



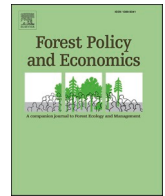
## **Herbal medicine promotion for a restorative bioeconomy in tropical forests: A reality check on the Brazilian Amazon**

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# Herbal medicine promotion for a restorative bioeconomy in tropical forests: A reality check on the Brazilian Amazon

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## ABSTRACT

Herbal medicine has experienced a renaissance both for health reasons and as part of a bioeconomy for regions rich in biodiversity and traditional knowledge. Medicinal plant value chains can promote local development and sustainable livelihoods that are critical for forest frontiers in need of inclusive economic alternatives. This sector can become an example of restorative bioeconomy, which not only maintains but enhances nature's contributions to people – notably to historically marginalized actors such as Indigenous peoples. However, a reality check is due. Using the Amazon as an emblematic case study, this article examines Brazil's context and policy framework on herbal medicine promotion. It draws from a literature review as well as 23 key-informant interviews and field visits to 10 local herbal medicine value chain initiatives. Our findings expose a closing window of opportunity, as while deforestation and forest degradation advances, Brazil's herbal medicine promotion has fallen short of its potentials for development and inclusiveness. Insufficient attention to traditional knowledge or to research on Brazil's native biodiversity, regulatory stringency without converse support to integrate marginalized actors, and ambivalent social acceptability of herbal medicine have been key barriers to advancing the sector. We conclude that herbal medicine offers a clear case of restorative bioeconomy with double potential to address historical inequalities both on healthcare access and socioeconomic inclusiveness, but delivering on that requires much more participatory research, attention to local capacity enhancement, and a better understanding of herbal medicine promotion in multicultural social settings.

## 1. Introduction

Herbal medicine, broadly understood as the utilization of plants for curative purposes, has been a mainstay of most human cultures. The World Health Organization (WHO) estimates that as much as 80% of the global population relies on some form of traditional medicine even if advancing deforestation and urbanization have eroded it (Brazil, 2016; WHO, 2013). Now herbal medicine is experiencing a renaissance of sorts, under concepts such as One Health (Mumford et al., 2023), bio-cultural conservation (Gavin et al., 2015), and bioeconomy (Brazil, 2023a). Using the Brazilian Amazon as a case, the objective of this article is to probe into that enthusiasm to understand how such a promotion takes place in practice and the issues it faces.

Three rationales underscore this renewed momentum for herbal medicine. First, herbal medicine value chains can strengthen local livelihoods and help promote development, understood as improved capacities to overcome deprivations (Sen, 2000). Value chains refer to

the various steps in the eventual transformation of raw materials into finished products, with economic value being added along the way (Gereffi et al., 2001). “Upgrading” – or climbing up to the value-added stages of production – has long been recognized as a key avenue for poverty reduction and social equity promotion (Mitchell and Coles, 2011; Zhou et al., 2022). Such value-added products could range from slightly processed plant material (e.g., dried leaves or seeds for infusions) to more elaborate phytotherapies and pharmaceuticals. If neglected communities could benefit more from such production by means of value addition, herbal medicine promotion could constitute a culturally appropriate pathway out of poverty (Astutik et al., 2023; Shahidullah and Haque, 2010).

Second, sustainable development alternatives are critical for endangered ecosystems such as the Amazon. In just a few decades, millions of hectares of forests have been lost to cattle ranching or to industrial agriculture, hampering livelihoods, eliminating biodiversity, and emitting greenhouse gases (Pendrill et al., 2022; Song et al., 2021). In the

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Amazon, further deforestation may soon take the ecosystem beyond a tipping point, where the remaining vegetation fails to form sufficient rainfall and triggers a gradual savannization process (Lovejoy and Nobre, 2018). Deforestation-free supply chain policies focused on corporate agriculture do little for – and risk excluding even further – the millions of people in poverty who often venture into illegal logging, wildcat mining, or cattle ranching for a living (Zhunusova et al., 2022). It is therefore vital to promote sustainable development alternatives that keep forests standing (Abramovay et al., 2021).

Third, there is a glaring need to improve access to healthcare, particularly in tropical countries. More than half of the world's population already lacked access to essential health services before the Covid-19 pandemic (WHO and WBG, 2017), which caused further financial disruption in many households (WHO and WBG, 2021). Often a familiar and relatively affordable option in many vulnerable regions, herbal medicine has been identified as key for improving healthcare access, particularly in developing countries (WHO, 2013; Patwardhan et al., 2023). Its promotion, if done in socially inclusive ways, can deliver much-due recognition to traditional knowledge while addressing the historical exclusion of vast segments of the population (Gebara et al., 2023).

Taken together, herbal medicine promotion may therefore offer a restorative bioeconomy pathway, one that not just maintains but enhances nature's contributions to people (NCPs), understood as benefits that humans enjoy from nature – particularly NCP 14, through “medicinal, biochemical and genetic resources” (Bastos Lima and Palme, 2022; IPBES, 2019). If promoted inclusively, it can also help redress the socioeconomic exclusion of historically marginalized communities such as Indigenous, Afro-Brazilian, or low-income rural peoples. Through such restorative justice, herbal medicine could then support a just transition to a bioeconomy (see Bastos Lima, 2022).

Nevertheless, understanding how herbal medicine promotion takes place in practice is paramount. Using Brazil and particularly the Amazon as a case study, our objective is to provide a reality check and identify bottlenecks, barriers, opportunities, and policy lessons. We first review the literature on herbal medicine's renaissance and its links to sustainable development. Then, we present our research methods and analyze the Brazilian case, before discussing the issue of herbal medicine promotion for a restorative bioeconomy more broadly.

## 2. The herbal medicine renaissance: Sustainable livelihoods for better healthcare?

Sustainable livelihoods have received growing attention both as an object of study and as an entry point for forest transitions, away from environmental degradation and towards sustainability (Ashraf et al., 2017; Ke et al., 2020; Radel et al., 2010; Serrat, 2017). They can be understood as those that produce goods or services to meet people's needs on the basis of local assets and capabilities without degrading their natural resource base (Serrat, 2017). Forests have traditionally provided many vital resources for those livelihoods, such as food, building materials, and a broad array of non-timber forest products including medicinal herbs (Angelsen et al., 2014; Rasmussen et al., 2017). However, livelihood options at forest frontiers are not always sustainable. Unsustainable practices such as poaching, illegal logging, and wildcat mining have been rampant in regions such as the Amazon (Pereira and Gebara, 2022; Siqueira-Gay and Sánchez, 2021). Many resort to such actions for lack of economic alternatives, which sometimes are limited to environmentally degrading practices (Russo Lopes and Bastos Lima, 2022).

As an economic alternative, herbal medicine production offers a promising avenue for sustainable livelihood promotion in forest regions. On the one hand, it has increasingly found a place within bioeconomy agendas to spur technological upgrading and address local poverty while supporting biodiversity and environmental conservation (Abramovay et al., 2021; Bastos Lima, 2022; Ollinaho and Kröger, 2023). On the

other hand, herbal medicine has experienced renewed interest as a way to address persistent gaps in healthcare access (see WHO and WBG, 2021). About 3.6 million people die every year in developing countries due to inadequate access to healthcare (Kruk et al., 2018). The Covid-19 pandemic, if anything, offered a somber reminder about widespread vulnerability and the need for better healthcare provision. Concurrently, the pandemic brought renewed interest in Amazonian ethnobotany and herbal medicine (Bussmann and Paniagua-Zambrana, 2022; Mafra et al., 2020).

The WHO defines herbal medicine as all care practices based on plant parts with therapeutic properties, such as leaves, flowers, fruits, seeds, roots, or barks (WHO, 2000). Historically, it has been the primary form of healthcare provision (Sendker and Sheridan, 2017). The dissemination of Western-style medicine and synthetic drugs made it lose some ground, while deforestation, forest degradation and societal changes have led to the steady loss of biodiversity and its associated traditional knowledge (Aswani et al., 2018). Nevertheless, most of the global population still depends on traditional forms of healthcare (WHO, 2019). Moreover, medicinal plants have provided the active principles of many synthetic drugs currently on the market (Leite et al., 2021; Mukherjee et al., 2022). For example, the bark of the *Cinchona officinalis* L. tree found in the Amazon rainforest was used to produce the world's first antimalarial drug (BBC, 2020; Cueva-Agila et al., 2019). Some argue that further research on plant-based active principles is vital in the race to develop new antiviral drugs (Gomes et al., 2022). Herbal medicine is also increasingly sought for treating mental health issues related to stress, depression, and anxiety (Faustino et al., 2010; Shahrajabian et al., 2021).

Herbal medicine may, therefore, help fill important gaps in healthcare access, understood as people's “opportunity or ease” to “use appropriate services in proportion to their needs” (Levesque et al., 2013, p.1). That depends on availability, accessibility, and social acceptability – all of which favor herbal medicine in many contexts (Gandhi et al., 2021). Its promotion can, therefore, aid in meeting multiple Sustainable Development Goals (SDGs) (Fig. 1) related not only to health but also to the protection of terrestrial biodiversity, climate change mitigation, and gender equity. In many contexts, women hold more medicinal plant knowledge than men (Aswani et al., 2018; Torres-Aviles et al., 2016). Even where men know more than women on the subject, women still hold unique knowledge on the specialized care for their needs and the needs of their children (e.g., on menopause symptoms, child delivery) (Albuquerque et al., 2011). In Brazil's case, women may have a particularly important role to play in filling family healthcare gaps as they predominantly are the main caregivers in the country's households (Da Costa et al., 2021; Voeks, 2007).

The growing recognition of herbal medicine's potential points to increased reliance on biodiversity for health. Such promotion can have multiple benefits, but the literature also has warnings and identifies several issues in need of attention. First, it is important to note that this is a closing window of opportunity. Tropical deforestation and forest degradation have severely threatened the biodiversity that underpins herbal medicine (Brandão et al., 2021; Ingram et al., 2017). Large-scale farming has also led to the neglect of many previously utilized plant species, often left behind despite their potential as food or herbal medicine crops (Mudau et al., 2022). As more biodiversity is lost and traditional knowledge dies out (Aswani et al., 2018), the potential for herbal medicine promotion is concomitantly being reduced.

Second, herbal medicine already links producers in biodiversity-rich countries of the tropics with advanced industrialized industries of the Global North, but often in poorly understood and usually uneven value chains (Heinrich, 2015). The economic potential for tropical developing countries has long been flagged (Van Andel et al., 2012), yet benefit-sharing has typically favored private pharmaceutical companies at the expense of local populations (CBD, 2011). Furthermore, plants that suddenly receive greater economic attention risk being suddenly over-exploited – as has happened to *Cinchona officinalis* L., now a threatened

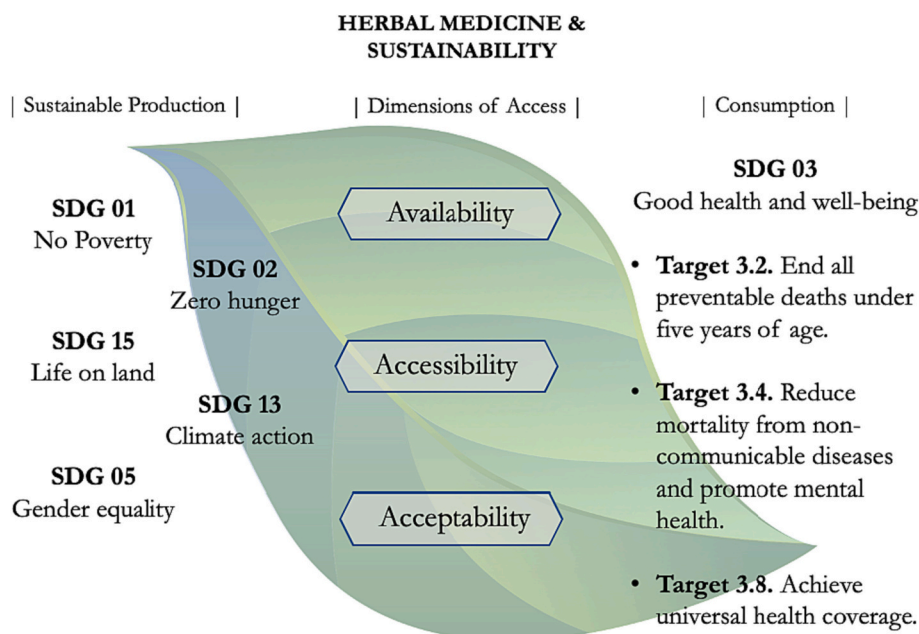


Fig. 1. A framework for improved access to herbal medicine and its related Sustainable Development Goals.

species due in part to unsustainable harvesting (Cueva-Agila et al., 2019). It is critical that herbal medicine production move beyond the currently typical extractive approach and be organized into inclusive and sustainable value chains (CBD, 2011). For that, some authors argue that climbing up to the value-added stages of production is essential, with some level of upgrading and vertical integration to benefit local producers and processors at the beginning of the value chain (Ndou et al., 2019; Shahidullah and Haque, 2010).

Third, herbal medicine is not a panacea, and much more research is needed on its efficacy and safety. Despite an increasing number of studies, there is limited scientific basis or standardization for the effectiveness of many herbal treatments, while traditional knowledge is often eroded or fragmented (Leite et al., 2021; Patwardhan et al., 2005). Furthermore, being natural does not mean that herbal medicine is harmless. As Lanini et al. (2012, p.21) put it plainly, “if herbs have an effect, they are also likely to have side effects.” Although complications from herbal medicines are relatively uncommon, they are most likely underreported and occur to a much larger extent than what is notified (Lanini et al., 2012). Scaling up herbal medicine therefore requires adequate sanitary surveillance and phytopharmacovigilance to enable the identification of risks (Mukherjee et al., 2022). Much remains to be known on both product and consumer factors such as dosage, variability of plant material, interactions with now-ubiquitous conventional drugs, etc. (Ferreira et al., 2014).

Fourth, while the upscaling of herbal medicine requires adequate regulations in place, its regulatory frameworks have typically been labyrinthine and inconsistent (Lensen et al., 2019). The same plant or product sometimes falls under distinct regulatory categories in different countries. For instance, the popular Chinese plant *Ginkgo biloba* was considered food in the UK until 2008 while being long categorized as medicine in Germany and as a food supplement in the US (Heinrich, 2015). Such confusion can exist even within the same country. In Brazil, herbal medicine products are haphazardly placed under various possible categories such as medicines, dietary supplements, or cosmetics, each requiring a distinct approval process (Lima and Gomes, 2014).

Lastly, the success of an herbal medicine product increases the risk that counterfeit or adulterated material enters the supply chain; therefore, quality controls are of paramount importance (Ichim and De Boer, 2021). Sometimes, incorrect species may be used and have unforeseen consequences (Kum et al., 2021). Mukherjee (2019) observes that

complete standardization may not be possible due to environmental and plant variability, yet ensuring some minimum quality is key. If its origin or cultivation conditions can change plant quality in important ways, some suggest they also open the way for geographical indication labeling and related value-added (Bi et al., 2020), with traceability technologies supporting quality assurance (Heinrich et al., 2019).

### 3. Research approach and methods

This qualitative study combines multiple data-collection methods to draw inferences. These methods include a literature review on herbal medicine promotion, particularly in Brazil, in addition to participant observations and key-informant interviews from two months of fieldwork in the country. The first two authors visited 10 local herbal medicine production initiatives in the Amazon (see Table 1 and Fig. 2) and conducted a total of 23 semi-structured interviews with Brazilian researchers, healthcare practitioners, members of civil society organizations, herbal medicine producers, and local entrepreneurs directly involved in those initiatives (see Table 2).

We initiated this research by contacting relevant stakeholders identified as “gatekeepers” in the northern states of Amazonas (AM) and Pará (PA), before using a snowball sampling technique for further interviews (Silverman, 2010). Interviewees were prompted to answer on what they identify as the main issues for herbal medicine promotion in Brazil and, particularly, in the Amazon. The interviews lasted for about an hour and were carried with the aid of local translators. Interviews were generally not recorded, as the participants felt more comfortable this way. Direct quotations from notes taken on site are sometimes used to portray issues in the stakeholders' own voices but preserving their anonymity. Besides the interviews, numerous informal conversations were held with the general public in the Brazilian Amazon as part of our participant observations to help understand the local context (Silverman, 2010).

### 4. Herbal medicine in Brazil: a literature and policy review

#### 4.1. The Brazilian context and policy framework

Brazil is a megadiverse and culturally rich country with well-rooted traditional knowledge on herbal medicine. That comes chiefly from its more than 300 Indigenous Peoples, though also from Europeans and

**Table 1**  
Ten different herbal medicine production initiatives visited in Brazil.

	Description	Location
Initiative A	Private company manufacturing and selling native plant-based cosmetics (e.g., moisturizers, oils, massage creams) in local drugstores, shops, and online. It both cultivates and buys the raw materials. Strict Anvisa regulations led the company to stop producing industrialized herbal medicines as such after 2014.	Manaus (AM)
Initiative B	Start-up company dedicated to “sustainable cosmetic products with high natural content,” including oils, creams, and shampoos. Local communities and agroforestry cooperatives supply the raw materials for products sold via social media, with growing demand. No herbal medicine production license, due to the high costs.	Manaus (AM)
Initiative C	NGO-led initiative sourcing plants from local communities to make vegetable oils used as cosmetics or medicine. To find buyers and increase transparency, they have developed an app where one can retrieve information about the cultivation and extraction process and order such oils online.	Manaus (AM)
Initiative D	Company selling herbal medicine marketed as dietary supplements with ingredients sourced from industrial suppliers in São Paulo, where they go through quality control and standardization. There are plans to build a local lab and compound pharmacy, but the founder reports struggling to find skilled professionals for that.	Santarém (PA)
Initiative E	Individual initiative from a local expert in Amazonian medicinal plants producing essential oils artisanally. He hopes to expand to herbal medicine, but an attempt to create a team to work with various local communities to systematize their knowledge with government support derailed as such support failed to materialize.	Manaus (AM)
Initiative F	A Living Pharmacy model III project to produce Anvisa-approved herbal medicine by a group of actors including a municipal government and a university. Still at an initial stage assembling technical knowledge on cultivation techniques, post-harvest (e.g., washing, separation, selection), and processing (e.g., dehydration).	Manaus (AM)
Initiative G	Church-based initiative with local communities to produce anti-stress herbal medicine based on passion fruit ( <i>Passiflora edulis</i> ). A European church organization finances it as government funding has failed to materialize. The communities retain the fruits while the leaves are processed into extract capsules at a local university.	Santarém (PA)
Initiative H	A private compound pharmacy producing both synthetic drugs and herbal medicine, though only 10% of the plant material used is Brazilian. It has Anvisa approvals and a pharmacist does additional quality control. The herbal material is manipulated into creams, lotions, and capsules that patients can order with a medical prescription.	São Paulo (SP)
Initiative I	A company that emerged out of a Catholic Church initiative and sells therapeutic herbal products regulated as food or as dietary supplements. It utilizes local traditional knowledge to produce tinctures and herbal concoctions (e.g., with anti-inflammatory properties), giving oral instructions on how to use them.	Manaus (AM)
Initiative J	An Indigenous cooperative selling herbal medicine in the city and providing it freely in rural areas. Plant material sourced by boat from communities deeper in the forest, while nearer ones manufacture herbal products assisted by public universities. It offers tinctures and bottled concoctions with native plants such as cat's claw ( <i>Uncaria tomentosa</i> ), copaiba ( <i>Copaifera langsdorffii</i> ), and andiroba ( <i>Carapa guianensis</i> ).	Manaus (AM)

Africans that together compose the country's cultural mix (Leite et al., 2021). Until the creation of Brazil's universal and free-of-cost Unified Health System (*Sistema Único de Saúde* – SUS) in 1988, healthcare access depended on social security linked to formal employment or on charity hospitals from the Catholic Church, often limited to larger cities (Abdala and Sena, 2020). Self-medication using traditional knowledge and plants has therefore been predominant, especially in rural areas (Leite et al., 2021). Still to this day, despite the existence of SUS, herbal medicine remains important. That is particularly the case in Brazil's countryside and regions more strongly influenced by Indigenous cultures, such as the Amazon, where economic and geographic challenges also hinder access to formal healthcare.

Although informal or customary uses remain dominant, there has been an effort to formalize, regulate, and thus promote the herbal medicine sector. In 2006 Brazil launched a National Policy on Integrative and Complementary Practices and a National Policy on Medicinal Plants and Phytotherapies as a framework (Brazil, 2006a; Brazil, 2006b). They define herbal medicines as all products with preventive, curative, or palliative functions and whose active pharmaceutical ingredients originate from a plant – except for highly purified or isolated substances (Brazil, 2013). In 2009 the government then created a National List of Medicinal Plants of Interest for SUS (RENISUS) to identify promising species (Brazil, 2009). That works as a stepping-stone for eventual insertion in the National List of Essential Medicines (RENAME), which compiles substances approved for legal use and distribution through the public healthcare system.

All formal approval comes from Brazil's Health Regulatory Agency (*Agência Nacional de Vigilância Sanitária* – Anvisa), which categorizes licensed plant-based products into two groups: herbal medicines and traditional phytotherapeutic products. The former are standardized substances that have been proven safe and effective through clinical studies, while the latter include various herbal products traditionally used for at least 30 years and documented in a so-called pharmacopoeia, i.e., a technical compendium with plants' therapeutic qualities and uses (Brazil, 2015). As of 2022, 85 species and 236 formulations (e.g., herbal oils, dry extracts, infusions) were described in Anvisa's Phytotherapy Compendium of the Brazilian Pharmacopoeia (Anvisa, 2021).

Still, only a small portion of Brazil's traditionally used plant diversity has been studied, and the formal approval of herbal medicines remains scant (Lopes et al., 2018). Carvalho et al. (2018) estimated that only about 8% of Brazil's flora has been researched and documented, leaving out many plants traditionally used. As of 2022 merely 71 plant species had made it into RENISUS, and of these only 12 were present in RENAME as licensed herbal medicines (Brazil, 2009; Brazil, 2022). Moreover, most of these few industrialized herbal medicines are based on exotic plant species. Only three of those 12 species are native to Brazil: guaco (*Mikania glomerata*), espinheira-santa (*Monteverdia ilicifolia*), and cat's claw (*Uncaria tomentosa*) (Silva et al., 2022). The country's formal herbal medicine sector thus relies heavily on research done elsewhere on those foreign species, which often are not even grown in Brazil but imported (Lopes et al., 2018; Leite et al., 2021).

#### 4.2. Equity, livelihoods, and the Living Pharmacy program

One key program created as an outcome of Brazil's herbal medicine policies is called Living Pharmacy (*Farmácia Viva*) (Brazil, 2010). Its origins date back to the 1980s in the works of Professor Francisco Matos at the Federal University of Ceará, where he undertook a project to set up medicinal plant cultivation in local communities (Leite et al., 2021). He conducted countless field expeditions in Ceará State to visit rural settlements, collect plant species, and compile information on their therapeutic qualities and uses (Ramos, 2017). His aim was two-fold: to set up an exchange between traditional and scientific knowledge, linking communities and universities; and to create spaces where the production and use of herbal medicine could be democratized. The latter goal would be accomplished through the establishment of community-



Fig. 2. Brazilian biomes and the cities visited for fieldwork in the Amazon and in Brazil's (wealthier Southeast), in addition to the country's capital, Brasília.

run medicinal plant gardens with workshops where herbs could be processed. In other words, those places would become “living pharmacies” to help improve communities' healthcare access. Meanwhile, they would help secure income through a sustainable livelihood to help address local poverty (Matos, 2006).

The living pharmacy concept was first taken up by the state-level government of Ceará in 1999, before being institutionalized at the national level in 2010. The idea has been to operationalize government procurement of traditional herbal products and provide them free-of-cost in SUS' public healthcare units (Brazil, 2010; Ramos, 2017). The focus is chiefly on plants recognized in the RENAME list, followed by those used traditionally and present in RENISUS. Besides the government purchases, the communities growing medicinal herbs can also receive assistance in the form of knowledge from the Brazilian Pharmacopoeia compendium. Table 3 details the three models or stages foreseen by the Living Pharmacy program.

To ensure safe herbal medicine production, Anvisa created a regulatory framework with strict requirements for cleanliness and standardization in approved living pharmacies (Brazil, 2013). It is a long and detailed legal piece with 171 articles covering everything from the management of resources to what the employees ought to be wearing (Ramos, 2017). Such heavily regulated requirements have meant much higher upfront investment costs than in Professor Matos's original idea, which envisaged something much simpler and – in principle – easy to implement in every community. His vision was of decentralized operational units that the federal government and SUS could enable across the country, without such heavy control (Matos, 2006).

Given those requirements, Brazil's Ministry of Health has set up funds for states or municipalities wishing to implement the Living Pharmacy program locally. Between 2012 and 2022 a total of 147 projects received financial support corresponding to a total of nearly EUR 13 million (BRL 68 million) (Brazil, 2023b). However, because local governments need to apply for such support and to already present then a well-designed project, there have been significant regional imbalances (Ferreira et al., 2017). Most funds have flown to richer municipalities in Brazil's South and Southeast Regions, while highly biodiverse but economically vulnerable regions such as the Amazon have continued to lack adequate support (Caccia-Bava et al., 2017; Gondim et al., 2022).

Furthermore, hardly any of the private companies licensed to produce approved herbal medicines are in the Amazon. In a survey, Carvalho et al. (2018) identified 77 companies holding such production licenses in Brazil. Most were from the country's (richest) Southeast Region, 32 from São Paulo State alone, and none were in Amazonian states. Moreover, the number of companies producing approved herbal medicines has been declining, with 41 leaving the business between 2010 and 2018 as large enterprises become dominant in an increasingly consolidated market (Carvalho et al., 2018). Many companies have instead chosen to market their herbal products as cosmetics or as food supplements, all of which go through simpler regulatory requirements (Linsen et al., 2019).

**Table 2**  
List of stakeholders interviewed.

Number	Area	Role	Related to initiative
1	Cosmetics	Herbal cosmetics producer	Initiative A
2	Cosmetics	Herbal cosmetics producer	Initiative B
3	Forest management	NGO representative	Initiative C
4	Herbal medicine	Herbal medicine retailer	Initiative D
5	Herbal medicine	Herbal medicine expert	Initiative E
6	Herbal medicine	Living Pharmacy coordinator	Initiative F
7	Herbal medicine	Living Pharmacy coordinator	Initiative G
8	Pharmacy	Compound pharmacy coordinator	Initiative H
9	Healthcare	Herbal medicine provider	Initiative I
10	Healthcare	Herbal medicine provider (Indigenous peoples cooperative)	Initiative J
11	Healthcare	Medical doctor	
12	Healthcare	Medical doctor	
13	Local university	Researcher	
14	Local university	Researcher	
15	Local university	Researcher	
16	Local university	Researcher	
17	Local university	Researcher	
18	Local university	Researcher	
19	Local university	Local university student	
20	Local university	Local university student	
21	Forest management	NGO representative	
22	Local university	Researcher	
23	Local university	Researcher	

**Table 3**  
The three different stages (or “models”) of a living pharmacy in Brazil.

Living Pharmacy stages	Description
Model I	Medicinal plant gardens to provide fresh supplies <i>in natura</i> to the local population, under the supervision of trained professionals who also teach about simple uses and homemade herbal medicines.
Model II	Facilities that include the production and dispensing of dried medicinal plants, processed according to best-practice guidelines and supplied to public healthcare units.
Model III	Full-fledged facilities that produce standardized herbal medicines under specific guidelines and with quality control for public healthcare units. These facilities may or may not include also the practices under Models I and II.

Source: Brazil (2012) and Ramos (2017).

## 5. A reality check on herbal medicine in Brazil and the Amazon

### 5.1. Overview of herbal medicine availability, accessibility, and acceptability

In Brazil, herbal medicine products are broadly referred to as phytotherapies (*fitoterápicos*), and they can be accessed in multiple forms. There is a steady process of formalization thanks to the country's policies of the past 20 years. In 2004 herbal medicines were formally accessible in public healthcare units only in 116 municipalities, a number that grew to 346 municipalities in 2008, 815 in 2012, and 1108 in 2017 (Brazil, 2023c, 2006b; Ribeiro, 2019). However, as much as 90% of all plant-based medicine purchasing in Brazil happens informally and without any medical prescription (Manderson et al., 2018). Such products – bearing all sorts of claims or none at all – are widely available in street markets, drugstores, food shops, and on the internet, besides being accessible (with a prescription) in compound pharmacies and SUS healthcare units. Moreover, many people cultivate medicinal plants

themselves in gardens or backyards to prepare homemade remedies, which are also shared in informal networks. Fig. 3 provides a synthesis of the various forms herbal medicine can be accessed in Brazil.

Herbal medicine availability differs radically depending on where one is in Brazil. In the Amazon region, they are ubiquitous in local markets where myriad plants with (alleged) curative properties can be easily bought fresh or dry. In addition, one finds a variety of minimally processed goods such as oil extracts, herbal syrups, and creams. Most such products are sold with little to no information regarding origin or (counter)indications on use. Some interviewees in the Brazilian Amazon were quick to point out, however, that locals generally have some knowledge of herbal medicine transmitted through the family and checked socially with peers – though drawbacks from inadequate use do exist (Interviews 19 and 20). Most of these products are, therefore, sold unregulated or regulated as food. Drugstores in the Amazon region commonly have a dedicated herbal medicine shelf named *Fitoterápicos*, even though many of those are technically licensed as cosmetics or food supplements.

Brazil's more urban, southern regions are different in this regard. There, it is significantly harder to find herbal products from Amazonian plants. Pharmacies generally do not have a *Fitoterápicos* shelf, and the staff may have little understanding about what kind of products they would be. That said, the concept of compound pharmacy is well recognized across the country and the interviewees argued that natural products have enjoyed increasing social appeal. Still, other interviewees in Brazil's southern regions contended that it is difficult to acquire knowledge on medicinal plants and pointed to skepticism about using products that are not proven safe and effective.

### 5.2. Herbal medicine production initiatives

Herbal medicine production in Brazil takes place in multiple ways. Table 1 offered a palette of ten different experiences we visited (chiefly in the Amazon) and which illustrate their contrasts as well as some of the challenges they commonly face.

Interviews with the people behind those initiatives and other key informants revealed general enthusiasm for herbal medicine promotion but also sobriety regarding its challenges. On the one hand, motivation appears to have grown under a bioeconomy agenda for the Amazon (Abramovay et al., 2021; Bastos Lima and Palme, 2022). Likewise, interviewees pointed to a growing demand for herbal medicines since the Covid-19 pandemic to relieve flu-like symptoms or stress-related issues (see also Mafra et al., 2020). Some highlighted the importance of preserving and rescuing traditional knowledge on medicinal plants (Interviews 5, 13; Eddouks et al., 2012; Kim and Oh, 2012). Interviewee 3, an NGO representative, communicated the growing excitement about the increasingly recognized economic potentials from Amazonian biodiversity: “*The most valuable [thing] we have here in Amazonas [State] is the bioeconomy, due to its extraordinary diversity.*” On the other hand, there was relative consensus that herbal medicine value chains are complex and that their promotion still faces numerous barriers (Interviews 1, 2, 4–8, 18, 19).

### 5.3. Challenges for herbal medicine promotion in the Amazon

#### 5.3.1. Biodiversity vs. capacity mismatch and logistical difficulties

The first key challenge for establishing herbal medicine value chains in the Brazilian Amazon is a mismatch between where the plants and the financial wealth are. Most of Brazil's consumer market, processing capacity, and investors are in the richer South or Southeast Regions, far from the Amazonian states (Simonetti and Pereira, 2021). Our interviews (1, 2, 3, 18) corroborated the observation that a few large companies from the more industrialized south dominate the herbal medicine market (Carvalho et al., 2018; Lopes et al., 2018; Ribeiro, 2019). Some stakeholders also noted a lack of laboratories in the Amazon region, a shortage of qualified suppliers, and often the need for

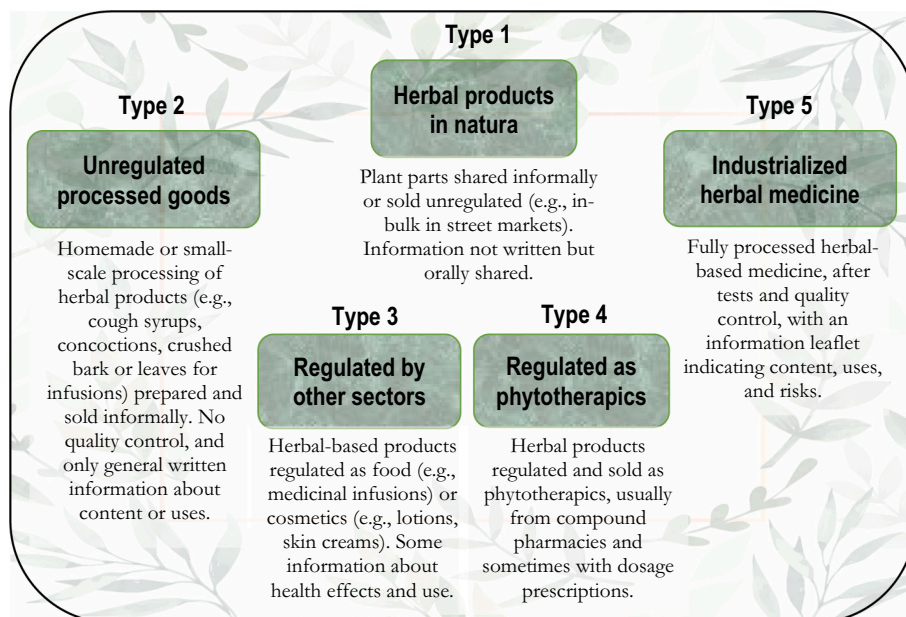


Fig. 3. Brazil's herbal medicine market. (Authors' own elaboration based on Corazza, 2021).

plant material to be transported 2000 Km to the Southeast for quality assurance and then back (Interviews 1 and 2). Interviewee 6, a living pharmacy coordinator in Manaus (AM), stressed this challenge: “*There is no infrastructure up here in the North, resulting in limited interest in investing in such facilities.*” Conversely, for southern companies it becomes much simpler and cheaper to source plant material from elsewhere. This underscores the neglect so far observed about Amazonian biodiversity in Brazil's pharmacopoeia and the country's fledgling herbal medicines industry. A local producer of herbal goods sold as cosmetics in Manaus observed that “*there are no real herbal medicines to be found in the [Amazon] region*”, in spite of its much-lauded potential (Interview 1).

Representatives of several initiatives (A, B, C, D, E) highlighted the importance of bridging the gap between Brazil's national interest in having a strong herbal medicine sector and local sustainable development promotion. A local NGO representative stressed that creating such economic opportunities through value-chain inclusion is key for preventing smallholders from abandoning the land (Interview 3). Initiatives E, G and I have accomplished such an inclusion, yet their representatives highlighted the accessibility challenges across the Amazon's immense physical distances. Commuting on its rivers can take several days, while during the dry season some communities cannot be reached at all by boat and become practically isolated (Interviews 2 and 3; see also Russo Lopes and Bastos Lima, 2022). These difficulties add to issues observed in the literature about losses of collected plant material exposed to heat, humidity, or being transported under poor hygiene conditions (Simonetti and Pereira, 2021).

### 5.3.2. Insufficient documentation and R&D gaps

Although up until the 1940s Brazil followed the growth of the international pharmaceutical industry, insufficient research and development (R&D) has turned the country into a laggard in this field despite its biodiversity wealth (CGEE, 2017). This is acknowledged as a key shortcoming in the development of an herbal medicine sector based on active plant ingredients from native species (Carvalho et al., 2018; Leite et al., 2021). For instance, even widely used native species such as copaiba (*Copaifera langsdorffii*) and andiroba (*Carapa guianensis*), which have therapeutic properties already noted in the literature (Silva et al., 2021; Soares et al., 2021), remain absent from Anvisa's Phytotherapy Compendium of the Brazilian Pharmacopoeia (see Anvisa, 2021).

Local researchers at Brazilian universities in the Amazon region argued that a lack of monographs or systematic studies has prevented

many native species from being taken up in formal herbal medicine production, leaving them to be inadequately marketed as cosmetics (Interviews 13, 14, 15, 16). One local researcher argued that “*the first step is [having] ethnobiology teach us about the plant's characteristics, resulting in the creation of monographs and eventually safe and efficient herbal medicines*” (Interview 14). Others pointed to a wealth of traditional knowledge on native species that remains neglected by scientists and by the health authorities (Interviews 2, 5, 21, 22). The literature indeed notes that far more species and traditional treatments could be going through clinical trials in Brazil (Carvalho et al., 2018; Leite et al., 2021). A local producer in Manaus contended that such a neglected traditional knowledge base is critical not just for understanding native plants' phytotherapeutic properties but also how to harvest and use them sustainably: “*It is only the traditional knowledge that can tell us how to preserve the forest and make sure that the cultivation and collection are done in a sustainable way*” (Interview 5).

Another challenge is plant-material variability, which has hindered standardization (Simonetti and Pereira, 2021). Besides genetic variability, geographic location, altitude, differences in temperature, rainfall, humidity, sunlight exposure, and soil quality all can alter a plant and its active principles (Hasenclever et al., 2017). For instance, one producer in Manaus claimed that their initiative utilizes cat's claw (*Uncaria tomentosa*) sourced from Peru because its therapeutic properties are more effective than those of the plants found in Brazil (Interview 4). Furthermore, a local researcher noted how the same species can go by different names in different regions, creating additional uncertainty and possible variability that would need to be captured in a national database (Interview 17). Finally, foundational studies not only on safety and efficacy but also on pharmacological interactions remain missing in Brazil (Ferreira et al., 2014).

### 5.3.3. Regulatory barriers without converse support

Brazil's increasingly stringent herbal medicine regulations may have helped improve their safety, reliability, and international harmonization in the past few years (Carvalho et al., 2018). However, several interviewees argued that stringency has come without converse support to assist small and medium enterprises in meeting the requirements. Consequently, many Amazonian producers remain excluded and fail to benefit from government procurement for the public healthcare system. For instance, one local producer told us their company quit formal herbal medicine production in 2010 but maintained the exact same

practices and now market their goods as “herbal cosmetics” instead (Interview 1).

Interviewees noted that regulations have become harder to follow, more complex to understand, and increasingly expensive to comply with (Interviews 1–5). Many producers in the Amazon have either eschewed herbal medicine registration to market their products as cosmetics or food, or abandoned formal registration altogether, which helps explain the persistence of a huge unregulated market with products that lack even an ingredient list. In other words, ongoing or prospective producers have felt alienated by strict regulations without converse support. A local cosmetics producer suggested that meeting the requirements for an herbal medicines license would require over BRL 50,000 (nearly EUR 10,000) upfront (Interview 2). Others were critical of Anvisa's exclusive focus on control while not being supportive. A local entrepreneur complained that “*they only show up to tell me I am doing it wrong*” (Interview 1). A compound pharmacy coordinator, likewise, resented not only the “demotivating” regulations but also their implementation: “*It is not like they come here to evaluate and teach us what can be improved. They want us to fail since it means they can give us a fine*” (Interview 8). Others blamed the pharmaceutical industry as the beneficiaries of rules that virtually exclude all producers but larger companies with the capacity to comply (Interviews 4 and 5).

In this context, interviewees generally acknowledged the importance of the Living Pharmacy program to enhance inclusiveness. Some emphasized how the program is critical for improving poor people's access to herbal medicine (Interviews 4, 6, 7; see [Pereira et al., 2015](#)). Still, organizational capacity remains wanting (Interviews 6 and 7). A local living pharmacy coordinator admitted lack of capacity for meeting even the first-level requirements: “*People do not even know how to do Model I, how are they supposed to know how to do Model III?*” (Interview 6). Most licensed living pharmacies supplying SUS units indeed are elsewhere in Brazil and do not use Amazonian plants ([Ramos, 2017](#); [Gondim et al., 2022](#)). In the Amazon, as [Ramos \(2017\)](#) and our interviewees noted, the “living pharmacy” label ends up being used inconsistently to characterize all sorts of local production arrangements that follow the basic concept. They, however, neither comply with the regulations nor receive government benefits for integration into the public healthcare system (Interviews 6, 7, 12).

#### 5.3.4. Uneven social acceptability and cultural prejudice

Despite the widespread dissemination of herbal medicine in Brazil, lack of knowledge and limited social acceptance still are important barriers. Some interviewees observed that Brazilian society displays growing interest in herbal medicine and natural treatments overall, especially among the urban middle class, but that these consumers generally lack knowledge or even awareness of native species and their uses (Interviews 3, 12, 13, 18). Indeed, only a few Amazonian species experience nationwide commercialization, such as açai (*Euterpe oleracea*) and Brazil nut (*Bertholletia excelsa*).

Two interrelated issues stand out in this regard. First, while some authors flag herbal medicine's wide social acceptability in contexts of longstanding common traditions (see [Gandhi et al., 2021](#)), in a racially diverse and multicultural society such as Brazil's, people in whiter and more urbanized regions sometimes negatively associate herbal treatments to Indigenous religious practices, Afro-Brazilian traditions, or faith healing ([Rosa et al., 2011](#)). To be sure, much of Brazil's traditional medicine indeed is historically linked to either Indigenous or Afro-Brazilian spiritual practices ([Eckel, 2020](#); [Maciel and Guarim Neto, 2006](#)), and that creates a double conundrum. On the one hand, some authors have critiqued the formal integration of traditional herbal medicine into the healthcare system (“cleansed” of its cultural or spiritual connotations) as a form of cultural appropriation and commodification – perhaps most notorious in the recent global diffusion of Amazonian ayahuasca ([Labate and Cavnar, 2019](#); [Tupper, 2009](#)). On the other hand, people who eschew such associations out of fear, unfamiliarity, or outright prejudice have also hindered a wider promotion of

herbal medicine in Brazil (Interviews 3, 11, 12; [Rosa et al., 2011](#)). A local NGO representative argued that people from Manaus itself – in the heart of the Brazilian Amazon – often wish to feel more urban, modern, and avoid association with the Indigenous culture prevalent in the region (Interview 3).

The second issue has to do with the training of medical doctors and other healthcare professionals. An absence of mandatory courses on herbal medicine in university curricula has long been noted as conspicuous in Brazil ([Santos et al., 2011](#); [Varela and de Azevedo, 2014](#)). [Rosa et al. \(2011\)](#) noted that Brazilian doctors fear prescribing something that is not “evidence-based.” A survey in Manaus found that despite the scientific evidence on herbal medicaments to address some Covid-19 symptoms or stress-related issues (e.g., anxiety, insomnia), only 2% of the patients said they had received any such information from a doctor ([Mafra et al., 2020](#)). [Mattos et al. \(2018\)](#) found that many Brazilian health professionals believe in the therapeutic effects of herbal medicine but do not work with it. Two medical doctors we interviewed noted they occasionally prescribe a few herbal medicines (e.g., anti-inflammatory creams or passion fruit-based medicaments against insomnia), yet they confirmed that they lacked mandatory courses related to herbal medicine in medical school, that the subject was only covered in elective courses, and that patients usually were the ones occasionally requesting such “alternative” treatments (Interviews 11 and 12).

The lack of involvement of healthcare professionals in turn creates another conundrum. On the one hand, many people self-medicate, believing herbal medicine to be harmless for being natural (Interview 6; [Costa et al., 2012](#)). As the medical establishment and, thus, the healthcare system distance themselves from it, people – often without adequate traditional knowledge either – are left at risk experimenting on their own. On the other hand, many patients are suspicious of herbal medicines' safety and effectiveness unless they are formally approved, distributed through SUS, and sanctioned by a medical doctor (Interview 16). For instance, a compound pharmacist interviewed in Manaus mocked that “*people in Amazonas [State] believe in bottled concoctions [garrafadas]*” (Interview 8).

The healthcare system has a clear legitimization role to play if herbal medicine is to be more widely promoted. [Haraguchi et al. \(2020\)](#) have found a positive correlation between the training of healthcare professionals in herbal medicine and their prescription of it in Brazil. Likewise, our interviewees broadly pointed to education – both for medical doctors and the public – as an important and still overlooked part of the puzzle (Interviews 6, 11, 12, 16). As a local university researcher noted: “*Doctors almost never prescribe herbal medicines, given that they are not 100% sure where the plants originate from and how they have been produced. Doctors only recommend herbal medicines if they trust it.*” (Interview 13). Therefore, traditional knowledge alone will not be sufficient for promoting herbal medicine more widely in Brazilian society and through its public health system.

## 6. Discussion: herbal medicine for a restorative bioeconomy

Our results expose multiple shortcomings in Brazil's attempt to promote herbal medicine for bioeconomy development and improved healthcare access. An analysis of who has benefitted from enhanced nature's contributions to people through herbal medicine promotion (NCP 14 - Medicinal, biochemical and genetic resources) shows that, to date, it has been mostly private companies from outside the Amazon and patients in wealthier Brazilian municipalities – or abroad – now enjoying better access to phytotherapies. The needs of patients in more vulnerable regions, in turn, remain unaddressed. Moreover, the growing institutionalization of herbal medicine has neglected smallholder and traditional producers, their knowledge, and the country's very own native biodiversity in favor of exotic plants. Those producers have been further excluded in an increasingly formalized market under a policy framework that imposes regulatory stringency without converse support for

productive inclusion (see [Medina and Barbosa, 2023](#)).

Anvisa's regulatory arm is the only face of the state that producers have seen, showing that policies have failed to take vulnerable stakeholders' realities into account. The present context also reveals a failure to think strategically about herbal medicine promotion as a form of economic development – beyond its health dimension. The Living Pharmacy program, while potentially inclusive, has emerged mostly in better-off and more urbanized regions of the country. It has, thus, fallen short of its potential to uplift poor producers or communities in deforestation frontiers who are regularly evicted or bought out because they lack the economic means to remain on the land ([Campbell, 2015](#); [Bastos Lima and Kmoch, 2021](#)). Those who anyway attempt to produce herbal medicines are either left to their own devices or to be supported by NGOs or charities. They may mimic the Living Pharmacy concept but without regulatory oversight, access to public funds, or integration into SUS.

It has not been uncommon for the bioeconomy to be promoted with euphoria about potentials that frequently fail to materialize, sometimes worsening social exclusion ([Bastos Lima, 2021](#)). In the Brazilian Amazon, [Ollinaho and Kröger \(2023\)](#) note that the concept hides a key tension between a conventional, purely extractive agenda and one of inclusive “sociobiodiverse” economies. A restorative bioeconomy requires that elements of restorative justice – redressing historical marginalization – be present alongside an increase in nature's contributions to people, notably to hitherto excluded social groups ([Bastos Lima, 2022](#); [Bastos Lima and Palme, 2022](#)). Otherwise, herbal medicine risks lending its “traditional” aura to systems that in reality are socially exclusive (see [Ollinaho and Kröger, 2021](#), for similar dynamics in the case of agroforestry). Here, we show that the potential for advancing a restorative bioeconomy through herbal medicine promotion does exist but remains unmet. Instead, there remains the risk that traditional botanical knowledge may be captured into herbal medicine production and consumption systems that presently are not tuned to benefit local Amazonian populations – knowledge appropriation that could aggravate instead redress historical injustices ([Gebara et al., 2023](#)).

As things stand, deforestation and forest degradation also remain unchecked. Strengthening sustainable livelihoods as an alternative to deforestation-based economies is critical to complement command-and-control public regulations or sustainable supply chain policies ([Londres et al., 2023](#); [Russo Lopes and Bastos Lima, 2022](#); [Trancoso, 2021](#)). However, to play that role herbal medicine promotion has to consider much more seriously the needs related to value chain development in addition to the dimension of healthcare access. That requires (1) further R&D on native Brazilian biodiversity, (2) local capacity enhancement in the Amazon, (3) policies that foster the economic inclusion of marginalized actors, (4) technical and financial support for value-added that meets the regulatory requirements, and (5) the creation of an interested market – which in the case of herbal medicine involves addressing fears, social prejudices, and medical-cultural issues. Here Anvisa and SUS have critical roles to play in further legitimizing and increasing access to it.

We argue that only then herbal medicine will thrive as a type of place-based initiative for local economic development in the Amazon (see [Brondizio et al., 2021](#)), where geographical indication labeling could support value-added. Yet, such steps that go beyond the usual foray of traditional medicine in terms of scale or technical requisites can be expensive. Meeting phytopharmacovigilance requirements, too, has proven hard for all the local producers we encountered. Transitioning producer associations into cooperatives has been instrumental, and supporting organizational capacity is likely to remain a key policy goal, but industrialization policy also has a clear role to play if herbal medicine is to be nationally distributed or eventually sold abroad as high-value exports. Collaborative arrangements with private businesses may become valuable, provided they are done under participatory and equitable terms ([Futemma et al., 2020](#)). Production systems where locals play a leading role – rather than being subjected to paternalistic terms by external actors – have been promising in the Amazon ([da Silva Medina et al., 2022](#)), and that is particularly critical in the case of herbal

medicine to avoid biopiracy.

Herbal medicine promotion faces a closing window of opportunity as deforestation and forest degradation advance, biodiversity is lost, and traditional knowledge disappears. The recently created WHO Global Centre for Traditional Medicine and the first high-level global summit on traditional medicine (alongside the G20 health ministers meeting in 2023) suggest growing interest in the subject. Engaging – and enabling – Indigenous peoples and other local communities in this context will be critical for redressing historical injustices and, thus, fostering restorative bioeconomic development. Some Indigenous people may have chosen to remain isolated, but most have instead been neglected (see [Bastos Lima and Kmoch, 2021](#); [Indigenous Peoples Rights International, 2021](#)). The creation of a Ministry of Indigenous Peoples in 2023 – led by an Indigenous woman – under President Lula's administration crowns ascending Indigenous and forest peoples' advocacy in Brazil. Still, the fulfillment of their wishes for further social recognition and participation in the country's economy remains pending. Crucially, the ministry has a key role to play in facilitating the interface between Indigenous knowledge and Brazil's state-led effort to integrate herbal medicine more broadly in society, the public healthcare system, and the country's economy. How to effectively devise and promote economic activities led by, and to the benefit of, such local communities through herbal medicine promotion (or other related bio-based sectors) remains a critical research frontier.

## 7. Conclusion

Herbal medicine promotion stands out as a key route for improving healthcare access and supporting sustainable livelihoods in tropical forest regions. It offers an alternative to expensive – and often unaffordable – synthetic drugs as well to unsustainable land-use practices that usually present themselves as the most economically appealing livelihood options in forest frontiers. However, although herbal medicine has attracted growing interest in the wake of the Covid-19 pandemic, our reality check on the Brazilian Amazon case makes clear that such potentials do not materialize spontaneously.

Our conclusions are three-fold. First, herbal medicine promotion still falls far short of its potential to advance a restorative bioeconomy. In Brazil's case, vulnerable stakeholders who stand to benefit the most remain excluded from value chains, while wealthier actors outside the Amazon have dominated both the emerging production and consumption of herbal medicines. They are the ones who have enjoyed enhanced nature's contributions to people from medicinal, biochemical and genetic resources (NCP 14), either as patients or as entrepreneurs. Exclusionary patterns have, thus, remained unaddressed and even deepened. Second, Brazil's regulatory framework for herbal medicine promotion remains dysfunctional. While stringent requirements may be justified, in practice they are skirted around as products are sold informally or regulated by other markets. Meanwhile, most of those who want to produce herbal medicines as such find it nearly impossible to do so, as the exigencies are significant and little to no support is offered for meeting them. Third, the social acceptability of herbal medicine cannot be taken for granted. Our analysis of Brazil's case shows how there may be skepticism in societies where not everyone is immersed in the same traditional culture, and it illustrates how racial or cultural discrimination can create additional resistance.

This work contributes to an emerging literature on a restorative bioeconomy. It makes it evident that more investments in inclusive value-chain development and adequate capacity building are essential if herbal medicine is to thrive in Brazil. Further research and development are needed not only on the potentials of the Amazon's traditional knowledge and biodiversity, but also on how producer cooperatives and collaborative arrangements with external actors could foster local sustainable development. Moreover, on the consumption side, education on herbal medicine and the training of health professionals can go a long way in ensuring uptake and demand for these products. If done equitably, with attention to gender inclusion and due support for historically

marginalized communities, herbal medicine offers one of the most promising avenues for restorative bioeconomy, but much work remains to be done.

### CRedit authorship contribution statement

**Klara Lindberg:** Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Investigation, Funding acquisition. **Amanda Martvall:** Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Investigation, Funding acquisition. **Mairon G. Bastos Lima:** Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision. **Caroline S.S. Franca:** Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data availability

The data that has been used contains sensitive information and is otherwise confidential, nonetheless authors remain available to respond to data inquiries.

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