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Medicinal and aromatic plants for climate change adaptation: Scope and prospects with special reference to North Eastern Himalayas

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Abstract
With the ever increasing global population, climate change is a serious threat to the food, health and livelihood security of millions of people. Across the larger part of the globe the productivity and profitability of agricultural systems are declining necessitating newer, more resilient and sustainable systems. Commercial cultivation of medicinal and aromatic plants (MAPs) could be a viable option as these plants have better adaptability to diverse climatic conditions, requires lower inputs and have higher value and demand than conventional crops. MAPs can be successfully introduced for diversification of agricultural, horticultural and agroforestry systems and also for reclamation of unproductive barren and wastelands. North eastern region of India harbors several unique and important MAPs species and with proper planning and management of these resources the MAPs sector has a great potential for agricultural resurgence in the region towards climate change adaptation and food, health and livelihood security.

Keywords: MAPs, climate change adaptation, agricultural diversification, wasteland reclamation

Introduction
Climate change is an serious threat to the food security and livelihood of millions of people and with the global population projected to increase from present 6.8 billion to 8.3 billion by 2030 and 9.3 billion by the middle of this century, the demand for health care, food, fresh water and industrial raw material will increase which will put more pressure on the already stressed environment. It has been projected that by the end of this century, global temperatures are likely to increase by 1.8 to 4.0° C, causing more frequent hot extremes, floods, droughts, forest fires, cyclones, recession of glaciers. These changes are bound to have a significant impact on global crop production and food availability. It has been widely recognized that the effects of global warming on agriculture would be more on developing countries since most of these countries have less capacity to adapt to climate change moreover, most of these countries are located in warmer parts of the globe with temperatures close to or beyond thresholds at which further warming will reduce agricultural output. The United Nations Intergovernmental Panel on Climate Change (UNIPCC) reported that an overall increase of 2°C temperature and 7% rainfall would lead to an almost 8% loss in net farm level revenue. In the present agricultural scenario, due to poor resource availability, high input cost, abnormal climatic phenomenon, increased pest and disease incidence etc. the productivity and profitability of traditional/conventional agricultural are gradually reducing and plateauing as a result farmers across the globe are looking for better alternatives to diversify from traditional/conventional agriculture. These changes put more threats on livelihood security of farmers, thereby, requiring alternative crops, which can withstand the changing climate conditions. The challenges of increasing food and fodder requirements and healthcare requirements in the face of growing population, natural resource degradation, climatic change, plateauing farm income, new global trade regulations and new parasites calls for development of diversified, more resilient, robust and sustainable productive systems incorporating non conventional crops and plants such as MAPs (medicinal and aromatic plants) which not only have better adaptability to the changing climate but also have higher value and demand than traditional crops while at the same time catering to the twin food and health care needs of the people.

MAPs and climate change mitigation
Medicinal and aromatic plants are known to be natural wealth that provides additional income to a large section of under privileged populations and tribes whose livelihood depends on

MAPs of forest resources. With the global climate change crisis threatening the livelihood security of farmers, increased adaptation of crops to withstand the changing climate is required wherein, introduction of medicinal and aromatic plants to the existing cropping patterns and systems can help mitigate the adversity of the changing climate. The increasing cost of food grain cultivation due to reducing productivity of traditional agriculture systems have driven the farmers towards cultivation of MAPs since they fetch better returns over traditional crops and have high export demand. Due to availability of large number of species with diverse climatic requirements medicinal and aromatic plants can be easily introduced into existing cropping systems or grown as sole crops. Diversification of conventional and traditional agricultural systems, agroforestry systems, forest and forest plantations, plantations crops, fruit orchards can be achieved through introduction of MAPs as intercrop, mixed crops, companion crops, shade providers, boundary markers etc. which can help maximize resource use efficiency and productivity and generate additional income and overcome economic loss caused due to adverse climatic conditions. Cultivation of medicinal and aromatic plants is considered less risky since many of them are largely tolerant to drought and floods conditions, have low incidence of pest and disease attack and, compared to conventional agricultural crops, cost of cultivation is much lower for MAPs, since most of them are not high input responsive. Additionally, due to their hardy nature, some of the MAPs can be successfully grow in barren/wastelands, degraded, eroded and problematic (saline, alkaline and acidic) soils and help reclamation of such underutilized lands for better remuneration to the farming community. Therefore, cultivation of MAPs not only serves as an alternative and a supplement for small and marginal farmers who cannot afford the high input cost of traditional and commercial crops but can help in upgrading and building more resilient, resource efficient and productive systems which can adapt to the changing climate and meet the challenges of food and health security.

MAPs in agroforestry systems

Traditional agroforestry systems: Many plants in traditional agricultural systems in the tropics have medicinal value and are found in home gardens, as scattered trees in croplands and grazing lands, on field bunds and as live fences. Plants like arjuna (*Terminalia arjuna*), tulsi (*Ocimum sanctum*), drumstick (*Moringa oleifera*) and curry leaf (*Murraya koenigii*) are common backyard plants in many Indian households and are routinely used for common ailments or in food preparations but are seldom used for commercial purposes. In fact, many of these plants are valued for fuel wood, fodder, shade, boundary demarcation, etc. and their medicinal value is secondary.

Forest and Forest plantations: Agroforestry system offers a convenient strategy for cultivation and conservation of MAPs since most of the medicinal plants are naturally found in the forest and are also shade tolerant. The integration of trees and medicinal plants which can provide a sustained and regular supply of an array of products ranging from food, fodder, fuel, fiber, pulp and medicinal plants etc. for consumption and trade while, simultaneously conserving the biodiversity and reducing the pressure on the natural resources. Cultivation of such MAPs can be taken up in thinned forests and cleared forest patches and as intercrops in new forest plantations. MAPs growing in forests should tolerate/prefer partial shade; moist soils high in organic matter, high relative humidity and mild temperatures. In addition to providing shade, the trees may also benefit the understory component from hydraulically lifted water. Light demanding understory species may be intercropped initially to provide early returns from plantations and after canopy closure, shade tolerant species can be intercropped**.** Large cardamom (*Amomum subulatum*), safed muslin (*Chlorophytum borivilianum*), rauvolfia (*Rauvolfia serpentine*), crepe ginger (*Costus speciosus*), himalayan yam (*Dioscorea deltoidea*), raicilla (*Cephaelis ipecacuanha*) are some understory herbs and shrubs that can be produced as part of forest farming or in new forest plantations to improve economic returns from forests in India.

Intercropping of MAPs

Medicinal plants as upperstory trees: In this system tall and perennial medicinal trees are planted at wide spacing and the interspaces are utilized for growing with agricultural crops and medicinal plants. Depending on spacing and nature of the trees, some of the medicinal trees may allow intercropping for many years or even on a permanent basis. Trees such as *Parkia roxburghii*, *Prunus africana*, *Santalum album*, *Saraca indica*, *Aegle marmelos*, *Anona squamosa*, *Emblica officinalis*, *Moringa*, *Sapindus mukorossi*, *Azadarichta indica*, *Terminalia chebula*, *Terminalia arjuna*, *etc.* can be successfully intercropped with annual crops in the early years until the tree canopy closes. Coffee (*Coffea arabica*), cacao (*Theobroma cacao*) and tea (*Camellia sinensis*) which are traditionally grown under the shade of multipurpose trees offers scope for cultivation of forest medicinal trees that grow tall and develop open crown at the top like *Parkia roxburghii* as shade providers in such plantations (Balasubramanian, 1986) [2].

Medicinal plants as lower strata plants: Many short statured and shade tolerant MAPs and culinary herbs can be successfully introduced as short-term intercrop, as lower strata species, during the juvenile phase of the trees in timber and fuel wood plantations, fruit trees and plantation crops. The number of years MAPs can be intercropped with a given tree species depends on the spacing and canopy of the tree species and also the nature of the MAPs. Shade tolerant and rhizomatic MAPs can be grown on a long-term basis in widely spaced plantations. Medicinal plants like *safed musli* (*Chlorophytum borivilianum*), rauvolfia (*Rauvolfia serpentina*), turmeric (*Curcuma longa*), wild turmeric (*C. aromatica*) and ginger (*Zingiber officinale*) have been successfully intercropped with fuel wood trees like *Albizia lebbeck*, *Eucalyptus tereticornis*, *Gmelina arborea*, and *Leucaeana leucocephala* (Mishra and Pandey, 1998; Prajapati *et al.* 2003) [8, 13]. Plantation crops like coconut (*Cocos nucifera*) and arecanut (*Areca catechu*) which allow 30-50 % of incident light underneath, are ideal for growing medicinal plants like cardamom (*Elettaria cardamomum*), *Kaempferia galangal*, black pepper (*Piper nigrum*), ginger (*Zingiber officinalis*), turmeric (*Curcuma longa*), etc. Rubber (*Hevia brasiliensis*) is another plantation crop, which has been successful intercropped with MAPs like *Dioscorea floribunda* in Assam. Aromatic plants like *Mentha spp.*, lemon grass (*Cymbopogon spp.*) Java citronella (*C. winterianus*) and palmarosa (*C. martinii*) can be successfully intercropped with *Populus deltoides* or *Eucalyptus spp.* for initial three to five years.

MAPs for reclamation of wastelands and problem soils

In India, degraded lands occupy 20.16 % of total geographical area and these degraded lands have reduced productivity and lacks the capacity to support desirable vegetation and maintain yield levels. A number of researches across the globe have found that many species of medicinal plants can grow successfully in degraded lands as well as reclaim such lands. The use of trees for rehabilitating marginal sites is a well-known forestry practice. Plantations of *Phyllanthus emblica* and *Azadirachta indica* were found to improve biological diversity viz., number of ground flora species, diversity index, population of bacteria, fungi, nematodes, micro arthropods and VAM fungi spores and available NPK status of degraded lands (Verma, 2004) [20]. The cummulative affects, over decades, of adding water with dissolved salts to the soils of arid and semi arid region has resulted in major problems of sodicity affecting about 1.5 billion hectares. Experiments on sodic wasteland management have shown the prospects of cultivation of aromatics crops like palmorosa *(Cymbopogon martini)*, lemon grass *(Cymbopogon flexuosus)*, vetiver *(Vetiveria zizanioides)* and German chamomile *(Matricaria chamomilla)* (Singh, 1997) [11, 17] and fruits plants like aonla, guava, ber, bael and karonda on sodic soils (Pandey and Singh, 1997) [11, 17].

Table 1: Estimated cost and benefits from medicinal and aromatic pants in sodic soils

Crop	Yield	Cost of cultivation (Rs.)	Gross returns (Rs./ha)	Net returns (Rs./ha)
Agricultural crops				
Paddy	3.0a (3.5b)	7000	20000	13000
Wheat	2.2a (2.8b)	8000	16000	8000
Medicinal & aromatic plants				
Palmarosa	150c	15000	50500	34500
Vetiver	30c	30000	75000	45000
Isabgol	1.0a (4.0b)	10000	60000	50000

a - grain yield (t/ha), b - straw yield (t/ha), c - oil yield (liter/ha)
(**Source:** Prasad and Patra, 2004) [14]

Dry land areas in India account for 68.4% of the net sown area and contribute 44 % to the total food grain production in India. These dry land areas are usually characterized by crop failures and low and unstable yields due to abnormal weather patterns and traditional crops are no more economical to the dry land farmers. With the changes in the climate due to global warming the conditions under dryland areas are bound to get more erratic and abnormal. Plants like Ashwagandha (*Withania somnifera*), Kalmegh (*Andrographis paniculata*), Senna (*Cassia angustifolia*), Makoi (*Solanum nigrum*), Tulsi (*Ocimum sanctum*), Sarpagandha (*Rauvolfia serpentine*), Guduchi (*Tinospora cordifolia*), Gudmar (*Gymnema sylvestre*), Shatavarai (*Asparagus racemosus*) and Langali (*Gloriosa superba*) can be suitably cultivated under dry land conditions (Narashima Reddy, 2006) [10]. These plants have wider adaptability to the adverse climatic conditions, does not require high maintenance and input cost and grow relatively fast with high reproduction rates and can be easily incorporated in such areas. About 10.3% of total net sown area is waterlogged in India and these lands are either lying vacant or the productivity is very low mainly because there in unavailability of suitable agricultural crops for economic utilization of such lands. Rice is the most predominant crop in these areas however; rice soils are one of the potential sources of methane emissions moreover excess water leads to failure of rice crop, poor soil structure and fertility, etc. MAPs like bacha *(Acorus calamus)*, brahmi *(Bacopa monnieri)*, nagar motha *(Cyprus scariousus)* and vetiver *(Vetiver zizanioides)* are found to suitably grow under water logged conditions and may be a better alternative to traditional rice based cropping systems (Singh *et al.* 2003) [18]. Cultivation of MAPs in degraded land will not only help minimize the pressure on croplands and reclaim the degraded lands but also help save the diversity of these herbal plants.

Table 2: Yield and economic potential of selected MAPs in waterlogged soils

Crop	Economic part	Cost of cultivation (Rs./ha)	Production (Kg/ha)	Rate (Rs./kg)	Gross returns (Rs./ha)	Net returns (Rs./ha)
Bacha	Rhizome	25000	2500	20	50000	25000
Brahmi	Whole herb	20000	2000	20	40000	20000
Nagar motha	Rhizome	30000	15000	5	75000	45000
Vetiver	Essential oil	40000	10	10000	100000	60000

(**Source:** Singh *et al.* 2003) [18]

Status and scope of MAPs with special reference to North East India

India has one of the oldest, richest and most diverse cultural traditions in the use of medicinal plants and a large number of traditional healing systems such as Ayurveda, Siddha, tribal and folk medicines, etc. are widely practiced for treatments from very complex diseases like cancers to simple requirement of primary health care. Out of 15,000 to 20,000 plants with medicinal properties, only about 7,500 plant species are used in ethnomedicines (Shankar and Majumdar, 1997) [15]. North East India comprising of eight Indian states covers an area of 2,62,060 sq. km representing 8% of the country's total geographical area. The region is one of the richest reservoir of plant biodiversity in India and is one of the 25 hot spots of mega diversity in the world with its species richness and endemism (Myers *et al.* 2000) [9]. The varied forests types found in the region covers 65.59 % of the total geographical area of the region (Forest Survey of India, 2015) [6] and are home to numerous plants and animals. The region is known as 'Cradle of Flowering plants' and harbors about 42% of the total 17500 flowering plants of the country out of which 40% of them are endemic (Chakravarty *et al.* 2012) [3]. As per records available in the database of FRLHT (Foundation for Revitalization of Local Health Traditions) over 6500 species are used medicinally in the country and NE India has a share of more than 60% presence. A perusal of the prioritized medicinal plants for promotion by NMPB (National Medicinal Plants Board) also revealed that over 80

% of the listed plants exists in the region. In fact most of the top traded medicinal plants in the country are found in the region. A number of rare and high value plants like *Aconitum heterophyllum, Aquilaria malacensis, Paris polyphylla, Homalomena aromatica, Podophyllum hexandrum, Taxus wallichi, Rubia cordifolia, Illicium griffithii, Valeriana spp, Swertia chirayita, Clerodendrum colebrookianum, Picorrhiza kurooa, Rheum emodi, Coptis teeta, Panax pseudoginseng, Sugandha kokila,* etc. are found in the region. Some of the untapped promising medicinal plants like black ginger and black turmeric are found to grow in the wild. The major usage of medicinal plants is in the form of traditional healing practices and local applications thus there is a large dependency of the healers on medicinal plants of the region. Each tribe and sub-tribe in the region has their own distinct and rich indigenous traditional knowledge system and with over 225 ethnic communities inhibiting the region (Chatterjee *et al.* 2006) [4]. This valuable indigenous knowledge if properly studied and researched upon could lead to new discoveries and advancement of modern science. There are several unique and important medicinal plants species in the Northeast region that are in high demand and most of this demand is met from wild collections. National level trade on some selected species found in the region, are given in Table 3. Unfortunately, there is no organized harnessing of these plant resources; the existing trend is to harvest these plants from the wild, as cultivation of MAPs is still negligible in the region. Another very important feature of the region is that it shares more than 4,500 km international border with China, Myanmar, Bangladesh and Bhutan and serves as a strategic international business and trade center. Given this rich resources, the Northeast region of India has great potential in the medicinal plants sector and with proper organization, planning and management of the available resources the MAPs sector could be the answer to agricultural resurgence in the region for climate change adaptation and food, health and livelihood security.

Table 3: National level trade information on selected species from the Northeastern region

Sl. no.	Name of species	Trade name	Estimated annual trade (MT)
1	*Aconitum ferox*	Vachnag	100-200
2	*Aquilaria malaccensis*	Agar	100-200
3	*Cinnamomum tamala*	Tejpat	500-1000
4	*Emblica officinalis*	Amla	16000
5	*Gmelina arborea*	Gambhar Chal	1000-2000
6	*Juniperus communis*	Hauber	500-1000
7	*Mesua ferrea*	Nagkesar	200-500
8	*Oroxylum indicum*	Batghila	1000-2000
9	*Picrorhiza kurroa*	Kutki	200-500
10	*Piper longum*	Pippali	1000-2000
11	*Rubia cordifolia*	Manjistha	500-1000
12	*Stereospermum chelonoides*	Patala	1000-2000
13	*Swertia chirayita*	Chirayit	500-1000
14	*Taxus wallichiana*	Yew	100-200
15	*Terminalia bellirica*	Bohera	2000-5000
16	*Terminalia chebula*	Harda	5000-10000
17	*Valeriana jatamansi*	Pompos	100-200

(**Source:** Ved & Goraya, 2008) [19]

Trade potential of maps

The global market for herbal medicines currently stands at US $ 62 billion growing at a rate of 7 per cent per annum (Planning Commission, 2000) [12] and is estimated to grow to US $5 trillion by the year 2050 (Joshi *et al.* 2004) [7]. About 80 % of the global imports and exports are being allotted to only 12 countries with the dominance of temperate Asian and European countries whereas Japan and the Republic of Korea are the main consumers of pharmaceutical plants. China and India are the world's leading producers and Hong Kong, USA and Germany stand out as important trade centers. In terms of export of medicinal plants India ranks second following China and is one of the major exporters of crude drugs mainly to six developed countries viz. USA, Germany, France, Switzerland, U.K. and Japan, who share 75 – 80 % of the total export market (Directorate of Medicinal and Aromatic Plants Research, 2011) [5]. The export of AYUSH products in India has increased from INR 33,419.0 million in 2010-11 to INR 190,693.9 million in 2011-12 with an annual growth rate of 471 per cent (AYUSH, 2013) [1]. Thus given the huge repository of rich traditional medicinal knowledge and enormous wealth of medicinal plants, India has a great role to play, as a supplier of herbal products not only to meet the domestic needs, but also to take advantage of the tremendous export potential.

Constraints in the maps sector

Increased demand for herbal raw materials has led to widespread unsustainable collection and habitat destruction which has forced some of the valuable medicinal plants such as *Taxus wallichiana, Aquilaria malaccensis, Swertia chirayita, Dendrobium spp, Homolomena aromatica, Rubia cordifolia and Paris polyphylla* towards near extinction. In India, about 90 % of medicinal plant used by the industries are collected from the wild (Planning Commission, 2000) [12]. Only 36 species are under commercial cultivation (Ved and Goraya, 2008) [19] and around 315 of the 6560 known medicinal species are threatened with extinction (Sharrock *et al.* 2014) [16]. Recently assessments of the threat status of medicinal plants using IUCN (International Union for the Conservation of Nature) designed CAMP (Conservation Assessment and Management Plan) methodology revealed that about 112 species in southern India, 74 species in Northern and Central India and 42 species in the high altitude of Himalayas are threatened in the wild. This poses a serious threat to the diversity of medicinal plants in the wild. Apart from unsustainable collection practices and loss of plant diversity, there are several other factors, which pose a great hurdle in development of the MAPs sector in the Northeastern region. Post harvest management, value addition, manufacturing, packaging, etc. are very limited due to lack of proper production technologies, infrastructure and facilities, human resource support resulting in undervaluation and underutilization of the products. Even there is no primary processing points worth mentioning in most of the states. Another major issue is the lack of quality control, cultivation of MAPs in the region is mostly unscientific due to lack of proper scientific production technology resulting in inferior and substandard quality of the produce which ultimately fetches lower prices. Remoteness and accessibility constraints and lack of regulated marketing centers, market intelligence, support prices, etc. also poses serious problems in transportation and marketing of the produce. The absence of proper resource survey and inventory of medicinal plants of the region is yet another issue of concern leading to rampant, unorganized and undocumented trade of MAPs and hindering development of the sector in the region.

Priorities to be addressed

1. Inventorization and documentation of information on medicinal plants available in different states and agroclimatic zones, their identification, availability and distribution for prioritization of species to be incorporated in developmental, remedial and conservational plans. This information will also help address the demands of the different stakeholders involved.
2. Systematic documentation of the plethora of information on ethnobotany and traditional indigenous knowledge of MAPs and selectively screening of some of the interesting ethno-medicinal plants for active chemical compounds which may lead to the discovery of new novel drugs.
3. In-situ conservation of germplasm of herbal plants specially RET species and endemic plants from different agro-climatic zones supplemented by collection, propagation and conservation of MAPs through ex-situ conservation *viz*., field gene banks, seed banks, herbal gardens in institutions, schools, parks, etc. to support viable research and promote education and awareness of MAPs among the public.
4. Introduction of MAPs as intercrop, catch crop, companion crops, border crop, etc. for diversification of agricultural, horticultural and agroforestry systems for reducing risk and sustaining productivity through optimization of resource use.
5. Cultivation of MAPs on degraded and wastelands for generating better remuneration to the farming community, minimizing the pressure on croplands and also conserving the diversity of these herbal plants.
6. Development and implementation of region specific good agricultural and collection practices (GACP) on important medicinal and aromatic plants of the region encompassing various facets of cultivation, collection and harvesting, post harvest handling and quality assessment, etc. to ensure premium quality of the produce and also for sustainable utilization of the natural resources of medicinal plants.
7. Application of frontier technologies of biotechnology for mass multiplication of high value MAPs, marker assisted breeding of varieties, DNA fingerprinting of MAPs germplasm for protection of intellectual property right (IPR), species identification by molecular markers, detecting adulteration of raw drugs and development of new varieties with better bio-molecule productive efficiency.
8. Capacity building, training programmes, seminars, demonstrations, etc. for various stakeholders involved for effective transfer of GACP technologies in the MAPs sector.
9. Promotion of organic farming for sustainable production system of MAPs and also to ensure natural products with zero pesticides and other contaminants, which can fetch premium prices and has high demand in both national and international markets
10. Proper regulation and monitoring of both public and private sector establishments for ensuring compliance of seed producer on required practices and parameters for quality seed production to ensure adequate availability of quality and certified seeds and planting materials.
11. Development of proper infrastructures, laboratory facilities and manpower support for post harvest management viz., storage, drying, processing, value addition, packaging and transportation and quality control and certification viz. testing for pesticide residue, heavy metal contamination and quality of raw drug material.
12. Marketing support in terms of market intelligence, support price, modernization and establishment of mandis, buyer and seller meets, web based price information mechanism would be critical for linking small cultivators to the buyers in bigger markets.
13. Development and promotion of Public Private Partnership models (PPP) with private sector organizations, NGOs and farmers' associations/ progressive farmers interested in cultivation of MAPs.

Conclusion

The medicinal and aromatic plants sector has a huge potential for the development of the Northeast region and with proper planning and management it can be integrated into the present conventional production systems to develop more resilient, robust, sustainable and productive systems to meet the challenges of global food, health and livelihood security.

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