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Contemporary global health is defined by complex challenges ranging from the escalating burden of non-communicable diseases to the profound inequities exposed by the COVID-19 pandemic, these challenges highlight the limitations of biomedicine-focused health strategies, which often fall short of addressing the holistic needs of populations. The strategic use of bilateral and multilateral cooperation to promote health systems that integrate evidence-based traditional medicines with modern medicine is being increasingly acknowledged. However, the credibility and sustainability of traditional medicines depend on establishing a regulatory framework that provides evidence based solutions through international GMP standards, advanced quality testing, regulatory compliance and clinical validation. Towards this end the Ayush sector has been harnessing the strength of new technologies and data mining. Digital transformation is reshaping the traditional medicine landscape, offering new pathways to strengthen evidence generation, optimize service delivery, and enable systematic integration into national health systems. Data lies at the center of this transformation where data functions not as static repositories but as dynamic, interoperable inputs that power AI-driven analytics, digital diagnostics, personalized treatment algorithms, and real-time decision-making for both clinical and policy applications. At the same time, quality research on traditional medicine has emerged as another imperative for integrative health strategies. This includes research on sustainable medicinal plants supply, a key component of raw material in manufacturing traditional medicines. While diverse conservation strategies, from community-led initiatives to advanced tissue culture and cryopreservation techniques, are being explored, there remains limited clarity on how research trends are evolving across disciplines and regions.

This issue explores the changing landscape of health diplomacy, the inclusion of integrative health comprising of evidence based traditional medicine in healthcare strategies, the role of regulatory standardization, digital technology and research in sustainable growth of the traditional medicine sector. Abhijit Dutta argues for a paradigm shift towards integrative health diplomacy, a more comprehensive and equitable model specifically suited for the framework of South-South Cooperation, while Rajeshwari Singh and Geetha Krishnan G Pillai examine the opportunities, challenges, and future trajectories of digital transformation in traditional medicine, with a specific focus on the strategic role of data, digital health technologies, and Artificial Intelligence in shaping evidence-based and sustainable health systems.

Raman Kaushik and Pragya Sharma analyse the governance and regulatory challenges of Ayush drug regulation in India, suggesting strategic reforms that could help align the sector with global benchmarks and strengthen its international credibility. Given the continued emphasis on evidence generation though quality research, Anjali Luthra maps the research landscape on medicinal plant conservation in India between 2015 and 2025. Her paper analyses over 4,313 peer-reviewed publications across major databases. Through bibliometric methods and visualisation using VOSviewer, the paper examines publication trends, journal and citational analysis, regional ecosystem focus, and disciplinary contributions. Biodiversity and bio economy being a critical component in the traditional medicine industry, Namrata Pathak reviews Ogwu *et. al.*, (ed) Sustainable Bioeconomy in the Global South: Status and Perspectives.

I am sure readers will find this issue of Traditional Medicine Review useful in understanding the emerging global narratives in traditional medicine systems and trends in technological adaptation in the context of present trade and industry linkages.

Professor Sachin Kumar Sharma
(DG, RIS and Editor-in-Chief, TMR)

Integrative Health Diplomacy in South-South Cooperation: A Policy Perspective

Abhijit Dutta*

Abhijit Dutta

Abstract: Contemporary global health is defined by complex challenges, from the escalating burden of non-communicable diseases to the profound inequities exposed by the COVID-19 pandemic. These challenges have revealed the limitations of conventional, biomedicine-focused health diplomacy, which often falls short of addressing the holistic needs of populations within the Global South. This paper argues for a necessary paradigm shift towards Integrative Health Diplomacy (IHD), a more comprehensive and equitable model specifically suited for the framework of South-South Cooperation (SSC). IHD is conceptualised as the strategic use of bilateral and multilateral relations to promote health systems that intelligently integrate evidence-based Traditional and Complementary Medicine (T&CM) with conventional medicine. Through a policy analysis of existing literature and illustrative case studies from India, China, and Brazil, this paper demonstrates that IHD offers a pathway to decolonise global health, accelerate progress towards Universal Health Coverage (UHC), and incorporate more resilient and culturally competent health systems. It concludes by offering a framework with actionable policy recommendations for national governments, regional bodies, and international organisations to operationalise IHD. This shift, it is argued, is fundamental to building genuine health sovereignty and solidarity among the nations of the Global South.

Keywords: Health Diplomacy, Integrative Health Diplomacy, South-South Cooperation, Traditional Medicine, Global Health Policy, AYUSH, Global South

Introduction

In the years following the global disruption of the COVID-19 pandemic, a new consensus has emerged in international policy circles: the pursuit of global health security cannot be divorced from the fundamental goal of building resilient, equitable, and sustainable health systems (Cylus, *et al*., 2021). The crisis of the early 2020s was a watershed moment, revealing not only the fragility of

*International Cooperation Section, Ministry of Ayush (Government of India), New Delhi; Email: drabhijitdutta1@gmail.com

global supply chains for medical goods but also the profound vulnerabilities within national health systems, particularly across the Global South. It demonstrated how the pre-existing and escalating crisis of non-communicable diseases (NCDs) acted as a threat multiplier, creating a syndemic that led to disproportionately severe outcomes (Horton, 2020). As nations now navigate this post-pandemic landscape, the central question is how to build a global health architecture that is better prepared for future shocks and more attuned to the holistic health needs of its populations.

Within this context, health diplomacy—the interface of foreign policy and health—has reaffirmed its role as a critical instrument of statecraft (Kickbusch and Kökény, 2013). Traditionally, its practice has been dominated by a biomedical paradigm, focusing on infectious disease control, pharmaceutical access, and the financing of hospital-centric infrastructure. While indispensable, this model is increasingly proving insufficient on its own. Concurrently, South-South Cooperation (SSC) has gained significant momentum as the principal framework for developing countries to share knowledge and resources on their own terms, fostering partnerships grounded in solidarity and mutual respect rather than the conditionalities of traditional North-South aid (UNOSSC, 2022).

This paper identifies a fundamental mismatch between the conventional tools of health diplomacy and the contemporary health realities and aspirations of the Global South. The continued marginalisation of legitimate, evidence-based Traditional and Complementary Medicine (T&CM) systems that often form the bedrock of primary healthcare for a majority of the world's population is not just a missed opportunity; it represents a form of epistemic injustice that undermines the pursuit of health sovereignty (Fricker, 2007). To effectively tackle the chronic disease burden and build truly resilient systems, a more inclusive and pluralistic approach is required.

Therefore, this paper argues for a necessary paradigm shift: from conventional Health Diplomacy to Integrative Health Diplomacy (IHD). We define IHD as a strategic foreign policy approach that facilitates the co-creation of health systems by intelligently integrating T&CM with conventional medicine. This model moves beyond aid to foster genuine collaboration, respects diverse knowledge systems, and offers a more sustainable path towards achieving Universal Health Coverage (UHC). Through a conceptual analysis, a review of case studies from India, China, and Brazil, and the formulation of actionable policy, this article will demonstrate that IHD is not merely a theoretical alternative but an essential evolution for the future of global health cooperation within the framework of the Global South (Dutta, 2025).

Methodology

This paper employs a qualitative, conceptual, and policy-oriented research design to develop and substantiate its central thesis. The primary objective is not to test a pre-existing hypothesis through empirical data, but rather to construct a new analytical framework, i.e. Integrative Health Diplomacy (IHD) and to explore its practical relevance and application within the contemporary context of South-South Cooperation. The methodology is therefore grounded in a synthesis of existing theories and an analysis of current policy practices.

The present studies was conducted in three distinct stages:

Conceptual Framework Development

The initial stage involved a critical review of foundational literature in the fields of global health, international relations, and public policy. Key concepts including Health Diplomacy, South-South Cooperation, and Integrative Health were deconstructed and analysed. The IHD framework was then developed through a process of conceptual synthesis, combining these existing ideas to propose a new, more nuanced model of diplomatic engagement in health.

Scoping Review and Thematic Analysis

The second stage involved a comprehensive scoping review of secondary data sources. This included peer-reviewed academic literature from databases such as PubMed, Scopus, and JSTOR; official policy documents and annual reports from national governments (e.g., India's Ministry of AYUSH, China's National Health Commission) and international organisations (e.g., World Health Organization, UN Office for South-South Cooperation); and grey literature from policy think tanks and research institutions (e.g., Research and Information System for Developing Countries (RIS). A thematic analysis of these documents was conducted to identify key drivers, strategic mechanisms, and existing challenges related to the international promotion of Traditional & Complementary Medicine.

Illustrative Comparative Case Study Analysis

The final stage employed a comparative analysis of three illustrative case studies: India, China, and Brazil. These cases were selected purposively as they represent three of the most influential and distinct models of T&CM promotion and integration originating from the Global South. The analysis is not an exhaustive empirical investigation of each country's foreign policy, but rather a focused examination of their approaches to illustrate the different facets, motivations, and potential of IHD in practice.

The Paper acknowledges its limitations. By relying on publicly available secondary data, the analysis provides a macro-level policy perspective. It sets the stage for future empirical research, such as in-depth interviews with policymakers and practitioners, which could further validate and elaborate on the proposed IHD framework.

Conceptual Framework-Deconstructing Diplomacy and Health

To fully appreciate the proposed paradigm shift, it is essential to deconstruct its constituent parts: the evolution of health diplomacy, the principles of South-South Cooperation, the definition of integrative health, and finally, the synthesis of these into the new concept of Integrative Health Diplomacy.

The Evolution of Health Diplomacy

Health diplomacy is not a new phenomenon. Its roots can be traced to the 19th-century International Sanitary Conferences, which aimed to manage the cross-border spread of cholera and plague through quarantine regulations (Lee & Ingram, 2012). This early form was primarily defensive and state-centric. During the Cold War, health became an arena for ideological competition, with the US and USSR offering medical aid

to win influence. The establishment of the World Health Organization (WHO) in 1948 institutionalized health as a domain of multilateral cooperation. In the post-Cold War era, particularly with the HIV/AIDS crisis and the rise of bioterrorism concerns, health diplomacy gained prominence as a key component of foreign policy, recognized for its "soft power" potential (Nye, 2004). Scholars like Kickbusch (2007) have framed it as a practice involving negotiation to resolve health challenges and using health to improve international relations. However, this dominant conception has largely operated within a biomedical framework, focusing on global health security, disease surveillance, and pharmaceutical access.

The Rise of South-South Cooperation

SSC emerged from the 1955 Bandung Conference, representing a collective desire among newly independent nations to chart their own development course, free from the political conditionalities of traditional North-South aid (Gray & Gills, 2016). It is fundamentally a political project built on solidarity and shared experience. Unlike the vertical, donor-recipient model of Official Development Assistance (ODA), SSC emphasizes horizontal partnerships, capacity building, and knowledge exchange on a basis of mutual respect and non-interference (UNOSSC, 2019). In health, this has manifested in collaborations like Cuba's deployment of doctors to other developing nations and Brazil's sharing of its successful HIV/AIDS treatment models. The SSC framework is therefore inherently receptive to alternative development paradigms that challenge Western hegemony, making it the ideal incubator for a new form of health diplomacy.

Defining Integrative Health

The term "integrative health" is often misunderstood as simply mixing conventional and alternative therapies. However, its modern definition is far more rigorous and philosophical. According to the Academic Consortium for Integrative Medicine & Health, it is an approach to care that "reaffirms the importance of the relationship between practitioner and patient, focuses on the whole person, is informed by evidence, and makes use of all appropriate therapeutic and lifestyle approaches, healthcare professionals and disciplines to achieve optimal health and healing" (Rakel, 2018). It is a patient-centered, holistic, and evidence-informed model. A key distinction is its emphasis on health and wellness, not just the treatment of disease. This aligns perfectly with the need to manage chronic NCDs, which are heavily influenced by lifestyle, diet, and mental well-being—domains where traditional medical systems often possess deep knowledge.

Synthesizing these concepts, we define Integrative Health Diplomacy (IHD) as:

> "A foreign policy practice, particularly within the framework of South-South Cooperation, that strategically facilitates the bilateral and multilateral exchange of knowledge, practices, products, and personnel from both conventional medicine and evidence-based Traditional & Complementary Medicine. Its primary goals are to build sustainable, resilient, and culturally competent national health systems; advance health equity and Universal Health

Coverage; foster mutual trust and respect between nations; and contribute to a more pluralistic global health architecture."

IHD moves beyond providing aid; it is about co-creating health systems. It is not anti-biomedicine; it is post-biomedical dominance. It treats traditional knowledge as a valuable resource for contemporary health challenges, subject to appropriate research and regulation. It is, in essence, the diplomatic expression of the integrative health philosophy on a global scale.

Key Imperatives for a Paradigm Shift

The continued reliance on a purely biomedical model of health diplomacy within SSC is not only a missed opportunity but is increasingly untenable for four key reasons.

The Epidemiological Transition: The health profile of the Global South has dramatically shifted. While infectious diseases remain a challenge, the primary burden of disease and cause of premature death are now NCDs (WHO, 2022). A biomedical model designed for acute, infectious conditions is ill-suited to manage these chronic, lifestyle-related diseases. Managing diabetes or hypertension requires long-term care, patient education, and lifestyle modifications—areas where T&CM systems like Ayurveda, TCM, and traditional African medicine offer sophisticated approaches to diet, stress reduction, and holistic wellness (Chopra & Doiphode, 2002). Ignoring this vast reservoir of knowledge is both inefficient and medically negligent. An integrative approach is better equipped to provide the comprehensive, preventative, and long-term care that NCDs demand.

The Decolonization of Global Health: The global health field is undergoing a critical self-examination of its colonial roots (Khan *et al*., 2021). Many existing structures and priorities perpetuate power imbalances, where knowledge, funding, and leadership flow from North to South. A health diplomacy that exclusively promotes Western biomedicine, even with the best intentions, can inadvertently devalue and displace indigenous health systems, a phenomenon often termed "epistemicide" (de Sousa Santos, 2014). This creates a dependency on foreign pharmaceuticals and technologies, undermining local capacity and health sovereignty. IHD, by contrast, is an inherently decolonizing practice. It validates and uplifts indigenous knowledge systems, placing them in dialogue with biomedicine on a more equal footing and empowering nations to build health systems that reflect their own cultural identity.

The Quest for Universal Health Coverage (UHC): The WHO defines UHC as ensuring all people have access to the health services they need, when and where they need them, without financial hardship. For many countries in the Global South, this goal is impossible to achieve using a high-cost, physician-centric biomedical model alone. There is a severe shortage of conventionally trained health workers, and health infrastructure is concentrated in urban areas (WHO, 2019). However, these same countries often have a vast, pre-existing, and trusted network of T&CM practitioners. By formally recognizing, training, and integrating this workforce into the primary healthcare system—

as countries like China and India are attempting—nations can rapidly expand healthcare access in a cost-effective manner. IHD facilitates the sharing of best practices on how to achieve this integration safely and effectively.

Economic and Environmental Sustainability: The pharmaceutical-industrial complex is a resource-intensive model. The reliance on imported drugs and diagnostics places a significant strain on the foreign exchange reserves of developing countries. Furthermore, the production and disposal of pharmaceuticals carry a substantial environmental footprint (Eickhoff *et al*., 2021). Integrative health offers pathways to greater sustainability. Promoting local cultivation of medicinal plants, for instance, can reduce import dependency, support local economies, and preserve biodiversity. Lifestyle-based interventions central to many T&CM systems are inherently more sustainable than lifelong medication for chronic diseases. IHD can foster trade and investment in sustainable health solutions, creating a virtuous cycle of economic and health benefits.

Integrative Health Diplomacy-Case Studies from the Global South

While the concept of IHD is new, its practice can be observed in the nascent diplomatic efforts of several key actors in the Global South.

India's AYUSH Diplomacy-Soft Power through Wellness: India has been explicit in using its traditional medical systems—Ayurveda, Yoga, Unani, Siddha, and Homoeopathy (AYUSH)—as a foreign policy tool (Ministry of AYUSH, 2020). Its approach is a prime example of emerging IHD. India has signed over 25 country-to-country MoUs on cooperation in traditional medicine and established AYUSH Information Cells abroad. In Africa, its diplomacy focuses on capacity building, while in ASEAN, the focus is on joint research and regulatory harmonisation (RIS, 2019). This strategy successfully combines cultural pride with health cooperation, though it faces challenges related to international standardisation and the need for more robust clinical research (Dutta, 2025).

China's TCM Diplomacy - A Component of the Belt and Road Initiative: China has accelerated the promotion of Traditional Chinese Medicine (TCM) abroad under the Belt and Road Initiative (BRI), creating a 'Health Silk Road' (Lee and Hirono, 2021). China has established dozens of TCM centres in BRI partner countries, often linking them to its broader economic projects. This approach is highly strategic and well-resourced, aiming to create new markets for its TCM industry. China's successful lobbying of the WHO to include a chapter on traditional medicine in its ICD-11 was a major diplomatic victory (Cyranoski, 2018), but the approach can be perceived as commercially assertive.

Brazil's 'Health in All Policies' and South-South Cooperation: Brazil offers a different model, focused on sharing its policy framework. In 2006, Brazil launched its National Policy on Integrative and Complementary Practices (PNPIC), formally integrating therapies like herbal medicine into its public health system (de Sousa, Tesser and de Sousa, 2018). Brazil has used its leadership in SSC to share its experiences in building a primary healthcare system that includes

integrative practices, primarily through technical exchanges and policy workshops. This model is arguably the most aligned with the core principles of SSC, as it is based on sharing policy learning rather than commercial or cultural projection, although it has been hampered by political instability.

Implications for South-South Cooperation and Health Sovereignty

The analysis presented in this paper argues that the evolution from conventional Health Diplomacy to a more inclusive Integrative Health Diplomacy (IHD) is not merely a semantic shift but a necessary strategic pivot for the nations of the Global South. This discussion interprets the key findings from our conceptual framework and case studies, contextualises them within broader debates on global health governance, and acknowledges the inherent challenges of this proposed paradigm shift.

Our primary finding is that a new model of health diplomacy is organically emerging from the Global South, even if it is not yet formally labelled as 'integrative'. The case studies of India, China, and Brazil reveal a clear strategic intent to leverage Traditional and Complementary Medicine (T&CM) as a tool of foreign policy. However, their approaches differ significantly, highlighting the multifaceted nature of IHD. India's AYUSH diplomacy is strongly rooted in a soft power and cultural wellness narrative. China's promotion of TCM is deeply embedded in a geo-economic strategy, closely tied to the Belt and Road Initiative. Brazil's model, by contrast, is primarily ideological, focused on sharing a policy framework for public health equity.

What unites these disparate approaches is a shared, implicit rejection of the post-colonial hierarchy in global health, which has historically privileged biomedicine and marginalised other knowledge systems. IHD, as we have conceptualised it, provides a lexicon to understand these emerging practices. It is a diplomacy of addition, not substitution. It seeks to add the rich therapeutic and philosophical assets of T&CM to the existing diplomatic toolkit, creating a more versatile and culturally resonant means of international engagement. This reframes health cooperation from a simple transfer of medical technology to a more profound exchange of health philosophies.

The implications of adopting an explicit IHD framework are significant. For South-South Cooperation (SSC), IHD offers a powerful, non-coercive platform for collaboration that is uniquely "of the South." Unlike negotiations over pharmaceuticals or high-tech medical equipment, where the Global North often holds a decisive advantage, T&CM is a domain where the Global South possesses immense indigenous capital and a competitive edge. By prioritising IHD, developing countries can foster collaboration on their own terms, strengthening regional alliances and building collective self-reliance in healthcare.

This directly contributes to the goal of health sovereignty. By validating and integrating their own medical traditions into foreign policy, nations assert the value of their cultural and scientific heritage on the world stage. This process challenges

the epistemic dominance of the biomedical model and empowers countries to build health systems that are less dependent on foreign aid and more reflective of local needs and resources (Khan, *et al*., 2021).

Advocating for IHD requires a clear-eyed view of its inherent challenges and potential pitfalls. The most pressing challenge is the tension between tradition and evidence. For IHD to be credible, it must be relentlessly evidence-informed. As highlighted in the policy recommendations, a massive investment in high-quality, collaborative research, our "Diplomatic Science," is non-negotiable. Without this, IHD risks being dismissed as medical nationalism or pseudoscience, undermining its diplomatic goals.

A second major tension exists between health as a public good and commercial interests. As the global wellness market expands, there is a risk that IHD could be co-opted, becoming less about building equitable health systems and more about opening markets for national T&CM industries. China's model, in particular, demonstrates this delicate balance. A successful IHD framework must therefore have strong ethical guardrails, including robust benefit-sharing protocols as outlined in the Nagoya Protocol, to ensure that cooperation genuinely serves public health and does not simply create new forms of dependency.

Finally, regulatory fragmentation remains a formidable operational barrier. The successful harmonisation of standards for T&CM products and practitioners, as envisioned in the recommendations for regional blocs, is a complex, long-term undertaking that will require sustained political will.

A Framework of Strategies for National and Multilateral Institutions

To transition from ad-hoc, often disconnected initiatives to a systematic and impactful practice of IHD, a multi-level strategic policy framework is required. Such a framework is essential because IHD operates at the complex intersection of domestic health policy, international trade, and foreign relations. Without coherent strategies at the national, regional, and global levels, efforts can become fragmented, contradictory, and ultimately fail to build the trust and mutual understanding necessary for success. This section outlines a series of actionable strategies for key institutions.

For National Governments in the Global South:

Develop Coherent and Truly Integrative National Policies: While many countries in the Global South have policies that recognise T&CM, this is not an assertion that none exist. Rather, the critical gap lies in the development of truly integrative policies. For instance, countries like India, with its National AYUSH Mission, and China, with its national-level support for TCM, have strong foundational policies promoting their traditional systems. However, these often run parallel to the conventional biomedical system rather than being fully integrated into a single, cohesive patient-care pathway. Many other nations have T&CM policies that are weak in implementation or lack legal force. The strategy, therefore, is to move beyond mere recognition towards creating a national health policy, where T&CM is a formal component of the public health infrastructure, particularly in primary care and for managing non-communicable diseases.

Establish Inter-Ministerial Coordination: The effective execution of IHD is impossible when left solely to a single ministry. Several countries have made progress in creating frameworks for such collaboration. A prime example is India, where the Ministry of Ayush works directly with the Ministry of External Affairs to establish Ayush chairs and information cells in foreign countries, and with the Ministry of Commerce and Industry to promote the export of traditional products. Similarly, China's promotion of TCM abroad is a coordinated effort between its National Health Commission, the Ministry of Foreign Affairs, and agencies linked to the Belt and Road Initiative. These examples serve as models for other nations to create formal working groups or task forces that align health, diplomatic, and trade objectives into a unified IHD strategy.

Invest in "Diplomatic Science": To build global credibility, investment in high-quality research is paramount (Dutta, 2025). This recommendation emphasises funding collaborative clinical research on T&CM with partner countries. The goal is to move beyond isolated national studies to international, multi-centre trials that can be published in high-impact journals. Such collaborations build a shared evidence base, foster trust, and serve as a powerful diplomatic tool. By co-authoring and co-funding research on health challenges of mutual concern, such as diabetes or mental health, partner countries can create a scientific dialogue that transcends political and cultural barriers, providing a neutral ground for building deeper relationships.

Strengthen National Implementation of Traditional Knowledge Protection: While significant international frameworks like the Nagoya Protocol on Access and Benefit-Sharing (Secretariat of the Convention on Biological Diversity, 2011) and the ongoing negotiations at the WIPO Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore (World Intellectual Property Organization, 2025) provide a foundation, this recommendation focuses on the urgent need for stronger national-level implementation and enforcement, as the existence of a treaty alone does not guarantee protection. A crucial domestic action is the creation of defensive protection mechanisms such as digital libraries of traditional knowledge. Emulating India's highly successful Traditional Knowledge Digital Library (TKDL), countries can create legally recognised, searchable databases of codified traditional knowledge that serve as prior art for international patent examiners, thereby proactively preventing the erroneous granting of patents on existing knowledge and combating biopiracy (CSIR, 2018). Furthermore, governments must move beyond ratifying treaties to legislating clear, transparent, and legally binding national Access and Benefit-Sharing (ABS) protocols. These protocols dictate precisely how benefits—both monetary and non-monetary—are to be shared with the indigenous and local communities who are the custodians of this knowledge, thereby operationalising the principles of the Nagoya Protocol at a domestic level (Oldham, 2017). By taking these concrete steps, nations demonstrate a robust commitment to ethical engagement, ensuring that international research collaborations are not extractive but are based on genuine, equitable partnerships, which is a fundamental prerequisite for building trust in any IHD initiative.

For Regional Blocs:

Regional blocs such as the African Union (AU) and the Association of Southeast Asian Nations (ASEAN) are critical force multipliers for operationalising Integrative Health Diplomacy. A key strategy is the harmonisation of regulatory standards for traditional medical products. The current fragmented landscape of national regulations acts as a significant non-tariff barrier to intra-regional trade and undermines consumer confidence. By working towards a common regional pharmacopoeia and shared standards for product registration and quality control, regional blocs can create a larger, more integrated, and safer market. The AU's effort to establish the African Medicines Agency (AMA) provides an excellent institutional model for this, creating a centralised body to oversee and standardise medical products, including traditional ones, across the continent (AU, 2019).

This regulatory harmonisation works in synergy with the second core strategy: the creation of Regional Centres of Excellence for integrative medicine. These centres would serve as collaborative hubs, pooling financial and human resources to conduct high-quality research and training focused on health challenges endemic to the region, such as diabetes or hypertension. They would foster a network of researchers and practitioners, accelerating innovation and the development of evidence-based clinical protocols (WHO, 2013). Together, these two strategies create a virtuous cycle: the Centres of Excellence would generate the credible, region-specific evidence needed to inform the standards set by the regional regulatory body, while a harmonised market would ensure that the safe and effective traditional medicines validated by this research can reach a wider population, thereby building collective self-reliance and positioning the region as a unified, influential actor in global health.

For International Organisations:

International organisations like the World Health Organization (WHO) and the UN Office for South-South Cooperation (UNOSSC) are indispensable for legitimising and scaling up Integrative Health Diplomacy. The WHO's Traditional Medicine Strategy 2014-2023 was a landmark achievement in setting global norms and encouraging member states to formulate national T&CM policies (WHO, 2013). The next logical step, however, is for the WHO to move from high-level goals towards developing specific, operational guidelines for clinical integration. For example, while the existing strategy supports T&CM, there is a clear gap in specific, evidence-based guidance for practitioners and health systems on how to integrate yoga protocols into primary care for managing hypertension, or how to safely co-administer specific herbal medicines with metformin for Type 2 diabetes. Developing such granular, condition-specific guidelines would provide national health authorities with the concrete tools needed to translate policy into safe and effective practice.

This normative work by the WHO is powerfully complemented by the facilitative role of UNOSSC. A major hurdle for many South-South initiatives is funding. UNOSSC can address this by actively facilitating "Triangular Cooperation" partnerships (UNOSSC, 2022). In this model, two or more Southern countries can design and lead an IHD project—such as a joint clinical trial based on new WHO guidelines—while a traditional donor country or a philanthropic foundation

provides the financial or technical resources. This innovative model preserves the core tenets of South-South cooperation, such as ownership and mutual partnership, while leveraging external resources to overcome financial constraints. Together, the WHO's normative guidance and UNOSSC's partnership facilitation can create a powerful ecosystem for mainstreaming IHD globally.

Conclusion

The global health architecture stands at a critical juncture. The old paradigms, rooted in a singular biomedical worldview and hierarchical North-South dynamics, are proving inadequate. The paradigm shift from Health Diplomacy to Integrative Health Diplomacy is therefore not merely a novel academic proposition; it is a pragmatic and ethical necessity.

This paper provides a conceptual framework for IHD, supported by illustrative case studies. As a policy-oriented analysis based on secondary sources, its primary limitation is its macro-level perspective. Future research is essential to test, refine, and deepen the IHD concept. Empirical studies, including in-depth interviews with diplomats and health officials, are needed to understand the on-the-ground realities and decision-making processes behind these initiatives. Furthermore, quantitative analyses of trade flows in T&CM products and services, as well as impact evaluations of specific IHD projects, would provide crucial data on the effectiveness and economic implications of this diplomatic approach. Investigating the perspectives of recipient countries would also be vital to ensure that IHD is perceived as a genuine partnership rather than a new form of cultural imposition.

By embracing IHD, the nations of the Global South can leverage their rich heritage of medical knowledge to build health systems that are more sustainable, equitable, accessible, and culturally attuned. Through strategic policy, investment in research, and a commitment to mutual learning, South-South Cooperation can become the engine of this transformation. Integrative Health Diplomacy offers more than a new set of tools for foreign policy; it offers a new vision for global health itself—one built not on aid but on solidarity, and not on a single truth, but on a shared commitment to wellness in all its diverse forms.

Conflict of Interests:

The author(s) have no conflicts of interest to declare. The views expressed in this article are those of the author(s) and do not reflect the official policy or position of their affiliated institutions, or the Government.

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AI and Data Driven Future: Digital Transformation of Traditional Medicine

Rajeshwari Singh* Geetha Krishnan G Pillai**

Rajeshwari Singh

Geetha Krishnan G Pillai

Abstract: Digital transformation is reshaping the Traditional Medicine landscape, offering new pathways to strengthen evidence generation, optimize service delivery, and enable systematic integration into national health systems. Data lies at the center of this transformation where data functions not as static repositories but as dynamic, interoperable inputs that power AI-driven analytics, digital diagnostics, personalized treatment algorithms, and real-time decision-making for both clinical and policy applications. This article critically examines the opportunities, challenges, and future trajectories of digital transformation in Traditional medicine, with a specific focus on the strategic role of data, digital health technologies, and Artificial Intelligence in shaping evidence-informed and sustainable health systems. The analysis highlights how AI and data-driven tools are reshaping the processes of knowledge generation, clinical validation, and implementation and the challenges of data fragmentation, interoperability, algorithmic bias, misappropriation of traditional knowledge.

Introduction

Traditional medicine (TM), deeply rooted in cultural heritage and community-centered practices, emphasizes holistic and individualized approaches to health and well-being (Chali *et al.*, 2021). With the growing global demand for personalized, evidence-based healthcare, integrating digital technologies into TM offers an unprecedented opportunity to preserve its relevance while enhancing accessibility, quality, and credibility (Muthappan *et. al.*, 2022; Zhang *et al.*, 2023). The past decade has witnessed a digital health revolution driven by

* Consultant, AI and Frontier Technologies, Data, Digital Health, Analytics and AI, Health Systems Division, World Health Organization

** Evidence Unit Head, World Health Organization Global Traditional Medicine Center (WHO-GTMC), Jamnagar, India

innovations such as artificial intelligence (AI), big data, the Internet of Things (IoT), telemedicine, mobile health, and electronic health records (EHRs). These advancements have reshaped healthcare delivery and governance worldwide (Hazra & Bora, 2025; Yeung *et al*., 2023).

Since, TM systems are contextually nuanced, TM based research and practice has historically faced significant challenges. Diagnosis and treatment in TM are based on multi-factorial reasoning which are often encoded in complex ontologies such as doshas in Ayurveda (Nayak, 2012) or pattern differentiation in Traditional Chinese Medicine (TCM) that integrate physiological, historical, cultural, and environmental dimensions (Chen *et al*., 2025; Long *et al*., 2019) Therapeutic interventions in TM are individually tailored and include poly herbal formulations with ingredients selected and modified according to patient-specific factors and local availability. Despite offering highly contextualized and adaptive care, these epistemologically diverse approaches are nonetheless challenging to investigate, validate, and scale using conventional biomedical research paradigms. (Veziari *et al*., 2021)

Digital technologies and especially AI now offer unprecedented means to unravel this complex web. For example, AI-powered data mining and pattern recognition can reveal latent connections among symptoms, constitutional types, and treatment modalities, allowing the construction of knowledge graphs that mirror practitioner reasoning. Machine learning can analyze large corpora of herbal prescription records to identify synergistic combinations, anticipate safety issues, and support efficacy assessments (Hou *et al*., 2025). These capabilities create an entirely new frontier for precision and evidence-based advancement in TM, opening pathways for both preservation and integration of ancient wisdom into contemporary health systems. Deep learning has been applied to pulse waveform analysis and traditionally interpreted through complex TM frameworks yielding objective, reproducible, and scalable diagnostics that can be compared across systems and populations.(E, 2022). Similarly, multi-omics data integration enables a molecular understanding of polyherbal formulations, translating centuries of practitioner experience into actionable biomedical insights. (Karalija *et al*., 2025). These capabilities create an entirely new frontier for precision and evidence-based advancement in TM, opening pathways for both preservation and propagation of ancient wisdom. However, the transition also brings challenges, including data standardization, privacy and governance concerns, and the risk of cultural erosion. (Ng *et al*., 2025; Liu *et al*., 2025).

This article aims to critically examine the opportunities, challenges, and future directions of digital transformation in TM, with a special focus on the role of data, digital health technologies, and AI in shaping evidence-informed sustainable health systems.

Current Landscape of TM Digitalization

The digitization of TM is gaining momentum, driven by the growing recognition of its potential to enhance healthcare delivery and evidence generation. (Ng *et al*., 2025) Digital health technologies, including AI are emerging as key enablers, offering opportunities to

strengthen research, clinical practice, and integration with modern health systems.

Yet the success of this transformation depends on addressing foundational challenges of data quality and interoperability, both of which are deeply tied to the epistemological complexity of these systems. Clinical records often combine narrative descriptions, practitioner reasoning, and context-specific variables, resulting in heterogeneous, non-standardized datasets that pose risks of semantic distortion when digitized. Interoperability similarly extends beyond technical harmonization to require conceptual alignment across pluralistic health models.The noteworthy progress in this area is the inclusion of TM chapter in ICD-11 as a landmark step in the global recognition of TM, offering visibility within international morbidity statistics and creating new opportunities for health systems integration (Singh & Rastogi, 2018). By standardizing syndrome patterns and linking them to morbidity codes, ICD-11 enables TM data to be reported in formats compatible with biomedical datasets, thereby strengthening surveillance, resource allocation, and policy planning. However, there is possibility of the categorical structure of ICD tends to compress complex, relational constructs such as dosha imbalances in Ayurveda or context-dependent syndromes in TCM into reductionist labels. This risks semantic loss, cultural distortion, and misinterpretation when applied outside their indigenous clinical contexts. (Singh & Rastogi, n.d.; Choi, 2020) To address these gaps, national initiatives such as India's NAMASTE portal have emerged, providing standardized terminologies and morbidity codes for Ayurveda, Siddha, and Unani. Unlike ICD, NAMASTE grounds its coding framework in indigenous epistemologies, thereby reducing heterogeneity in documentation while preserving conceptual integrity. Such efforts are essential prerequisites for achieving meaningful global integration of TM. With further expansion, increased practitioner awareness, and systematic adoption, platforms like NAMASTE could not only strengthen health information systems at the national level but also lay the groundwork for Ayurveda and related systems to be more fully represented in future revisions of ICD. (Thrigulla & Narayanam, 2023) Its integration of multilingual terms, electronic health record modules, and visualization dashboards provides a foundation for interoperability with global classification systems, including the ICD-11 TM modules, thereby embedding TM more firmly within broader health information ecosystems. (Muthappan *et al*., 2022)

Policy frameworks further underscore this transition. Reflecting this trend, the WHO Draft Traditional Medicine Strategy 2025–2034 identifies digital technologies including AI as key enablers for advancing research, service delivery, and evidence generation in traditional, complementary, and integrative medicine (TCIM).[1] Complementing this vision, initiatives such as the Global Initiative on AI for Health (GI-AI4H); a collaboration between International Telecommunication Unit (ITU), WHO, and World Intellectual Property Right (WIPO) and the WHO Global Traditional Medicine Centre (GTMC) aim to accelerate digital integration in TM ("Global Initiative on AI for Health," n.d.). The Gujarat Declaration (2023) further supports responsible AI use in TM. The WHO has significantly advanced integration of TM with digital technologies through standardisation and digitalisation

efforts, which include key initiatives like 2019 benchmark documents for Ayurveda and standardised terminologies for Ayurveda, Siddha, Unani, and Traditional Chinese Medicine (TCM) and the inclusion of TM morbidity codes in the International Classification of Diseases, 11th Revision (ICD-11). These efforts facilitate the inclusion of TM practices into electronic health records (EHRs) and global health data systems (Zhang *et al*., 2024; Srikanth, 2025). Furthermore, Member States' individual prerogatives to approach the International Organization for Standardization (ISO) for TM standards under ISO/TC 215 – Health informatics standardization, marks a significant step toward integrating digital health technologies with TM.

Several countries rich in TM traditions are embracing the digital transformation of TM, signalling both the opportunities and challenges. For instance, India has developed the Ayush Grid, a digital health platform aimed at unifying various TM systems, which promotes the digitalization of whole Ayush sector, enhancing the reach and accessibility TM (Kumar *et al*., 2025). China is advancing the integration of digital technologies into Traditional Chinese Medicine (TCM) as a part of its 14th Five-Year Plan(W.-Y. Wang *et al*., 2021). Similarly Japan, Korea, Brazil, new Zealand and other countries have noteworthy digital initiatives in TM. (Erlina *et al*., 2022) .

Digital Health Tools and their Applications in TM

Digital health tools and technologies are increasingly being leveraged in TM across various applications, from diagnosis and drug development to knowledge preservation and policy-making. Key digital health tools and their applications in TM include:

Digital Health Platforms and Data Infrastructure AI-enabled EHRs enhance data accuracy and streamline collection. Integration with handwriting recognition and Optical Character Recognition (OCR) accelerates data entry and converts unstructured text into analyzable formats (Ye *et al*., 2024a). In India, platforms like NAMASTE Portal and the Ayush Hospital Information Management System (AHMIS) support standardised data collection and morbidity reporting for Ayush systems (Srikanth, 2025), aligning with ICD-11 Traditional Medicine Modules.

Online Repositories and Digital Libraries: The Virtual Health Library on Traditional, Complementary, and Integrative Medicine (VHL TCIM) in the Americas leverages AI-driven backend processes to accelerate cataloguing and optimize term identification for TCIM resources (Gallego-Pérez *et al*., 2021). Several national projects demonstrate how digital tools are revolutionising TM. A notable advancement in Indian TM is Traditional Knowledge Digital Library (TKDL), which has digitized various traditional practices from Ayurveda, Siddha, Sowa Rigpa, and Yoga. This multilingual database helps preserve indigenous knowledge and protects it from biopiracy by providing crucial resources to patent offices worldwide (Finetti, 2011). The TCM Bank established by Sun Yat-sen University in China offers standardized information on TCM, their constituent ingredients, associated diseases, and corresponding gene targets, thereby facilitating data-driven approaches to modern drug discovery (Lv *et al*., 2023).

Mobile Applications: India has launched digital platforms and initiatives to promote digital literacy and integrate TM in modern health systems. These include online consultations and mobile app-reported use of T&CM such as AYUSH Sanjivani mobile app (Srikanth *et al*., 2021)) to promote digital literacy and integrate TM with modern health systems.

Internet of Things (IoT) devices: These devices can be integrated to facilitate real-time assessment of various parameters aligned with the fundamental principles of TM.

Specialized AI Tools and Languages- AI is increasingly integrated into TM through diverse applications aim to enhance clinical precision, research, and quality assurance. AI-based Clinical Decision Support Systems (CDSS) enable personalized interventions by recommending treatment plans derived from patient data and classical TM texts. Natural Language Processing (NLP) underpins these systems by extracting relevant knowledge, analyzing vast literature for research gaps, and summarizing emerging trends. When combined with geotagging and ethnic language processing NLP further promotes equitable TM utilization and safeguards against biopiracy (Ng *et al*., 2025). Advanced computational frameworks such as Context-Oriented Directed Associations (CODA), developed in the Republic of Korea, model complex biological interactions to assess drug effects in TM (Kwon *et al*., 2019). AI-powered virtual health assistants and chatbots provide real-time patient–provider interaction, facilitating feedback and dynamic treatment adjustments (Aggarwal *et al*., 2023). Innovations such as AI-driven electronic tongues and noses contribute to herbal standardization by delivering objective, reproducible sensory analyses of taste and quality attributes. These analyses include precise identification of fundamental taste profiles through chemical markers (Liu *et al*., 2023; Feng *et al*., 2021).

Governance and Standardization Tools- Robust data governance frameworks and international standards are emerging as critical enablers of digital health integration in traditional medicine. Countries like New Zealand and Canada have adopted tailored governance models that address privacy, storage, processing, utilization, and identification of health data. These models prioritise safeguarding the rights of Indigenous Peoples and local communities with notable examples including the Māori Data Governance Model which emphasises self-determination in managing Māori data across public service agencies (Malliga and Balamayuranathan, 2025). International Organization or Standards (ISO) is developing global standards for TM through ISO/TC 215 on health informatics. These standards include Ayurveda informatics (ISO/DTR 4421:2023) (Dua *et al*., 2023) and TCM decision support, which advance interoperability and the responsible integration of AI-driven digital health technologies (Shuting *et al*., 2022). Member States have the individual prerogatives to approach the ISO for TM standards under ISO/TC 215 – Health informatics standardization, marks a significant step toward integrating digital health technologies with TM.

Importance of Data in TM Digital Transformation

Data serves as a crucial foundation for the digital transformation in TM ecosystem

underpinning advances in diagnostics, drug discovery, knowledge preservation, and health-system management. In a digitally enabled ecosystem, data functions not merely as static records but as dynamic inputs driving AI-powered analytics, personalized treatment algorithms, and real-time decision support.

Data acts as the foundation for digital transformation in TM ecosystem in the following ways :

Data Collection and Generation: The digital transformation of TM depends fundamentally on the systematic collection, generation, and integration of diverse datasets. These datasets serve as the foundation for various digital and AI applications. AI in TM leverages multidimensional data sources, including EHRs, medical imaging, historical TM manuscripts, pharmacopoeias, scientific literature, and patient-generated health data. This digitization process converts unstructured and analog data such as handwritten notes and classical scripts into structured, machine-readable formats through Optical Character Recognition (OCR) and handwriting recognition technologies. This enables interoperability across platforms (AlKendi *et al*., 2024). Traditional diagnostic parameters such as pulse waveforms, tongue morphology, urine characteristics, speech patterns, tactile assessments, and energetic profiles in acupuncture and Ayurveda (Mukerji, 2023) are increasingly quantified through AI algorithms, including deep convolutional neural networks (CNNs) and machine vision systems. This enables objective, reproducible, and scalable diagnostics (Lu *et al*., 2024).The genomic, metabolomic, and phytochemical datasets are being integrated into TM frameworks to identify predictive disease markers and elucidate the molecular mechanisms underlying herbal formulations (Mukerji, 2023; Luo *et al*., 2024). These multi-omics datasets, combined with AI-powered analytics, bridge traditional theories with modern biomedical evidence, laying the foundation for personalized TM interventions. Real-time data streams from Internet of Things (IoT) devices such as wearable sensors for pulse analysis or smart cameras for tongue imaging further enrich this ecosystem, enabling continuous health monitoring and remote patient management. Advanced computer vision algorithms enable AI-assisted species identification from plant images, supporting pharmacognosy and quality assurance in herbal medicine supply chains (Azadnia *et al*., 2022). In healthcare, AI-enabled EHR systems play a pivotal role in structured data collection and interoperability. These systems use standardized terminologies like SNOMED CT and ICD codes to capture diagnostic and therapeutic information (Ye *et al*., 2024b). This digital infrastructure ensures high-quality, shareable data that supports large-scale analytics, evidence synthesis, and global integration of TM practices into modern healthcare systems.

Data Analysis and Insight Generation: AI revolutionises TM by harnessing advanced computational techniques across multiple domains. Pattern recognition methods such as frequency analysis, correlation mapping, complex network modeling, and clustering, enable the uncovering of drug usage trends from extensive TM literature. This information aids in novel drug discovery and formulation analysis. ML algorithms further explore associations between constitutional types and genetic factors (Lu *et al*., 2024; Mukerji,

2023). AI-driven analysis of large-scale medical records, supported by reverse pharmacology approaches and high-performance computing for docking and simulation studies, contributes to evidence-based drug development. These studies elucidate drug action mechanisms, particularly for polyherbal formulations. Ontological analysis and NLP enable AI to process vast repositories of literature and patient-generated data, expanding the knowledge base, identifying research gaps. Semantic frameworks are established for integrating diverse TM practices. Predictive analytics enhances personalized care by modeling patient histories to forecast therapeutic outcomes and risks. CDSS powered by AI recommend personalized treatment plans. AI-driven data augmentation addresses data scarcity by generating synthetic datasets for hypothesis testing and facilitates cross-disciplinary learning, applying methodologies from other scientific domains to strengthen TM research and innovation (Sultan *et al*., 2023).

Knowledge Preservation and Biopiracy Prevention: Digital technologies play a critical role in preserving and promoting TM knowledge. Online repositories and digital libraries host scientific, technical, and educational resources enabling systematic documentation and structured access to TM based data (Malliga & Balamayuranathan, 2025; Srikanth, 2025; Gallego-Pérez *et al*., 2021). This facilitates long term preservation and global dissemination of TM knowledge. Beyond static knowledge storage, AI and ML significantly enhance conservation efforts. Remote sensing and satellite imagery are used to monitor vegetation dynamics and habitat degradation, contributing to the sustainable management of medicinal plant resource (Sur *et al*., 2024). AI-driven NLP systems support the digitization and translation of oral traditions and under-documented TM practices, converting indigenous knowledge into structured, accessible formats suitable for integration into research, policy, and innovation frameworks. Initiatives such as TKDL demonstrate how AI and digital tools can prevent biopiracy while ensuring equitable benefit sharing and protecting intellectual heritage.(Finetti, 2011)

Data Governance and Ethical Considerations - Customized data governance models are essential for managing the privacy, security, and ethical use of health data pertaining to Indigenous Peoples and local communities. These models prioritize collective stewardship, compliance with legal and cultural norms, and strict adherence to principles such as Free, Prior, and Informed Consent to safeguard community autonomy and rights (Griffiths *et al*., 2021). Ethical documentation practices further reinforce these principles by ensuring prior informed consent, equitable access to knowledge, and fair benefit-sharing mechanisms to prevent misappropriation and biopiracy of TM resources. (Griffiths *et al*., 2021) (Finetti, 2011). These approaches align with global frameworks on Indigenous Data Sovereignty, emphasizing the CARE Principles (Collective Benefit, Authority to Control, Responsibility, Ethics) to balance innovation with equity (Carroll *et al*., 2020). International initiatives led by WHO and ISO toward standardization are crucial for ensuring interoperability and preserving data integrity. These efforts include the development of harmonized terminologies and ontologies, which underpin the safe, ethical, and effective integration of digital technologies within TM ecosystems.

Challenges and Risks in Digitizing Traditional Medicine

The digital transformation of TM particularly through AI and digital technologies, presents multiple challenges and risks that demand careful consideration for responsible integration.

Knowledge Representation and Loss of Context - TM systems encode meaning through nuanced, context-rich concepts such as syndrome patterns, dosha states. Forcing these into rigid data models can distort intent and clinical semantics. Even with emerging ontologies, mapping heterogeneous vocabularies and preserving relational nuance remains difficult, risking decontextualization of knowledge. This reductionism not only threatens the epistemological integrity of TM but also risks misinterpretation when applied outside its cultural and clinical context, highlighting the need for digital tools that can accommodate pluralistic knowledge systems rather than forcing homogenization. (Chen *et al*., 2007)(Long *et al*., 2019).

Data standardization and interoperability gaps - Digitization efforts often struggle with inconsistent terminology, uneven coding practices, and fragmented databases, which hinder cross-study synthesis and machine readability. Ayurveda/Siddha/Unani morbidity coding (NAMASTE) is progressing, but variability in adoption and granularity still limits interoperability and secondary use (Thrigulla and Narayanam, 2023).

Data quality, authenticity, and reproducibility - Ethnopharmacology databases frequently suffer from incomplete, outdated, or heterogeneous entries. Misidentified species, inconsistent preparation details, and limited metadata undermine evidence synthesis and computational analyses. Calls to improve curation and methodological rigor are longstanding (Lim *et al*., 2024).

Product integrity and safety risks amplified online - Digital catalogues and e-commerce can scale access to products with adulteration, contamination, or mislabeling. DNA-based audits have revealed safety and legality concerns in some traditional formulations; methodological best practices and confirmatory analytics are essential (Coghlan *et al*., 2012).

Misinformation and misinterpretation by end-users - Open access to digitized content such as databases, applications and social media can enable self-diagnosis, unsafe self-medication, and delay of effective care when information quality is poor or context is missing. Evaluations of herb-related web information show persistent quality deficits and safety omissions, underscoring the need for provenance, plain-language risk flags, and clinician mediation. (Molassiotis and Xu, 2004).

Intellectual property (IP), biocultural rights, and inequity - While initiatives like TKDL aim to pre-empt biopiracy, scholars highlight tensions around consent, benefit-sharing, and potential dispossession when knowledge is catalogued for external regimes such as patent systems. Ethical governance and community-controlled access are critical (Finetti, 2011)

Privacy, security, and trust in clinical digitization - EHRs and registries for TM must meet modern privacy and security expectations. Practitioner surveys in Ayurveda indicate concerns about confidentiality and reliability of health IT, reflecting the need for robust safeguards, auditability, and clear consent workflows tailored to TM contexts (Sinha and Shetty, 2015).

The robust, standardised, and ethically governed data ecosystems are the foundation upon which AI-enabled TM systems can be built, validated, and sustainably integrated into global health frameworks. This ensures equity, safety, and cultural respect.

Future Directions and Policy Implications

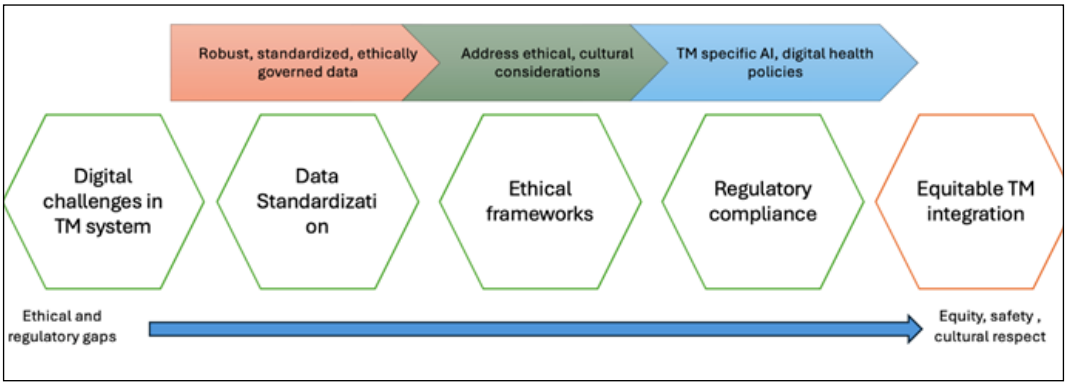
The future of digitizing TM through broader digital health innovations requires a comprehensive, culturally sensitive, and ethically grounded approach. It is essential to integrate frontier technologies without compromising the authenticity of traditional knowledge, while ensuring equity, safety, and sustainability. This vision demands coordinated action across policy, infrastructure, governance, and capacity-building domains as reflected in figure -1.

The following are suggested for harnessing digitisation and AI.

Advancing Regulatory and Policy Frameworks - Developing tailored regulatory frameworks is a priority to ensure responsible integration of AI and digital health in TM. WHO's guidance on AI and frontier technologies should be adapted to reflect unique cultural and clinical dimensions of TM. Member States must update TM surveys to include digitalization and establish mechanisms such as toolkits and capacity-building programs to translate global recommendations into national policies. Early-stage AI legislation offers an opportunity to embed TM considerations, safeguarding intellectual property and traditional knowledge while ensuring compliance with ethical principles such as privacy and informed consent.

Establishing Benchmarking and Quality Assurance Mechanisms - Standardized benchmarking frameworks must be developed to evaluate AI systems in TM, covering technical performance, safety, and cultural relevance. These frameworks should incorporate ethical and regulatory compliance metrics and prioritize interpretability and explainability to build practitioner trust. Addressing data disparities and improving the quality and diversity of TM datasets is crucial to ensure fairness and reduce algorithmic bias.

Figure 1: Responsible Digitization of Traditional Medicine



Source: Authors' Compilation.

Protecting Traditional Knowledge and Ensuring Data Governance - Robust data governance models must be co-created with Indigenous Peoples and local communities to prevent biopiracy, ensure equitable benefit-sharing, and uphold community data sovereignty. Engagement with global initiatives, such as WIPO's frameworks and the WHO Global Traditional Medicine Centre can facilitate protective measures. Examples like TKDL demonstrate how digital repositories can both preserve and safeguard knowledge while deterring unauthorized commercialization. Future strategies should include mandatory patent disclosure requirements for inventions based on traditional knowledge and genetic resources.

Strengthening Digital Infrastructure and Building Capacity - Digital transformation in TM cannot progress without addressing infrastructure and capacity gaps. Investments in reliable internet connectivity, electricity, and health information systems are essential, especially in rural and underserved regions where TM is widely practised. Capacity-building efforts should include digital literacy programs for TM practitioners, policymakers, and developers, along with institutional readiness assessments to evaluate technological preparedness. Addressing workforce shortagesin TM and promoting cross-training in AI and digital health are equally important for sustainable adoption.

Promoting Engagement and Multistakeholder Collaboration - Inclusive, participatory design approaches are necessary to ensure AI solutions align with the cultural values and practical realities of TM. Communities of Practice (CoPs) can serve as platforms for knowledge exchange, legal design discussions, and technical collaboration. Global cooperation to harmonize TM lexicons, develop interoperable data standards, and share best practices will be critical for scaling solutions across borders.

Fostering Public Awareness - Awareness campaigns should communicate the benefits and risks of AI in TM, dispelling misconceptions and promoting informed adoption.

Promoting Equity - Equity-driven policies must address affordability, linguistic diversity, and cultural appropriateness. Targeted strategies to bridge the digital divide especially among Indigenous and rural communities will be vital to prevent exclusion and underrepresentation in AI training data.

Designing Context - Specific, Human-Centered AI Solutions-Future AI applications in TM should adopt hybrid models that balance global interoperability with local adaptability. Human-centred innovation processes, involving TM practitioners, patients, and communities throughout the AI lifecycle from data collection and modelling to validation and deployment are essential.

The digital transformation of TM presents a historic opportunity to harmonise ancient wisdom with frontier technologies. By leveraging data, digital health tools, and AI, TM can evolve into a more evidence-based, personalised, and accessible component of integrated health systems. However, realising this potential requires a holistic approach grounded in regulatory foresight, ethical governance,

robust digital infrastructure, cultural sensitivity, and inclusive innovation. Safeguarding traditional medicine and traditional knowledge, ensuring data protection, and addressing workforce and infrastructure gaps are critical to building trust and sustainability. Global collaboration, interoperable standards, and capacity-building initiatives must underpin these efforts to prevent inequities and protect cultural heritage. When implemented responsibly, digital innovation can position TM as a vital pillar of future health systems, bridging tradition and technology to promote well-being for all in the digital era.

Endnotes

[1] draft-traditional-medicine-strategy-2025-2034.pdf?sfvrsn=dd350962_1, n.d..

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From Tradition to Global Standards: Governance, Regulatory Challenges and Strategic Reforms in Ayush Drug Regulation

Raman Kaushik* and Pragya Sharma**

Raman Kaushik

Pragya Sharma

Abstract: Ayush systems represent one of the oldest codified traditions of medicine, providing holistic approaches to health and wellness. Today, the relevance of these systems is growing, both domestically and globally, as demand for integrative and herbal healthcare increases. However, the credibility, sustainability, and international acceptance of Ayush drugs depend on establishing a regulatory framework that harmonizes traditional wisdom with modern scientific standards. Despite several policy initiatives challenges persist. Domestically, variability in raw material quality due to unsustainable harvesting and climate change undermines reliability. The sector is dominated by MSMEs that face constraints in meeting international GMP standards, advanced quality testing, and regulatory compliance. Fragmentation of regulatory enforcement across states, uneven laboratory infrastructure, and limited large-scale clinical validation further restrict global competitiveness. Internationally, Ayush products face barriers in market access due to divergent pharmacopoeial standards, limited harmonized dossiers, randomized controlled trials and toxicological studies. In addition, issues of supply chain traceability, consumer trust, and unethical marketing practices affect both domestic and international credibility. This article explores the governance and regulatory challenges of Ayush drug regulation in India while suggesting strategic reforms that could help align the sector with global benchmarks and strengthen its international credibility. By integrating traditional heritage with evidence-based practices, Ayush drug regulation in India can achieve a balance between cultural authenticity and scientific rigor.

*OSD (Technical) to Secretary, Ministry of Ayush. Email- drraman47@gmail.com

**Associate Professor, Department of Samhita & Siddhant, GS Ayurveda College & Hospital, Uttar Pradesh. Email – dr.pragya03@gmail.com

Introduction

Ayurveda and other Ayush systems of medicine represent a vast repository of traditional therapeutic knowledge, deeply rooted in cultural practices and codified textual traditions. For centuries, these systems have provided holistic approaches to health, disease prevention, and wellness that continue to play a vital role in India's healthcare landscape. In recent decades, Ayush has not only retained its domestic relevance but has also gained visibility on the global stage, particularly as interest in integrative medicine and natural products grow.

Recognizing this potential, the World Health Organization's Traditional Medicine Strategy 2014–2023 underscored the necessity of strengthening evidence-based approaches to ensure the safety, quality, and efficacy of traditional medicines. This global shift has put increasing pressure on national governments to create robust regulatory ecosystems that can support international trade, scientific credibility, and patient safety. In India, the regulation of Ayush drugs is regulated by the Drugs and Cosmetics Act of 1940[1] and the Drugs Rules, 1945[2] providing a robust regulatory framework for ensuring quality and safety. However, to strengthen international credibility and facilitate wider global acceptance, strategic reforms may be required to align this framework with evolving global standards of evidence, safety, and efficacy.

By addressing existing regulatory asymmetries and building upon the significant reforms already undertaken at both the central and state levels, regulatory frameworks for Ayush systems can strengthen domestic confidence and enhance their prospects for integration into the international healthcare landscape. Sustained progress requires not only the consolidation of these reforms but also a judicious balance between safeguarding traditional heritage and adhering to modern scientific benchmarks. Such an approach is essential to ensure that Ayush systems contribute meaningfully to global health discourse while preserving their cultural identity and authenticity.

This paper analyses the governance and regulatory framework of Ayush drug regulation, reviews reforms at central and state levels, and identifies strategic measures to address regulatory asymmetries and align traditional medicine with global standards for wider international acceptance.

Current Policy and Regulatory Framework for Ayush Drugs

The regulation of Ayush drugs in India is primarily governed by the Drugs and Cosmetics Act, 1940, which was amended in 1964 to include specific provisions for Ayurveda, Siddha, and Unani (ASU) drugs. The regulatory framework, further includes the Drugs Rules, 1945 with specific sections addressing licensing, quality control, drug testing laboratories, good manufacturing practices (GMP), and labelling standards for ASU drugs (Kaushik *et. al.*, 2025). Several amendments to the Act and the rules framed thereunder have been enacted from time to time to strengthen the regulatory mechanism, addressing emerging challenges related to quality control, licensing, good manufacturing practices, labelling, and export facilitation. Sowa-Rigpa drugs

have recently been incorporated into the regulatory framework under the Drugs and Cosmetics Act, 1940, along with the corresponding rules, thereby bringing these traditional medicines under formal regulatory oversight. The enforcement of quality control and licensing of Ayush drugs/ medicines is delegated to State Drug Controllers and State Licensing Authorities. Licensing is contingent upon adherence to prescribed manufacturing standards, proof of safety and efficacy, and compliance with Good Manufacturing Practices (GMP) as detailed in Schedule T of the Drugs Rules, 1945.

Pharmacopoeia Commission for Indian Medicine and Homoeopathy (PCIM&H) develops pharmacopoeial standards and formulary specifications for Ayurveda, Siddha, Unani, and Homoeopathy drugs/ medicines. It also functions as the central drug testing and appellate laboratory for these systems, ensuring rigorous quality control, safety, and efficacy assessments. Additionally, it plays a vital role in capacity building by conducting training programs for regulatory professionals and stakeholders, promoting compliance with Good Manufacturing Practices (GMP).

International Expansion and Market Integration of Ayush Products

The global outreach of Ayush products has seen substantial growth, with India exporting to over 150 countries worldwide (MoA, 2024). Research and Information System for Developing Countries (RIS) estimates that the Ayush manufacturing industry expanded from approximately USD 2.85 billion in 2014-15 to an estimated USD 18.1 billion by 2020, with the service sector similarly exhibiting rapid expansion, signifying a sixfold increase in less than a decade (RIS, 2021). According to Exim Bank Research based on DGCI&S data, India's exports of Ayush and herbal products have grown significantly, increasing from Rs. 3,997.1 crore (USD 539.9 million) in 2020–21 to Rs. 5,831.4 crore (USD 689.3 million) in 2024–25.[3] This represents a healthy compound annual growth rate (CAGR) of 9.9 per cent, highlighting the rising global demand and expanding export opportunities for the sector.[4] This growth is supported by government initiatives such as the Central Sector Scheme for Promotion of International Cooperation in Ayush and the establishment of the AYUSH Export Promotion Council (AYUSHEXCIL), which facilitate market access and address trade barriers.

As a flagship initiative, Ministry of Ayush is implementing Ayush Oushadhi Gunvatta evam Uttpadan Samvardhan Yojana (AOGUSY),[5] a central sector scheme designed to enhance the quality, safety, and efficacy of Ayush drugs through adherence to international standards. The scheme focuses on upgrading and modernizing Ayush pharmacies and drug testing laboratories across India to align with global benchmarks. Key components include capacity building, adoption of Good Manufacturing Practices (GMP) consonant with WHO guidelines, pharmacovigilance, and strengthening regulatory frameworks at central and state levels, collaboration with scientific institutions like the Bureau of Indian Standards (BIS) and Quality Council of India (QCI) for the development of accreditation and certification processes.

Domestic and Global Challenge for Ayush Products

Domestic Challenges

Raw Material Supply and Sustainability

Overharvesting, habitat loss, and seasonal or geographical variability directly impact herbal products by disrupting the steady supply of medicinal plants, leading to scarcity and forcing reliance on inferior or substituted raw materials. Such unsustainable collection practices, especially the destructive harvesting of roots, barks, and whole plants, not only threaten species survival and genetic diversity but also compromise the quality of raw drugs by reducing the levels of key phytochemicals. Seasonal and climatic changes further alter phytochemical profiles, resulting in batch-to-batch inconsistency that affects the safety, efficacy, and reliability of formulations. Climate change exacerbates this by shifting growth patterns and biosynthetic pathways, making it harder to standardize products in line with global regulatory expectations. Consequently, without adopting conservation strategies such as cultivation, community-based management, seed banking, harvest quotas, and Good Agricultural and Collection Practices (GACP), the long-term sustainability, therapeutic value, and international credibility of herbal products remain at risk (Nishteswar, 2014).

Quality Assurance and Standardization:

In the year 2022, 8705 Ayush drug manufacturing units in India have been reported.[6] However, despite the presence of these certified units, challenges persist in achieving consistent quality across the sector. Variability in manufacturing practices, including differences in extraction methods, processing techniques, and formulation protocols, combined with uneven adherence to Good Manufacturing Practices (GMP), results in significant inconsistencies in the quality, potency, and stability of Ayush products. Such inconsistencies can compromise therapeutic outcomes, reduce efficacy and raise safety concerns due to contamination, adulteration or improper storage. To mitigate these issues, harmonization of pharmacopeial standards, adoption of validated analytical and quality control methods such as HPLC, TLC and strengthening of laboratory infrastructure are essential. Government-supported initiatives like the Ayush Observational and Governance for Upgradation of Standards and Yojana (AOGUSY) play an important role in standardizing manufacturing processes, enabling rigorous quality testing and improving reproducibility of formulations, thereby ensuring that Ayush products consistently meet safety, efficacy, and global regulatory requirements.

Regulatory Compliance and Fragmentation

Although the regulatory framework for Ayush drugs is well established under the Drugs and Cosmetics Act, 1940 and Rules 1945, its implementation remains uneven across states due to variations in capacity, resources, and interpretation of guidelines. This regulatory fragmentation results in varying inspections, licensing, and pharmacovigilance, creating uncertainty for manufacturers and affecting product quality oversight. Therefore, establishing uniform protocols and strengthening coordination mechanisms is essential to

ensure consistent compliance across the country.

Infrastructure and Capacity Building

A significant number of Ayush manufacturing units and drug testing laboratories still lack high-end modern analytical facilities like High-Performance Liquid Chromatography (HPLC), Gas Chromatography-Mass Spectrometry (GC-MS) and this limit the ability to accurately assess phytochemical profiles, detect contaminants, and ensure batch-to-batch consistency, which are critical for validating the safety, efficacy, and reproducibility of complex polyherbal formulations. Without such infrastructure, it becomes difficult to meet stringent regulatory requirements set by global markets, thereby restricting the international acceptability of Ayush products. Addressing this gap requires a multipronged approach that includes modernization of public and private sector laboratories, establishing common facility centers to support MSMEs, and promoting capacity building through continuous skill-development training, hands-on workshops, and technology transfer programs. Such initiatives would not only strengthen quality assurance frameworks but also empower the Ayush industry to scale up production, comply with international pharmacopoeial standards, and build consumer trust both in domestic and export markets.

Majority of Ayush Manufacturers are Micro, Small, and Medium Enterprises (MSMEs)

Ayush sector is dominated by MSMEs, often lack the financial and technical resources to fully comply with GMP, regulatory requirements and advanced quality testing protocols. High costs associated with quality certification, regulatory filings disproportionately burden smaller firms, leading to compliance gaps and reduced competitiveness in export markets. Targeted policy support, common testing facilities, and simplified compliance mechanisms are needed to strengthen MSMEs.

Research and Development

Despite centuries of experiential use, many Ayush formulations lack rigorous clinical validation by modern scientific standards. The absence of large-scale randomized controlled trials, validated biomarkers, and harmonized documentation restricts global acceptance. Scientific validation through integrative clinical research, pharmacological studies, and collaboration with international institutions is necessary to bridge the evidence gap and build credibility. Stronger R&D investment and translational research can expand the therapeutic reach of Ayush systems.

Market and Business Dynamics

While domestic demand for Ayush products continues to grow, global expansion faces challenges related to intellectual property (IP) protection, innovation in formulation development, and branding strategies. Traditional formulations often do not qualify for patents, leading to weak IP protection. Moreover, marketing strategies and export logistics for Ayush products remain underdeveloped compared to nutraceutical and pharmaceutical sectors. Strengthening IP frameworks, promoting innovation in novel dosage forms and adopting aggressive export and branding strategies are critical for positioning India as a global hub for traditional medicine

Global Challenges

Alignment with International Standards and Regulations

Ayush products face significant hurdles in aligning with international pharmacopoeial standards and regulatory compliance norms. Global markets demand stringent quality assurance, validated analytical methods, and harmonized labeling practices, while many traditional formulations fall outside the scope of existing pharmacopoeias. Bridging this gap requires systematic standardization, scientific validation, and adherence to Codex/WHO guidelines to make Ayush products internationally acceptable.

Regulatory Barriers and Market Access

Gaining approvals in diverse regulatory regimes, particularly in firmly regulated markets, remains a challenge due to the lack of harmonized data, uniform dossiers, and safety documentation. Variations in requirements for toxicology studies, stability data, and clinical trial evidence limit the entry of Ayush products into these high-value markets. Developing a globally acceptable regulatory framework and common technical documentation will help improve market access.

Scientific Evidence and Validation

Global consumer confidence in Ayush products is fundamentally dependent on the availability of robust scientific evidence. Although centuries of traditional knowledge provide strong empirical credibility and considerable efforts have already been made by both government bodies and private institutions to generate supporting evidence-based data, international acceptance demands higher levels of scientific rigor. Regulatory authorities and consumers in global markets increasingly look for well-designed randomized controlled trials, pharmacokinetic and toxicological studies, and long-term post-market surveillance to establish both safety and efficacy. Strengthening collaborative research with reputed international universities, research consortia, and regulatory bodies, along with publishing findings in high-end peer-reviewed journals, will not only enhance the credibility of Ayush formulations but also facilitate their entry into regulated markets and broaden their acceptance as evidence-based healthcare solutions worldwide.

Supply Chain Traceability and Quality Control

Ensuring authenticity of raw materials and preventing adulteration or contamination during procurement, processing, and export are critical for safeguarding product quality. Modern traceability tools such as blockchain-enabled supply chain tracking, and Good Agricultural and Collection Practices (GACP) can help to ensure quality consistency. Stronger quality control mechanisms reduce the risk of spurious products entering the global market, thereby protecting both consumer safety and India's reputation as a supplier.

Global Marketing, Awareness, and Branding

Ayush products, despite a strong domestic market, remain underrepresented globally due to limited branding, inadequate dissemination of scientific evidence. An aggressive global marketing strategy, driven by authoritative scientific communication, effective participation in international expos and strategic collaborations with wellness and healthcare

industries, is essential to increase visibility. Establishing clear, credible, and distinctive brand identities such as "Evidence-Backed Ayush," "Safe and Standardized Ayush," and "India's Wellness Science" will strengthen consumer trust, enhance competitiveness, and firmly position Ayush products as reliable, science-based healthcare and wellness solutions in international markets.

Strategic Reforms Pathways for Global Reach of Ayush Product

Regulatory Strengthening

A unified regulatory structure is essential to overcome the current fragmentation in the Ayush sector caused by variations in state-level licensing procedures and regulatory interpretations. At present, manufacturers face inconsistent requirements across states, which not only leads to delays in obtaining approvals but also increases compliance costs and creates uncertainty in production and trade. Establishing a centralized, harmonized framework would ensure that Good Manufacturing Practices (GMP), quality testing, and safety standards are uniformly applied across the country. This would streamline regulatory processes, reduce duplication of efforts, and build confidence among both domestic and international stakeholders. Ayush vertical within the Central Drugs Standard Control Organization (CDSCO) can play a pivotal role in ensuring uniform enforcement of regulatory provisions across states, thereby eliminating inconsistencies in licensing and compliance. By serving as a central authority, it can oversee quality assurance mechanisms, and strengthen regulatory monitoring, ensuring that Ayush products consistently meet required safety and efficacy benchmarks.

Quality Assurance

Expanding pharmacopoeial coverage to encompass the entire spectrum of Ayush formulations is a vital step toward setting uniform quality benchmarks. At present, only a fraction of classical and proprietary formulations are officially documented, leaving significant gaps that contribute to inconsistencies in safety, efficacy, and reproducibility. By systematically integrating more formulations into Ayush pharmacopoeias, comprehensive reference standards for identity, purity, strength, and dosage can be established, which will serve as a common guide for both manufacturers and regulators.

Regular batch-wise quality testing further ensures that every product released into the market aligns with these standards. Modern analytical tools such as HPLC, GC-MS and stability chambers provide precise validation of raw materials and finished products. Digital traceability mechanisms, including blockchain-enabled supply chain systems, can also be deployed to create end-to-end transparency from raw material sourcing to distribution. This not only minimizes risks of adulteration, contamination, or substitution but also strengthens consumer confidence.

Evidence-Based Validation

The global acceptance and credibility of Ayush medicines hinge on their rigorous scientific validation through clinical research. While traditional usage provides empirical support, international health systems and regulatory bodies increasingly demand robust evidence from randomized

controlled trials (RCTs), pharmacokinetic studies etc. to establish both safety and efficacy.

Institutionalizing multi-centric, randomized clinical trials across diverse populations and healthcare settings is essential to generate high-quality data that meet global pharmacological and evidence-based medicine standards. For instance, Central Council for Research in Ayurvedic Sciences under Ministry of Ayush and Indian Council of Medical Research (ICMR) has undertaken multicentric trials, such as the study on the efficacy and safety of Punarnavadi Mandura alone and in combination with Drakshavaleha compared to iron folic acid in treating moderate iron deficiency anaemia among non-pregnant women of reproductive age (PIB, 2024).

Strategic collaborations between Ayush and other scientific agencies, such as the AYUSH-ICMR initiative for integrative clinical trials and AYUSH-CSIR partnerships for drug discovery, standardization, and phytochemical analysis, have demonstrated the potential for generating credible evidence. Scaling up such initiatives with dedicated funding, training, and infrastructure is vital for methodological rigor and enhanced international visibility.

Expanding global collaborations with leading universities, international research councils, and regulatory authorities, can facilitate cross-cultural validation of Ayush drugs. These partnerships will not only strengthen consensus on safety and therapeutic value but also position Ayush formulations within international pharmacopoeias and health policy frameworks. Ultimately, this evidence-based integration will accelerate the acceptance of Ayush in global healthcare systems and enhance India's role in advancing traditional medicine as a scientifically validated, complementary component of global health.

Industry Support and Global Alignment

Ayush industry is predominantly driven by micro, small, and medium-sized enterprises (MSMEs), which form the backbone of production, distribution, and innovation in the sector. While Schedule T of the Drugs and Cosmetics Rules, 1945, provides extensive provisions for Good Manufacturing Practices (GMP) that must be complied with by manufacturers of Ayurveda, Siddha, Unani, and Sowa-Rigpa drugs, these regulations primarily address domestic standards. To achieve global credibility and acceptance, there is an urgent need to revise and upgrade these GMP provisions to align with internationally recognized quality benchmarks, such as WHO-GMP standards.

Targeted incentives for MSMEs, including financial support, technical assistance, and training programs, are important to facilitate compliance with upgraded GMP norms. Such support will not only help standardize production processes and documentation but also enhance quality assurance, reproducibility, and safety of Ayush products. Aligning GMP protocols with global standards will improve export readiness, reduce regulatory barriers in key international markets, and enhance trust among consumers and regulators alike.

Moreover, integrating GMP compliance with strategic trade diplomacy can

accelerate market penetration in regulated economies. Participation in international trade fairs, bilateral agreements, and collaborations with regulatory authorities can increase visibility and acceptance of Ayush medicines.

Innovation Ecosystem for Ayush Products

To accelerate innovation in Ayush products, robust incentives and strategic support for industry and academia are essential Further, coherent intellectual property. (IP) framework is also vital. By balancing the protections offered by the Traditional Knowledge Digital Library (TKDL) with pathways for patent commercialization, this framework safeguards indigenous knowledge while promoting innovation-driven growth. Such a dual approach ensures that entrepreneurs and researchers can leverage India's rich heritage for product development, generate competitive IP, and expand market reach without risking misappropriation of traditional practices. Release of the Guidelines for Processing Patent Applications of Ayush Systems and Related Inventions (GoI, 2025) by the Office of the Controller General of Patents, Designs and Trade Marks is a significant step towards strengthening intellectual property protection in the Ayush sector. These guidelines aim to facilitate patents in Ayush systems by providing clear guiding principles to assist both patent officers and applicants, thereby promoting innovation and effective translation of Ayush systems.

A specific scheme to promote research and innovation in the Ayush drug sector is essential to enhance scientific validation, product development, and global competitiveness. Recognizing this need, the Department of Pharmaceuticals, Ministry of Chemicals and Fertilizers, Government of India, has launched the Scheme for Promotion of Research and Innovation in Pharma MedTech sector (PRIP), aimed at transforming India into a global hub for research, development, and innovation in pharmaceuticals and medical technology which includes Ayush drugs and medical devices also.[7]

Medicinal Plant Policy

Ensuring a sustainable and resilient raw material supply chain for the Ayush industry requires a comprehensive Medicinal Plant Policy that balances ecological conservation with economic viability. The policy should emphasize sustainable cultivation practices, including organic farming, integrated pest management, soil health maintenance, and water-efficient irrigation techniques, which can improve both yield and phytochemical quality of medicinal plants. For instance, cultivation of Ashwagandha in Madhya Pradesh has demonstrated higher active ingredient concentration and market acceptability.

To incentivize quality production, contract farming models under Good Agricultural and Collection Practices (GACP) may be promoted. These models ensure assured procurement for farmers while standardizing raw material quality for manufacturers. The implementation of in-situ and ex-situ conservation programs, including community-managed medicinal plant reserves and botanical gardens, helps preserve biodiversity while supplying sustainable raw material for research and industry use.

Active collaboration with the Ministry of Agriculture, state agriculture departments, and rural development agencies is

necessary to integrate medicinal plant cultivation into mainstream agricultural programs. This convergence can extend technical support, facilitate access to credit, crop insurance, and market linkages and promote agroforestry practices that enhance ecological sustainability.

By securing a reliable supply of quality raw materials, such measures will not only safeguard ecological integrity and support biodiversity but also strengthen the economic resilience of rural communities. In the long term, a robust supply chain under a Medicinal Plant Policy may catalyze the sustainable growth of the Ayush industry, facilitate evidence-based product development, and improve global competitiveness.

Consumer Awareness

Unethical practices in the Ayush sector, such as misleading advertisements of products claiming unproven therapeutic benefits and unqualified individuals falsely presenting themselves as Ayush practitioners, pose significant risks to public health and undermine the credibility of traditional medicine systems. Such malpractices not only erode consumer trust but also create barriers for scientifically validated Ayush products to gain wider acceptance both nationally and internationally.

Strengthening regulatory enforcement is a critical step to mitigate these risks. Regulatory authorities, including the Ministry of Ayush and Ayush vertical in Central Drugs Standard Control Organization (CDSCO), play an essential role in monitoring claims, inspecting manufacturing facilities, and taking legal action against violators. The enforcement of Schedule T of the Drugs Rules, 1945, which mandates Good Manufacturing Practices, and the implementation of stricter labelling can help ensure that marketed products are safe, effective, and accurately represented.

Alongside enforcement, evidence-based consumer awareness campaigns are crucial. Programs that educate the public on distinguishing scientifically validated Ayush products from unverified remedies can promote rational use. Initiatives such as "Ayush Suraksha Abhiyan" and outreach campaigns by Research Councils under Ministry of Ayush and NMPB have focused on educating consumers and healthcare providers about authentic practices, verified product standards, and the dangers of unqualified practitioners.

A dual approach combining stringent regulatory oversight with widespread awareness campaigns ensures both protection of public health and enhancement of the sector's credibility. By promoting responsible marketing, informed decision-making, and adherence to evidence-based standards, Ayush industry can foster sustainable growth, gain consumer confidence, and support the integration of traditional medicine into mainstream healthcare systems.

Conclusion

The regulation of Ayush drugs in India stands at a turning point, where the wisdom of traditional systems must be aligned with the demands of modern science and global healthcare. Ayush systems of healthcare have been trusted for centuries for their holistic approach to health. However, in today's interconnected world, where patients and regulators demand proven safety, quality, and

efficacy, Ayush medicines need strong regulatory and scientific support to gain wider global acceptance.

Over the last decade, important reforms have been undertaken by the Ministry of Ayush to strengthen the credibility of this sector. Initiatives such as Ayush Oushadhi Gunvatta evam Uttpadan Samvardhan Yojana (AOGUSY), the establishment of the Ayush Export Promotion Council (AYUSHEXCIL), and the expansion of pharmacopoeial standards have helped in creating a robust framework for quality assurance. The integration of Good Manufacturing Practices (GMP), modern analytical tools and pharmacovigilance mechanisms has improved consistency in product quality. In addition, clinical research collaborations with ICMR, CSIR, and global universities have started bridging the evidence gap, demonstrating the safety and efficacy of Ayush formulations in ways acceptable to international regulators.

Alongside these important reforms, certain opportunities for further strengthening remain. Certain Ayush drugs still face variability in raw materials due to unsustainable harvesting and climate change. Most manufacturers are micro, small, or medium enterprises (MSMEs) that lack access to advanced technology and resources needed to meet international quality benchmarks. Regulatory implementation is often uneven across states, leading to fragmented compliance. In addition, global markets demand high-quality clinical evidence such as randomized controlled trials (RCTs), pharmacokinetic studies, and long-term safety data, areas where Ayush still needs large-scale investment and capacity building. Misleading advertisements and unqualified practitioners further harm the credibility of authentic Ayush medicines, creating mistrust among consumers.

Therefore, the way forward requires comprehensive and multi-pronged reforms, which is as follows:

- Regulatory harmonization across states, supported by Ayush vertical within CDSCO, will ensure uniform licensing and compliance.
- Systematic expansion of pharmacopoeial standards and regular batch-wise quality testing will provide consistent benchmarks for safety and efficacy.
- Global alignment with WHO-GMP standards and Codex/WHO guidelines to open international markets.
- Sustained clinical research through multi-centric trials and global collaborations will provide the scientific evidence required for wider acceptance.
- Innovation and intellectual property protection, supported by government schemes, will encourage new product development without losing traditional authenticity.
- A dedicated Medicinal Plant Policy will ensure sustainable cultivation, conservation, and traceability of raw materials, securing both biodiversity and industry needs.
- Enforcement against misleading claims combined with evidence-based consumer awareness campaigns will protect public health and build trust in the Ayush sector.

Ayush drug regulation must balance two equally important goals i.e. preserving traditional heritage and meeting modern scientific benchmarks. India has the opportunity to position Ayush as a global leader in integrative healthcare by combining cultural knowledge with evidence-based practices. If regulatory reforms, scientific validation, sustainable resource management, and consumer protection are pursued in a coordinated manner, Ayush can evolve into a credible, resilient, and globally accepted healthcare system. Such progress will not only enhance India's role in global health but also provide safe, effective, and holistic solutions for the growing health challenges of the 21st century.

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Research Landscape of Medicinal Plant Conservation in India – A Bibliometric Analysis

Anjali Luthra*

Anjali Luthra

Abstract: India's rich botanical heritage and cultural reliance on plant-based healing systems place medicinal plant conservation at the intersection of health, biodiversity, and indigenous knowledge preservation. This paper offers a mapping of the research landscape on medicinal plant conservation in India between 2015 and 2025, analysing over 4,313 peer-reviewed publications across major databases. Through bibliometric methods and visualisation using VOSviewer, the paper examines publication trends, journal and citational analysis, regional ecosystem focus, and disciplinary contributions. A comparative analysis with China is included due to its expansive repository of medicinal plant resources, making its scholarly output a critical point of reference for the field.

Findings highlight a concentration of research on ecologically sensitive zones like the Himalayas and Western Ghats. Dominant research themes include ethnobotany, agroecology, and biotechnological conservation. High-quality publication outlets feature prominently, indicating both rigour and visibility.

Despite these strengths, the research landscape shows limited attention to underrepresented regions like the Northeast, weak integration of new technologies, and global collaborations. The paper calls for more inclusive, cross-sectoral, and technology-driven approaches that prioritise both ecological resilience and holistic development of the community, ensuring long-term sustainability of India's medicinal plant resources.

Introduction

Conservation and sustainability of medicinal plants have emerged as a critical concern within the domain of traditional medicine. With increasing reliance on plant-based therapies both in indigenous systems and modern pharmaceuticals, the pressure on natural medicinal resources has grown exponentially (Mykhailenko *et al*., 2025). The conservation of medicinal plants encompasses a multifaceted approach that includes

* MSc Biosciences, Jamia Millia Islamia.

the identification of species with therapeutic value, their sustainable utilisation, and the protection of both the plants and the knowledge systems within which they are embedded. This process includes the documentation, restoration, and transmission of ethnobotanical knowledge, particularly that held by indigenous communities, who have historically practised sustainable management of these bioresources (Rashmi, 2021). Contemporary conservation strategies therefore necessitate both in situ and ex-situ approaches, such as tissue culture, cryopreservation, and habitat restoration, alongside the domestication and cultivation of threatened species. Furthermore, the protection of these biological resources requires the integration of traditional ecological knowledge, community-based conservation models, biotechnological interventions to enhance resilience and efficacy, and policy frameworks that safeguard medicinal plant diversity.

According to the International Union for Conservation of Nature (IUCN), 21 per cent of all medicinal plants used globally are under threat, with forty-four Indian species listed as vulnerable, endangered, or critically endangered as of 2015 (Anurag Dhyani & Dhyani, 2016). More than 90 per cent of India's medicinal plants are facing threats from excessive and unsustainable collection, utilisation, overexploitation, or unskilled harvesting, highlighting the urgent need to conserve these vital bioresources in their native ecosystems (Kumar *et. al*., 2011).

There is a pressing need to critically assess the state of research to understand whether conservation efforts are inclusive, science-backed, and community-responsive. While diverse conservation strategies, from community-led initiatives to advanced tissue culture and cryopreservation techniques, are being explored, there remains limited clarity on how research trends are evolving across disciplines and regions. This paper undertakes a systematic mapping of published research on medicinal plant conservation in India, specifically focusing on journal-based scholarly output to examine regional ecosystem patterns, quality of publications and thematic patterns in conservation-related literature. By analysing over 4,313 academic articles, this study evaluates the quality and direction of conservation research stemming from India, identifying concentrations and sparsities in scholarly efforts and providing a structured understanding of how medicinal plant conservation is being addressed academically.

A comparative analysis with China is also included to examine the research landscape within a system characterised by its vast repository of medicinal plant resources. This comparison provides a crucial counterpoint, particularly given China's substantial scholarly output of 8,094[1] articles in this domain between 2015 and 2025.

The study aims to map and analyse the research landscape of medicinal plant conservation in India and compare it with the scholarly output of China.

Methodology

Data Source

The dataset for this study was compiled by merging research outputs from ScienceDirect, ResearchGate, and PubMed, with a focus on publications from 2015 to 2025. Using keyword combinations

such as *"medicinal plants," "conservation," and "India,"* approximately 4,313[2] articles were initially retrieved and screened for relevance. For this study, the inclusion criteria comprised peer-reviewed journal articles and book chapters published in English between 2015 and 2025. The exclusion criteria ruled out books and encyclopedias, as well as conference abstracts, book reviews, editorials, correspondence, errata, and discussions. Mini-reviews, short communications, video articles, and news pieces were also excluded to ensure the focus remained on substantive, peer-reviewed research contributions.

Data Cleaning and De-duplication

Since multiple databases were used, there was a significant degree of overlap between retrieved articles. A process was carried out using manual cross-checking and spreadsheet filters, during which duplicate entries were identified and removed. In addition, articles not meeting the inclusion criteria or falling under the exclusion list were filtered out.

Data Extraction

For each included study, relevant information was systematically extracted and organized in Microsoft Excel. The extracted variables included the type of publication (such as journal article, book chapter, or field study), year of publication, author(s), and title. To facilitate thematic mapping, each work was also classified by discipline, for instance botany, ecology, or ethnopharmacology. Additional bibliometric details such as citation count and the journal's quartile ranking based on the Scimago database were recorded to assess the scholarly impact and quality of the publications.

The same procedure was carried out with China by replacing "India" with "China" as a primary keyword. This search, using the keywords "medicinal plants," "conservation," and "China," yielded approximately 8,094 articles.

Analytical Framework

The curated dataset was analysed along multiple dimensions to capture the depth of research on medicinal plant conservation. Temporal trends were examined through the year-wise distribution of publications, while the regional ecosystem focus was assessed by identifying the ecological zones and geographic regions under study. Disciplinary distribution was mapped to understand the contributions of different research fields such as botany, ecology, and ethnopharmacology. In addition, the type of research was categorised into empirical studies, review-based analyses, ethnobotanical investigations, ecological assessments, and policy-related contributions, thereby enabling a comprehensive evaluation of the literature landscape.

VOS viewer,[3] a tool which enables the construction and visualisation of bibliometric networks such as co-authorship networks and keyword co-occurrence maps, was used to generate co-occurrence maps and visualise the thematic structure of the field.

Overview of Publication Trends

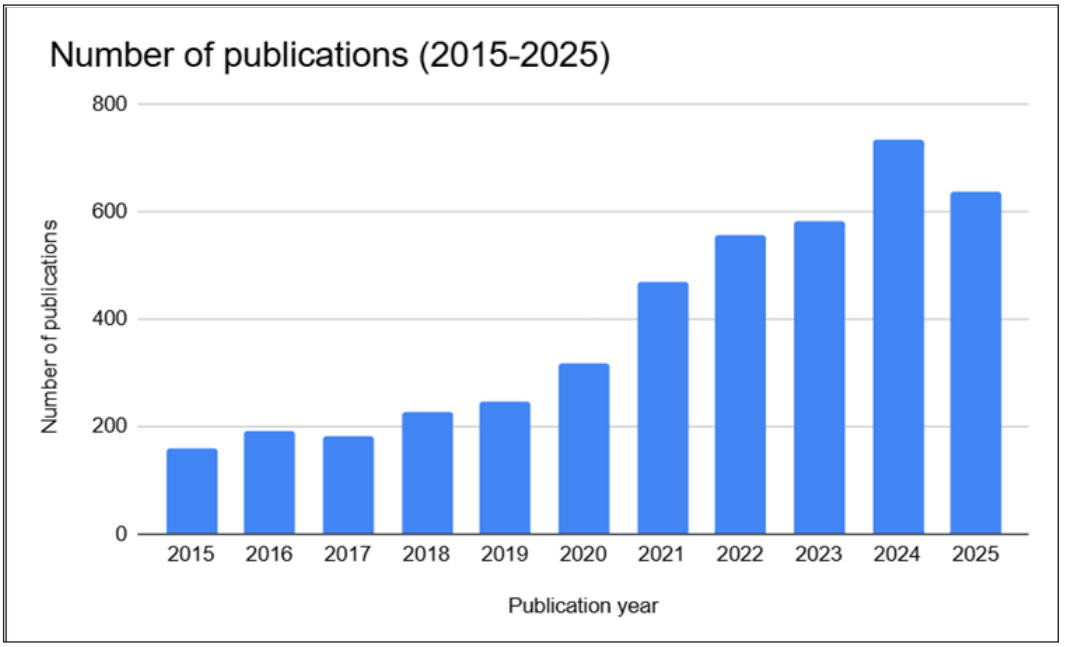
Over the past decade, research in this field has gained consistent momentum, reflecting an expansion in scholarly interest. As Figure 1 shows, the trend in publications from 2015 to 2025 illustrates this growth clearly, with outputs rising

steadily year after year and reaching a peak in 2024. In 2015, the number of publications was below 200, whereas by 2024 it had crossed 700, marking a substantial increase. The slight decline observed in 2025 is not indicative of reduced activity, as the data was collected only

Journal Rank (SJR)[4] quartiles, to assess journal quality and research impact.

The SJR is a journal ranking metric derived from Scopus data. Unlike raw citation counts, SJR assigns weighted values to citations based on the prestige of

Figure 1: Number of Publications on Medicinal Plant Conservation in India (2015 to 2025)



Source **:** Author's compilation

until July and is expected to rise further by the end of the year. While assessing these patterns, multiple dimensions of analysis were considered, including journal distribution and citation trends to evaluate research impact, thematic mapping to trace evolving subject areas, and regional as well as ecosystem focus.

Journal and Citational Analysis

This study included publications across 663 journals, which were evaluated using key bibliometric indicators, such as the Hirsch index (H-index) and SCImago

the citing journals, thus emphasising the quality of citations. Journals are classified into quartiles based on their SJR within the subject area. The top 25 per cent are labelled Q1, while the bottom 25 per cent are classified as Q4.

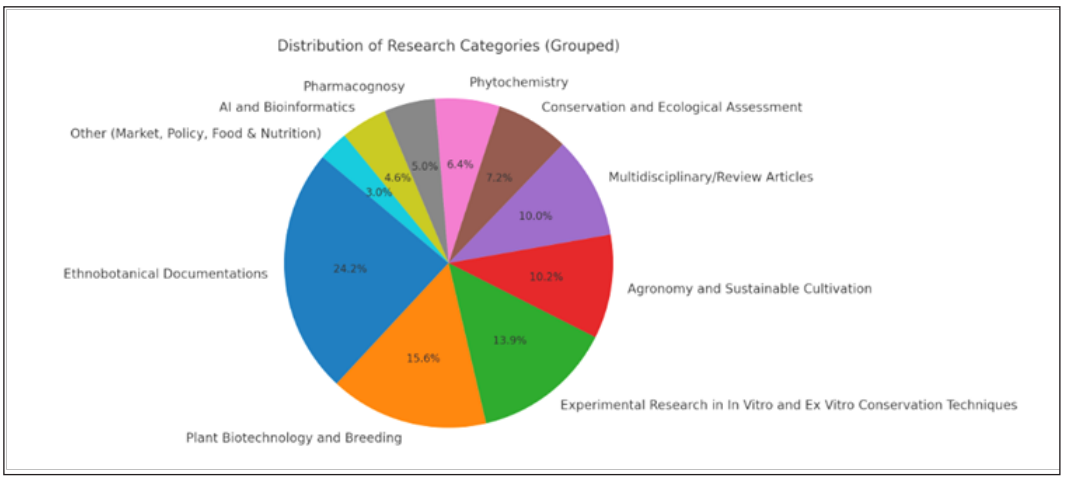
Several journals that hosted a notable volume of papers from this study are the South African Journal of Botany,[5] Journal of Ethnopharmacology,[6] Journal of Applied Research on Medicinal and Aromatic Plants[7] and Industrial Crops and Products.[8]

These journals reflect the intersection of ethnobotany, pharmacology, and ecological sciences, highlighting the multidisciplinary nature of conservation research. The majority of records are classified as Quartile 1, comprising approximately 62.6 per cent of the dataset. Quartile 2 journals follow at around 19.3 per cent, and Quartile 3 contributes close to 16.7 per cent, indicating a substantial presence in the middle range. A very small fraction, roughly 0.6 per cent, falls into Quartile 4, while an additional 0.6 per cent of journals did not have quartile information available, a negligible proportion compared to the rest.

Computational biology and informatics constitute a rapidly expanding domain. For instance, *Computers in Biology and Medicine*[9] (H-index 142) holds Q1 status, while *Pattern Recognition*[9] (H-index 257) illustrates interdisciplinary linkages between computer science and the life sciences. *Knowledge-Based Systems*[10] (H-index 188) further exemplifies the application of artificial intelligence methodologies in biological research. Many regional or culturally embedded journals may not be indexed in Scopus, but still serve a critical role in documenting traditional knowledge and indigenous practices.

A substantial proportion of publications authored by Chinese researchers are concentrated in Quartile 1 journals, denoting the highest levels of academic prestige and impact. This pattern suggests that Chinese scientists predominantly publish their research through internationally recognized, high-impact journals. 81.3 per cent of the recorded journals fall into Quartile 1, publications in Quartile 2 make up 13.5 per cent, Quartile 3 contains just 4.4 per cent of the total, and Quartile 4 contains 0.8 per cent, reflecting a minimal presence in lower-tier journals.

Figure 2: Proportional Distribution of Research Categories in Publications from 2015 to 2025



The pie chart presents the predominance of Ethnobotanical Documentation, followed by Plant Biotechnology and Breeding and Experimental Research in In Vitro and Ex Vitro Conservation Techniques.

Source **:** Author's compilation.

Overview of Prevalent Themes and Disciplines in Publications

A richly interdisciplinary field that spans from indigenous knowledge documentation to biotechnological innovation, encompassing ecology, agronomy, policy, and computational sciences, was observed during the analysis of these articles. The following clusters outline the core themes and disciplinary intersections observed in contemporary medicinal plant studies, supported by bibliometric network insights.

Ethnobotanical Documentation and Community-based Conservation Practices

This fundamental theme involves documenting indigenous and local knowledge on medicinal plant uses, through field-based surveys, interviews and questionnaires. The network map highlights ethnobotany, traditional medicine, and community conservation as closely linked and central to the broader research landscape. Ethnopharmacology emerged as one of the themes which dominated the research landscape. Ethnopharmacology investigates how communities identify, prepare, and use traditional remedies, and seeks to validate these practices through experimental, phytochemical, and pharmacological analysis. This theme accounted for 24.09 per cent of all publications.

Breeding and Biotechnology

Advances in molecular biology and tissue culture enable genetic improvement and propagation of medicinal plants. Biotechnology enhances traits such as yield, active compound concentration, and stress resilience, addressing challenges posed by overharvesting and habitat loss. Thematic mapping shows strong clustering around molecular biology and biotechnological techniques, reflecting the growing role of laboratory-based approaches in medicinal plant conservation and quality assurance. This theme accounted for 15.52 per cent of all publications.

Agronomy and Sustainable Cultivation

This cluster focuses on optimising cultivation practices for medicinal plants through agro-ecological principles. The map connects agroecology tightly with both conservation and ethnobotanical practice, underscoring a trans-disciplinary approach to sustainable medicinal plant production. This theme accounted for 10.17 per cent of all publications.

Conservation and Ecological Assessment

Ecological studies assess the distribution, population dynamics, habitat requirements, and threats to medicinal plants. Techniques include field ecology, GIS-based spatial modelling, climate impact assessments, and conservation prioritisation. Research on conservation ties to climate change, habitat restoration, and endangered species. This theme accounted for 7.2 per cent of all publications.

Policy Reviews

Reviews on Policy and governance research in the field of medicinal plants in India are relatively limited in number. It examines the legal and institutional frameworks that support sustainable conservation and equitable use of medicinal plant resources.

Experimental Research: In Vitro and Ex Vitro Conservation Techniques

Laboratory-based experimental techniques such as micropropagation, tissue culture, cryopreservation, and synthetic seed

technology are vital for conserving the germplasm of threatened or slow-growing medicinal species. Safeguarding genetic diversity through in situ and ex situ conservation measures ensures the long-term availability of medicinal plant resources. This theme accounted for 13.83 per cent of all publications.

Review articles

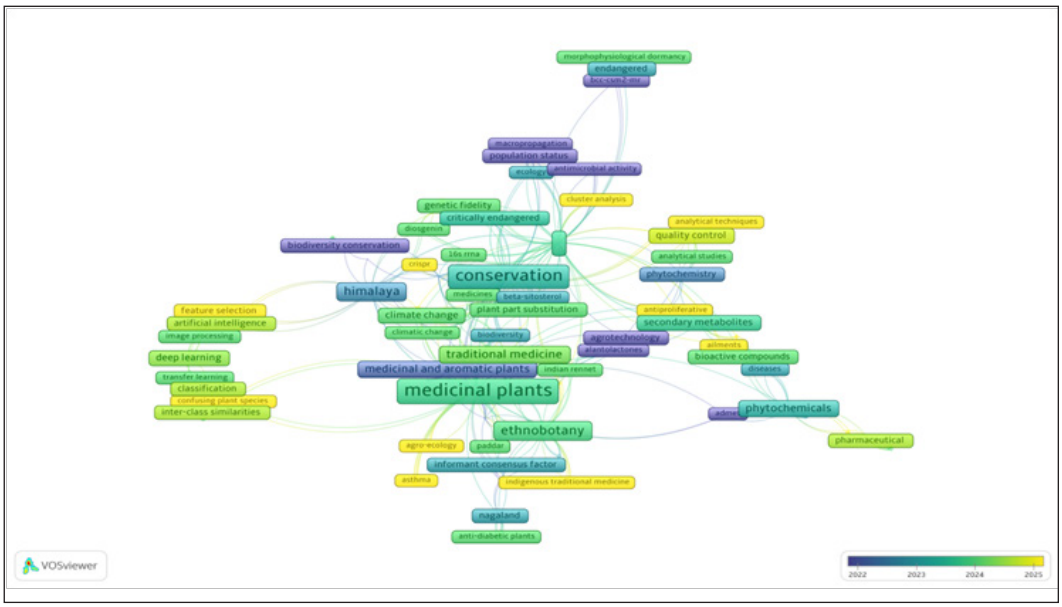
Review articles include research across multidisciplinary themes to identify knowledge trends, gaps, and future priorities.

Ethnobotanical Documentations continues to dominate with 24.09 per cent of all entries, Plant Biotechnology and Breeding maintains its position as the second-largest category at 15.52 per cent, while Experimental Research in In Vitro and Ex Vitro Conservation Techniques accounts for 13.83 per cent. Agronomy and Sustainable Cultivation comprises 10.17 per cent and Multidisciplinary/ Review Articles make up 9.99 per cent of the dataset. Conservation and Ecological Assessment represents 7.14 per cent, Phytochemistry accounts for 6.33 per cent, and Pharmacognosy contributes 5.00 per cent. AI and Bioinformatics represent 4.55 per cent, while smaller specialised fields include Market and Trade at 1.25 per cent, Policy Review at 1.16 per cent, and Food and Nutrition at 0.54 per cent. Figure 3 the key research themes in research.

Regional and ecosystem focus

The spatial distribution of research on medicinal plant conservation in India reflects a pronounced focus on specific ecological regions. The majority of

Figure 3: Visualisation of Keyword Co-occurrence in Medicinal Plant Conservation Research in India (2015–2025)



***Source*:** Author's compilation using VOSviewer-generated overlay where node size indicates keyword frequency, while colour gradient reflects average publication year, with yellow representing more recent research focus.

scholarly attention is concentrated on the Himalayan ecosystems, which are known for their rich biodiversity and longstanding traditions of ethnomedicinal knowledge. Research in these regions often emphasises in situ conservation, sustainable harvesting practices, and the documentation of traditional uses by local communities.

The Western Ghats region, known for its rich endemic biodiversity and being a global biodiversity hotspot, has also seen significant conservation-oriented research.

The Eastern and Northeastern regions of India, including the Eastern Himalayas and Indo-Burma biogeographic zone, are represented in the research landscape but are less central in terms of scholarly output and collaborative density. These areas possess unique ecological characteristics and house culturally diverse communities with rich ethnobotanical traditions. Despite this, the volume of indexed research and integration into national-level discourse remains relatively limited. This suggests an untapped potential for conservation science in regions that are ecologically critical yet underrepresented in academic literature.

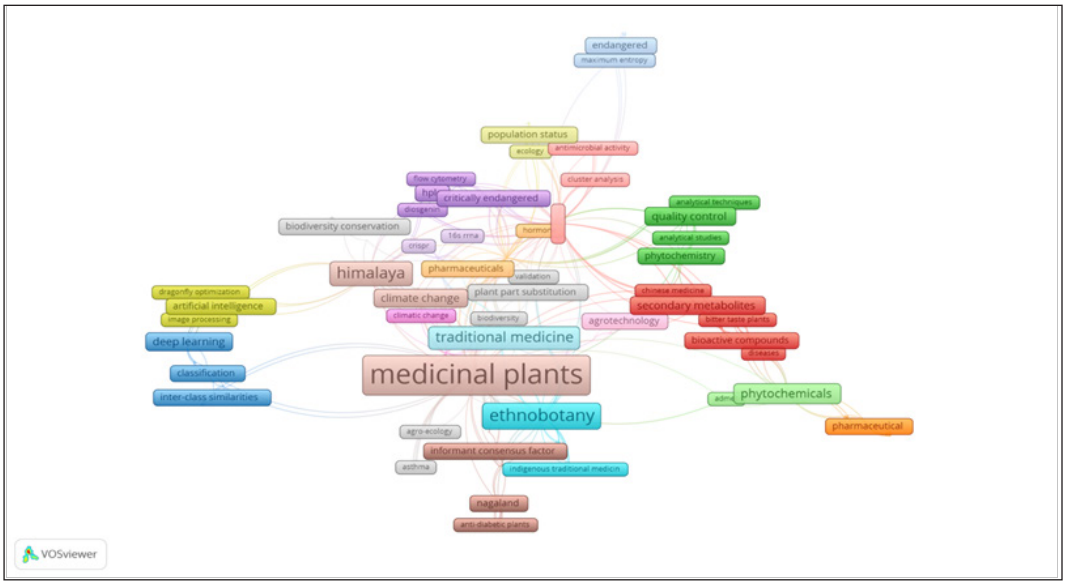
Analysis of Research and Publications: Gaps and Prospects

The field of medicinal plant conservation in India has seen a growing body of research, providing valuable insights into the country's rich biodiversity while also pointing to persistent gaps and challenges. An analysis of publications using VOSviewer maps (Figure4) reveals a high number of studies concentrated in ethnobotanical documentation, while themes like deep learning and AI are emerging as new frontiers. The growing volume and quality of this academic literature is reflected in many studies being published in high-impact journals.

Artificial Intelligence (AI) and Bioinformatics can play a transformative role in addressing these challenges. AI and its subfields, such as machine learning and computer vision, offer powerful tools to analyse vast datasets from satellite imagery and climate models. This allows conservation efforts to be proactive and data-driven, helping to create dynamic, real-time habitat maps to model the distribution of threatened species and optimise the placement of conservation zones.

To address the observed gaps, research on medicinal plant conservation in India must prioritise underrepresented ecological regions such as the Northeastern hills and Eastern Ghats. There is a need for interdisciplinary approaches that integrate conservation science with climate studies, policy analysis, food and nutrition, informatics, and holistic development of the community. International partnerships should be actively pursued to facilitate global knowledge exchange and shared methodologies. In addition to strengthening in situ efforts, there is a need to scale up the research on ex-situ conservation strategies, especially for endemic and threatened species. Collaboration with indigenous and local communities, whose traditional knowledge systems and cultural practices offer valuable insights for sustainable conservation, is also crucial. The use of emerging technologies such as GIS-based habitat modelling and mobile-based biodiversity monitoring should be expanded.

Figure 4: Map Illustrating Major Research Themes and Frequently Used Terms in Medicinal Plant Conservation Literature in India (2015–2025)



***Source*:** Author's compilation using VOS viewer, the size of a node directly corresponds to the recurrence of the keyword. A larger node indicates that the keyword appeared more frequently in the analysed dataset.

Conclusion

The increasing reliance on medicinal plants for the production of both traditional and modern medicines, conservation has emerged as a critical concern. This urgency is reflected in the growing volume and quality of academic literature, with many studies published in high-impact journals. The strength of India's academic institutions in producing scientifically rigorous, peer-reviewed work underscores their central role in advancing conservation goals.

While the research landscape shows concentrated efforts on key biodiversity zones, several prospects present exciting research opportunities. There is a need to broaden the scope of research on ecological regions like the Northeast and Eastern Ghats. This expansion would provide a more complete picture of India's medicinal plant diversity and the unique conservation challenges in these areas. Additionally, integrating with fields such as climate science, health policy, and digital informatics can offer new, innovative solutions. For example, using climate models to predict future threats to medicinal plant habitats or employing digital tools like GIS and AI to monitor and manage conservation efforts more effectively. Scaling up technological innovation and international collaborations is also vital to align with global conservation standards. Partnering with countries like China, which has a highly structured and prolific scholarly output focused on modernising and scaling Traditional Chinese Medicine (TCM), can provide valuable insights and a model for future research. Moving forward, more inclusive, regionally diverse, and multidisciplinary research approaches are needed. Collaborating with indigenous communities, coupled with

the use of emerging technologies, will be key to achieving a holistic and sustainable conservation of medicinal plant resources in India.

Endnotes

[1] The articles were taken from the following websites:
- https://pubmed.ncbi.nlm.nih.gov/?term=medicinal+plants%2C+-conservation%2C+china&filter=-years.2015-2025&size=200
- https://www.sciencedirect.com/search?articleTypes=REV%2C-FLA%2CCH%2CCRP%2CDAT&lastSelectedFacet=years&qs=medicinal%20plant%2C%20conservation%2C%20china&years=2020%2C2019%2C2018%2C2017%2C2016%2C2015%2C2025%2C2024%2C2023%2C2022%2C2021
- https://www.researchgate.net/search/publication?q=medicinal+plants+AND+conservation+AND+china%2C+2015-2025

[2] The articles were taken from the following websites:
- https://pubmed.ncbi.nlm.nih.gov/?term=medicinal+plants%2C+conservation%2C+india&size=200&filter=-datesearch.y_10
- https://www.sciencedirect.com/search?qs=medicinal+plant%2C+conservation%2C+india&years=2025%2C2024%2C2023%2C2022%2C2021%2C2020%2C2019%2C2018%2C2017%2C2016%2C2015&lastSelectedFacet=articleTypes&articleTypes=REV%2C-FLA%2CCH%2CCRP%2CDAT
- https://www.researchgate.net/search/publication?q=medicinal%2Bplants%2BAND%2Bconservation%2BAND%2Bindia%252C%2B2015-2025&page=8

[3] https://www.vosviewer.com/

[4] https://www.scimagojr.com/journalrank.php

[5] https://www.scimagojr.com/journalsearch.php?q=17257&tip=sid&clean=0

[6] https://www.scimagojr.com/journalsearch.php?q=23015&tip=sid

[6] https://www.scimagojr.com/journalsearch.php?q=21100366771&tip=sid

[7] https://www.scimagojr.com/journalsearch.php?q=32791&tip=sid&clean=0

[8] https://www.scimagojr.com/journalsearch.php?q=17957&tip=sid

[9] https://www.scimagojr.com/journalsearch.php?q=24823&tip=sid

[10] https://www.scimagojr.com/journalsearch.php?q=24772&tip=sid&clean=0

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Mykhailenko, O., Jalil, B., McGaw, L.J., Echeverría, J., Takubessi, M. and Heinrich, M. 2025. Climate change and the sustainable use of medicinal plants: a call for 'new' research strategies. Frontiers in Pharmacology, 15. doi: https://doi.org/10.3389/fphar.2024.1496792

Sustainable Bioeconomy in the Global South: Status and Perspectives Vol

Edited by : Matthew Chidozie Ogwu, Sylvester Chibueze Izah, Humberto Merritt, Raul Delgado Wise, Attachai Jintrawet
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Namrata Pathak*

Namrata Pathak

The term bioeconomy was first used by Dr Bernadine Healy in 1992 for a new kind of economy that can revolutionize nations through the use of biotechnology and other biology-related applications. Over the last two decades, there has been a surge of interest in the concept of a bioeconomy and a focus on economic, technological, and security policy. As a result, the number of research articles on the bioeconomy began to increase in the mid-2000s. Today more than 40 countries have adopted formal programmes to promote their bioeconomies.

The Global South, with its rich biodiversity and diverse natural resources, offers immense potential for the bioeconomy. The use of some resources like botanical dietary supplements, nutraceuticals, and phytopharmaceuticals while being a dominant in the global South as traditional medicines are fast growing in the global North as well. Similar is the case with several other resources whose consumption is projected to increase in the near future. However, the pathway to realizing this potential is complex, requiring tailored strategies that address regional disparities, environmental sustainability, and economic inclusivity. This volume by Ogwu *et al.*, compiles perspectives, reviews, and case studies on the status of biological resources, the development of raw materials, technological innovations, and policy frameworks that can support sustainable bio-based economies.

* Consultant, RIS, New Delhi.

Comprised of 16 chapters, this volume covers topics ranging from baseline assessment of biological resources and technologies to the processes and innovations that can drive bioeconomy development. The chapters in this volume are contributed by experts across the Global South although, as acknowledged by A. O. Fajinmolu *et al*., there is a high level of economic differentiation within the Global South itself. While some nations, for instance, China and India, are now experiencing high economic growth, others still face numerous difficulties, including high debt and high dependence on agriculture and natural resources. The efficiency of utilization and success of the bioeconomy in the global South therefore varies. The effort by editors of this Volume appears to focus on all countries of the Global South while acknowledging, through case studies, the emerging technologies and policies promoting bioresources in countries like India.

A brief review of the chapters highlights the focus on resources and technology. For example, Ogwu *et al*., provide an overview of primary (agricultural biomass, forestry biomass), secondary (organic and agricultural waste) and novel materials such as invasive species and urban green waste as opportunities for bio-based industries in the South. Enerijiofi *et al*., also map bioeconomy resources along with technologies and factors impacting technology adoption in the countries. O. I. Ogidi *et al*., analyze specific biological resources drawn products i.e. pharmaceuticals. It includes technologies involved, manufacturing process and medical and pharmaceutical applications. In another chapter, O. I. Ogidi *et al*., review sustainable production and utilization of waste as raw materials. Some authors have attempted analysis of data and management strategies. For example Fajinmolu *et al*., map assessment strategies for bioeconomy management such as use of focus group discussions, youth studies method assessment methods like PRA, structured socio-economic surveys, mixed-methods approach that combines quantitative surveys and qualitative interviews along with new and more advanced technologies like geographic information systems (GISs) and mobile data gathering technologies.

The Volume appears to map the major supply and value chain of the bio economy from backend linkages such as raw materials to processes, finished goods, value added goods, data framework for bioeconomy transition to regional cooperation and public policy frameworks for Global South. However an estimation of the economic value of bioeconomy is not attempted by any author. While highlighting the relevance of biological resources and the bioeconomy, the key processes, policies and innovations it would have brought out the relevance of these resources had the editors attempted a monetary estimation for the economies of the global South. Overall, the Volume brings out very useful information on the sector through case studies, challenges in implementation of policies favorable to growth of the sector and success stories that may have relevance to countries looking to replicate such strategies in their respective countries.

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In-text referencing should be embedded in the anthropological style, for example '(Hirschman 1961)' or '(Lakshman 1989:125)' (Note: Page numbers in the text are necessary only if the cited portion is a direct quote). Footnotes are required, as per the discussions in the paper/article.

Use's' in '-ise' '-isation' words; e.g., 'civilise', 'organisation'. Use British spellings rather than American spellings. Thus, 'labour' not 'labor'. Use figures (rather than word) for quantities and exact measurements including percentages (2 per cent, 3 km, 36 years old, etc.). In general descriptions, numbers below 10 should be spelt out in words. Use fuller forms for numbers and dates— for example 1980-88, pp. 200-202 and pp. 178-84. Specific dates should be cited in the form June 2, 2004. Decades and centuries may be spelt out, for example 'the eighties', 'the twentieth century', etc.

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Core IV-B, Fourth Floor, India Habitat Centre
Lodhi Road, New Delhi-110 003, India.
Ph. 91-11-24682177-80 Fax: 91-11-24682173-74-75
Email: dgoffice@ris.org.in Website: www.fitm.ris.org.in,; www.ris.org.in