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REVIEW ARTICLE

Factors affecting long-term availability of medicinal plants in India

Preet Amol Singh[1] · **Subhransu Dash**[1] · **Abinash Choudhury**[1] · **Neha Bajwa**[1]

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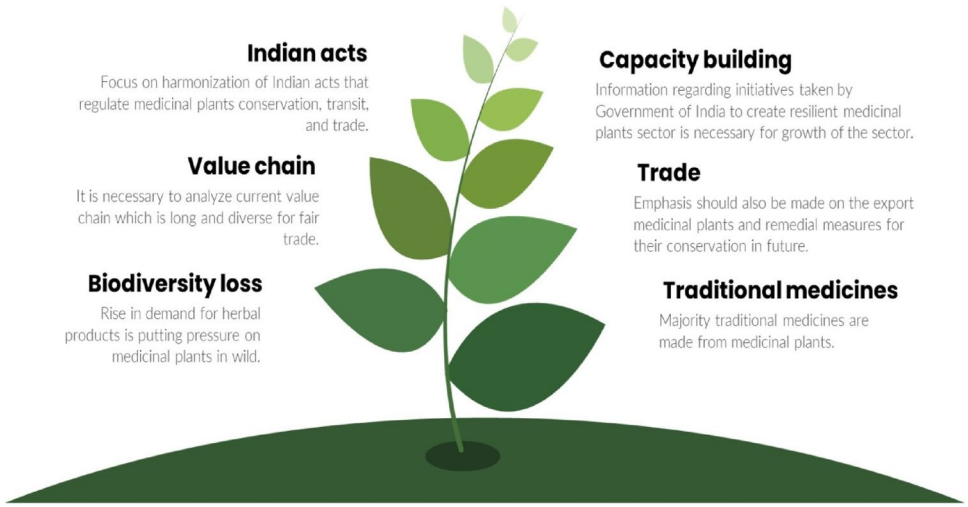
Abstract

The majority of conventional medications and food supplements are created following the processing of medicinal plants. As majority of the medicinal plants are collected from the forests, the rise in the demand for herbal goods is placing significant strain on the forests while encouraging unsustainable wild harvesting of therapeutic plants. The current study's objective is to gain insight into current debates on the value chain of medicinal or therapeutic plants, role of various Indian acts, i.e., Forest Act, Forests Right Act, export, and other variables affecting the sustainable supply of herbs. A targeted literature search on online databases, scientific studies, and authentic texts was performed to understand the value chain, consumption, export, Indian laws, endangered species, and capacity building institutions, limitations, and future of medicinal plants. The World Flora Online database was used to verify the scientific names of the plants. Value chains for medicinal plants are wide and complex. There is need to weaken the role of middlemen and giving forest gatherers and farmers more negotiating leverage especially through artificial intelligence. The Ministry of AYUSH and National Medicinal Plants Board both play significant roles in India's medicinal plant sector. The different acts and rules pertaining to medicinal plants conservation, usage, transit, and trade should work in harmony and there is need for exclusive medicinal plants policy across India. Maintaining a balance between the protection of medical plant species and a sustainable supply of herbs to support the sector based on medicinal plants while empowering forest gatherers is urgently needed.

Graphical abstract



Keywords Biodiversity · Export · Food supplements · Indian acts · Medicinal plants · Policy

Extended author information available on the last page of the article

List of abbreviations

AICRP	All India Coordinated Research Project
ATMA	The Agricultural Technology Management Agency
BMCs	Biodiversity Management Committees
BRs	Biological resources
CAT	Catchment area treatment
CDSCO	Central Drugs Standard Control Organization
CFR	Community forest resource
CIMAP	Central Institute of Medicinal and Aromatic Plants
CITES	Convention on International Trade in Endangered Species of Wild Fauna Flora
CR	Critically endangered
CSIR	Council of Scientific and Industrial Research
DD	Data deficient
DMAPR	Directorate of Medicinal and Aromatic Plants Research
EN	Endangered
FAO-UN	Food and Agricultural Organization-United Nations
FRA	The Forest Rights Act
GMP	Good manufacturing practices
GOI	Government of India
HS	Harmonized system code
IPR	Intellectual property rights
IUCN	International Union for Conservation of Nature
JFMCs	Joint Forest Management Committees
LC	Least concern
LDCs	Least developed countries
MAP	Medicinal and aromatic plants
MAP& B	Medicinal and aromatic plants and betel vine
MFP	Minor forest produce
MIS	Management information system
MoU	A Memorandum of Understanding
NAM	National Ayush Mission
NBA	National Biodiversity Authority
NBPGR	National Bureau of Plant Genetic Resources
NCBI	National center for Biotechnology Information
NHWP	Nature, Health, Wealth, and Power
NMBP	The National Medicinal Plants Board
NT	Near threatened
NTFPs	Non-timber forests produce
OTFDs	Other traditional forest dwellers
SBR	Sundarban Biosphere Reserve
SHGs	Self-help groups
SMPB	State Medicinal Plants Board
SSB	State Biodiversity Boards
STs	Schedule Tribes
USD	United States Dollar

Highlights

- Majority of traditional medicines are made after processing of medicinal plants.
- This increased demand is placing an undue strain on the forests.
- Value chain needs to be shortened giving more bargaining power to gatherers.
- Special focus on CITES species, export, and sustainable harvest is required.
- There needs to be harmonizing among various Indian acts regulating herbs.

Introduction

Plant-based medications are used by 80% of people especially the underdeveloped nations for their health care (Singh et al. 2018; Ndamba, et al. 1994). Because of this, herbal medicine is becoming more and more well-liked on a global basis (Gunjan et al. 2015). These aforementioned considerations make it necessary for a continuous supply of medicinal plants rich in quality to be used as a source for diverse herbal formulations, taking sustainability into account. A quality-rich therapeutic plant may be defined as "economically derived from naturally approved farms and woodlands, legally procured, fully compliant with a fair-trade standard, and to the full fulfillment of required eminence specifications with documents demonstrating traceability and legal procurement" (Paroda et al. 2013). Only a small portion of medicinal plants are actually grown, according to current trends; the majority are gathered from the nature. As a result, the forests are being stressed by the increasing demand for healthcare and wellness services around the globe (Singh et al. 2021, 2015). Several studies indicate that it will be difficult to maintain consumption in the future because the demand for curative plants is presumably rising while the forests are contracting.

Understanding the value chain has taken on a very high significance as a result of worries about the sustainability of the supply of raw herbs and the preservation of therapeutic plants (Kala et al. 2006). A value chain, in its broadest definition, depicts the series of operations needed to create a completed product from the raw materials (Chopra and Meindl 2001). There is a lack of consensus across several disciplines about the variables that affect the use of therapeutic plants; therefore, for systematic consideration of traditional medicine in healthcare systems, it is crucial to comprehend the patterns of the global supply chains for medicinal plants (Street and Prinsloo 2013). India has

a reputation as one of the first civilizations with a massive wealth of medicinal herbs (Nayar and Sastry 1987); 7500 of the 17,000 species of plants that are thought to exist in India are recognized to have therapeutic use. The country has one of the greatest proportions of medicinal plants to total flora. (Kala et al. 2006). The great majority of the therapeutic and scented plants that are gathered from India's forests are extensively used as raw materials to make pharmaceuticals and perfumery goods (Singh et al. 2018).

The factors that affect the long-term supply of herbs in India deserve special consideration because of the numerous widely practiced traditional medical systems, thousands of collectors and growers who harvest medicinal plants, rural folk healers, and various Indian acts that control the transient and conservation of medicinal plants (GoI UNDP, 2008). In the current work, the writers have outlined the various bottlenecks and prospects in the medicinal plants sector, along with recent trends in the worldwide supply chains of curative plants, Indian consumption and export patterns, importance of TA schedule in Drugs and Cosmetics Act, 1945, and numerous Indian laws that control the sector.

Literature review

The literature was searched using a targeted literature review strategy. Online scientific databases such as Science Direct, PubMed, National Center for Biotechnology Information (NCBI), Springer, Wiley Online Library, Google scholar were explored using keywords "medicinal plants, value chain, supply chain, Indian Acts, Endangered species". Along with this, policy papers, annual reports of Ministry of Ayush, textbooks, newspapers were studied for obtaining the desired information. The botanical name of the plants mentioned in the manuscript was checked with "World Flora Online" (www.worldfloraonline.org).

Value chain of therapeutic plants

Recklies in the year 2001, discusses that a value-chain research has focused on two areas: understanding the mechanism behind different types of value chains that bestow competitive dominance by altering the pathway a product is handled or marketed has been one focus and also use of analyzing the value chain to know the socioeconomic benefits, drawbacks, and risks that each member of a chain faces. The second area discusses about the benefits of fair-trade items, benefits of harvesting non-timber forest products, particularly high-value animal- and plant-derived commodities (Alnawaiseh et al. 2014). The current value chain of therapeutic plants is distinguished by the casual character of its upstream core (gatherers, producers, and collectors) and the more ordered and officially organized downstream actors (processors and retailers/ wholesalers). The common stakeholders of medicinal plants value chain are represented in Fig. 1**.** While there are several publications on a variety of food products, there are comparatively lesser studies on recent discussions on the value chains of raw herbs.

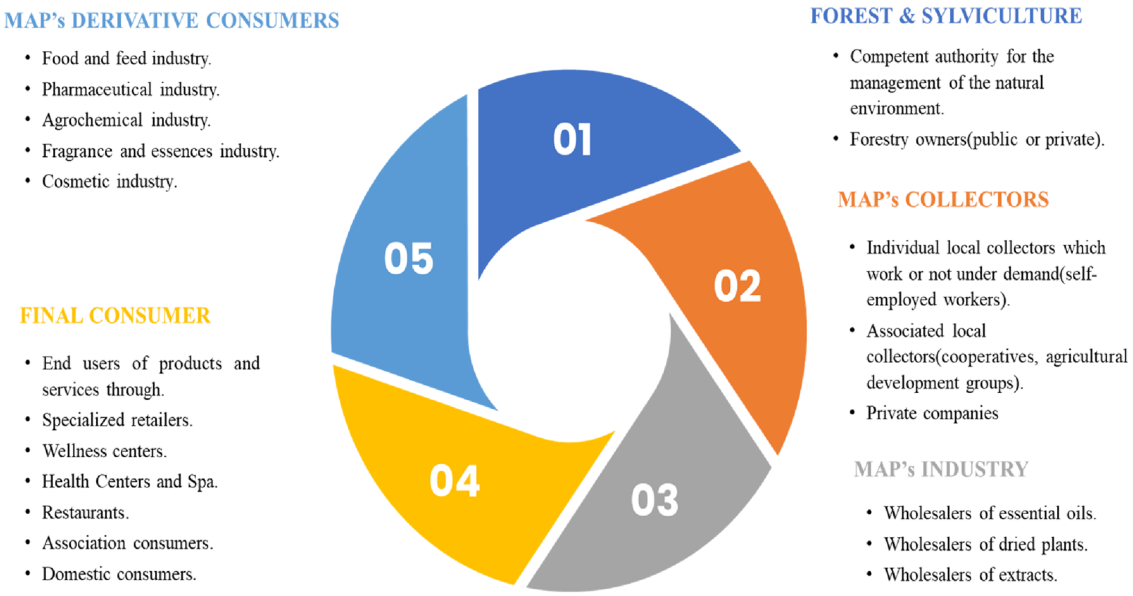


Fig. 1 Common stakeholders of medicinal plants sector

Overall, there is limited vertical integration and essentially little horizontal collaboration in the value chain. Gathering and selling medicinal plants obtained from the wild is an essential source of income for many underprivileged people in developing countries. Value chain strengthening has the potential to be a significant instrument for advancing Nature, Health, Wealth and Power (NHWP)-associating development goals, but purposeful measures are required to provide possibilities for the rural population (Juliard et al. 2006). There are studies that investigated ecological hazards with respect to species of medicinal plants that are quickly depleting due to overharvesting in natural habitats. In Nepal, for example, over 300,000 households are involved in the medicinal herbs collection. A prominent value chain should enable equitable flow of capital share to all the stakeholders while also calling for tighter limits on collection procedures, as well as pushing for large-scale production (Alam and Belt 2009). In contrast, there is a need for providing information to different stakeholders group with the details they need to create informed choices and design interventions aimed at creating constructive and worldwide skilful industries that are reliant on the wise use of finite natural resources for the good of the region. A robust value-chain system must fairly compensate individuals or groups for their efforts and contribution (technical expertise, labor, marketing abilities, etc.) and extent of risk chosen in order for commerce to be equitable (Hishe et al. 2016). Additionally, improved value chains through economic coordination that connect production with the improvement of producers' livelihoods may be helpful for the sector of medicinal plants to grow sustainably.

Some value-chain patterns of medicinal plants at global scale

Since there is no existence of systematic tools for the analysis of medicinal plants value chains, there are numerous studies that mentioned the value chain can have up to six or seven publicizing phases and involve key collectors and manufacturers, local servicers, local extensive markets, big wholesale markets, and specialized markets (Shahidullah and Haque 2010).

As per a report published by the FAO-UN, the producers and primary collectors, local traders, local wholesale markets, big wholesale markets, and specialist suppliers are all part of the value chain, which can span six or seven marketing stages. Due to the large quantity and diverse stretch of raw materials required, industry purchases from suppliers and distributors rather than directly from smallholders. This makes tracing products virtually impossible. Contract farming with assured buy-back arrangements seems the only viable options for exporters whose consumers want traceability (Marshall 2011). A study conducted by Adewumi and co-workers compared various routes for products that reach a market. The study exposed that the value-chain upstream is casual, and that the chain comprises gatherers, farmers, herbal medicine producers, and final customers (Adewumi et al. 2020). The various common worldwide value-chain channels of medicinal plants are represented in Fig. 2**.**

In line with this, a study conducted in Ethiopia, highlighted that approximately 56 000 tons of medicinal plants are consumed annually by 48 million people, who receive raw herbs through traders, local healers, or by self-harvesting (Mander et al. 2006). A study also examined the impacts of trading seven commonly used herbs on their long term. The study concluded that the farmers/collectors have the smallest profit margins, while the large share was enjoyed by the retailers. The average margin of wholesalers' behind per gram of species components sold on city markets is 1.37 to 20.69 times more than collectors. In contrast, the study underlined that low profit margins and a desire to raise revenue lead to increased harvesting, and damage to collected species (Vodouhê et al. 2008). Analyzing numerous talks

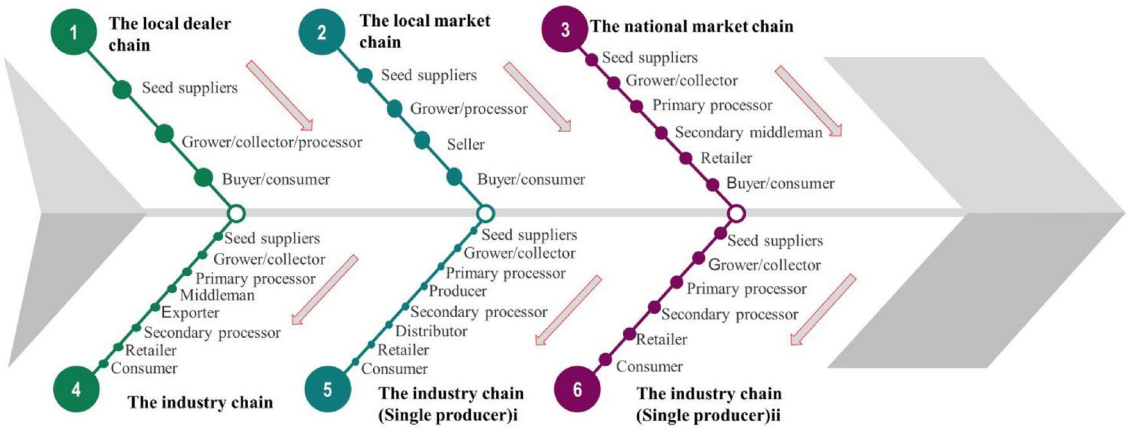


Fig. 2 Common value-chain channels of medicinal plants worldwide

on value chains, it can be commonly observed that due to intrinsic vulnerabilities in the chain, downstream customers, particularly consumers and manufacturers, spend the majority of their money for intermediates' value addition opportunistic pricing (Dejouhanet 2014).

Some studies also classified the gatherers or the collectors of therapeutic plants on the basis of gender. The discovery of the financial advantages of economically viable medicinal plants was detailed in a case study from Pakistan. According to the study, the Middle Hill tribes' children and women typically gather the plants, which are then sold by nearby farmers as a means of supplementing their livelihood. The majority of the material gathered was sold to village middlemen. After that, there is a complex, varied trade pattern involving numerous partners. However, the lack of consistency and frequently poor quality of the material given, the extent of the supply chain, and poor marketing methods are all contributing to the decline of the medicinal plant market in Pakistan (Sher et al. 2014). Therefore, attention can be drawn on methods enabling sustainable collection of natural resource base so that the livelihood of rural women is not jeopardized. In a study, authors underlined medicinal plants business and highlighted swot analysis in value chain of medicinal plants in Bangladesh. According to the report, the sector is threatened by unbalanced government policies, an unorganized market, a lack of access to the newest technology, and a lack of market intelligence (Palash et al. 2021). To access the potential players of the sector in Antananarivo, Madagascar, a study highlighted operators, collectors, harvesters, rural harvesters, urban harvesters, public resellers (vendors) as the probable players in the therapeutic plants sector. According to the study's estimates, the selling of therapeutic plants on the domestic market brought in money for all of the participants, enabling them to either augment or completely cover their yearly income (Randriamiharisoa et al. 2015). Therefore, it is essential to understand the true repercussions for conservation issues to fully explore the impact of the trade in medicinal plants on the ecological health of the forests.

Considering nascent value-chain strategies, increase in the prices of raw material, diminishing plant availability, shady supply systems, and middlemen-controlled raw material chains, it is important that the gross margin is fairly distributed to the main producers for sustainable growth of the sector (Dejouhanet 2014). For sustaining the livelihood of local gatherers and farmers, a fair-trade scheme, which shall largely cover agricultural goods, having a positive impact on both farmers' incomes and the quality of their production shall be devised. The fair-trade overall goal must be to provide a better offer for collectors/farmers by giving them the price above the marketplace rates for the assets in question in exchange for growers adhering to fair-trade production policies and following quality-driven standards in critical areas, especially during the collection or cultivation stages (Booker et al. 2012). To analyze the legal and policy frameworks to prevent major obstacles and ensure better use of these priceless goods, more insights into the problems relating to the picking, processing, and trade of MAPs are, therefore, necessary. Regarding the topic of entrepreneurship support, national authorities should assist small- and medium-sized businesses because they have a significant potential to promote job and income growth. Likewise, a commitment to openness, observance of laws and regulations, dedication to long-term financial and economic effectiveness, use of suitable quality standards by farmers and millers, environmental stewardship and preservation of natural resources and biodiversity, consideration of employees as well as people and communities impacted by growers and mills, responsible creation of new plantings for the reinforcing of value chain and procurement, and environmental responsibility all go hand in hand (Schmidt 2012). Also, a study underlined improving the harvesting, manufacturing, and marketing skills, encouraging domestication of non-timber forests produce (NTFPs), giving credit to farmers of NTFPs, prohibition of deforestation, NTFPs construction materials, substantial NTFPs promotion, encouraging studies on NTFP's as the methods for enhancing the NTFP supply chain in Ghana (Ahenkan and Boon 2011). Similarly, one of the tactics for ensuring a sustainable supply chain shall be an NTFP policy to direct the harvesting, production, adoption, and sale of the goods.

The prevalent value chain of medicinal plants in India

The therapeutic plant trade in India is described as being extremely intricate, secretive, traditional, perplexing, poorly organized, undervalued, and unregulated. There is no single agency having systematic statistics on the number of species traded, quantities, pricing, or other factors at the local, regional, or national level (Doungous et al. 2020; Rathore 2019). The majority of the information is disconnected, dispersed, insufficient, and incomparable. In general, the farmers (producer), local traders, wholesalers and retailers are the stakeholders in the value chain of the crops (Singh et al. 2022). A further study showed that the marketplaces for medicinal plants are not in the best possible shape because of an awkwardly long supply chain that is entangled with numerous vulnerabilities and requires legislative actions on medicinal plant production for preservation of medicinal plants (Joshi et al. 2017).

In India, local communities typically engage in wild harvesting; more than 50% of these gatherers are women. The collection typically depends on a market triggered by significant traders who formally advertise the need of a specific material for the year (Paroda et al. 2013). The information

about the need for traders spreads through word of mouth, primarily through aggregators, traders, and commission agents operating in various layers of the trading web (Singh et al. 2022; Ved and Goraya 2017). Another study described the current value chain of medicinal plants that comprises collectors, mainly small-scale farmers and landless laborers, are employed by the contractors. After paying royalties to the cooperative, the contractors can sell the supplies they have bought to cooperatives or directly to independent sellers. The companies market their products to regional representatives of wholesalers, urban dealers, and pharmaceutical firms (Van de Kop and Ghayur 2006). A study pertaining to value chain emphasized that after equating the amounts of each plant used by Oushadhi in 2005 and 2013, they saw a 40-ton increase overall. Only 173 of the 443 different materials were used in higher quantities, 167 in smaller amounts, and 45 were never used again. Twenty-three of the products that vanished were no longer consumed fresh, but were taken in dried form. This trend underlines the upsurge in the percentage of dehydrated materials and replacing of fresh raw materials with dried form (Marshall 2011; Sasidharan and Muraleedharan 2000; Dejouhanet 2014).

In relevant discussions, it is also mentioned that reasonable and regulated collection calls for strong local communities, public–private partnerships, and strict governmental control systems (Van de Kop and Ghayur 2006). In line with digital India campaign launched by the Government of India, a lot of emphasis and attempts are made to directly connect farmers/collectors with the consumers (mainly industries) digitally. NMPB has developed *e.charak* mobile application that provides the current market rates of the specific herb and enable farmers to directly communicate with the consumers. Information on performance, condition, and requirements is current and comprehensive with a digital supply chain (https://play.google.com/store/apps/details?id=com.cdac.ayush&hl=en_IN&gl=US). The digital and demand-driven supply chain of medicinal plants is represented in Fig. 3**.**

With the use of digital data, it is possible to manage and optimize processes like flow of raw material, stock levels, operational logistic support, resource management, and forecasting. This reduces the time required for information to flow compared to the traditional supply chain and makes medicinal plants, especially those that are in danger of extinction, more transparent.

Consumption by Indian herbal industry and exports

According to the All India Ethnobiology Survey, 4,635 ethnic communities in the nation use almost 7,500 different plant types for both human and veterinary health care (https://pib.gov.in/newsite/erelcontent.aspx?relid=47377). It is difficult to paint a clear picture of India's economic demand and supply for medicinal herbs. There are millions of primary producers engaged in the gathering in the wild or cultivating more than a thousand medicinal plant species needed for commercial use, as well as about 9,000

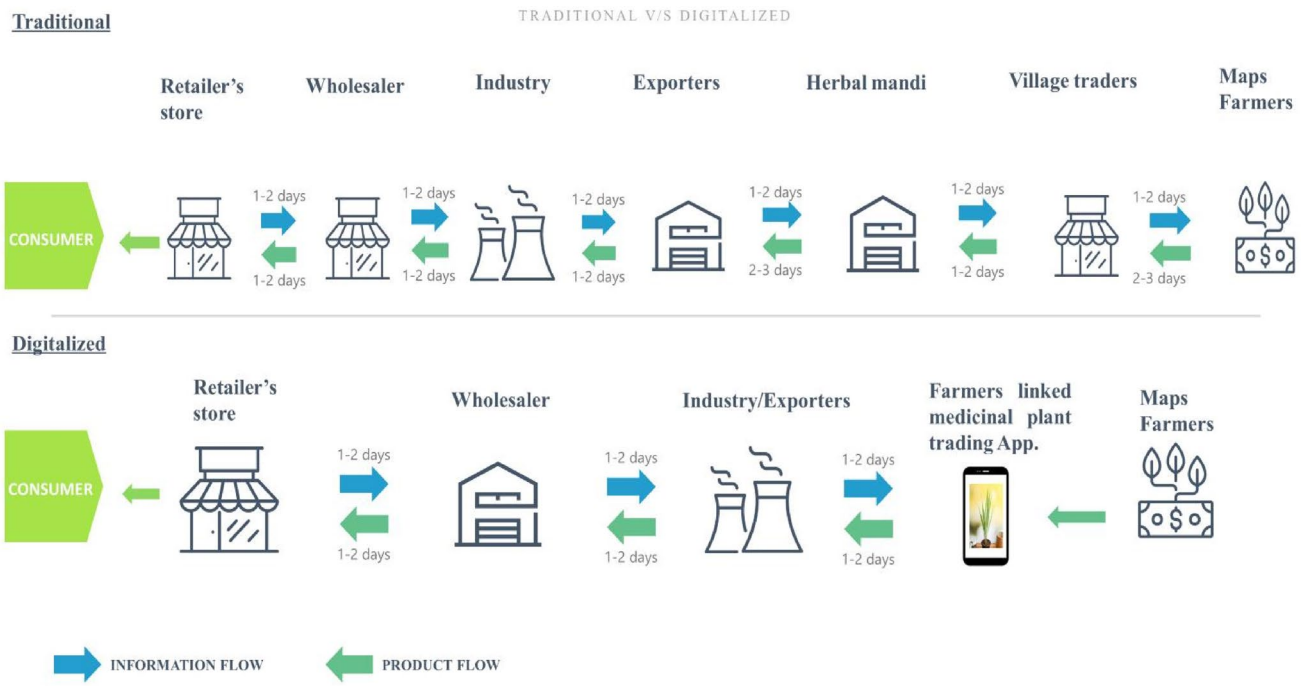


Fig. 3 Traditional and demand-driven digital value chain of medicinal plants

manufacturing facilities authorized to prepare herbal remedies under different streams of Indian systems of medicine. The commercial demand for herbal pharmaceuticals is significantly impacted by the consumption of herbal raw drugs by more than a million folk healers selling home-made formulations and over 138 million rural households using herbs for pharmacological and wellness purposes (Ved and Goraya 2017). Delhi, Chennai, Calcutta, Punjab, Maharashtra, and West Bengal are known to be the major markets of therapeutic plants in India (Rathore 2019).

The National Medicinal Plants Board (NMPB) commissioned two studies to access the requirement of raw herbal drugs for the year 1999–2000 at 2,34,675 MT including the material distributed, and the second study was conducted nation wide in the year 2005–06 to get more holistic picture of the sector resulting in inventory of 960 species with total trade of 3,19,500 MT including exports of 56,500 MT and 86,000 MT expended by the rural household. The authors claimed that their report has been only source to acquire the supply and demand information of medicinal plants until NMPB in collaboration with Indian Council of Forestry Research and Education, Dehradun published the 'Medicinal plants in India: An assessment of their demand and supply" in the year 2017 (Ved and Goraya 2017; Kala, et al. 2006). As per their latest study, the estimated annual demand of raw herbal drugs (Dry Wt. In MT) for 2014–2015 was 1,95,000 for domestic herbal industry, 1,34,500 for exports, 1,67,500 for rural households, 14,910 and wastage summing it around 5,12,000 MT. Subsequently, they assessed INR 7,000 crores as the estimated nation's annual trade of herbs. The report also mentioned that large and medium industries (Category A and B) forming less than 3% of the total 8610 licensed units consume more than 66% of the herbal raw drug while the others (Category C and D) consume only the remaining one third of the herbal raw drugs (Ved and Goraya 2017).

To comprehend the current state of the global trade in medicinal plant materials, a study was carried out. The trade map, Comtrade, country data, technical documentation, etc., were used to compile trade data for medicinal plants with commodity code HS 1211 (SITC.4, code 292.4) and its derived/related items that are traded under other commodity codes from 2001 to 2014. The average export of medicinal plants (annually) classified as HS 1211 was 601,357 tons for USD 1.92 billion over a 14-year period, while it was 702,813 tons for USD 3.60 billion in 2014. The top two exporting and importing nations account for around 30% of global trade. Important supply sources come from India and China in Asia, Bulgaria, Poland, and Albania in Europe, Peru and Chile in South America and Morocco and Egypt in Africa (Vasisht et al. 2016). The world's three largest consumers are the USA, Europe, and Japan. Eight hundred eighty different species of medicinal plants are traded throughout India. Forty-two spices are imported and forty-eight species are exported from this group. According to the WHO, the global market for herbal products is currently worth approximately $6.2 billion and is anticipated to grow to $5 trillion by the year 2050 (Kumar and Janagam 2011).

The most significant report published by RIS and Ministry of Ayush found that US$18.1 billion is the current turn over at the moment, and the size of the Indian Ayush market overall has increased by 17% during 2014–2020. Similarly, the report underlined significant rise in total exports of Ayush products. According to the analysis, this is consistent with the expected growth rate of herbal medicines and supplements globally by different industries (RIS 2020). The export data of medicinal plants as per RIS are mentioned in Table 1**.** China and India were the two largest exporters of MAPs worldwide, representing approximately 29.9% and 11.2 percent of the total value of MAPs exported in 2020 (Kumar and Janagam 2011).

Questions about the reliability and quality of the material have been raised due to the dramatically growing demand for herbal medicines. The lack of comprehensive and dependable data on the variety of therapeutic plant species used commercially and the annual volume of use per species raises all of these concerns. It is further complicated by the commerce in medicinal plant species known by regionally distinct local names. To execute effective resource management techniques, it is crucial to comprehend the diversity of medicinal plant species and herbal raw medicines in creating a market, as well as to calculate yearly requirements for each of these entities (Kala et al. 2006).

Endangered species

Numerous therapeutic plants are also under danger due to overuse, habitat destruction, and harvesting (Mehta et al. 2020; Rajaram et al. 2019). They are being over-harvested as a result of population increase, urbanization, and the unregulated collecting of medicinal plants from the wild. As a result, it is now urgent to manage the resources required for traditional medicines. Some drug-producing plant families contain endangered species, which strongly confirms the need to prioritize the protection and evaluation of these fragile and endangered groups (Sharma and Thokchom 2014; Sangzhu et al. 2009). Some of these medicinal plants are *Ginkgo biloba* L.*, Diplostephium rhododendroides* Hieron.*, Saussurea lappa* (Decne.) Sch. Bip.*, Celastrus paniculatus* Willd., *Picrorhiza kurroa* Royle ex Benth.*, Gymnema sylvestre* (Retz.) R.Br. ex Sm., *Swertia chirata* Buch.-Ham. Ex Wall., *Salacia oblonga* Wall.*, Glycyrrhiza glabra* L.*, Oroxylum indicum* (L.) Benth. ex Kurz*, Bacopa occultans* (Hiern) Hutch. & Dalziel*, Rauwolfia serpentina* (L.) Benth. ex Kurz*, Tylophora indica,* etc. (Gowthami et al. 2021; Yadav 2016). Some

Table 1 Export of Ayush products defined in medicinal and aromatic plants (US$ Million)

HS code	Plant name	Botanical name	Plant parts used	2018	2020
12,112,000	Ginseng	*Panax ginseng* C.A.Mey	Root	0	0.07
12,113,000	Coca	*Erythroxylum coca* Lam	Leaf	0.01	0
12,114,000	Poppy	*Papaver somniferum* L	Straw	–	0
12,115,000	Ephedra	*Ephedra intermedia* Schrenk & C.A.Mey	Seeds, Fruits	–	0
12,119,011	Musk mallow	*Abelmoschus moschatus* Medik	Seeds	0.01	0.02
12,119,012	Nux vomica	*Strychnos nux-vomica* L	Seeds (dried ripe)	0.06	0
12,119,013	Isobgul	*Plantago ovata* Forssk	Seed	5.48	3.18
12,119,014	Neem	*Azadirachta indica* A.Juss	Seed	0.03	0
12,119,015	Jajoba	*Simmondsia chinensis* (Link) C.K.Schneid	Seeds	–	0.01
12,119,021	Belladonna	*Atropa belladonna* L	Leaves	0.04	0
12,119,022	Senna	*Senna alexandrina* Mill	Leaves and pads	12.48	18.42
12,119,023	Neem	*Azadirachta indica* A.Juss	Leaves	0.28	0.44
12,119,024	Gurmar	*Gymnema sylvestre* (Retz.) R.Br. ex Sm	Leaves, Flowers	0.46	0.36
12,119,025	Java pepper	*Piper cubeba* L.f	Fruits	0.02	0.01
12,119,026	Spanish chamomile	*Anacyclus pyrethrum* (L.) Lag	Leaves, Flowers	0.01	0
12,119,031	Cascara	*Frangula purshiana* (DC.) A.Gray ex J.G.Cooper	Bark	0	0
12,119,032	Psyllium husk	*Plantago indica* L	Bark	200.92	259.24
12,119,041	Belladona	*Atropa bella-donna* L	Roots	0	0
12,119,042	Greater Galangal	*Alpinia galanga* (L.) Willd	Roots	0.21	0.41
12,119,043	Ipecac	*Carapichea ipecacuanha* (Brot.) L.Andersson	Roots	0.01	0.03
12,119,044	Sarpagandha	*Rauvolfia serpentina* (L.) Benth. ex Kurz	Roots	0.05	0.01
12,119,045	Zedoary	*Curcuma aromatica* Salisb	Roots	14.98	19.66
12,119,046	Kutha	*Dolomiaea costus* (Falc.) Kasana & A.K.Pandey	Root	0.13	0.01
12,119,047	Sarsaparilla	*Smilax glauca* Walter	Seeds, Fruits	0.42	0.94
12,119,048	Sweet flag	*Acorus calamus* L	Seeds, Fruits	0.3	0.13
12,119,050	Sandalwood	*Santalum album* L	Roots	0.64	0.56
12,119,060	Vinca rosea	*Catharanthus roseus* (L.) G.Don	Roots	0.96	0.39
12,119,070	Mint	*Mentha aquatica* L	Roots	0.45	0.45
12,119,080	Agarwood	*Aquilaria malaccensis* Lam	Wood	0.55	1.17
12,119,091	Kirata	*Swertia chirayita* (Roxb.) H.Karst	Seeds, Fruits	0.03	0
12,119,092	Basil	*Ocimum basilicum* L	Seeds, Fruits	4.26	1.45
12,119,093	Unnab	*Ziziphus jujuba* Mill	Seeds, Fruits	–	0
12,119,095	Lovage	*Levisticum officinale* W.D.J.Koch	Seeds, Fruits	0	0.01
12,119,096	Garcinia	*Garcinia epunctata* Stapf	Seeds, Fruits	0.1	0.23

Source: Ayush Sector in India: Prospects and Challenges. FITM, RIS, New Delhi (RIS 2020)

of the endangered plant species, IUCN status, geographical region, and pharmacological uses are mentioned in Table 2**.**

Implementing the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) non-detriment finding guidance and management plans for the species is necessary, according to a study, for sustainable availability of medicinal herbs. Species recovery plans must be implemented in order for critically endangered plants to be returned to their natural environment. To guarantee adherence to CITES Appendix II, harvesting limits must be more strictly enforced. For sustainability, conservation, and fair trade of medicinal plants from the wild, market-based tools like Fair Wild certification must be used in this situation (Badola and Yadav 2019).

Effect of climate change on therapeutic plants

Over the past 20 years, climate change has been one of the major global concerns for experts and governments. Increases in CO_2 concentration have become a challenging issue for both normal human life and plant physiology since the industrial age (Cleland et al. 2012). This has resulted to negatively impact everyday human activities,

Table 2 List of some endangered species

S. no	Common name	Scientific name	Parts used	Estimated current annual consumption (dry weight in mt)	IUCN Red list	FRLHT Red list	Geographical location	Pharmacological uses	References
1	Kutki	*Picrorhiza kurroa* Royle ex Benth	Root (tuber)	1,000–2,000	–	CR	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim	Anti-inflammatory, anti-ulcer, anti-pyretic, laxative, anthelmintic, anti-malarial, carminative	(Kumari et al. 2021; Thani 2021; Bhardwaj et al. 2021; Debnath et al. 2020; Freire et al. 2020; Pandit, et al. 2013)
2	Jatamansi	*Nardostachys jatamansi* (D.Don) DC	Root (rhizome)	500–1,000	CR	CR	Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh	Anti-depressant, anti-cancer, hepatoprotective agent, anti-fungal	(Chauhan et al. 2021, 2008; Bose et al. 2016; Gautam and Raina 2016; Singh et al. 2013; Disket et al. 2012; Ghimire et al. 2005)
3	Red Sanders	*Pterocarpus santalinus* L.f	Wood	200–500	NT	CR	Andhra Pradesh, Tamil Nadu, and Karnataka	Anti-pyretic, anti-inflammatory, anthelmintic, aphrodisiac, digestive tract problems	(Zhang et al. 2019; Azamthulla et al. 2015; Arunkumar and Joshi 2014; Babar et al. 2012; Walpola et al. 2011; Rao and Raju 2002)
4	Himalayan Yew	*Taxus wallichiana* Zucc	Leaf	100–200	EN	CR	Himachal Pradesh, Jammu & Kashmir, Uttar Pradesh	Common cold, cough, anti-cancer (ovarian and breast cancer)	(Rathore et al. 2019; Bhuju and Gauchan 2018); Vu et al. 2017; Yang, et al. 2009; Mohapatra et al. 2009)
5	Agarwood	*Aquilaria malaccensis* Lam	Bark (stem), heart wood	50–100	CR	CR	Bangladesh, Bhutan, north-east India, Sumatra and Kalimantan of Indonesia, Iran, Malaysia, Myanmar, Philippines, Singapore and southern Thailand	Carminative, gastric problems, rheumatism, anti-asthmatic, anti-inflammatory	(Giri et al. 2021; Ali and Kashem 2019; Lee et al. 2017; Kashyap et al. 2016; Singh et al. 2015; Tabin and Shrivastava 2014; Manohara 2013; Moitreyee et al. 2013)
6	Elephant's Foot	*Dioscorea deltoidea* Wall. ex Griseb	Root	10–50	–	EN	Arunachal Pradesh, Sikkim, Assam, Meghalaya, Himachal Pradesh, Jammu & Kashmir, and Uttarakhand	Insomnia, diabetes, diuresis, bronchitis, viral and bacterial infection, leukemia, rheumatism	(Nazir et al. 2021a,b; Bano et al. 2021; Nazir et al. 2021a, b; Semwal et al. 2021; Hernández-Teixidor et al. 2020; Tahir et al. 2016; Mandal and Dixit-Sharma 2007)
7	Salam Panja	*Dactylorhiza hatagirea* (D.Don) Soó	Root (Tuber)	10–50	–	CR	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh	Aphrodisiac and immunostimulatory activities, demulcent, gastrointestinal problems	(Jamloki et al. 2021; Thakur et al. 2021; Wani et al. 2021, 2020; Warghat et al. 2014)

Table 2 (continued)

S. no	Common name	Scientific name	Parts used	Estimated current annual consumption (dry weight in mt)	IUCN Red list	FRLHT Red list	Geographical location	Pharmacological uses	References
8	Himalayan Mayapple	*Podophyllum hexandrum* Royle	Fruit, Root	10–50	–	CR	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh	Intestinal purgative, emetic, warts and skin cancer, liver ailments	(Kumar et al. 2022; Chaudhari and Yamin Bibi 2021; Zuhra et al. 2021; Goswami et al. 2019; Kumar 2017; Gupta and Dutta 2011; Li et al. 2018)
9	Queen Sago	*Cycas circinalis* L	Flower, Pith	< 10	EN	CR	Kerala, Karnataka, Tamil Nadu, South of Maharashtra	Dizziness, headache, sore throats, malignant ulcers, rheumatism	(Deora and Shekhawat 2020; Marler and Cascasan 2018; Krishnamurthy et al. 2013; Raju and Rao 2011; Raju and Jonathan 2010; Marler and Moore 2010; Dominic and Joseph 2007)
10	Ginseng	*Panax notoginseng* (Burkill) F.H.Chen	Root	< 10	–	CR	Sikkim, Arunachal Pradesh, Manipur, Meghalaya	Anti-inflammatory, vasorelaxation, anti-allergic, anti-diabetic, anti-cancer	(Deora and Shekhawat 2020; Zheng et al. 2017; Jamir et al. 2016; Kumar et al. 2019; Dominic and Joseph 2007; Hiremath et al. 2002; Rinaldi 1999)

CR critically endangered, *EN* endangered, *NT* near threatened

agriculture, biodiversity, forestry, and ecosystem function (Anand et al. 2017; Lepetz et al. 2009). Each type of plant requires unique environmental circumstances for growth, and abiotic variables play a significant role in the development and evolution of plants (Mongalo et al. 2016).

Climate is the main factor affecting species distribution; hence, a change in climate is quite likely to have an effect on that distribution. Climate change can have a beneficial or negative impact on productivity or quality, even if a species' range is unaltered. In the case of medicinal plants, this is especially true of their bioactivities or chemical composition (Petropoulos et al. 2008). Whether autogenous or produced by endophytic symbionts, the secondary metabolite content of the plant is the main source of these bioactivities. The main reason for consuming or otherwise using medical plants is to gain health benefits from their bioactivities, and the climate change contributes to variance in chemical content in plants. Therefore, those who benefit from a plant's use would suffer if the composition of the plant changed in a negative or unpredictable way. Consumers from traditional communities and less wealthy groups are particularly at danger in this sense because they lack the resources to conduct complicated chemical testing to uncover such changes and modify doses to adapt (Ninou et al. 2017).

Low yields, detrimental effects on secondary metabolites, and plant evolution are caused by the recent temperature increase because it alters the metabolic pathways that control signaling, physiology, defence systems, and also the intermediates of the Krebs cycle in many medicinal plant species (Bhatla and Tripathi 2014; Prashantkumar and Vidyasagar 2013). Although medicinal plants have the ability to adapt to their environment, the effects of climate alteration impact the flexibility of this metabolic pathway and the synthesis of metabolites that are responsible for therapeutic efficacy (Field et al. 2014). According to a study, exposure to high CO2 concentrations considerably lowers the percentage of glycosides, including digoxin-mono-digitoxoside, digitoxin, and digitoxigenin, in *Digitalis lanata*, a plant used to treat heart failure. The period of exposure is a crucial element in addition to CO_2 concentration when determining the concentration of secondary metabolites in plants (Mishra 2016). Subsequently, *Hymenocallis littoralis* bulbs, which are well-known for their antiviral and anti-cancer properties, reported significant decrease in the concentration of three alkaloids i.e., 7-deoxy-trans dihydronarciclasin, pancratistatin, and 7-deoxynarciclasine with time when exposed to CO_2 (Saravanan and Karthi 2014). According to a study, *Ginkgo biloba* used to treat dementia caused by vascular disease and Alzheimer's disease is reported to decrease concentrations of isorhamnetin, kaempferol aglycon, and bilobalide when exposed to higher levels of CO_2 (Ibrahim and Jaafar 2012).

As per a study, the ecosystems of the Himalayas are undergoing numerous irreversible changes due to climate change. The possible habitat spreading of 163 medicinal plant species in present and future climates (2050, 2070) was examined using the maximum entropy species distribution modeling (SDM) method in the Sikkim Himalayan Region, India. It was observed that most of the species' distributions are anticipated to shift upward and northward in future temperatures in Sikkim Himalaya region. Maximum species-rich zones are likely to move by 200 m and 400 m, respectively, in 2050 and 2070. By 2050 and 2070, it's predicted that 13–16% of the medicinal plant species currently found in the area will have lost their prospective habitats. Numerous studies have confirmed that the spatial distribution of medicinal plants would decline as a outcome of climate variation. Medicinal plants like *Schisandra sphenanthera* in China and a number of other plants in Egypt have shown evidence of these modifications (Tshabalala et al. 2022). Additionally, a study found that medicinal plants can act as displayed species for campaigns to safeguard biodiversity, monitor it, and raise public awareness of conservation efforts. As a result, it is essential to conduct a climate change research in relation to India's conservation plans for medicinal plants (Qian et al. 2020). In Poland and Germany, recent unusually hot summers have hindered the reseeding of medicinal plants like chamomile (*Matricaria recutita*), and increasing amounts of extreme floods in Hungary have decreased harvests of fennel (*Foeniculum vulgare*) and anise (*Pimpinella anisum*). In the Himalayan locations, a study discovered that valuable medicinal plants accounted for 62% of all plant species (Bhardwaj et al. 2021) and it was observed that overall species richness decreased with raise from the lowest summits to the highest (Das et al. 2016).

In 2006, 2007, and 2008, Indian states like Rajasthan and Gujarat witnessed hailstorms and rain at times when such occurrences often did not occur over the previous 50 years. Psyllium (*Plantago ovata*, Plantaginaceae), cumin (*Cuminum cyminum*, Apiaceae) crops have also been harmed in the region by hail and storms. The year 2008 saw a lower annual production than typical due to the damage that hail and rainstorms caused to Indian psyllium crops. Similarly, wild mint (*Mentha arvensis*, Lamiaceae) crop damage and early monsoon rains that occurred in Northern India had an impact on the supply of menthol crystals (Sharma et al. 2020).

The availability of beneficial medicinal plants is predicted to decline while rising environmental extremes and economic losses brought on by climate change are expected to have a negative impact on public health in many parts of the world. If immediate action is not taken, it is probable that additional individuals will suffer as a result. To decrease the negative effects of climate change on ecosystems and human societies worldwide, a change in the current patterns would be ideal, and urgent mitigation measures are required. Local adaptation efforts are essential, nevertheless, as it seems that

swift and robust mitigation will be politically difficult to fully avert disruptive climate change. To support all communities in maintaining access to high-quality traditional medicines, particularly those that rely on medicinal plants for their health care or as a source of income, non-governmental organizations, local and federal governments, as well as the ethnobotanical and public health communities, must take action.

Laws and regulations governing medicinal plants in India

The Drug and Cosmetics Act of 1940 and 1945 (amendment), Ministry of Ayush, and the Central Drugs Standard Control Organization (CDSCO) all usually govern the use of herbal medicines in India (Sen et al. 2011). Since the early 1990s, the Government of India (GoI) has given medicinal plants the attention they deserve, and numerous initiatives have been taken to protect and conserve these species both locally and abroad (biosphere reserves, national parks, wildlife sanctuaries, sacred groves), and *ex situ* (seed gene bank, botanical gardens, field gene banks, crypto gene bank, and in-vitro gene banks). In terms of in situ conservation, India's entire geographic area is made up of 16.5 million ha (5.02%) of protected areas and 70.8 million ha (21.54%) of forests. In total, India has 870 declared protected places, including 104 national parks, 551 wildlife sanctuaries, 127 community reserves, along with 88 conservation reserves. In addition, India is home to between 100,000 and 150,000 sacred groves (Gowthami et al. 2021).

There is a wide range of laws and rules governing the medicinal plants industry, but no single national policy that is applicable to all medicinal plants. And as a result, there may not always be a well-coordinated strategy for medicinal plants, and many of them may simply disappear with time (Badola and Yadav 2019). With more than 70% of plant collections, it sometimes leads to destructive harvesting of stems, bark, roots, wood, and, in rare instances, the entire plant. The Indian Forest Act, The Biological Diversity Act, 2002, The Forest Conservation Act of 1980, The Wildlife Protection Act, 1972, among other acts provide significant protection for medicinal plants (Ved and Goraya 2017). The various acts and their objectives are described in Table 3**.** The materials taken directly from the forest are covered by the Indian Forest Act. The *in situ* conservation of medicinal plants is made possible by the Forest (Conservation) Act of 1980 and the Wildlife (Protection) Act of 1972. While outside of the protected zones, the Wildlife (Protection) Act of 1972 provides a legal framework for six endangered plant species under its Schedule VI. There is only one of these that have medical benefit. The framework for India's export and import policies is provided by the CITES, Appendix 1, which essentially includes the same six plant species that are under schedule VI of the Wild Life Protection Act (https://www.devalt.org/newsletter/jan98/of_2.htm).

Concerns have also been raised about the necessity for the Biological Diversity Act of 2002's Sects. 38 and 40 to be reviewed and the need to harmonize the rules governing the transportation of forest produce (Bhutani and Kohli 2012). Pertaining to the Biological Diversity Act, 2022, there were some disagreements over whether State Biodiversity Boards (SSB) have the authority to grant approvals for commercial use of biological resources (BRs) or bio-survey by Indians, as well as to issue notices to those who do so without prior consent (Prathapan et al. 2006). Many disputes related to power to endow approvals for commercial usage of BRs or for bio-survey between SBB'S and industries have surfaced, one example is from Madhya Pradesh. In this case, the government was informed that the amount of benefit to be shared by the industry was not a tax, but rather an amount to be deposited with the National Biodiversity Authority (NBA) for the favor of the indigenous and local people of the area where the industries were accessing the BR for commercial purposes (Devi et al. 2019; Devi and Padmavati 2016; Kadir et al. 2012).

The Forests Rights Act, 2006

To remedy the injustice done to tribes, *adivasis*, as well as other forest inhabitants, Parliament approved the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act 2006. It grants the lands they have been tending for millennia legal rights (Tripathi 2016). The unnoticed and mistreated women who lived in the forests labored peacefully in Gandhi's footsteps and to them, the Forest Rights Act (FRA) of 2006 provides important solutions (Bose 2010). Adequate local advice and support for women's skill development in agriculture and forestry can further strengthen group efforts. If women collectively develop community claims and rights, it will be vital to get their consent before allotting that land to enterprises enabling preservation of forest minor products (Sharma 2017). The Forest Rights Act, 2006 does have the ability to democratize forest management by enabling over 200 million forest residents in over 1,70,000 villages by recognizing community forest resource (CFR) rights throughout an estimated 85.6 million acres of India's forests. However, only a few areas, including Gadchiroli, Narmada, and Mayurbhanj, have been able to completely realize their true potential for the development, empowerment, alleviating poverty, and conservation (Kumar et al. 2022). Categorization of states in context to FRA implementation is represented in Fig. 4**.**

There are studies that consider some of the obstacles to the execution of this law in different regions of the nation. The study, carried out in the Sundarban Biosphere Reserve

Table 3 Some acts and policies of medicinal plants sector in India

S. no	Acts/policy	Contents
1	The Biological Diversity Act, 2002	This law safeguards biodiversity, responsible use of its constituent parts, and just and equitable distribution of benefits attributable to the utilization of biological resources, cognition, and incidental considerations • The National Biodiversity Authority's main goal is to manage access to BRs in India and make sure the relevant benefits are distributed fairly • The BMCs also keep data about local *vaids and hakims* (traditional healers) practicing traditional medicine and creating People's Biodiversity Sign up (PBR) in collaboration with the locals • To encourage conservation through channelizing funds received as fees, and royalties • Normally traded raw materials are exempt from the act under Sect. 40 of the BDA
2	The Environment (Protection) Act, 1986	An act to promote environmental protection and improvement and matters related thereto: • They relate to protecting the environment and improvement and preventing human hazards, other organisms, and plants • Conducting and funding investigations and research on environmental pollution problems • Gathering and dissemination of information on environmental pollution issues • This law emphasizes the protection of the environment regarding various pollutants or hazardous substances affecting the environment
3	The Foreign Trade (Development and Regulations) Act, 1992	This act encourages exports and imports to promote and regulate international trade Export of plant species that are banned as per the act: • *Cycas beddomei* Dyer • *Sarracenia purpurea* L • *Dolomiaea costus* (Falc.) Kasana & A.K.Pandey • *Cypripedium X alaskanum* P.M. Br • *Vanda concolor* Blume • *Vanda arcuata* J.J.Sm • *Caralluma frerei* G.D. Rowley • *Ceropegia abyssinica* Decne • *Rauvolfia serpentina* (L.) Benth. ex Kurz • *Podophyllum hexandrum* Royle • *Cyathea* J. E. Smith • *Cycas aculeata* K.D.Hill & H.T.Nguyen • *Aconitum abietetorum* W.T.Wang & L.Q.Li • *Euphorbia anisopetala* (Prokh.) Prokh • *Orchidaceae* L. Watson and M. J. Dallwitz • *Taxus wallichiana* Zucc • *Pterocarpus santalinus* L.f • *Aquilaria malaccensis* Lam • *Dioscorea deltoidea* Wall. ex Griseb • *Coptis chinensis* Franch • *Coscinium fenestratum* (Gaertn.) Colebr • *Kaempferia galanga* L • *Gentiana kurroo* Royle • *Gnetum arboreum* Foxw • *Dactylorhiza hatagirea* (D.Don) Soó • *Panax notoginseng* (Burkill) F.H.Chen • *Nardostachys jatamansi* (D.Don) DC • *Swertia chirayita* (Roxb.) H.Karst • *Picrorhiza kurroa* Royle ex Benth The export of these species is subject to producing a certificate of cultivation from the Regional Deputy Director

Table 3 (continued)

S. no	Acts/policy	Contents
4	The Forest (Conservation) Act 1980	The legislation calls for restrictions on the use of forest land for non-forest purposes, which include breaking or clearing any forest property or a portion thereof for: • Cultivation of medicinal plants also comes under non-forest produce • Advocates conservation through re-afforestation
5	The Wild Life (protection) Act, 1972	This act is provided for the protection of birds, plants, and wild animals This act highlighted the protection of following specified plants: • *Cycas beddomei* Dyer • *Vanda coerulea* Griff. ex Lindl • *Dolomiaea costus* (Falc.) Kasana & A.K.Pandey • *Paphiopedilum acmodontum* M.W.Wood • *Nepenthes khasiana* Hook.f • *Renanthera imschootiana* Rolfe • According to this act, these specified plants are not supposed to be used for cultivation, business or occupation and purchase, etc., without a license. These specified plants are the government property • Declaration of sanctuary for propagation and protection of wild life and their environment • Protection of sanctuaries • The declared area should not be used for commercial purposes • Management of a conservation reserve**:** A conservation reserve is used to safeguard natural areas such as lands, oceans, flora and fauna, and their habitats

Table 3 (continued)

S. no	Acts/policy	Contents
6	Trade of plants listed in CITES appendices	The CITES mentioned some of the following plant species in its Appendix i, ii, iii: • *Yucca queretaroensis* Piña-Luján • *Nolina interrata* Gentry • *Agave victoriae-reginae* T. Moore • *Galanthus alpinus* Sosn • *Hoodia alstonii* (N.E. Br.) Plowes • *Operculicarya decaryi* H. Perrier • *Rauvolfia serpentina* (L.) Benth. ex Kurz • *Operculicarya pachypus* Eggli • *Sternbergia clusiana* ker-Gawler • *Pachypodium rosulatum* subs. cactipes • *Operculicarya hyphaenoides* H.Perrier • *Podophyllum hexandrum* Royle • *Panax ginseng* C.A.Mey • *Beaucarnea gracilis* Lem. • *Panax ginseng* C.A.Mey • *Tillandsia kammii* Rauh • *Tillandsia harrisii* Ehlers • *Tillandsia xerographica* Rohweder • *Pilosocereus leucocephalus* f. cristata hort • *Caryocar costaricense* Donn.Sm • *Dolomiaea costus* (Falc.) Kasana & A.K.Pandey • *Caryocar costaricense* Donn.Sm • *Cycas revoluta* var • *Widdringtonia whytei* Rendle • *Pilgerodendron uviferum* (D.Don) Florin • *Fitzroya cupressoides* (Molina) I.M.Johnst • *Cyathea arborea* L • *Zygosicyos* tripartitus Humbert • *Cibotium barometz* (L.) J.Sm • *Euphorbia rothiana* Spreng • *Alluaudia procera* Drake Bull. Mus • *Dioscorea deltoidea* Wall. ex Griseb • *Dionaea muscipula* J.Ellis • *Dicksonia sellowiana* (C.Presl) Hook • *Fouquieria fasciculata* (Willd. ex Roem. & Schult.) Nash • *Quercus mongolica* subsp. crispula (Blume) Menitsky • *Fouquieria columnaris* Kellogg ex Curran • *Fouquieria* purpusii Brandegee • *Oreomunnea pterocarpa* Oerst • *Aniba rosaeodora* Ducke • *Gnetum montanum* Markgr • *Dalbergia latifolia* Roxb • *Pericopsis elata* (Harms) Meeuwen • *Senna meridionalis* (R.Vig.) Du Puy

Table 3 (continued)

S. no	Acts/policy	Contents
		• *Pterocarpus velutinus* De Wild • *Aloe percrassa* Tod • *Aloe alexandrei* Ellert • *Aloe albida* (Stapf) Reynolds • *Aloe bellatula* Reynolds • *Aloe albiflora* Guillaumin • *Adansonia gregorii* F.Muell • *Nepenthes rajah* Hook • *Swietenia humilis* Zucc • *Podocarpus neriifolius* D.Don • *Nepenthes khasiana* Hook.f • *Cedrela balansae* C. DC • *Swietenia macrophylla* King • *Uncarina grandidieri* (Baill.) Stapf • *Uncarina stellulifera* Humbert • *Avonia recurvata* (Schönland) G.D. Rowley • *Prunus africana* (Hook.f.) Kalkman • *Anacampseros affinis* H.Pearson & Stephens • *Osyris lanceolata* Hochst. & Steud • *Lewisia serrata* Heckard & Stebbins • *Cyphostemma laza* Desc • *Bowenia* Hook • *Sarracenia leucophylla* Raf • *Taxus wallichiana* Zucc • *Taxus wallichiana* Zucc • *Nardostachys jatamansi* (D.Don) DC • *Cyphostemma montagnacii* Desc • *Cyphostemma elephantopus* Desc • *Picrorhiza kurroa* Royle ex Benth CITES's species-specific agenda currently concern medicinal plants Recent examples include *Prunus africana* (Hook.f.) Kalkman, *Osyris lanceolata* Hochst. & Steud, Orchids and Agarwood
7	The Joint Forest Management	The JFM Circular is an action outcome of National Forest Policy of I988's that recogniszes communities for protection and management of forests • Advocates involvement of rural communities for the protection and management of forests • JFM Committee promotes saving and managing nearby forests • Benefit generation from regional ecosystem like pollination, water recharge, wildlife, etc • JFMC works with micro-plan. A micro-plan is an official document used to balance conflicting and complementary demands on the resources present as forest produce • Training on cultivation of medicinal plants • Introduction of medicinal plants in the degraded forest area With the help of this scheme, plantations might be grown using grafted Amla (*Phyllanthus emblica* L.), Harrad (*Terminalia chebula* Retz.), Baheda (*Terminalia bellirica* (Gaertn.) Roxb), and many other species that are readily accessible in the area

Table 3 (continued)

S. no	Acts/policy	Contents
8	Himachal Pradesh Medicinal Plants Sector Policy, 2006	A policy for developing and preserving species of medicinal plants both within and outside of forest regions for use in improving the state's population's health-care and livelihood security on a sustained basis: · The state represents the highest families that belong to Asteraceae, Rosaceae, Ranunculaceae, and Fabaceae · Enjoy customary 'right' to collect medicinal plants · Converting the important species into knowledge products · Cultivation pertaining to Kuth, Pushkarmool, Taxus, Basanti medicinal plants · Ethical bio-prospecting through Indian Scientific Institutions · Setting up seed-cum-germplasm banks in agro-climatic zones and certification for seeds to consumers · Launching of organic cultivation of herbs via grower cooperatives · Potential modeling based on community organization for trade of medicinal plants · Creation of dedicated budget for medicinal plants from state plan budget · Allocation of separate funds for catchment area treatment (CAT) for conservation of herbs
9	National Forest Policy, 1988	Advocates evaluation of the situation and develop a new forestry strategy for the future • Articulates for stability of ecology and social justice • Creating environment stability through balancing restoration, and preservation of ecology • Preserving surviving natural forests • Investigating soil erosion • Effective use of forest products and maximize the replacement of wood • To protect minor forest produce for livelihood of tribal • Use of village and common land (not needed for other productive utilization) for trees and feed covers and income generated should belong to *Panchayats* • Ownership rights for trees to farmers, landless labors, tribal women, and Scheduled Castes • The rights and concession to fulfill demands pertaining minor forest produce • Collection of forest products along with institutions for marketing • Forest-based industry should raise raw materials to meet its requirements by linking people who grow raw materials by supporting them with finance, advices, harvesting, and transportation • Forest-based industry to bestow employment and produce support in raising trees • Forest not to be undertaken for plantation or any other activity to industries • Consciousness for forest education to be encouraged
10	National Policy on Indian Systems of Medicine and Homeopathy, 2002	It underlines that the supply chain is carried out on an informal basis There are restrictions on wild extraction and procurement Highlighted shortage of raw materials for industry, Adulteration as a major threat to supply chain and quality Highlights conservation and encourages medicinal plants cultivation Advocates buy-back agreements between farmers and purchasers Encouraging R&D, gene conservation of endangered medicinal plants Endorse regulation of farmers registration Encourages women and tribes participation in the sector

S. no	Acts/policy	Contents			
11	EXIM policy	The policy reaffirmed that the plant quarantine order 2003, as amended, would govern all importation of seeds and planting materials. The following species are considered under the act:			
		Species	Common Name	IUCN Red list status	CITES (Appendix)	Reference

Table 3 (continued)

S. no	Acts/policy	Contents				
		Cycas beddomei Dyer	Beddome's Cycad	EN	I	(Deora and Shekhawat 2020; Gowthami et al. 2021; Moshi and Mhame 2013)
		Vanda coerulea Griff. ex Lindl	Blue Vanda	–	I	(Nag and Kumaria 2018; Bodeker et al. 2014)
		Dolomiaea costus (Falc.) Kasana & A.K.Pandey	Kuth	CR	I	(Schippmann 2006; Olsen 2005)
		Paphiopedilum acmodontum M.W.Wood	Lady's slipper orchids	–	I	(Kuniyal et al. 2013; Van de Kop and Ghayur 2006)
		Nepenthes khasiana Hook.f	Pitcher Plant	EN	I	(Xia et al. 2022; Phelps et al. 2010)
		Renanthera imschootiana Rolfe	Red Vanda	–	I	(Cahyaningsih et al. 2021; Kafle et al. 2018)
		Rauvolfia serpentina (L.) Benth. ex Kurz	Sarpagandha	–	II	(Sharma et al. 2022; Kunwar 2019; Gopi et al. 2018; Van Andel et al. 2015)
		Ceropegia ambovombensis Rauh & Gérold		–	–	(Posthouwer et al. 2018; Smith et al. 2011)
		Caralluma frerei G. D	Shindal Mankundi	–		(Umdale et al. 2021; Mishra and Arya 2010; Saxer 2009)
		Podophyllum hexandrum Royle	Indian Podophyllum	–	II	(Rathore et al. 2021; Joshi et al. 2017)
		Cyathea J. E. Smith	Tree Ferns	–	–	(Medeiros et al. 2017; Sangzhu et al. 2009)
		Dioscorea deltoidea Wall. ex Griseb	Elephant's Foot	–	II	(Bose et al. 2016; Moffat 2013)
		Euphorbia rothiana Spreng	Euphorbias	–	II	(Perdue et al. 2021; Abensperg-Traun 2009)
		Osyris lanceolata Hochst. & Steud	Orchids	–	–	(Molares and Ladio 2014; Sajem et al. 2008)
		Pterocarpus santalinus L.f	Red Sanders	NT	II	(Mollel et al. 2022; Hilonga et al. 2019)
		Taxus wallichiana Zucc	Common Yew or Birmi leaves	EN	II	(Dhiman and Bhattacharya 2020; Uprety et al. 2012)
		Aquilaria malaccensis Lam	Agarwood	CR	II	(Rajasekharan and Wani 2020; Milugo et al. 2013)
		Aconitum napellus L		–	–	(Rafiq et al. 2021; Rawal et al. 2009; Larsen et al. 2005)
		Coptis chinensis Franch		EN	–	(Nadda et al. 2020; Lavorgna et al. 2018)
		Coscinium fenestratum (Gaertn.) Colebr	Calumba wood	DD	–	(Danapur et al. 2020; Thakar and Sharma 2020; Senarath 2010)
		Dactylorhiza hatagirea (D.Don) Soó	Wanpolagpa, Hathajodi, Salam panja	LC	II	(Dey et al. 2020; Kadir et al. 2012)

Table 3 (continued)

S. no	Acts/policy	Contents				
		Gentiana kurroo Royle	Kuru, Kutki	CR	–	(Sharma et al. 2021; Voravuthikunchai and Kitpipit 2005)
		Gnetum arboreum Foxw	–	–	–	(Astutik et al. 2019)
		Kaempferia galanga L	Galangal, Chandramula	–	–	(Cahyaningsih et al. 2022; Parida et al. 2019; Preetha et al. 2016; Kotwal 2014)
		Nardostachys jatamansi (D.Don) DC	Jatamansi	CR	II	(Tahir et al. 2016; Broad et al. 2014)
		Panax notoginseng (Burkill) F.H.Chen	Ginseng	–	II	(Kafle et al. 2018; Dolly 2014)
		Picrorhiza kurroa Royle ex Benth	Kutki	–	II	(Thakar and Sharma 2020; Van Andel and Havinga 2008)
		Swertia chirayita (Roxb.) H.Karst	Charayatah	–	–	(Wu et al. 2022; Samaddar et al. 2019; Schippmann 2018; Kumar and Van Staden 2016)

Source: https://legislative.gov.in/documents/list-of-central-acts

CR critically endangered, *DD* data deficient, *EN* endangered, *LC* least concern, *NT* near threatened

(SBR) region of West Bengal, demonstrated that it is crucial to look into how local politics affect access to forest rights in areas where the act has implementation gaps or is underappreciated. The study identifies the political forces that have an impact on how the act has been implemented (or not) in the SBR. Despite being a rights-based law, it contends that FRA implementation is closely linked to vested political interests in certain places. The study concludes that it is insufficient to elucidate the constraints of FRA implementation by criticizing the political economy of forest conservation (Sen and Pattanaik 2019).

Some discussions also highlight that the implementation of this Act, which recognizes the fundamental rights to a livelihood for forest residents, is plagued by several issues at multiple institutional levels. A study highlighted tension between conservation efforts and local residents' livelihoods, with particular emphasis on the FRA in protected areas in Odisha (Sarangi 2017). The appropriate application of the FRA upholds the rights of forest inhabitants to diverse forest products as well as stable property rights on forest land. The tension between conservation and livelihoods within protected areas might be lessened by this entitlement (Bose 2010). The current individual, community, and areas vested under this act are mentioned in the below table dated: 24-June-2022. Table 4.

Some initiatives taken by Ministry of Ayush in context to medicinal plants

In 2014, a unique ministry with the name Ministry of Ayush was created to regulate conventional medical practices. The Ministry of Ayush, Government of India, is responsible for carrying out the Centrally Sponsored Scheme of the National Ayush Mission (NAM). The "Medicinal Plants" component of the NAM system is deployed in mission mode and promotes market-oriented farming of prioritized medicinal herbs in specified groups or zones within selected districts of states (https://www.nmpb.nic.in/content/schemesproposals). The creation of nurseries with backward links for the growing and supply of high-quality planting stock, post-harvest administration with forward links and primary processing, infrastructure facilities, etc., are all supported according to the scheme's rules.

In the National AYUSH Mission (NAM) program, the Ministry of AYUSH has sponsored the production of medicinal herbs on 56,396 hectares of land. The Atma Nirbhar Bharat for Preferment of Herbal Cultivation program has been announced by the Ministry of Finance with packages totaling Rs. 4000 crores. The "*Pradhan Mantri Vriksh Ayush Yojana*" scheme, which the Ministry of AYUSH has created for the manufacture and selling of

Fig. 4 Categorization of states in context to FRA implementation

Table 4 The current trends in Forest Rights Act

Rights		Reference
Individual rights	21,32,217	https://tribal.nic.in/FRA.aspx
Community rights	1,02,075	
Area vested under individual rights	18.40 lakh hectare	
Area vested under community rights	45.99 lakh hectare	

medicinal plants, is also under consideration by the Government of India (https://www.pib.gov.in/PressReleasePage.aspx?PRID=1703485).

National Medicinal Plants Board

In spite of such resource base, the medical plant industry is mainly unregulated and not well researched even at the national level, despite its enormous resource, engagement of labor, and livelihood option. In line with this, the Government of India established the NMPB on November 24, 2000, with the goal of strengthening the nation's medicinal plant industry while also protecting the wild stock (https://nmpb.nic.in/). The main goal of this board under Ministry of Ayush is to create a body that would be incharge of coordinating all activities related to the medicinal plant industry, including developing policies and plans for in situ preservation, growing, harvesting, marketing, processing, medication research, etc. (Kala and Sajwan 2007). Soon after it was established, NMPB began to take active steps to understand the sector's diversity in terms of trade and calculate yearly consumption. The NMPB has developed a range of policies, plans, and projects for protection, responsible harvesting, price-effective cultivation, research and innovation, manufacturing, and commercialization of raw materials to promote and grow the market for medicinal plants. A Memorandum of Understanding (MoU) for the secure preservation of medicinal plants genetic materials for lengthy preservation in the National Gene Bank of ICAR-NBPGR was recently signed between the two parties on July 6, 2020 (Gowthami et al. 2021). The National Medicinal Plants Board (NMPB) has also implemented the Central Sector Scheme on "Conservation, Development and Sustainable Management of Medicinal Plants," which supports *in situ* and *ex situ* preservation, livelihood connections with Joint Forest Management Committees (JFMCs), Biodiversity Management Committees (BMCs), Panchayats, and self-help groups (SHGs), as well as IEC tasks like schooling, trainings, and seminars (https://nmpb.nic.in/).

Drugs and Cosmetics Rules, 1945, Schedule T(a)

The National Medicinal Plants Board and the State Drug Licensing Authorities are required to receive an annual report from Ayurvedic, Siddha, and Unani (ASU) drug manufacturers detailing the raw resources used in the production of their goods during the previous fiscal year in accordance with the Drugs and Cosmetics Rules 1945 by 30th June of the successive fiscal year, as stated in notification No. K. 11,020/2/2006-DCC (Ayush) (Kumar 2017). The Schedule T of Drug and Cosmetics Act, denotes good manufacturing practices (GMP) for ASU medicines (https://cdsco.gov.in/opencms/export/sites/CDSCO_WEB/Pdf-). Many herbal industries consuming raw herbs for manufacturing of herbal formulations are submitting the record of raw materials pertaining to their source, plant part, and quantity used. To increase strength, the supply chain for therapeutic plants, and increase the monitoring of the natural resource base, more efforts are required to raise awareness about the submission of data in NMPB's online portal (Ved and Goraya 2017).

Some state-level initiatives on medicinal plants conservation in India

The Agricultural Technology Management Agency (ATMA) started medicinal plant projects to aid relatively underprivileged farmers in the Patna District of Bihar. The primary crop was *Catharanthus roseus* (L.) G.Don., and the study highlighted the medicinal plants' high potential while also stressing the necessity to create stable marketplaces for their goods and minimize the use of middlemen (Singh et al. 2013). They necessitated for the need of creating biopartnerships that link rural communities with industry, new government regulations for medicinal plants creating new market opportunities and developing a second supply chain for other curative plants. According to a study, the state of Uttarakhand has created a structured supply chain for MAP items, which includes the purchase and distribution of goods through a number of government organizations that serve as mediators, such as Bhesag Corporation. But relatively little of the entire amount of produced goods is passing through this chain because of various shortcomings. The study suggested that the government set up a management information system (MIS) under Bhesag Corporations, auction pricing could be made dynamic and could be linked to the current market demand, price control should be carried out by the administration in accordance with demand and supply of various plants, and also recommended promoting herbal tourism in the state (Pangriya 2015). To integrate maintenance and sustainable use objectives into sustainable forestry policies and practices at the local, state, and national levels in three Indian states—Uttaranchal in the north-west, Arunachal Pradesh in the north-east, and Chhattisgarh in the center —the State Medicinal Plants Board (SMPB), Uttarakhand, completed a project in 2012. They discussed the significance of harmonizing the current policy and legal framework for India's medicinal plant preservation and sustainable use (GoI, UNDP, 2008).

The state government of Punjab, India has chosen to encourage the farming of therapeutic plants to protect the 20,000 hectares of forest land in Pathankot district. This initiative will not only give the locals who live in the hills and forest a source of income, but it will also develop a volunteer force of forest guards. As per reports, different self-help groups had been formed to promote the use of *Phyllanthus emblica* L., *Cymbopogon citratus* (DC.) Stapf, *Terminalia chebula* Retz, *Terminalia bellirica* (Gaertn.) Roxb, and *Ocimum tenuiflorum* L. (https://timesofindia.indiatimes.com/city/chandigarh/punjab-to-promote-medicinal-plant-cultivation/articleshow/59519397.cms).

To improve the healthcare and livelihood stability of its residents on a consistent way, Himachal Pradesh—an Indian state introduced a policy for the conservation and improvement of medicinal plant resources in both forest areas and outside of forests in 2006. This policy aims to raise awareness of the issues surrounding the growth of medicinal herbs in woods and to launch extensive programs for their continuous production. As stated in the National Forest Program, 1988, this policy also strives to satisfy the minor forest harvest needs of the countryside and indigenous communities (sub-Sect. 3.5 under Section Value chain of therapeutic plants i.e., essentials of forest management). Additionally, the policy emphasized broad recommendations for extracting minor forest resources, such as medicinal plants in the forestry working plans, and special laws in the instance of the regions of Mandi and Chamba (Gouri et al. 2004).

Major research institutions working on medicinal plants in India

The Indian Council of Agricultural Research (ICAR) and the Council of Scientific and Industrial Research (CSIR), through their respective Directorates of Medicinal and Aromatic Plants Research (DMAPR) and All India Coordinated Research Project on medicinal and aromatic plants and betel vine (AICRP on MAP&B) centers located in State Agricultural Universities, respectively, are conducting organized work in the quality improvement of therapeutic plants on a national scale. A number of organizations such as National Institute of Science Communication and Information Resources (NISCAIR), Botanical Survey of India (BSI), Pharmacopoeia Commission for Indian Medicine and Homeopathy (PCIM&H) along with state agricultural

universities are also active as government agencies and voluntary non-governmental groups in various states (Ved and Goraya 2017). The National Bureau of Plant Genetic Resources (NBPGR) is indeed focusing on medicinal herbs as a nodal institution for the gathering, classification, recording, and conservation of medicinal and aromatic plants (Paroda et al. 2013).

Constraints in strengthening medicinal plants sector

While there are prospects for growing markets for therapeutic plants and their products in developing nations, particularly in the least developed countries (LDCs), there are also a number of obstacles that must be addressed to satisfy the country's as well as the market requirements of advanced countries (Sen et al. 2011; Kala et al. 2006). End consumers markets require medicinal herbs and their ingredients that are uniform in quality and clear from impurities for use in medications and healthcare. They need materials that have valid botanical identity, and adhere to the (sometimes diverse) regulatory standards of various markets (Hishe et al. 2016; Shahidullah and Haque 2010).

According to these requirements, resources must be carefully picked, collected, and handled and stored sensitively during the post-harvest and transit processes. Many of these requirements are difficult to fully adhere to in areas where natural harvesting occurs as well as where there really are small-scale, frequently inexperienced operators involved. Indiscriminate harvesting and treatment practices, a deficiency of research into creating high-yielding variations, ineffective processing methods that result in low yields and low-quality products, challenges with marketing, a lack of local markets for primary processed goods, an absence of technology, and an insufficient knowledge about market data, and a lack of understanding of supply capacity are all problems (Volenzo and Odiyo 2020). Even under cultivation, these requirements are less likely to be consistently met when numerous smallholders are involved. Beyond conventional knowledge and belief, there is little information about the medical characteristics of herbs, which limits their usage and marketability (Booker et al. 2012). Grazing by farm animals and use of forage, the long-term consequences of large-scale scale seed "predation", and deleterious harvesting practices, when crops are cut down to reap the seed pods, are other challenges. Invasive plants that have been introduced have also had a deleterious impact on the future supply chains (Rathore 2019). Along the supply chain, operations are now becoming more specialized, giving individuals or small groups of individuals additional possibilities to exercise their market power and create barriers to entry of others. The question of intellectual property rights (IPR) could be extremely significant to all exporters from emerging nations. Plants cannot be patented because they have been utilized in traditional medicines for a very long time. They can be registered as distinct national or regional trademarks with clear origin requirements (James 2016). In developing nations, there is little understanding of the entire topic of IPR. Improved monitoring, quality control, and cautious pricing of wild stocks are all lacking. Better training, information gathering, testing, post-harvest infrastructure, and a viable, customer-driven supply chain for the industry can all be used as markers of improvement.

Way forward

To advance the medical plant business and foster efficient trade in medicinal plants and their derivatives in emerging nations, a number of actions may be deemed crucial at the national level. It is necessary to build a critical mass of arable land to guarantee a bigger, more consistent supply. To achieve this, collaboration among farmers at the village or regional level must be encouraged. To introduce changes effectively and economically, collectors must be grouped into associations and clusters. It is necessary to reduce the number of brokers in the marketing and distribution network and to strengthen the negotiating position of farmers and collectors. This would be financially advantageous for primary producers and collectors, who are often among the poorest people.

Exploring cultivation methods for lengthy continuous stream may be advantageous for the preservation of the species as well as for creating income opportunities for farmers in India, especially in light of the likelihood that wildlife species of CITES-listed medicinal plants are declining due to unfettered collection to satisfy the rapidly growing international demand. Implementing CITES' non-detrimental guidelines and management plans for the species is necessary to ensure sustainability. Additionally, it is advised that species recovery programs be put in place for critically endangered species to return them to their original habitats. To accomplish this, establishing regeneration blocks locally can be crucial. The statewide distribution of numerous species may also use these blocks as nodes. India's commerce in herbal raw drugs is not open, and there is not much to show that it reflects fair trade principles. To ensure adherence to CITES Appendix II, there is also necessity for greater enforcement of harvesting quotas.

Data management or record management system for medicinal plants collected in the wild shall be strengthened at grass-root levels including village *Panchayats*. In addition to preventing unlawful wild collection, a strong chain of command and traceability system would ensure that harvesters receive greater compensation for their goods on both

international and domestic markets. In this situation, it is necessary to implement market-based instruments like fair wild certificates for the conservation, stability, and fair trading of the wild medicinal herbs. On the other hand, vertical integration in the supply chain, which would bring growers and manufacturers of medicinal plants closer together, could have a number of advantages in terms of cost, lead time, quality, and management of supply chains (Shahidullah and Haque 2010).

Additionally, post-collection processing, value addition, and product presentation need to be improved. Important factors to take into account include classifying or converting more perishable medicines into simple goods, such as dried leaves, oil extracts, etc., to increase value as much as possible and extend their shelf life. It is necessary to develop the chemical research and study the impact of poor practice on the active components of the species. These initiatives would benefit from increased cooperation and coordination across the many groups interested in this topic, especially those involved in education, research, manufacturing, distribution, and commercialization. Researchers and farmers need to work together more. To help find new product kinds or market niches for existing items that could be filled, it is also necessary to become familiar with current marketplaces and trading routes.

The regulation of the trade in cultivated and wild therapeutic plants is complex and varies from state to state. There is also need to undertake studies pertaining to global review of the trade of herbal products, clarifying market issues and consider more effective solutions. Due to different market conditions, approaches used, materials, and products, many issues need more country-specific market analysis for generating different sub-enterprises based on local knowledge of manufacturing of indigenous herbal medicines (Palash et al. 2021). To meet the Sustainable Development Goals by 2030, there is a requirement for better coordination between players for a national policy or strategy on protection while facilitating fair trade medicinal plants. To access markets early in the supply chain, developing nations should work to grow their resources sustainably and start by exporting their raw materials to wealthier nations. For that, they can start offering herbal supplements before going after the tightly controlled herbal remedy industry.

It is also imperative that strict implementation of Biological Diversity Act, 2002, Patents Amendment Act, 2005, TRIPS agreement, classifying medicinal plants under non-timber forests products (NTPS) than minor forest produce (NFP) as a solution to strengthen transparency in supply chain of medicinal plants. Additionally, programs like the National Mission on Medicinal Plants, training for growers of medicinal herbs, the establishment of distillation/processing units, nursery raising for quality planting materials, the establishment of government agencies, and herbal agro marketing federation, etc., are crucial for the sustainable use of medicinal herbs.

Conclusion

Considering the diversity of medicinal plants sector, its value-chain analysis is really complicated. In general, the value chain of medicinal plants is very long and there is urgent need to shorten the chain via less participation by the middlemen and enabling more bargaining power to the producers. To maintain consistent supply of medicinal plants, their cultivation and record management system shall be developed. Furthermore, many acts and rules govern medicinal plants; therefore, there needs to be a harmonization between different acts and rules for conservation, utilization, transient, and trade of the medicinal plants. Also, policy makers and conservationists should devise an exclusive medicinal plants policy for the nation. Research and development on medicinal plants, especially those that are in danger of extinction, should receive more attention. To trade successfully, one needs to have a variety of skills, understanding, and experiences. Value chain assessment can assist individuals in better comprehending how trade networks operate, who the major players and organizations are and what their key tasks are, how and where to trade medicinal herbs in a wide range of options.

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Declarations

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Authors and Affiliations

Preet Amol Singh[1] · Subhransu Dash[1] · Abinash Choudhury[1] · Neha Bajwa[1]

✉ Preet Amol Singh
preetnabha67@gmail.com

Subhransu Dash
subhransuabc@gmail.com

Abinash Choudhury
abinashchoudhury078@gmail.com

Neha Bajwa
nehabajwa2765@gmail.com

[1] University Institute of Pharma Sciences (UIPS), Chandigarh University, Mohali, Punjab, India