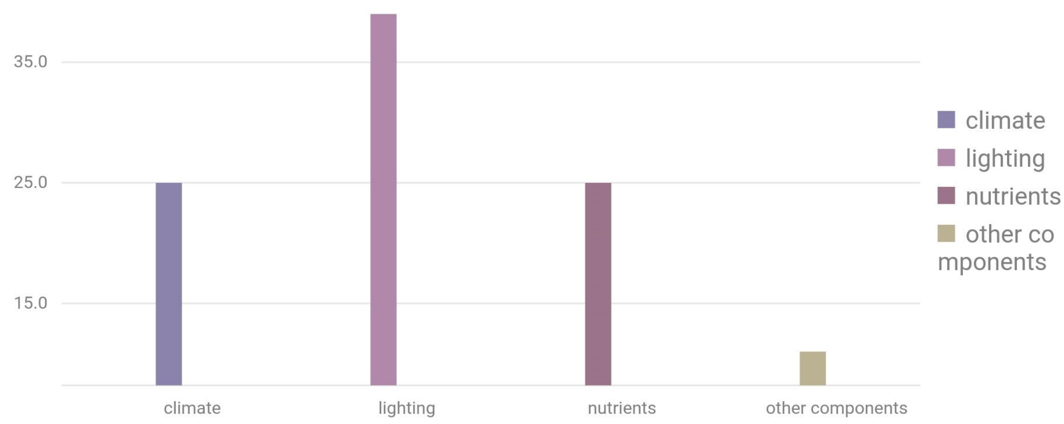

Figure 3. **Controlled Environment Agriculture (CEA)**

farming employs various solutions to increase productivity without relying on external inputs, especially pesticides (Schmid et al., 2009). It involves controlling soil fertility, managing crops, animals, farms, and ecosystems and optimizing nutrient use. Organic farming produces nutritious food while maintaining the balance of the ecosystem. The connection between organic farming and herbal medicine lies in the ability of organic cultivation to ensure the quality and purity of plant-based ingredients used in herbal medicine. This is essential, especially when these plants serve as the basis for pharmaceutical drugs, contributing to the pharmaceutical industry's positive growth globally.

Agroforestry

Agroforestry, the intentional combination of agriculture and forestry, offers several benefits that promote the sustainability of agroecosystems (Santoro et al., 2020). By restoring damaged land, protecting sensitive areas, and diversifying agricultural production, agroforestry contributes to effective land stewardship (162). When integrated into an ecologically oriented land management system, agroforestry techniques can help preserve ecosystem variety and processes, supporting long-term sustainability and environmental quality (Garrett et al., 2009). In the face of environmental challenges in modern agriculture and the push for sustainable agricultural practices, agroforestry holds potential for long-term economic, environmental, and social impacts (Shapiro et al., 2004). Essentially, agroforestry creates integrated systems that align with both environmental and commercial goals, bridging the gap between agriculture and forestry. This approach aids agricultural systems in mitigating and adapting to the impacts of climate change (Brown et al., 2019).

Integrating medicinal herbs into agroforestry systems offers significant benefits for pharmacy. As many medicinal compounds come from plants, agroforestry systems with medicinal herbs become crucial sources for pharmaceutical research. Cultivating medicinal plants in agroforestry provides essential raw materials for the pharmaceutical industry, facilitating the development of new drugs and herbal remedies. Agroforestry systems support the preservation and commercialization of traditional medicinal practices, contributing to their protection and sustainability. The use of medicinal plants in agroforestry supports the pharmaceutical sector and promotes sustainable agriculture, environmental conservation, and community well-being.

Germplasm

As explained by Wilkes (1991), Germplasm refers to the genetic material transferred from parents to offspring through germ cells. It serves as the essential raw material for breeders in creating diverse crops, encompassing the overall gene content (Duvick, 1982). In simpler terms, germplasm is living tissue—like seeds, leaves, stems, pollen, or even a few cells—that holds the potential to develop into a new plant (Witt, 1985). Williams (1991) defines germplasm as live genetic material preserved for breeding, conservation, and research for animals and plants. This material includes seed banks, nursery plants, animal breeding lines, and gene banks (Juma, 1989), providing valuable insights into a species' genetic makeup and contributing to natural plant diversity.

According to Peefers and Calwey (1988), the primary purpose of germplasm collection is to conserve the genetic diversity of a specific plant or genetic stock for future use. The benefits of germplasm include cryopreserving cell and tissue cultures for many plant species, preserving plant material from threatened species, maintaining long-term viability of cell cultures producing secondary metabolites, storing recalcitrant seeds, preserving disease-free plant material, conserving somaclonal variances, storing rare germplasms from genetic modification methods, extending the life of pollen, and facilitating international information exchange through germplasm banks.

Pharmacy and the pharmaceutical industry heavily rely on germplasm in various ways. Germplasm collections play a crucial role in preserving the genetic diversity of medicinal plants, ensuring a consistent source of plant materials for medication production. This steady supply maintains a reliable source of active ingredients for pharmaceutical drugs, as plants are a key natural resource for medication development. Researchers can explore various plant genetic material from germplasm banks to discover new bioactive substances with potential therapeutic properties. By preserving various plant genetic resources, germplasm banks contribute to the sustainable supply of medicinal plants, reducing the pressure on wild populations and promoting the long-term sustainability of therapeutic ingredient sources. In summary, germplasm is essential in pharmacy, supporting pharmaceutical development, aiding drug discovery, facilitating genetic improvement of medicinal plants, conserving rare species, and promoting sustainability in the pharmaceutical industry.

The role of technology in Pharmacy

Hydroponic

In recent times, hydroponics, an ancient farming technique, has found new medical applications. While its roots trace back to the Hanging Gardens of Babylon and early soilless cultivation, modern applications, especially in pharmaceutical research, have evolved significantly (Nicholls, 2016). Hydroponics offers several advantages over traditional soil-based farming, with increased crop yields being a notable benefit. Precise control of fertilizer supply and environmental factors allows for faster growth and higher yields in hydroponic systems (Savvas & Passam, 2017). Moreover, hydroponics is an excellent choice for urban agriculture and food production in areas with poor soil quality or limited access to arable land (Zhang et al., 2019). The environmental sustainability aspect of hydroponics is crucial. Traditional farming methods are often associated with resource waste, water pollution, and soil erosion. In contrast, hydroponics can significantly reduce water usage and eliminate the need for chemical fertilizers through recirculation systems, contributing to a more environmentally friendly agriculture (Resh, 2012).

In pharmaceutical research, hydroponic techniques are increasingly being employed to cultivate medicinal plants and herbs. This approach allows researchers precise control over the growth environment, ensuring consistent and high-quality plant yields for the production of medicinal chemicals (Jensen, 2017). Pharmaceutical companies and research organizations have adopted hydroponics to cultivate plant species with medicinal qualities, particularly those containing bioactive chemicals, alkaloids, or secondary metabolites. The intersection of hydroponics and pharmacy is evident in the cultivation of medicinal plants, which serve as natural sources for many pharmaceutical medications. Hydroponic systems offer advantages such as optimal nutrient supply, reduced pollution exposure, and enhanced growth rates for producing pharmaceutical-grade plants (Savvas & Passam, 2017). Challenges remain in regulatory compliance, quality control, and scaling up hydroponic cultivation for large-scale pharmaceutical production. Ongoing research and collaborations among horticulturists, agronomists, and pharmaceutical scientists aim to address these challenges and unlock the potential of hydroponics in pharmacy (Khosla et al., 2020).

Controlled Environment Agriculture (CEA)

Controlled environment agriculture (CEA) addresses traditional agriculture's challenges, offering potential solutions (see Figure 3). Several studies have highlighted the advantages of CEA, such as increased agricultural yields, reduced resource consumption, and enhanced sustainability (Smith et al., 2019). Jones et al. (2020) emphasize that CEA provides a regulated environment where factors like temperature, humidity, and light can be precisely adjusted to optimize plant growth, leading to higher production. Moreover, CEA enables year-round cultivation, mitigating the impact of climate change on agriculture (Gomez et al., 2018).

In pharmacy, controlled environment agriculture (CEA) plays a crucial role by offering a controlled and ideal environment for the cultivation of medicinal plants. The benefits of CEA in pharmacy include:

Precise Control: CEA allows for the precise management of essential factors like temperature, humidity, light, and nutrient levels, ensuring the consistent chemical profiles and therapeutic performance of medicinal plants (Rahman et al., 2018).

Year-Round Cultivation: Traditional agriculture is often affected by seasonal variations, impacting the availability of specific medicinal plants. CEA enables year-round cultivation, reducing the reliance on wild harvesting and ensuring a steady supply of raw materials for pharmaceutical production (Barnes et al., 2019).

Purity and Safety: The contained nature of CEA systems enhances the purity and safety of medicinal plant extracts used in pharmaceutical formulations, reducing the risk of contamination from pesticides, pollutants, or infections (Siddiqui et al., 2020).

Pharmaceutical research has embraced Controlled Environment Agriculture (CEA) for developing medicinal plants and exploring their pharmacological qualities. CEA facilitates the investigation of lesser-known plant species with therapeutic potential, aiding in the discovery of lead molecules for new drug development (Gupta et al., 2021; Patel et al., 2022). The controlled environment of CEA streamlines the isolation and identification of active chemicals in medicinal plants, enhancing in-depth phytochemical studies (Chowdhury et al., 2021).

Advanced CEA systems incorporate automation and data analytics, allowing precise adjustments to cultivation settings and real-time monitoring of plant development, especially beneficial for pharmaceutical research (Singh & Sharma, 2023). Moreover, CEA has become a valuable platform for integrating genomics and genetic editing methods, enabling scientists to manipulate plant genetics to increase specific pharmaceutical chemical production (Lee et al., 2020).

CEA is a dependable source of superior medicinal plants, crucial in cutting-edge pharmaceutical research. The symbiotic relationship between CEA and pharmaceuticals has paved the way for exploring novel phytochemical directions and ensuring year-round cultivation. While addressing economic and regulatory challenges is vital to fully realize CEA's potential in pharmaceutical applications, ongoing technological advancements continue to propel progress.

Advanced irrigation systems

Recently, once limited to traditional agriculture, advanced irrigation systems have found a new role in growing pharmaceutical plants, particularly medicinal herbs and botanicals. This innovative approach is reshaping how the pharmaceutical industry sources raw materials and ensures the consistency and quality of herbal treatments.

Research by Patel et al. (2022) focused on applying sophisticated irrigation techniques to grow medicinal plants like Echinacea purpurea. The study revealed that targeted nutrient supply and precision irrigation systems can enhance the bioactive components in certain plants, thereby increasing the effectiveness of herbal medicines. This indicates a transformative potential for modern irrigation methods in the cultivation of medicinal plants.

Smith and Brown (2019) explored how pharmaceutical agriculture utilizes advanced irrigation for environmental sustainability. Their analysis demonstrated that regulated irrigation optimizes resource utilization and reduces the environmental impact of growing therapeutic plants. This aligns with the pharmaceutical industry's growing emphasis on ethical manufacturing and sustainable sourcing.

Lee and Johnson's research (2021) concentrated on integrating data-driven irrigation management systems in medicinal plant farming. They found that automated irrigation, with real-time monitoring, can provide nutrients and maintain consistent moisture levels, enhancing the predictability and output of medicinal crops. This technical advancement aligns with the pharmaceutical industry's commitment to reliable supply chains and high-quality products.

A broader study by the International Pharmaceutical Association (2020) underscores the financial benefits of modern irrigation systems in pharmaceutical agriculture. It highlights how increased agricultural yields and improved product quality can lead to cost savings for pharmaceutical businesses and enhance market competitiveness.

In conclusion, integrating cutting-edge irrigation systems in cultivating pharmaceutical plants presents a revolutionary approach to producing medicinal herbs and botanicals. These systems can potentially transform the pharmaceutical industry's relationship with raw materials, optimizing resource consumption, improving product quality, and fostering sustainability.

Regulatory Frameworks

People have cultivated and harvested medicinal herbs for centuries, offering various therapeutic benefits from traditional remedies to modern pharmaceuticals. Different regions have distinct legal and regulatory systems for medicinal plants. In the United States, the Dietary Supplement Health and Education Act (DSHEA) of 1994 established regulations for herbal dietary supplements, emphasizing safety and labeling (United States Congress, 1994). Meanwhile, the European Medicines Agency (EMA) set standards for evaluating herbal medicines, focusing on quality, safety, and efficacy. These regulatory frameworks serve as guidelines globally.

A crucial aspect addressed by these frameworks is the sustainable production of medicinal plants. Organic certification schemes, like the National Organic Program (NOP) in the United States (United States Department of Agriculture, 2020), encourage herb cultivation using environmentally friendly methods. Similarly, the FairWild Standard promotes ethical wild harvesting to protect both plant populations and collectors' financial security (FairWild Foundation, 2020). Legal frameworks for ethically cultivating and harvesting therapeutic plants are essential to preserve ecological biodiversity and public health. Continuous research, international collaboration, and community involvement will be necessary to enhance and strengthen these frameworks as the global herbal sector evolves.

Conclusion and future recommendations

The sustainable cultivation of medicinal herbs in Australasia and Asia faces a crucial juncture where the pharmaceutical industry's growing needs intersect with the imperative to conserve biodiversity and respect indigenous cultural traditions. The path toward ethical herb farming combines historical knowledge, modern precision, and supportive legal frameworks. It underscores the urgent need to preserve our natural environment for future generations and recognizes these herbs' vital role in healing. A significant challenge is the past overharvesting of medicinal plants from the wild, leading to habitat destruction and species endangerment. To address this, sustainable farming is crucial.

Indigenous communities possess valuable knowledge about these plants and their uses. Preserving and respecting this traditional expertise, often passed down orally, is essential for responsible cultivation. Balancing the rising demand for herbal products, especially in the pharmaceutical sector, requires careful planning and investment.

To tackle these challenges and ensure a sustainable future for medicinal herb cultivation in Australasia and Asia, several recommendations can be considered:

- Further research into growing methods, including genetic conservation and controlled environment agriculture, can enhance the production and quality of medicinal herbs.
- Governments should continually review and revise rules to promote ethical production and discourage harmful practices.
- Educating consumers about the value of ethically sourced herbal products can increase demand for herbs grown sustainably.

Author contribution

M.K.A.B. wrote, drafted, reviewed and edited the paper.

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