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Development Strategies for Artemisia Cultivation in Indonesia

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Abstract: *Artemisia annua* L. is a strategic medicinal plant and the primary source of artemisinin, a key sesquiterpene lactone used in ACT-based malaria therapy. Rising global malaria cases and increasing resistance to conventional antimalarial medicine have driven higher demand for artemisinin in the past two decades. Besides artemisinin, *A. annua* contains valuable secondary metabolites such as flavonoids, terpenoids, and coumarins, which exhibit anticancer, antiviral, anti-inflammatory, and immunomodulatory potential. Although Indonesia has suitable highland agroclimatic conditions for cultivating this species, its utilization remains limited, and the national pharmaceutical sector still depends on imported raw materials from major producers like China, Vietnam, and Madagascar. This study applies a descriptive–qualitative method through a structured literature review to examine global cultivation trends, development prospects in Indonesia, and partnership strategies based on SWOT analysis and change-management concepts. The findings show strong opportunities for *A. annua* development, supported by market growth, the need for import substitution, and the availability of tropical-adaptive varieties. However, challenges persist, including price fluctuations, extreme climate variability, limited access to high-quality planting material, and low farmer technical capacity. Strengthening technology-based core–plasma partnerships, providing certified seeds, improving cultivation and post-harvest standards, and ensuring supportive government policies are crucial for building a sustainable *Artemisia* supply chain. With appropriate strategies, Indonesia could become a competitive producer of strategic pharmaceutical raw materials and reduce dependence on imports.

Keywords: *Artemisia annua*, Artemisinin, Malaria, Partnership Strategy, SWOT Analysis

1. Introduction

The artemisia plant (*Artemisia annua* L.), also known as sweet wormwood, is an important medicinal plant that has gained global attention due to its secondary metabolites, particularly artemisinin. Artemisinin is a sesquiterpene lactone widely recognized as the main active compound in Artemisinin-based Combination Therapy (ACT) for malaria. Globally, the World Health Organization (WHO) reported 249 million malaria cases in 2022 with approximately 608,000 deaths across 85 countries (Rustam et al., 2025). In Asia, especially Southeast Asia, malaria cases reached 443,530 in 2022 (Mahendra & Savitri, 2023). Along with the rising trend of global malaria cases and the emergence of resistance to conventional antimalarial medicine such as chloroquine and sulfadoxine–pyrimethamine, the demand for artemisinin has significantly increased over the past two decades (Fitri et al., 2023). These conditions position *A. annua* as a strategic commodity in the phytopharmaceutical industry and global health.

Considering that malaria incidence remains high worldwide, including in Indonesia, the demand for Artemisia continues to grow. However, artemisinin procurement is highly challenging due to its low natural yield (only about 0.1–1.8% in *A. annua*) and a lengthy cultivation period of 12–14 months (Gusmaini & Nurhayati, 2007). In Indonesia, the development of *A. annua* remains suboptimal despite favorable highland agroclimatic conditions. The national pharmaceutical industry still relies on imported artemisinin from China, Vietnam, and India (Khasanah, 2019). Meanwhile, recent research indicates that tropical-adaptive Artemisia clones released by institutions such as BRIN and Balittro have artemisinin levels comparable to international varieties.

In addition to artemisinin, *A. annua* contains various high-value secondary metabolites that have potential as new medicine candidates, including flavonoids, terpenoids, coumarins, and aromatic acids (Al-Sowayan et al., 2024). These compounds exhibit anticancer, anti-inflammatory, antiviral, immunomodulatory, and antioxidant activities, thereby expanding its potential use not only for malaria but also for infectious, chronic inflammatory, and degenerative diseases (Kim et al., 2014). Considering the continuously growing global market opportunities, development strategies

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for Artemisia in Indonesia should focus on varietal innovation, strengthening farmer–industry partnerships, and integrating supply chains from upstream to downstream. These efforts are essential to achieving national self-sufficiency in pharmaceutical raw materials.

2. Research Methods

This study employs a descriptive–qualitative approach using a structured literature review design. This approach was selected to examine the development of Artemisia cultivation partnerships in various countries, analyze its development prospects in Indonesia, and identify relevant partnership strategies based on change-management concepts and SWOT analysis to assess strengths, weaknesses, opportunities, and threats.

3. Result and Discussion

3.1 Artemisia Cultivation Partnership Data

Over the past decade, global dynamics in *A. annua* cultivation have shown significant changes in terms of production, pricing, and partnership models between farmers and artemisinin extraction companies. According to reports from the World Health Organization (WHO), Medicines for Malaria Venture (MMV), and the ACT (Artemisinin-based Combination Therapy) development consortium up to 2023, Artemisia cultivation has expanded across major producing countries such as China, Vietnam, Madagascar, Kenya, Tanzania, and Uganda (Lee et al., 2023). These countries implement strong partnership schemes between farmers and pharmaceutical companies or extraction facilities to ensure a stable supply of leaves and price stability.

According to the PATH (2025) report, global demand for *Artemisia annua* leaves is estimated to remain stable at around 25,000–26,000 tons per year, with artemisinin demand reaching 420–430 tons per year, of which 95–97% is supplied by China. Agronomically, *A. annua* in China is cultivated on an area of about 100 km² or approximately 10,000 hectares, with planting area fluctuations strongly influenced by market prices and farmer interest. China's production capacity far exceeds global needs, with the ability to extract more than 700 tons of artemisinin per year and potential leaf production reaching 50,000 tons. However, actual output varies significantly each year: around 50,000 tons in 2022, decreasing to 32,000 tons in 2023, and dropping drastically to less than 10,000 tons in 2024 due to low prices that discouraged cultivation. Historically, the price of *A. annua* leaves ranged from US$0.83–1.24/kg, but increased to US$1.51–1.65/kg in 2024 as harvest volumes declined. Meanwhile, artemisinin prices—previously stable at US$151–178/kg—have experienced volatility since the COVID-19 pandemic, peaking at US$283/kg and reaching a low of US$91/kg between 2021 and 2024. Several major challenges in cultivation include:

1. Limited young agricultural labor
   Many countries face a shortage of new farmers, leading to higher labor wages and increased production costs for *Artemisia annua* cultivation.
2. Land competition with food crops
   Farmers prefer fast-harvest, lower-risk food or horticultural crops, making Artemisia cultivation less attractive without stronger incentives.
3. Extreme climate variability
   Climate change such as prolonged droughts and irregular rainfall, reduces plant biomass and artemisinin content, particularly in tropical East Africa.
4. Artemisinin market fluctuations
   Prices depend heavily on ACT (Artemisinin-based Combination Therapy) demand. When ACT demand falls, artemisinin prices drop sharply, affecting farmer income.
5. Raw material quality issues
   - Early harvesting results in low artemisinin content.
   - Harvesting wild plants leads to inconsistent quality.
   - Non-standard post-harvest handling (drying, storage) decreases dried leaf quality.
6. Suboptimal seed quality and cultivation practices
   Producing countries report that seed quality, harvesting techniques, and drying methods are key determinants of production stability and artemisinin content, highlighting the need for improved farmer capacity and technical support.

3.2 Partnership Strategy

Changes in the era of globalization and digitalization are becoming increasingly rapid and dynamic, influencing nearly all sectors, including healthcare systems and the medicinal plant industry. In the context of malaria treatment and the potential for exporting herbal raw materials, the demand for *Artemisia annua* has risen again since the COVID-19 pandemic due to the high need for immunomodulatory products and artemisinin as a pharmaceutical raw material in global markets. These shifts in market demand require companies and farmers to adapt through more modern, transparent, and technology-driven partnership models.

Public perspectives on malaria therapy have also evolved. Resistance to quinine and several early-generation ACT medicine has pushed producing countries to rely on higher-quality artemisinin sources. As a country with suitable agroclimatic conditions—particularly in its highland regions—Indonesia needs to develop strong domestic partnership strategies so it does not remain merely an importing market but can become a producer of strategic pharmaceutical raw materials. Within this dynamic, change management becomes essential for building effective partnerships between processing companies (core) and farmers (plasma). Change is driven not only by global market forces but also by internal factors such as the need for production efficiency, quality improvement, and the adoption of agro-industrial technologies.

To respond to these dynamics, the core companies must strengthen farmers' technical capacity through the provision of high-artemisinin elite planting materials, precision cultivation training, and guidance in harvesting and post-harvest handling based on Good Agricultural Practices (GAP) to ensure stable dried-leaf quality despite climate variability. Quality-based incentive schemes—such as minimum price guarantees that protect farmers from global market volatility and bonuses for high-artemisinin leaves are essential, particularly for farmers who tend to avoid high-risk crops. Additionally, providing certified seeds through centralized nurseries, establishing demonstration plots to educate and build confidence among highland farmers, and implementing transparent and accountable partnership mechanisms are crucial to ensuring equitable core–plasma relationships.

Risk protection through crop-failure insurance schemes, the use of digital technologies such as supply-chain traceability systems, improved trust through regular communication and timely payments, and efforts to engage younger generations via IoT technologies and promising economic opportunities are integral components of modern partnership strategies. Thus, the partnership structure must be capable of aligning farmers' psychosocial aspects, work culture, and technical production processes to create a sustainable, innovative, and competitive Artemisia cultivation ecosystem, while simultaneously supporting Indonesia in reducing its dependence on imported pharmaceutical raw materials.

3.3 SWOT Analysis

From the perspective of strategic management as described by Rangkuti (2006), the results of the SWOT analysis on the current development of the Artemisia industry reveal four interrelated aspects. In terms of Strengths, *Artemisia annua* cultivation offers a continuously growing global market potential, driven primarily by the demand for artemisinin used in ACT malaria medicine and the rising trend of immunomodulatory herbal products following the COVID-19 pandemic. Major producer countries such as China, Vietnam, and Madagascar continue to expand their cultivation areas, indicating that this commodity remains highly promising. In Indonesia, most pharmaceutical raw materials are still imported, creating a significant and strategic opportunity for import substitution through domestic cultivation. Furthermore, advancements in extraction technology which has become more efficient and strengthen the competitiveness of the artemisinin industry.

From the perspective of Weaknesses, the development of Artemisia still faces technical and social constraints. Artemisinin production requires specialized extraction technology, high-quality elite seeds, strict harvesting standards, and controlled post-harvest handling, factors that are not yet consistently mastered by Indonesian farmers. Shifting farmers' cropping patterns from familiar commodities to a new crop such as Artemisia is not easy and requires clear, demonstrable economic benefits. In addition, the availability of young agricultural labor continues to decline, labor costs are increasing, and dependence on certified planting material remains a fundamental issue in ensuring consistent leaf quality.

From the perspective of Opportunities, the potential for developing Artemisia is considerable, given the relatively stable global demand for artemisinin, the opportunities to enter the export market for dried leaves, and the growing need for Indonesia's pharmaceutical industry to reduce its dependence on imported raw materials. Government policies supporting standardized herbal medicines and phytopharmaceuticals also create space for Artemisia to emerge as a strategic national commodity. Moreover, other producing countries are experiencing climate-related constraints and production fluctuations, providing opportunities for new producers such as Indonesia to enter the market as an alternative supplier.

However, several Threats must be anticipated. Price fluctuations in the international artemisinin market may reduce farmers' interest if no price-protection scheme is in place. Extreme climate conditions (drought, irregular rainfall) also have the potential to lower artemisinin content. In addition, major producing countries such as China and Madagascar possess far more advanced technologies and production systems, enabling them to dominate the global market. If these opportunities are not utilized, other countries will capture the market potential that Indonesia could actually fill.

In response to the SWOT analysis, a strong partnership model is required between a competent core company and farmers as plasma partners, based on the principles of Good Corporate Governance such as transparency, accountability, and fair profit-sharing. Local deliberation approaches, continuous technical guidance, and assistance during harvest and post-harvest processes are essential elements in building trust between both parties. On the other hand, the role of the government is crucial through genuine support for the agricultural sector not merely political rhetoric, but in the form of policy measures, credit facilities, technical assistance, the provision of superior planting materials, and the strengthening of downstream industries. With these efforts, opportunities for developing Artemisia in Indonesia can be maximized to reduce dependence on imported raw materials and strengthen the national pharmaceutical industry.

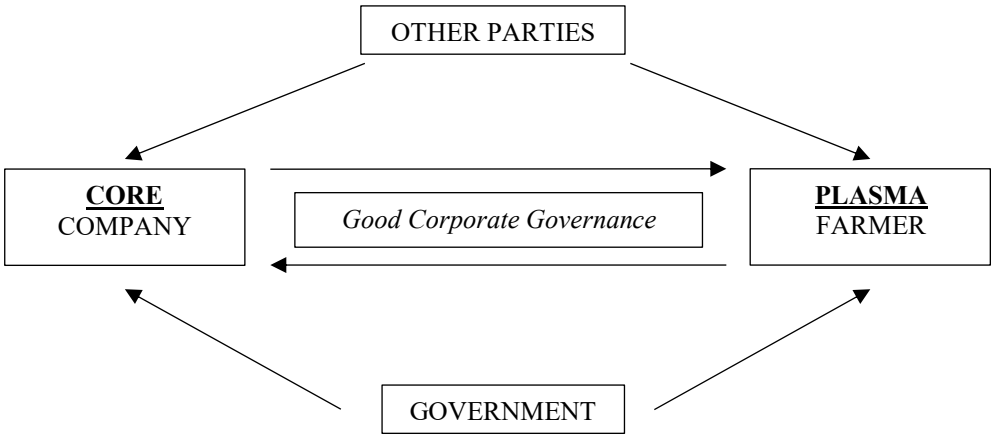

Fig. 1: Scheme of Partnership Design for the Development of *A. annua*

4. Conclusion

The development of *Artemisia annua* holds significant potential both globally and nationally due to the high demand for artemisinin and the growing trend of immunomodulatory herbal products. However, various challenges such as price fluctuations, extreme climate conditions, limited availability of superior planting materials, and the low technical capacity of farmers remain major obstacles. Through transparent, technology-based core–plasma partnerships supported by government policies including the provision of quality seeds, cultivation assistance, and price protection. Indonesia has the potential to become a strategic producer capable of reducing dependence on imported pharmaceutical raw materials and strengthening the national pharmaceutical industry.

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Conflict of Interest

The authors declare no conflicts of interest.

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