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ASSESSMENT OF MEDICINAL PLANT DIVERSITY OF RACHILA MEDICINAL PLANTS CONSERVATION AREA (MPCA) IN WEST BENGAL, INDIA

Project No. CONS/WB-01/2014

FINAL TECHNICAL REPORT

2023

Final Technical Report

On

ASSESSMENT OF MEDICINAL PLANT DIVERSITY OF RACHILA MEDICINAL PLANTS CONSERVATION AREA (MPCA) IN WEST BENGAL, INDIA

Project No. CONS/WB-01/2014

Sponsored by

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FOREWORD

The Medicinal Plants Conservation Area (MPCA) program was evolved and implemented for the *In-Situ* conservation of genetic diversity of highly traded and threatened medicinal plants of India. The program has special focus on capturing the gene pools among the wild plant populations of endemic and threatened medicinal plants. This would ensure the long term survival of such plants. These gene pools then provide the source of propagules for selection, breeding and ex-situ conservation of such plants.

The West Bengal Forest Department in collaboration with ITSCEED, Kolkata has implemented the project on "Assessment of medicinal plant diversity of Medicinal Plants Conservation Areas (MPCAs) in West Bengal, India" during 2015 onward. Studies have been conducted at two levels that involves (i) Inventorisation and (ii) Ecological assessment. The information and database developed during the current study will help in future informed conservation action programs. The Forest Department has extended full support to the survey team at the field level through various Divisional Forest Office and Range Office to achieve the objectives of this project in all the seven MPCAs established in West Bengal in the second phase.

Like the 1st phase (2007-09), many new species and gene pools have been captured in new MPCA in the 2nd phase. The gene pools of many species identified during the study will help in better conservation action programs through establishing a national network of MPCAs. About 334 species were assessed and documented of which around 6 species are placed under the threatened category. The MPCA with the rich gene pool acts as a hotspot of genetic diversity and needs to be brought under the conservation action program. Further, the training programs on the objectives of the MPCA needs to be conducted more frequently for capacity building of the front line staff as well as the surrounding community engaged in the conservation action programs.

We thank National Medicinal Plants Board (NMPB) for providing financial support for the current (2^{nd}) phase of MPCA program.

Shri Piyarchand, IFS

Principal Chief Conservator of Forest

FOREWORD

Medicinal plants have been an integral part of our tradition and also the modern pharmacopeia. In 2007-09, seven (7) Medicinal Plant Conservation Areas (MPCAs) were established in the State of West Bengal for promoting Conservation of Medicinal Plants and Traditional Knowledge to enhance the health and livelihood security of the surrounding indigenous communities. In the face of global warming and climate change the MPCA's can facilitate carbon sequestration, habitat protection, gene pool conservation, improve health, reduce poverty and maintain other ecosystem services. Given the multiple benefits ofan MPCA in the second phase four new MPCAs namely Bichabanga, Panchanai, Rachila and Phalut were established in the State to strengthen the in-situ conservation of medicinal plant gene pool.

Assessment of the plant population of the MPCAs' and their ecological significance brings forward the understanding of the long term goals of such conservation programs. ITSCEED, Kolkata has been effectively collaborating with the frontline staff of the forest department and local people for carrying out the ecological survey of the new MPCA's. This report has the baseline data for the new MPCAs. ITSCEED has further been creating an awareness regarding the objectives and presence of the MPCA's as a tool for achieving Sustainable Development Goals (SDG) of the country.

Shri Debangshu Mullick, IFS
CCF, West Bengal Forest Department

FOREWORD

The Medicinal Plants Conservation Area (MPCA) program was initiated in the year 1993. This is considered as one of Asia's largest *In-Situ* conservation network in the form of about 112 MPCAs across 12 states of India of which 14 MPCAs are in West Bengal established in two phases. This report encompasses the unique findings on genesis of MPCAs and primary base-line data; various indices related to the biodiversity and population status of many threatened medicinal plants. The most important aspect covered in this report is the regeneration status of many conservation concern species and their gene pools.

The survey has established a strong base-line data that will help in long-term monitoring and management regime of MPCAs as well as the surrounding forest stands. Further the gene pool of the important species documented during the survey will help in meeting the objectives of National Medicinal Plants Board (NMPB) through developing and connecting with the national network of the medicinal plants gene pool conservation.

The current study has recorded around 334 species of medicinal plants in the MPCA. This report will help future researchers, Forest Officials and other stakeholders for better resource management, developing long term strategy for sustainable wild collection, cultivation and utilization pattern.

Shri Bidyut Sarkar

Conservator of Forest, IFS

PREFACE

We are pleased to submit this report on the project "Assessment of medicinal plant diversity of Medicinal Plants Conservation Area (MPCA) in West Bengal, India". The second phase of this project has been implemented by The International Tagore Society for Cultural, Educational and Environmental Development (ITSCEED), Kolkata in collaboration with the West Bengal Forest Department and Darjeeling Govt. College. This project has been financially supported by National Medicinal Plants Board (NMPB), New Delhi. ITSCEED has been engaged with assessment of vegetation and imparting training on medicinal plants conservation, sustainable collection, value addition as well as marketing. The overall objective of ITSCEED is towards capacity building of the local communities for sustainable development while evolving strategies and doing action research. The foundation has been associated with biodiversity conservation with long term association and support of the West Bengal Forest Department.

The list of threatened medicinal plants of seven MPCAs of biogeographically different zones of West Bengal starting form Sal Dominated Forest of Purulia to foot hills of North Bengal plains and high altitude Darjeeling Himalaya were published by ITSCEED in collaboration with West Bengal Forest Department. Special attention has been given on medicinal plants conservation as the forests in India have been recognized for their rich diversity of medicinal plants. On the other hand tremendous pressure from the Pharmaceutical industries has increased the supply demand and unsustainable extraction of Medicinal Aromatic plants (MAPs). The West Bengal Forest Department conducted CAMP assessment to identify the threatened medicinal plants in the year 2007. It is one of the pioneering states and established seven MPCAs during the year 2007-09 in the first phase and seven more in the current efforts to conserve around 2800 medicinal plant species. This report, which encompass the result of the current extensive survey, will re-assure about the capture of the gene bank of various threatened medicinal plants, augmentation and other forest management activities through development of MPCA working plan. We look forward for more such productive action research and implementation programs between ITSCEED and WBFD to ensure conservation and sustainable use of wild resources vis-a-vis addressing the climate change issues.

Dr. Biswarupa Ghosh,
PI & Director, ITSCEED Foundation

ACKNOWLEDGEMENTS

The joint effort of State Forest Department, West Bengal and The International Tagore Society for Cultural Educational and Environmental Development (ITSCEED) in the field of medicinal plants conservation as well as training and capacity building of the local communities such as FPC, JFMCs, SHGs has been going on for long time. This effort has resulted towards better management of MPCAs, conservation of gene pools and sustainable wild collection, value addition and marketing of medicinal plants. We are obliged to the State Forest Department, West Bengal and National Medicinal Plants Board (NMPB), New Delhi for funding the Project.

We are grateful to Shri Piyarchand, the Principal Chief Conservator of Forests (PCCF), Research and Monitoring Division, West Bengal Forest Department, Shri Debanshu Mallick, IFS, the Chief Conservator of Forest, Shri Bidyut Sarkar, Conservator of Forest, Research Circle, West Bengal Forest Department for their coordination and Cooperation in the implementation of the project. We are also thankful to Mr. S.K. Mollay, IFS, Silviculture (Hills) Division, DFO, Mr.Surendra Prasad Sharma, WBFS, ADFO, Sri Raju Pradhan, FR, West Bengal Forest Department.

We also express our special thanks to Dr. Biswarupa Ghosh, Asst. Prof. BKC College, Dr. Debabrata Saha, Asst. Prof. ITSCEED, Kolkata for their active participation in the survey work and preparation of the project report.

We are very much thankful to Dr. Binod Chandra Sharma, Head, P.G. Department of Botany, Darjeeling Govt. College, Darjeeling. West Bengal, Mr. Nayan Thapa, Assistant Lecturer, Department of Botany, St. Joseph College, Darjeeling, Mr. Niraj Rai, Mr.Nitesh Ghatani, Mr.Leo Chhetri, Miss. Riya Das, Miss. Soumita Bhattacharjee, Mr. Amalesh Isore, Mr. Arpan Rai, Mr. Nishen Roy, Mr. Provanandan Barman, Researchers who actively participated in the project work without which the project would not get the present form. Thanks to Mr. Chobilal Kami, FG, Lataguri for the cooperation during the field survey. We are thankful to Dr. Arthur Mark for helping in data analysis and designing the layout of the report. Special thanks to Miss. Shreyashe Kar. Miss Aditi Saha, Mr. Anjan Singha, Miss. Dipika Jani, Mr. Baivab Saha, Ms Tista Debnath for their active participation in completion of the project report.

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EXECUTIVE SUMMARY

The State Forest Department of West Bengal has established seven Medicinal Plants Conservation Areas (MPCAs) across the state in the year between 2007 and 2009 identifying natural habitats that are relatively undisturbed forest areas hosting rich diversity of medicinal plants, and maintained as *in-situ* conservation sites to conserve and protect the medicinal plant resources covering different forest types in the state. At the time of establishment of MPCAs, a checklist of medicinal plants for each MPCA was prepared. Overall, there were 891 medicinal plant species recorded. This is around 32% of total medicinal plant diversity of the West Bengal state (2800 species). Out of 891 species, 241 were trees, while 232 and 410 species were shrubs and herbs respectively. MPCA-wise medicinal plant species recorded were 30, 154, 206, 249, 209, 216 and 254 respectively in Bonnie camp, Dhotrey, Garpanchkot, North Rajabhatkhawa, North Sevoke, Sursuti and Tonglu (Saha et.al. 2022).. Furthermore, during the current project, a total of seven additional MPCA areas have been surveyed and assessed during 2014 to 2018 for their biodiversity particularly the species diversity of medicinal plants while Rachila MPCA is one them which shows many important conservation concern medicinal plants with rich gene pool.

Considering the importance of the management of MPCAs, the West Bengal Forest Department sanctioned this project to assess seven additional MPCAs and evaluate the current status in terms of understanding the coverage of medicinal plants especially threatened plants within MPCA areas, and also estimating the population of plants across plant types viz. trees and climbers/lianas (adults, sapling, seedlings), shrubs and herbs. The outcomes of this project would provide information to plan better resource management and strategies at state level.

As a first step in this project, the detailed profile of the MPCA was prepared with the secondary information collated from various document sources to understand the nature and characteristics of MPCA sites selected in West Bengal. Site disturbance levels for the MPCA were assessed by scoring 15 factors and sites were grouped into three disturbance categories. Based on the field observations, the current status of the MPCA was described covering following aspects: entrance structure, boundary information, disturbance level, communication and interpretation utilities, trekking paths, departmental interventions, and presence of important medicinal plants.

Systematic mapping of MPCA landscapes with a help of satellite images provide insights on the areas or locations where the protection is needed, and how efficiently and effectively it

could be undertaken. An innovative application of using open-source GIS (Q GIS ver. 2.8.2) software technology was used for mapping the MPCA landscapes. The mapping process was carried out with latitude and longitude coordinates collected along the boundary of MPCAs to develop the spatial distribution maps.

In the next step, the qualitative assessment was attempted to inventorise and document the medicinal plant diversity of the MPCA through conducting seasonal vegetation surveys. The qualified and experienced botanists conducted the botanical surveys in the MPCA and collected medicinal plant samples in reproductive stages for herbarium specimen with appropriate field number and notes. This exercise was repeated in all the seasons to familiarise with the vegetation in different phenological stages and also to record the existence of even ephemerals. The survey was done keeping the IUCN methods and criteria for threat assessment in consideration (IUCN .2020; Pollock et al., 2003). The botanical surveys conducted under this study yielded a total of 334 medicinal plant species that are wild in the MPCA site.

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Threatened status	No. of species	Traded	High traded*
Critically Endangered	3	1	2
Endangered	2	1	1
Vulnerable	1	1	0
Total	**6**	3	3

* Trading >100 MT of dry weight per year

As an interesting outcome of qualitative assessment four angiospermic taxa, namely, Valeriana hardwickei Wall., Taxus wallichiana Zucc., Berberis aristata DC., Panax pseudoginseng Wall., Swertia chirayita (Roxb.) H.Karst. etc.

These species were found in reproductive state and hence the morphological features of fruits and seeds were provided *Paris polyphylla.*

The quantitative assessment of medicinal plants especially of conservation concern species was undertaken to quantify the population of medicinal plants through standardised sampling procedures and to assess the growth and structure of plant population in the MPCA. Field works for ecological survey were carried out using nested quadrat method. In a single 20m x 20m quadrat, which is used for the enumeration of woody plants of above 30cm gbh, one 5m x 5m

sub-quadrats within (nested quadrats) for shrubs or saplings (≤30cm gbh size) and four 1m x 1m plots within the 5m x 5m sub-quadrats were laid for herbs or seedlings.

Summary of inventorization undertaken in Rachila Medicinal Plants Conservation Area (MPCA) in West Bengal

Tree species recorded	
# of species recorded	57
# of genera	37
# of families	25
# of threatened species	1
Shrub species recorded	
# of species recorded	75
# of genera	53
# of families	40
# of threatened species	1
Herb species and seedlings recorded	
# of species recorded	202
# of genera	130
# of families	54
# of threatened species	4

A total of 57 woody plant species (>30 cm gbh) belonging to 37 genera and 25 families were recorded across the Medicinal Plants Conservation Area (MPCA)..

A total of 75 plant species (≤30 cm gbh) belonging to 53 genera and 40 families were recorded in Medicinal Plants Conservation Areas (MPCAs) in West Bengal.

The survey helped to document 202 plant species belonging to 130 genera and 54 families across the Medicinal Plants Conservation Areas (MPCAs) .

Species-area curves for plant species enumerated in non-contiguous 20m x 20m quadrats, 5m x 5m quadrats and 1m x 1m sub-quadrats were drawn in the MPCA. Species curve reached an asymptote in all three plant habits indicating adequate sampling effort.

Tree species richness and abundance decreased with increasing girth class except for the largest size class (>100 cm) in the MPCA. The lower girth classes (31-40, 41-50 cm) contributed large proportion of woody plant species richness.

Out of 6 threatened plant species recorded in the qualitative assessment, 4 plants were found in the quadrat study. Overall, 1 woody plant species belonging to threatened species category was recorded in 20m x 20m sampled quadrats. The primary outcome of this project is very encouraging in a way that the current MPCA proving to be a gene pool of medicinal plants of the state especially a number of conservation concern species with good and viable population.

Threatened species those were recorded during the botanical inventorisations *are Taxus wallichiana* Zucc., *Berberis aristata* DC. *Panax pseudoginseng* Wall., *Swertia chirayita* (Roxb.) H.Karst., *Valeriana hardwickei* Wall., *Paris polyphylla* Sm.

This MPCA representing a specific forest ecosystems and landscape of the state is found to be rich in medicinal plant diversity in terms of number of species, number of threatened species, etc. In this MPCA, only a minimal percent of West Bengal state's medicinal plants diversity could be covered. It suggests that there are still more prospective medicinal plants rich forest sites, which could be established as MPCAs. As part of deduction, number of recommendations for medicinal plants conservation and its sustainable use have been described in details (Ved et al., 2003; Goraya and Ved. 2017). In the end, these endorsements were converted into activities or projects that are eligible for funding from the NMPB through Central Sector scheme. This exercise was intended to support the West Bengal Forest Department to make proposals in the prescribed formats for availing necessary funding from various funding agencies specially National Medicinal Plants Board.

MEDICINAL PLANTS CONSERVATION AREAS (MPCAS): NATIONAL AND WEST BENGAL PERSPECTIVE

Medicinal Plants Conservation Areas (MPCAs)

The West Bengal lies between the Himalayas in the north and the Bay of Bengal in the south. It is the only state in India where Himalayas are in the north bordering Sikkim and Bhutan and Sea is at the south with Assam and Bangladesh bordering the east, with both plains and plateaus covering the remaining region. On the west, it is bounded by Odisha, Bihar and Nepal. At present it has a total area of about 88,752 km^2. The state has a coastline of about 210 km. The varied and unique physical features in the state support to harbour diverse vegetation with enormous species diversity. The state has five well-defined phyto-ecological zones, viz. (i) The Himalayan zone of Darjeeling, between 500 and 3800 m, (ii) Sub-montane Terai region and the adjacent plain, (iii) Vast alluvial plain on both sides of the river Bhagirathi and its northern and western tributaries, (iv) The Western dry flanks of Chhotanagpur plateau and (v) Mangrove forests of Sundarbans majorly confined to South 24-Parganas. However, forest types and patterns of vegetation in certain subdivisions have been further classified after critical analysis by the ecologists and plant sociologists.

Total recorded forest land in the state is 11879 km2, of which 7054 km2 is Reserved Forest, 3772 km2 is Protected Forest and 1053 km2 is Unclassified State Forest, thus constituting 13.38% of the geographical area of the state. The forest cover including the forests created outside the recorded forest area is 15.68% of the geographical area in the year 2006. The vegetative cover of the state is around 27% of the geographical area, which includes village orchards/groves, tea garden and horticulture plantations. As per Champion's and Seth classification, out of 16 forest types present in India, West Bengal represents 10 forest types ranging from Darjeeling hills to Sundarbans Mangroves.

Based on the floristic studies, it reveals that the angiosperm flora of West Bengal state harbours about 3580 species under 1333 genera in 200 families. Besides, the state supports 21 species of Gymnosperms, 416 species of Pteridophytes, 771 species of Bryophytes, 873 species of Algae, 539 species of Fungi and 329 species of Lichens. There are 37 rare and threatened taxa in the state and 19 taxa have been described from West Bengal, which are not collected after type collection. There are about 850 species of medicinal plants in the state and about 1600 species are used by various tribal communities in the state. West Bengal harbours an enormous biodiversity of medicinal plants that occur right from the humid river valleys to the cold trans-Himalayan desert.

This biodiversity of medicinal plants and its sustainable utilization sustain the health, medicinal, spiritual and other need bases response offer to us. This biodiversity is the treasure house from which future food needs, cures for deadly diseases and various elements for knowledge and transfer of technology in near future. Recently, the biodiversity is seriously threatened by anthropogenic activities such as destructive activities, ill-harvesting, loss of habitats or degradation in its quality as well as quantity that leading to extinction of medicinal plants and also resultant dying out of our local traditional practices.

West Bengal is the pioneer state in India initiating Joint Forest Management Committees (JFMCs). The idea of establishing JFMCs had its origin at Arabari in Midnapur district of West Bengal. A movement was started with 618 families of the 11 villages to rejuvenate 1186 ha of degraded Sal forests in the early 70s. The community members participated in a set of activities of employment generation and enjoyed the sharing of NTFPs/medicinal plants from such forests. This community movement was adopted by the government and allowed a share of 25% of usufructs and net profit of the intermediate and final yield respectively. The JFMCs in the name of Forest Protection Committees (FPCs) and Eco-development Committees (EDCs), led to reasonable success in rejuvenating the degraded forests and bringing about economic upliftment of fringe population constituting the FPCs and EDCs through series of measures including implementation of people oriented development programs.

The people around forests are integral part of forest ecosystem and their livelihood needs are to be met as it is a critical issue in ensuring long term conservation of resources especially medicinal plants. There is a need to prepare a detailed action plan to conserve and sustainable use of medicinal plants to protect the cultural heritage, scientific manipulation, transfer of technology, sustain the spiritual beliefs and traditions. It correlates the recent activities of culture, resource and environment in the same ecosphere, which is directly related to innovations, and to prosper the equitable share of resource and the share of benefits arising from sustainable use in *in-situ* environment.

Medicinal Plants

Medicinal plants play an important role in supporting healthcare in India. According to the World Health Organization (WHO), 80% of the rural population in developing countries utilizes locally available medicinal plants for their primary healthcare needs. Medicinal plants are not only a major resource base for the traditional medicine & herbal industry but also

provide livelihood and health security to a large segment of Indian population. About 8000 species of medicinal plants are in current use by local communities all over India. There are about an estimated 40,000 herbal formulations recorded in India. About 90% of the country's medicinal plants are found in forest habitats. Only 10% of the medicinal plants are distributed among other landscape elements like open grasslands, agricultural pastures and in and around freshwater bodies, etc. About 1178 species of medicinal plants are estimated to be in trade of which 242 species have annual consumption levels in excess of 100 metric tons/year. The domestic demand of medicinal plants has been estimated 1,95,000 MT for the year of 2014-2015 and export demand of medicinal plants has been estimated 1,34,500 MT during 2014-2015. Total consumption of herbal raw drug in the country for the year 2014-15 has been estimated at 5,12,000 MT with corresponding trade value of ₹ 5,500 Crore. The major increase has been recorded in export value which has increased from ₹ 345.80 Crore in 2005-06 to ₹ 3211 Crore in 2014-15, registering a nine fold increase in during last decade.

According to the All India Trade Survey of Prioritised Medicinal Plants report, the medical plants market in India stood at Rs 4.2 billion in 2019 and expected to increase to Rs 14 billion by 2026. The market for medical plants in India stood at Rs. 4.2 billion (US$ 56.6 million) in 2019 and is expected to increase at a CAGR 38.5% to Rs. 14 billion (US$ 188.6 million) by 2026. The total world herbal trade is currently assessed at US$ 120 billion. There is an urgent need to conserve the wild populations of medicinal plant diversity at least in prioritized forest regions of India.

Medicinal Plants Conservation Areas (MPCAs)

Medicinal plants Conservation Area (MPCA) is a concept developed under the tenets of *in-situ* conservation methods. It is a well-defined and demarcated area within a protected and conserved forests and known for harbouring medicinal plants especially the threatened plant species. The establishment of a network of MPCA sites across different ecological zones is critical for conserving intra-specific gene pools of threatened and endemic medicinal plants, with special focus on species that are known to be in high volume trade. If their gene pools are not urgently conserved, these valuable medicinal species may soon go extinct. In that context, the central purpose of establishing MPCA network has been the in-situ conservation of the genetic diversity of wild populations of highly traded species with special focus on endemics and threatened species in order to firstly ensure their long term survival and secondly to provide

access to breeders of reproductive material for selection, breeding and also for ex-situ cultivation and plantations.

The selection of forest areas for the establishment of MPCAs is done based on the four important criteria. They are (1) the forest area with rich medicinal plants species (preferably endemic species) diversity; (2) undisturbed area by biotic factors as much as possible; (3) fairly larger area (about 200-500 ha) for better management; (4) reasonably accessible. The presence of viable population of conservation concern species was taken into consideration when MPCAs are established for specific species (conservation concern/threatened medicinal plants). Two approaches are followed for the selection of MPCA sites: (1) capturing maximum diversity of medicinal plants; (2) capturing conservation concern medicinal plants. To cover maximum medicinal plant diversity, MPCAs were established across different forest types and forest landscapes.

The scientific execution of MPCA network needs four kinds of prior information: (1) knowledge about medicinal plant species, which are in high volume trade, and are largely sourced from wild forest habitats; (2) threatened status of medicinal plants as per IUCN criteria especially for high-traded and/or endemic species; (3) reliable information on the natural geographical distribution of the high-traded and endemic or threatened species; (4) ready access to data base on the medicinal flora of region. Based on this information, forest managers and policy makers are supposed to decide on the establishment of MPCA at a specific site.

There are eight steps strategy followed for the execution of this MPCA program:

1. Create database on medicinal plants of India (from referenced medical literature including ethno botany and ethno medicine sources) with accurate correlation between vernacular, Sanskrit and botanical names
2. Generate sub-databases of medicinal plants of every State, District and Taluka in the country
3. Generate geographical distribution data on medicinal plants of India (sourced from floras, herbaria) and place it on appropriate GIS platforms particularly for species of conservation concern
4. Identify medicinal botanicals in all India trade with accurate correlation between trade and botanical names
5. Apply IUCN criteria to identify threatened medicinal botanicals at State levels

6. In respect of high priority threatened species, undertake genetic sampling across their distribution range in order to identify hot-spots of intra-specific genetic variability of threatened species
7. Identify ecologically suitable sites for creation of MPCAs for in-situ conservation of both species diversity and for species of conservation concern
8. Review the gaps at State levels every 3 years in the national in-situ conservation MPCA program

The number of MPCAs needed to conserve gene pool of a particular species depends on the extent of its distribution range. For example, an endemic species may require only one MPCA to conserve its gene pool, but a widely distributed species may require several MPCAs to capture its diverse gene pool. The number of MPCAs established currently is far less than the required number of MPCAs to capture the diversity of wild medicinal plants in the country. This is because the 108 MPCAs established could capture only little more than half of the wild medicinal plants of India. Forest ecosystems generally have different patterns of species composition and distribution pattern. Some species exhibit gregarious distribution, and some are sparsely distributed. Some forest patches show high diversity, while some are dominated by few species only.

Realising the concern on the conservation of natural resources in general and medicinal plants in specific, the pioneering nation-wide program of establishing MPCA sites for medicinal plants was initiated. In the last two and half decades, a network of 108 MPCAs has been established across 13 Indian states involving the respective State Forest Departments and local communities with financial support from external funding agencies including DANIDA, UNDP and GEF grants under the guidance of Ministry of Environment, Forests and Climate Change (MoEF & CC), Government of India. The list of MPCAs established so far in 13 states is provided in Annexure 1. Through this network of MPCAs, now the representative populations of more than 3500 medicinal plant species are being conserved in the wild through the network of MPCAs.

Having understood the importance of a network of wild gene banks for medicinal plants, the National Medicinal Plant Board (NMPB), Government of India, is currently involved in establishing Medicinal Plant Conservation and Development Areas (MPCDAs) through State Forest Department across the country. There are 72 MPCDAs already established by the NMPB across 13 states. According to NMPB website, as of 30th November 2016, around

18,889.45 hectares of forest cover have been brought under MPCDAs (96 in numbers) in India. Besides, the NMPB extends financial support for the establishment and maintenance of MPCDAs across country under their central sector scheme. Though MPCDA program has been best implemented by State Forest Departments with the support and coordination from the NMPB, considering the complexity of the program, a technical support for the program from competent knowledge institutions is certainly warranted for the execution of this program at national level.

Medicinal Plants Conservation Areas (MPCAs) in West Bengal

As part of conservation efforts, the FRLHT in collaboration with West Bengal Forest department had conducted series of threat assessment workshops involving 53 subject experts to identify conservation concern species and locate their wild populations across the state. The Conservation Assessment and Management Prioritisation (CAMP) workshop was conducted on Kolkota in December 2007 to assess medicinal plant species for Red Listed status following IUCN guidelines. Out of 148 medicinal plants proposed for assessment, 46 species were assessed for threatened status. The breakup of taxa is as follows: Critically Endangered (CR): 6, Endangered (EN): 19, Vulnerable (VU): 15, Near Threatened (NT): 3 and Least Concern (LC): 3. One of the important outcomes of organising CAMP workshop was the identification of flagship species and of potential sites for the establishment of MPCAs in West Bengal.

As part of the implementation of National Program on Promoting Conservation of Medicinal Plants and Traditional Knowledge for Enhancing Health and Livelihood Security in West Bengal, the State Forest Department established a network of Medicinal Plants Conservation Areas (MPCAs) across the state. Based on the inputs from the Conservation Assessment and Management Prioritisation (CAMP) workshop, different conservation sites were identified for in-situ conservation of medicinal plants. These sites were selected in order to cover each of the four major biogeographic zones of West Bengal, different forest types, the distribution and abundance of high-traded and threatened medicinal plants and habitats important for them. Following criteria were considered at the time of selecting potential sites for the establishment of MPCAs in West Bengal: (1) sites with a varied diversity of vegetation comprising medicinal plants; (2) relatively undisturbed patch with reasonable accessibility; (3) sites representing a particular forest/vegetation type; (4) sites traditionally known for its medicinal plant richness; (5) a compact block under Biodiversity Conservation Working Circle in territorial and wild life areas so that no felling operations are legal; (6) sites that are part of

Protected Area or Reserve Forest or Tiger Reserve area, etc. with legal protection. Subsequently, seven sites were identified for establishing MPCAs to protect the critically endangered and endangered medicinal plant species (Table 1 and 2, Figure 2). To conserve and protect the medicinal plant resources in the wild, as part of in-situ conservation methods, the State Forest Department with technical support from the FRLHT has established seven Medicinal Plants Conservation Areas (MPCAs) between 2008 and 2010 across different forest types in West Bengal.

Table 1. Locations of seven MPCAs previously formed in West Bengal

Sl.No	MPCA	Forest range	Forest division	District
1	Bonnie camp	Raidighi	24-Parganas (South)	24-Parganas (South)
2	Garpanchkot	Raghunathpur	Kangsabati (North)	Purulia
3	North Rajabhatkhawa	Buxaduar	Buxa Tiger Reserve (East)	Jalpaiguri
4	Sursuti	Lataguri	Jalpaiguri	Jalpaiguri
5	North Sevoke	10th mile	Wildlife-I	Jalpaiguri
6	Dhotrey	Dhotrey	Darjeeling	Darjeeling
7	Tonglu	Tonglu	Darjeeling	Darjeeling

MPCA sites were carefully identified by the West Bengal Forest Department with inputs taken from the CAMP workshop and consultations with subject experts and local forest officers. They were established to capture the gene pools of the regenerating populations of high-traded endemics and threatened medicinal plants that were assessed during the CAMP workshop. Nevertheless, there is a lack or inadequacy of field data especially about the medicinal flora, traded and threatened species or their geographical distribution. It is important to generate relevant field data at least for the prioritised species and followed by the ground truthing and assessment to examine the changes in population of conservation concern medicinal plants. Better understanding and knowledge of different components in the MPCAs are expected to strengthen the MPCA program and ensure the protection of gene pools of medicinal plants in its natural landscapes.

Table 2. Details of seven MPCAs previously established in West Bengal

Name of MPCA	Year formed	Forest types	Area (ha)	Latitude	Longitude
Bonnie Camp	2008-09	Littoral and Swamp – Mangrove (4B)	300	21° 83’	88° 63’
Dhotrey	2008-09	Montane wet temperate (11B)	180	27° 05’	88° 07’
Garpanchkot	2008-09	Tropical dry deciduous (5B)	250	23° 63’	86° 77’
North Rajabhatkhawa	2008-09	Tropical moist deciduous (3C)	400	26° 68’	89° 55’
North Sevoke	2008-09	Tropical moist deciduous (3C)	100	26° 87’	88° 45’
Sursuti	2008-09	Tropical moist deciduous (3C)	100	26° 63’	86° 77’
Tonglu	2008-09	Montane wet temperate (11B)	230	27° 03’	88° 08’

Considering the importance of establishing MPCAs across West Bengal, the Office of the Conservator of Forests, Research Circle, West Bengal Forest Department has identified 4 more sites for MPCA program with the support of the National Medicinal Plants Board (NMPB) under the AYUSH ministry of Govt. of India. This project was proposed to evaluate the medicinal plants diversity of four MPCAs newly established in West Bengal. At the time of establishment, field data on plant diversity was mandated to prepare a checklist of medicinal plants of each MPCA. In the current survey, the presence of threatened plants needs to be noted, and the population of those plants need to be measured and assessed. This report is expected that there will be better understanding of medicinal plants diversity and their population status in newly established MPCAs.

Figure 1. Map locations of seven MPCAs previously established in West Bengal

PROJECT OBJECTIVES

Objectives

The overarching objective of this work was to survey the newly established Rachila MPCA in West Bengal to understand the status of MPCA in terms of medicinal plants diversity and population level through thorough botanical surveys and quadrat assessment. Following activities were planned to be undertaken in Rachila MPCA:

- inventorisation and documentation of medicinal plants diversity in the MPCA;
- conducting vegetation surveys in the MPCA;
- measuring the overall diversity of medicinal plants;
- measuring the species diversity and frequency of medicinal plants in MPCA;

Following are the tangible deliverables expected from the implementation of this project

- A checklist of medicinal plants recorded in Rachila MPCA
- Population assessment of medicinal plants especially conservation concern species through quadrat study
- Major threats identified in Rachila MPCA and recommendation for management of selected species

In the end, this work was expected to generate information and knowledge on medicinal plant species diversity and their status in newly established Rachila MPCA in West Bengal. So that better resource management and strategies can be planned at the state level. It would also provide the scope and opportunity available for the participation of local community members.

CHAPTER 1: GENERAL INFORMATION ABOUT PANCHANAI AND SEVEN OTHER OLD MPCAS ESTABLISHED IN WEST BENGAL

Introduction

In West Bengal, forests cover an area of 11,879 sq. km, which is 13.38% of the state's geographical area (India State of Forest Report 2019). State is rich in the biodiversity of both flora and fauna. Vegetation in West Bengal varies from temperate and sub-alpine forests of Darjeeling to Estuarine plains of Sundarban. Forests in West Bengal have a rich assemblage of diverse habitats and vegetation designated with the help of eight different forest types. The diverse fauna and flora of West Bengal possess the combined characteristics of the Himalayan, sub-Himalayan and Gangetic plain. Covering just 2.7% of the Indian landmass it is home to 12.27% of Indian biodiversity known till date. The state has more than 7000 species of described flora including bacteria, algae, fungi, bryophytes, pteridophytes and angiosperms and more than 10000 species of described fauna. According to the database developed by the Foundation for Revitalisation of Local Health Traditions (FRLHT), the checklist of medicinal plants of West Bengal consists of a total of 2800 taxa. Out of 2800 medicinal plant species recorded in West Bengal, a large portion of species, around 80-85% are sourced from wild, out of which, around 46% of medicinal plant species are herbs, followed by trees (23%) shrubs (21%) and climbers (10%). These plants spread over different types of ecosystems like mountain ecosystem of the north, forest ecosystem extending over the major part of the state, freshwater ecosystem, semiarid ecosystem in the western part, mangrove ecosystem in the south and coastal marine ecosystem along the shoreline.

As part of conservation efforts, the West Bengal Forest department had conducted series of threat assessment workshops, which is called the Conservation Assessment and Management Prioritisation (CAMP) workshop, to identify conservation concern species and locate their wild populations across the state. Through organising CAMP workshop, flagship species and potential sites for the establishment of MPCAs in West Bengal were identified. To conserve and protect the medicinal plant resources in the wild, as part of in-situ conservation methods, the State Forest Department established Medicinal Plants Conservation Area (MPCA) in Rachila, Darjeeling district in West Bengal. While selecting this area for MPCA, following criteria were used and not merely based on the natural forests and visual richness of population: (a)a varied diversity of vegetation with some known plant species having proven medicinal value; (b) relatively undisturbed and has a reasonable accessibility; (c) vegetative cover of the areas is representative of forest/vegetation type; (d) area exists as a compact block

under Biodiversity conservation and plain timber working circle that no felling operations are allowed even in future also; (f) under legal protection.

The short listed areas in Rachila were identified, surveyed and demarcated using a GPS system. The establishment of the MPCAs involved demarcation of the area as an entry point activity. This was followed by botanical inventorization through sampling process, enumeration and plant specimen collection, preparation of herbarium through processing and accession of specimens. The detailed profile of Rachila MPCA was prepared with the secondary information collated from various document sources to understand the nature and characteristics of Rachila MPCA in West Bengal.

Physical features

Following are the site wise physical features documented during the field surveys.

MPCA site	**Rachila MPCA**
Location information	
Compartment no	13
Beat	Lava beat
Block	Rachila
Range	Neora valley
Forest division	Gorumara Wildlife Division
Panchayat	Lava Giddium panchayat
Revenue Block	Kalimpong
District	Darjeeling
Boundaries	*North*: Sikkim state *South*: Samdoala and Lumthond dandas, Labha-Tangata *East*: Recai La danda and Neora river *West*: West Nar block
Nearby villages	Lava, Samsing, Todey, Bhujel Gown, Kumai and Bindu - Situated at 15 to 20 km from MPCA
Distance from nearest towns	Lava, Kalimpong, Darjeeling and Siliguri (100 km)

Approach from nearby places	*Road*: Lava to Choudaphari is a 20 km drive on forest road. From Choudaphari to Aaloobari Camp by foot for about 6 hrs. Halt at Aaloobari camp. Next day, take 8 km walk to reach site *Rail*: New Jalpaiguri (NJP) (112 km) *Airport*: Bagdogra airport (115 km)
Area covered (in ha)	200
Latitude	N $27^0$07'52.41"
Longitude	E 88°46'09.44"
Altitude	2288 to 2286 m above sea level
Waterbodies (inside & outside)	Neora river that flows from Rechnilla chawk within the Rachila block
Climate information	
Temperature in ^{0}C (at nearby station)	Summer (April–May) - 3–6 ^{0}C (minimum) to 20–21 ^{0}C (maximum) Monsoon (June-September) - 7–8 ^{0}C (minimum) to 22–23 ^{0}C (maximum) Autumn (October-November) - 1–4 ^{0}C (minimum) and 20–22 ^{0}C (maximum) Winter (December–February) – minus 3–1 ^{0}C (minimum) to 18 ^{0}C (maximum) Spring (March) - 2 ^{0}C (minimum) to 20 ^{0}C (maximum)
Precipitation in mm (at nearby station)	Summer - 95.2–239 mm; monsoon - 589–620 mm; Autumn - 16.4–30.0 mm; Winter - 4.2–10.9 mm Along the foothills, the rainfall varies from 95" to 250" per annum and increases eastwards from the Kalimpong Range to the Jaldhaka Range. Monsoon clouds brings hill areas (Chel, Neora and Jaldhaka Range) plenty of rainfall and moisture to the extent of 200 inches. The inwards regions receive less rainfall on the average about 120 inches. Kalimpong receives 95 inches due to comparatively low altitude. Monsoon lasts from the middle of May to the Middle of October.

Seasons & monsoons	Months from November to February are marked by a number of foggy days, while July has the maximum number of rainy days. Storms of moderate velocity are frequent during pre-monsoon showers. Such storms create damages by dislodging of trees
Soil information	
Rock formation	Typical moderate to precipitous formation. Following rocks were found: Bhabar (recent alluvium glacial), Nahan (lower tertiary), Damuda (lower Gondwana, carboniferous), Baxa series (Algonkian), Daling series (Archaean), Darjeeling gneiss (Ditto)
Soil type	Clayey loam with deep humus
Administration information	
Legal status	Neora valley National Park, Wildlife area
Local community information	
FPCs/EDCs & area assigned	Lava, Samsing, Todey, Bhujel Gown, Kumai and Bindu
Means of livelihood	Home-stay , Eco-Tourism, Daily labour, Agriculture
Percentage of NTFP collectors	Moderate

Topographic details of locations

The river Teesta has divided the North Bengal region into two parts- (a) terai or sub-Himalayan lowland, characterised by tall grasslands, scrub savannah, sal forests and clay-rich swamps and (b) western dooars or duars, the alluvial floodplains with savanna grasslands and foothills of the eastern Himalayas, which is the gateway to the North-East India and Bhutan (the hilly region of Darjeeling and the swamps of plains, south of terai and dooars up to the left bank of the Ganges, known as 'Tal', 'Barind' and 'Diara', being erstwhile habitats), Southern region: mangrove swamps of Sundarbans, the largest in the State (beyond the purview of this article). During the 19th and 20th century, the land-use pattern in North Bengal was changed radically with spread of (i) agriculture, (ii) establishment of hundreds of tea gardens (since 1835), including the shut down and sick ones, where more than 1.1 million people, mostly forest-dependent, live in, (iii) conversion of forest land to army cantonments, (iv) diversion of forestland for railways and highways, etc. These changes have gradually made the forest highly fragmented.

Rachila MPCA is situated in Neora Valley National Park. Neora has been identified with four main habitat types: Subtropical Mixed Broadleaf Forest, Lower Temperate Evergreen Forest, Upper Temperate Mixed Broadleaf Forest and Rhododendron

Systematic mapping of landscapes with a help of satellite images provides insight into the areas or locations where the conservation has to be initiated. Such topographic maps are required to understand the extent of protection needed and how efficiently and effectively it could be undertaken. This was attempted through documentation of secondary information available in the previous forest management plans and mapping of the boundary of Rachila MPCA to arrive at a complete picture of topographic details. The mapping process was carried out to understand the topography of newly established Rachila MPCA in West Bengal. Through this exercise, the precise locations were depicted in the state map with the information provided by current field surveys. The GPS coordinates of multiple locations along the boundary was helpful in this process.

Figure 3. Locations of newly established MPCAs in the Darjeeling district, West Bengal

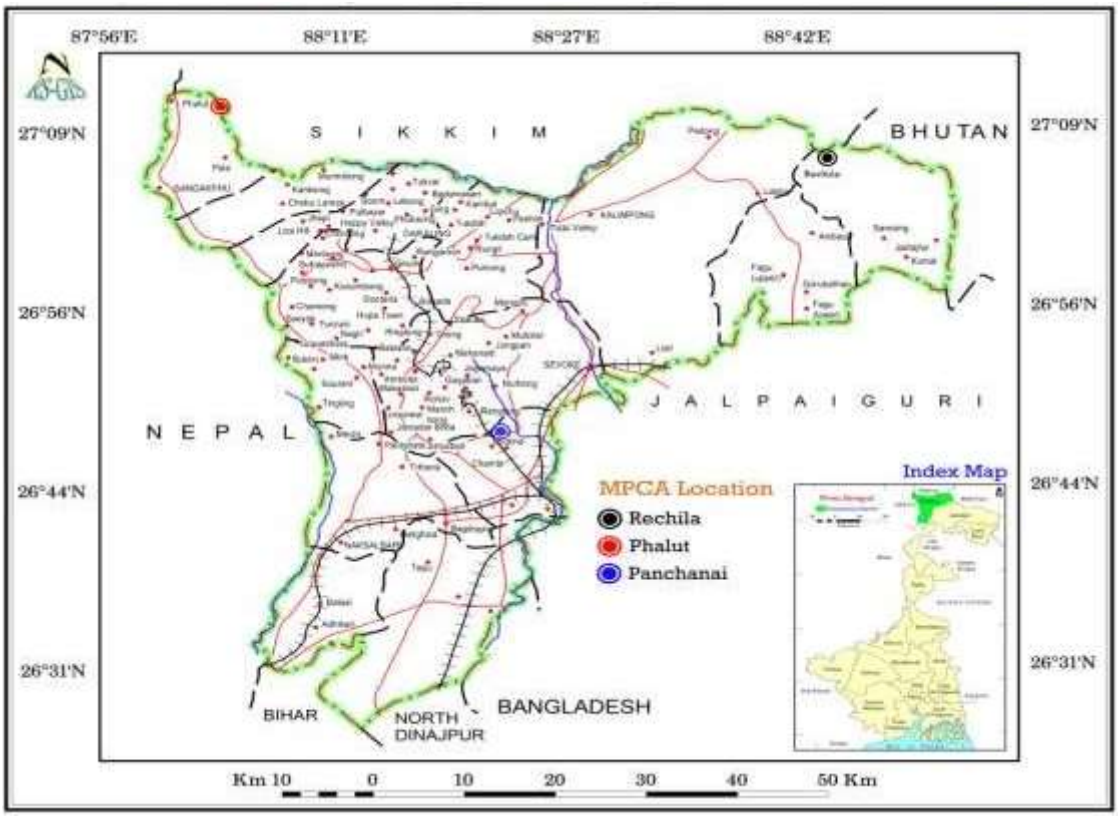
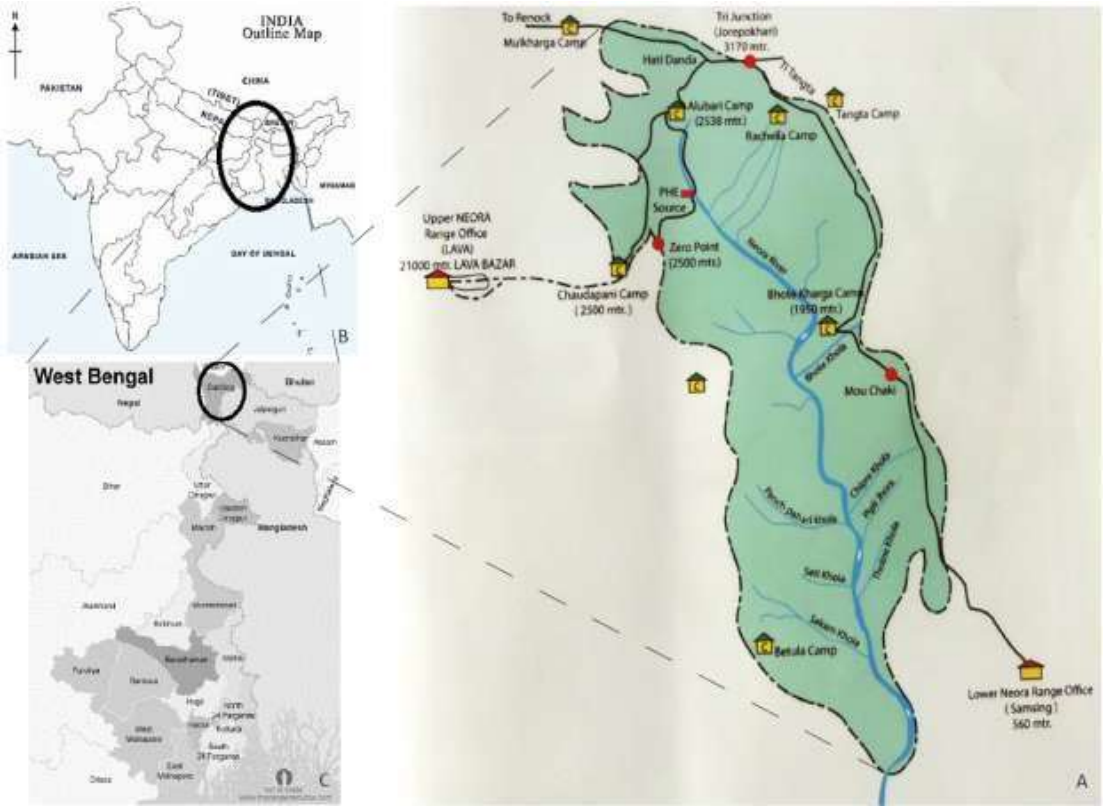


Figure 4. Topographic map of Rachila MPCA in the Darjeeling district, West Bengal



Forest and vegetation types

Forest types of Rachila MPCA has been classified as Sub-Tropical, Sub-Temperate vegetation system. These forests consist one of the last tracts of virgin wilderness in the state, sustains a unique ecosystem that still harbours a wealth of flora especially medicinal plants. Rhododendron is one of the dominant plant groups in this locality. Besides, it is also associated with Bamboo, Oak, ferns, Sal as main species in these forest types. Following are the important plant species recorded in Rachila MPCA: *Quercus lamellose* (Oak), *Betula alnoides* (Birch), Acer spp. (Maple), *Alnus napalensis* (Alder), *Lyonia*, *Castanopsis*, *Lithocarpus* sp, *Sorbus* sp , etc. Further, Sal (*Shorea robusta*), Jarul (*Lagerstroemia speciosa*), Pakasaj (*Terminalia alata*), Gamar (*Gmelina arborea*), Sidha (*Lagerstroemia parviflora*), Chikrasi (*Chukrasia tabularis*), Chilauni (*Schima wallichii*), Simul (*Bombax ceiba*), Champ (*Michelia champaca*), Kadam (*Anthocephalus chinensis*), Lasune (*Aphanomixis polystachya*), Odal (*Sterculia villosa*), Malagiri (*Cinnamomum cecidodaphne*), Jamun (*Syzygium* sp.), Kanchan (*Bauhinia pupurea*), Bankathal, Tatari *(Dillenia pentagyna*), etc were also recorded in the lower forest patches. There are number of orchids present in this MPCA. The undergrowth consists mostly of *Leea* species, *Urena lobata*, *U. Lobata* var. *sinuata,* Purandia, Bokshikara (*Toddalia* sp.), *Indigofera* spp., *Acacia* spp. etc. The presence of climbers are prominent in this MPCA. They are *Calamus erectus* Roxb., *Smilax ferox* Wallich ex Kunth, *Smilax zeylanica* Linn., *Lonicera macrantha* DC., *Lonicera glabrata* Wallich., *Aristolochia griffithii* Hook.F. & thoms. Ex Duchartre *and Zanthoxylum armatum* DC.

Disturbance and threat perception

Dry fuel wood collection is negligible in this MPCA. There are no usufruct rights and concessions within the MPCA are prescribed as per the Management Plan. However, rights and concessions are provided as per the relevant provisions laid under Acts and Regulations. Rachila MPCA is mostly visited by local forest dwellers for collecting fuel wood, NTFPs etc. Besides, the MPCA site is not free from grazing and other biotic interference like illicit felling etc. The collection of non-wood forest products from the MPCA site is very least and occasional as per demand. Forests adjoining the MPCA areas are not allowed for grazing or other anthropogenic activities. Some of the issues like rotational grazing as well as discarding of unproductive cattle and raring of high yielding mulching cow followed by stall feeding, illicit felling, etc., are present in this MPCA site. It is inevitable that Rachila MPCA

needs some sort of protection from grazing & other human interference etc. Majority of plant species are of broad leaved deciduous in nature, so there is always chance of incidental fire at forest floor. Most of the incidences like wanted or unwanted fire are usually caused by the deliberate action of cattle herdsmen from outside the MPCA. No visitors and tourists can enter MPCA areas except the eastern boundary of MPCA, which is close to PWD road. The most common weeds in an around the MPCA are *Mikania cordata* (Aselu, asare) and *Girardinia palmata* (sisnu). Species of *Strobilanthes* form a thick undergrowth in the old forests. No such major erosion nearby this Rachila MPCA site except a few channels and jhoras of smaller sizes are formed due to under current flow of rain during the monsoon which usually dries up during the month of winter.

Site disturbance levels were assessed with the information documented from the literatures and field observations. Site disturbance levels were examined by scoring 15 factors that are reported to disturb the intrinsic nature of ecological and anthropological interactions present in the MPCAs, which include distance from the human habitation, nature of surroundings, access to MPCA, boundary wall/fence, presence of RET species, regeneration ability, vegetation canopy openness, trekking paths, tourist attractions, public entry inside MPCA, details of resource removal from MPCA, fire incidences, weed and invasive species, and departmental activities. Based on the site disturbance scores arrived for Rachila MPCA, it can be considered as 'least disturbed' site (Table 4). Sites with low score experience least disturbance. The categorization of MPCA sites is made to examine whether the population levels of medicinal plants in MPCA are faring regardless of different levels of disturbance.

Following are the list of threats perceived for this Rachila MPCA site especially for medicinal plants population:

- Lack of knowledge amongst villagers regarding use and threat of species
- Commercial demand from outside the state
- Unscientific destructive harvesting from the wild without any proper reason.
- Reduced focus on cultivation of medicinal plants and their fate
- Unwanted Cattle sheds and grazing within the forests
- Exotic weed pressure or pressure due to alliance species
- Soil erosion in open areas without big trees
- Illicit management

Table 4. Assessment of disturbance levels in Rachila MPCA sites by scoring 15 factors

Sl. No	Site elements	SL. No	Score
1	Nature of surroundings – sides surrounded either by agricultural lands/plantations or human settlements (4) 1 = One side only 2 = Two sides 3 = Three sides 4 = All four sides		
2	Boundary wall/fence around MPCA especially areas bordering with human settlements/non-forest landscapes (5) 0 = Barbed wire fencing in all four sides 1 = Barbed wire fencing in part of sides 2 = Barbed wire fencing in sites bordering roads 3 = Barbed wire fencing in sites nearing the entrance 4 = no boundary walls/fence		
3	Access to MPCA site from main road/human settlement (2) 1 = mud road 2 = Metal road/concrete road		
4	Distance from human settlement (5) 1 = >500 meters from site 2 = 100 – 500 meters from site 3 = 100 meters from site 4 = houses bordering with MPCA 5 = houses within MPCA		
5	Presence of RET species (3) 1 = > 10 species 2 = 5 – 10 species 3 = < 5 species		
6	Regeneration of conservation concern species (seedling and sapling stages) (3) 1 = > 10 species 2 = 5 – 10 species 3 = < 5 species		
7	Vegetation canopy openness (3) 1 = Small canopy gaps, but few 2 = Small canopy gaps, but many 3 = Large canopy openness		
8	Number of trekking paths (3) 1 = One 2 = Two 3 = More than two		
9	Frequency of general public entry inside MPCA areas (3)		

Sl. No	Site elements	SL. No	Score
	1 = Occasional 2 = Pilgrimage times 3 = Fair & festival times		
10	Presence of tourist attraction (5) 1 = Water falls 1 = Temple structure 1 = Passage to towns 1 = Historical or ancient sites 1 = Trekking areas		
11	Resource extraction (6) 1 = Firewood 1 = Fodder 1 = Timber 1 = Medicinal plants 1 = Soil or manure 1 = Water for agricultural/domestic purpose		
12	Vulnerability of fire incidences (4) 0 = No history of fire incidences 1 = Less chance 2 = Moderate chance 3 = High chance		
13	Extent of area vulnerable for fire incidences (4) 0 = No history of fire incidences 1 = < 10 ha 2 = 10-50 ha 3 = > 50 ha		
14	Presence of weed and invasive species (3) 1 = 1-5 weed species 2 = 6-10 weed species 3 = more than 10 weed species		
15	Departmental activities apart from what is approved (3) 0 = No interventions undertaken 1 = Planting of plant materials 1 = Removal of NTFPs and fuelwood 1 = Grazing of animals		
		Total	

Management interventions

The MPCA site falls under Neora Forest Range under Lava beat. It comes under the administrative control of Divisional Forest Officer, North (Hills). The forests have been reserved from unoccupied waste. Later, the condition of forests called for planed management and an outline of Working Plan was drawn up in 1892-93. In the 7th Working Plan (1970-71 to 1989-90) the Sal Working Circle was constituted comprised of 13,106.11 ha. of all *Rhododendron* Spp. bearing forests areas ofRachila MPCA and other areas. The main prescription was clear felling followed by artificial regeneration by Taungya. Guras *(Rhododendrons*) was the principal species. Both rotation and conversion period were fixed at 80 years to produce good quality timber. In the 8th Working Plan submitted as 9th Working Plan (1997-98 to 2017-18), the Biodiversity and Wildlife Conservation and Preservation Working Circle was continued.

The area of the Working Circle was kept as 8929.374 ha. The prescriptions of the Working Circle for complete preservation and development of floral and faunal biodiversity were approved. Wind fallen, dead and diseased trees were salvaged. Wherever clear felling was prescribed it was not allowed. Later days, 15,875.43 hectares of natural forests were kept under this Working Circle. Though no specific prescription for their management were given in the Working Plan, no felling of green trees in these areas were permitted. Only wind fallen, dead, dying and diseased trees were permitted to be removed for the health and hygiene of the forests with the submission of compartment wise annual statement to the Conservator of Forests, Working Plan. It was notified as a protected area in April 1986 and was gazetted in December 1992. The park authorities divided Neora Valley into two ranges, namely the upper range with its headquarters at Lava, serving as its western entry point.

CHAPTER 2 : MATERIALS & METHODS

Vegetation at a particular site is the result of interaction of various climatic and biotic as well as edaphic (soil) factors. This study was envisaged as a composite study related with living and non-living components as a whole in the selected MPCA areas. In the community, during the course of succession, many tree species compete with each other to establish their hold on the vacant niches. The study of association in response to community structure was also attempted with the help of ecosystem indices available for herbs, shrubs and trees. This work had field research activities to undertake a rapid population assessment of medicinal plants species of Rachila MPCA. The quantitative plant diversity inventories are the fundamental tool for conservation and management of forest ecosystems, but as far as MPCAs are concerned they are limited. Much of the current knowledge was still based on the qualitative surveys conducted as part of establishment of MPCAs, which mainly dealt with the floristic account of trees and climbers. However, quantitative inventories of medicinal plant species in Rachila MPCA were still lacking. Hence, the present investigation was undertaken.

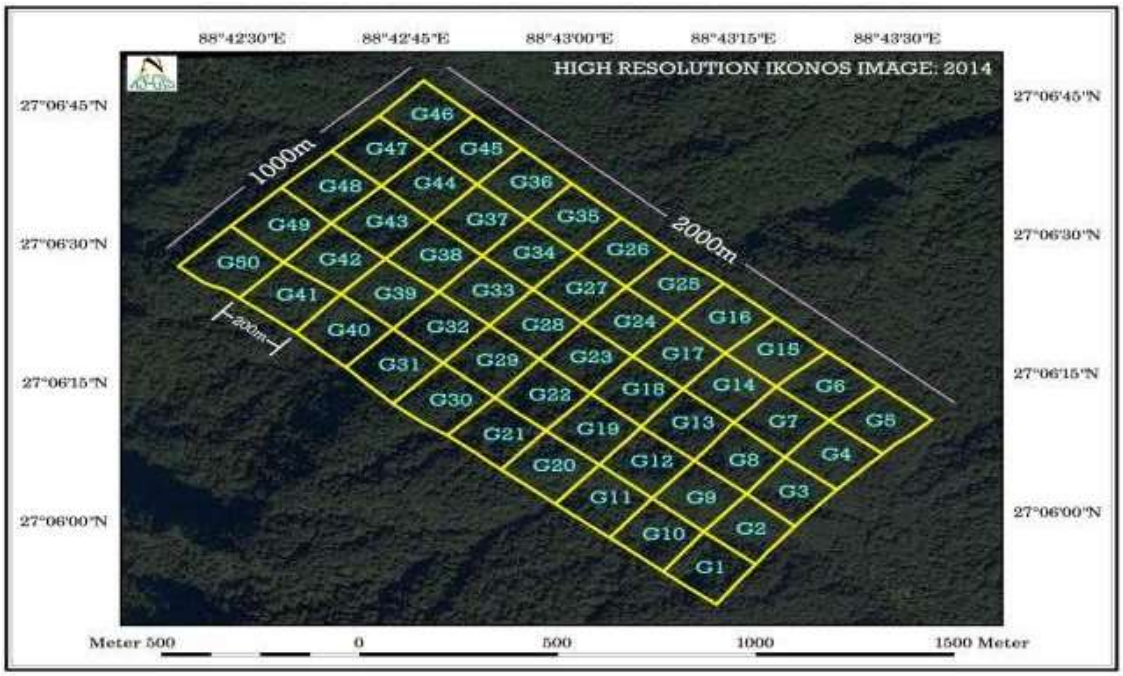
Grid layout

It is quite difficult to survey the whole area covered under MPCA as surveying takes more time and money. Therefore, the sample survey method was attempted. Out of 200 ha of total area (1000 m x 2000 m), 5 % i.e., 20 ha was selected as a sample area. The method of choosing the sample have to be unbiased and efficient one, otherwise the results would be erroneous. The samples should represent the population in all respect. Since the density of forest need not be the same across entire MPCA area to look homogenous. To avoid, the technique of stratified random sampling method of sampling was attempted through sub-divide the MPCA area into grids. These grids are known as strata coming from stratified sampling. From these strata, samples were taken randomly using random number technique of choosing the samples.The strata were allotted serial numbers as 1, 2, 3, 4….50 for consideration. The whole MPCA area was divided into grids of equal size with the help of GPS reading. Each grid was 4 ha size. In order to get 20 ha (5%) of areas, five such grids were selected for survey. If two grids came close to each other in the random sampling method, then again, the same technique was used to get another grid to avoid any bias. Once five grids were selected for survey, the latitude and longitude of the grids were collected for survey purpose.

The site related information documented in the Wildlife Management plans was collected. Following details: latitude, longitude, altitude, boundaries of the Rachila MPCA locations, were gathered from the records. An innovative application of using open source GIS

software technology was used for preparing a grid layout for Rachila MPCA landscape. In this work, maps were generated with actual location information. The grid layouts were developed for Rachila MPCA sites using GIS tool. The grids have been superimposed on the elevation to get the grid distribution correlated with topography and elevation (Figure 6). The grid layouts were processed from multiple measurements latitude and longitude coordinates collected during the field surveys of botanical team. These grids on the topographic sheet are expected to provide reliable information to researchers and botanical team and guide the field activities to be undertaken in the MPCA area.

Figure 5. High resolution image of Rachila MPCA with grids laid across MPCA covering the entire selected areas



The vegetation surveys were planned in the sites by laying quadrats as random. In open tract the vegetation study was made by belt transect on three exposures i.e. margin (nearer to forest road), centre and deeper part the forest, according to the principles of "landscape" approach as followed by Whittaker. The laying out of grids has been made on the basis of the guideline of National Working Plan Code- 2014. The points of grids and small quadrats have been made using GPS and grids were conveniently marked by serial number as per the procedure of the said code.

Figure 6. Contour maps of Rachila MPCA showing the grids laid across selected areas of MPCA

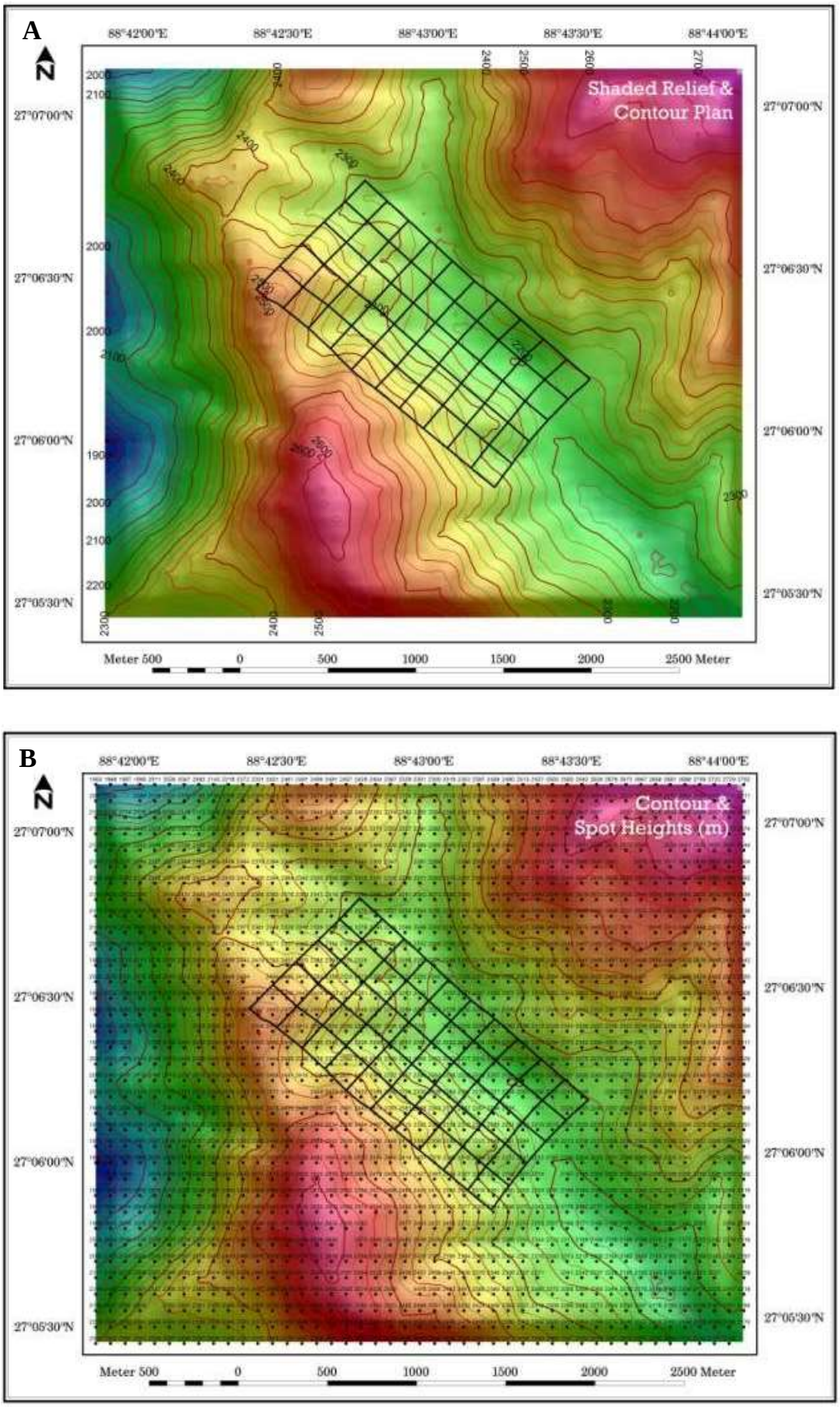
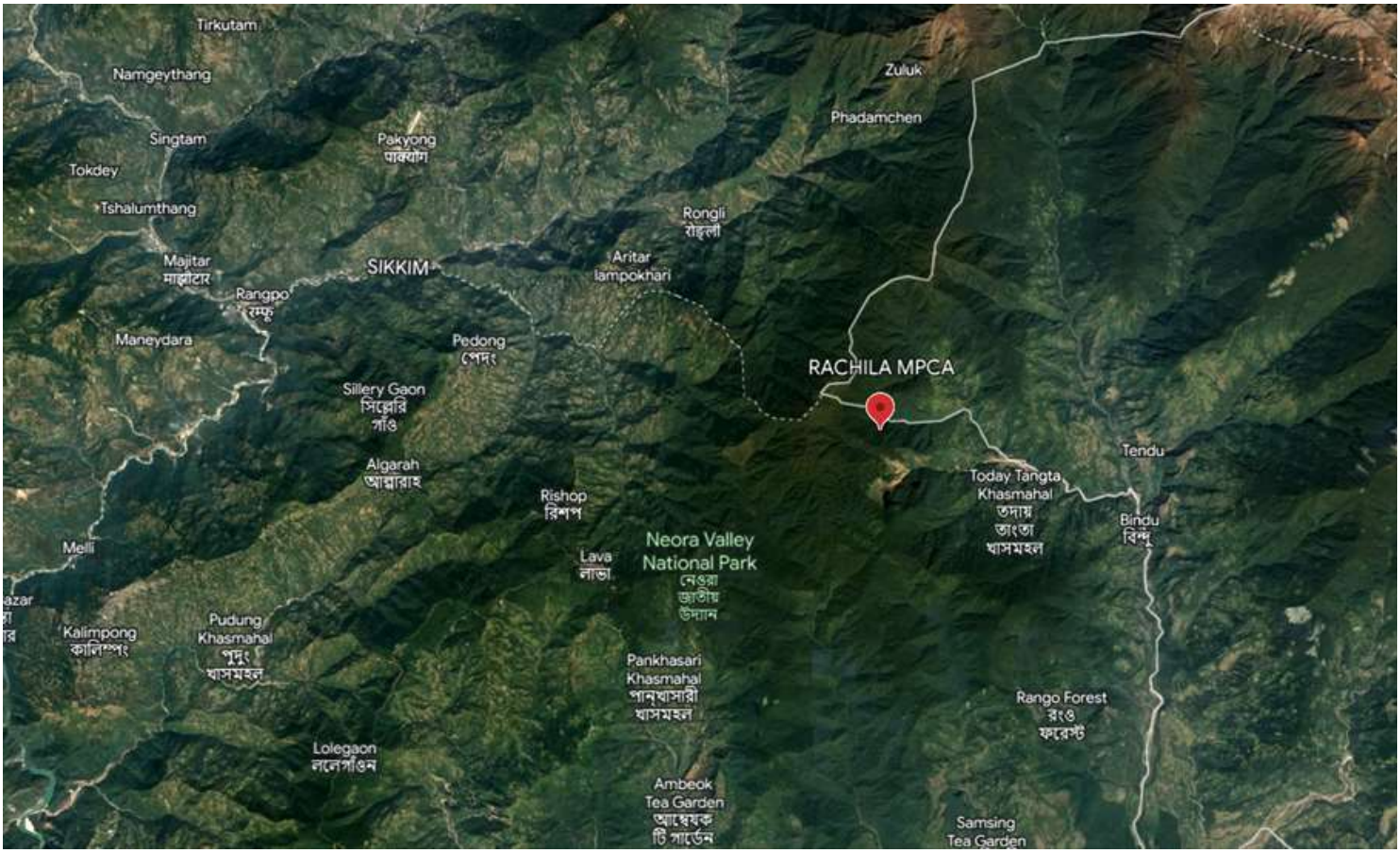


Fig 6a. Google earth map showing location of Rachila MPCA and the surrounding areas



Sampling plots layout

Sampling sites were selected randomly in 200 hectares of demarcated MPCA areas as specified by the guidelines. Topographically, the elevation of sites was around 392 ft above mean sea level as a reserved forest. Five sampling quadrats were laid down in each of five working grids (Figure 8). So totally, there were 25 quadrats of 20 m x 20 m size studied for phytosociological analysis. In each study site quadrats were (20 m X 20 m plots for trees and 5m X 5m plots for shrubs, 1m x 1m for herbs) critically studied and data for each kind was recorded. With the help of local people, local names and common use along with medicinal values of ethnic kinds were documented. During the vegetation survey, the presence of wild fauna and some big animals, birds was observed to understand the species interaction. Vegetation in a community is a dynamic biological system consisting of a number of plant and animal species. So, for the study of constrains and dynamics parallel data was collected from nearby forest as check list of species directly and indirectly with the help of local people.

The size of the quadrats was prepared and fixed by the method of "species area curve". The numbers of quadrats required was determined by plotting the number of species against the number of quadrats. Species-area and species-individual curves have been central to community ecology for decades. The observation that the species number tends to increase, continuously and monotonically with area was first published in the work of Watson (1835) and latter it was reiterated. The species-area curve was later considered as one of the few 'laws' of community ecology. In the 20^{th} century the emphasis shifted from observing the relationships to expressing them from mathematical perspective. The increase in species number with forest area been attributed to ecological processes and also to sampling effects, whereby larger forest fragments contain more plots that sample more of the community. Loss of diversity can only be predicted using species-area relationships at the appropriate scale and in the correct place, as trajectories of species accumulation differ according to forest type and disturbance history. Most models of community structure based on habitat partitioning suggest that there will be an asymptote in the species-accumulation curve, but the real question is about reaching the flat curve at what extent of sampling (for e.g., 50 ha or beyond that). Notwithstanding, species-area curves are widely used to determine the capacity of forests of all sizes in terms of supporting species diversity.

The quadrats analyses were made by following Dombois and Ellenberg. In a grid, 25 quadrats of 1m x 1m, 25 quadrats of 5m x 5m and 5m quadrats of 20m x 20m for herbs, shrubs and trees were laid out at random for study of vegetation of all kinds (Figure 7).

For trees, five specific quadrats at each study grid for each type or exposure of the selected localities were marked by paint (yellow coloured paint) through the help of pole where the poles were natural kind. Peripheral areas were demarcated by white coloured paint by tracing double circle through the girth at breast height (GBH) of trees. Girth of each tree species in the quadrat was recorded by red paint by using 3 inches brush. In each quadrat, the following characters were taken for calculation of result: (i) abundance of each species (for the calculation of density), (ii) basal cover of species taken by measuring girth of a tree (> 10 cm girth) at breast height i.e., at 1.37 m (4 feet 6 inches) is individually measured for all the species, (iii) data on Non Timber Forest Produce species following Economic Botany Data Collection standard, (iv) advent growth and new recruits were recorded using Slide callipers and measuring tape along with the foot rule from 2m x 2m area after pointing station by GPS, (v) photographs were taken and local names also recorded by the help of forest guards and local people working in the said field.

Similarly, for shrubs 25 quadrats (4 at the 4 corners and one at the centre of each big quadrat) of 25 square meters each and for herbs (5 quadrats in each tree quadrat) 1 square meter area for each were made. Plant species encountered in each quadrat was listed out and identified on the basis of floristic studies of regional vegetation made by Prain, Mabberley and the names was cross-checked with the help of Bennet. To know the importance of plant species, information was taken from internet. In each quadrat, the following special character was recorded. In case of herbs, above ground biomass was estimated by destructive method for calculation of abundance (dominance) of a species. Frequency density and abundance values were calculated for each species.

Diversity index of each sample stand was calculated as per Shannon and Wiener. Frequency density and abundance values will be calculated for each species. The importance value index (IVI), an integrated measure of relative frequency, relative density and relative dominance will be derived following Curtis (1959). After collecting the data from field, the following indices were calculated in detail to establish the status of plants in Rachila MPCA

Figure 7. Layout of sampling plots and design of sampling efforts for medicinal plant species population assessment in Rachila MPCA

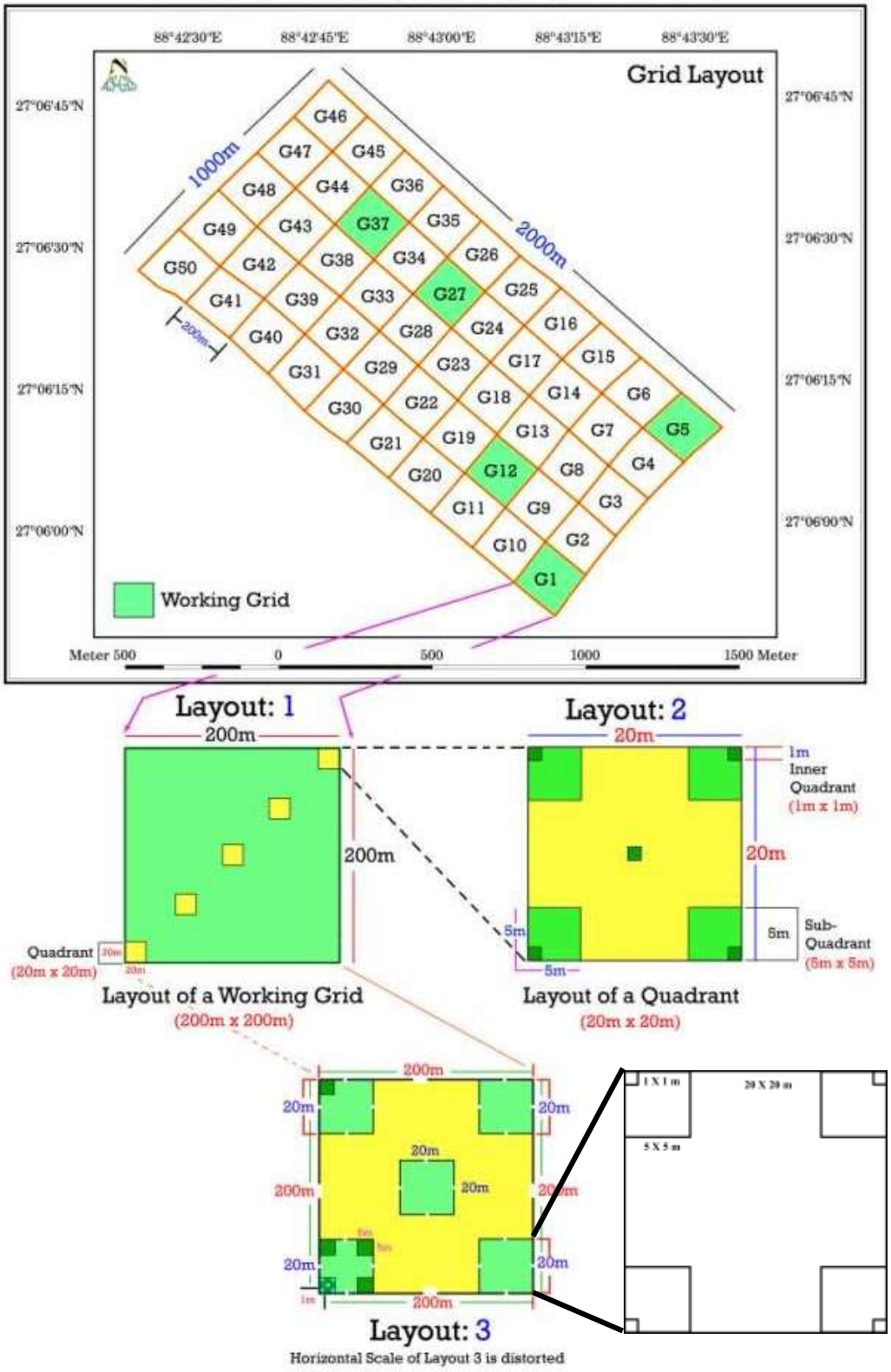
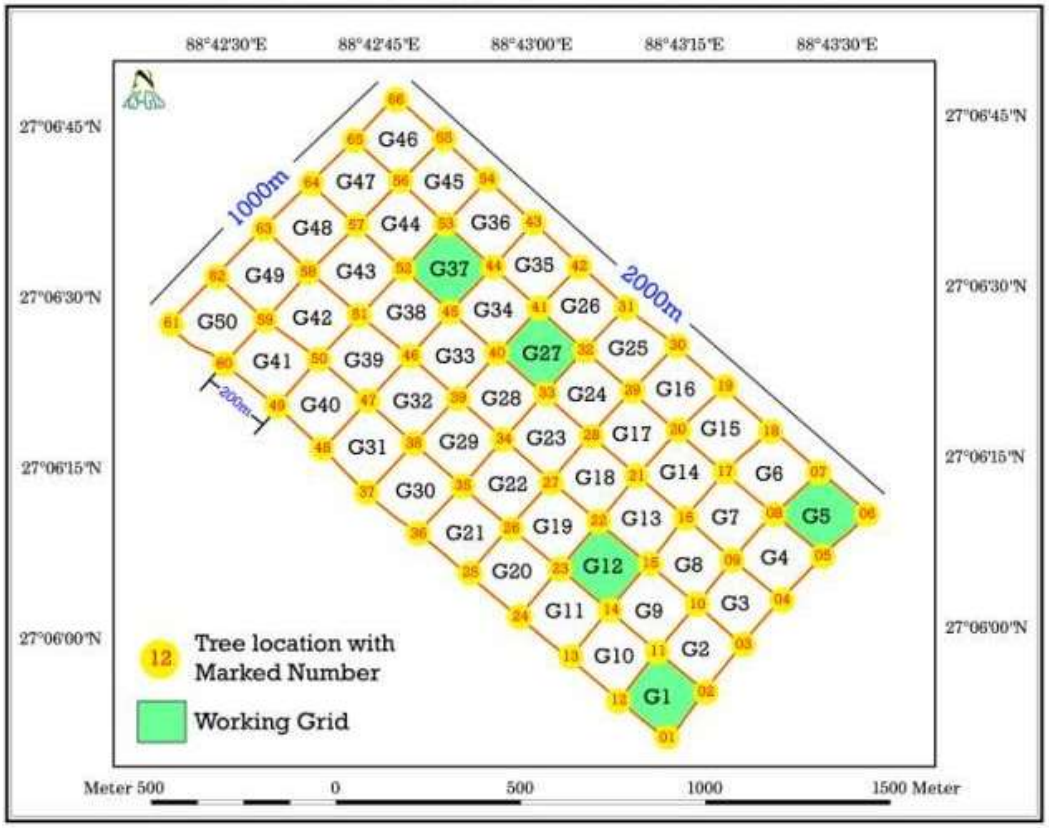


Figure 8. Numbering of grids and selection of working grids for sampling purpose in Rachila MPCA



Diversity measurements

These voucher specimens were then mounted on the standard herbarium sheets, properly pasted and stitched wherever required (particularly having large fruits or capsules with seeds). They were then identified by the expert taxonomist consulting various related published flora viz., Flora of West Bengal, Flora of Bhutan, Flora of India and various herbaria and rawdrugs repository viz., Herbarium in University of North Bengal, Siliguri, Herbarium in Botany Department and Calcutta University. They are then properly labelled with the standard labels having taxonomic and habitat information.

Forest ecosystem is one of the most species-rich vegetation formations on earth. Typically, hundreds of plant species coexist in a single hectare of forest. One of the key goals of ecology is to explain the distribution and abundance of species. Diversity of a community is assessed by the proportional species abundance data either by using statistical sampling theory (Fisher α) or by a variety of nonparametric measures (Simpson, Shannon, etc.). Ecosystem

diversity on a spatial and areal scale is subdivided into alpha, beta, gamma and delta diversity (Whittaker, 1972). In forest ecosystems, alpha diversity operates within forest stands. Beta diversity refers to the variation between forests stands, i.e., how species composition varies from one area to another. Gamma and delta diversity operate on large scales. Most diversity studies, especially for large extents, considered only one or two components of diversity, species richness within local communities (α-diversity), species richness within a region (γ-diversity), or similarity between communities (β-diversity). Various indices have also been formulated for depicting species diversity. The most common of these are Simpson's heterogeneity index and the Shannon index.

Species similarity

In vegetations studies it is often desirable to compare two plant communities and determine how similar they are. This can be accomplished with a similarity index. The similarity index determines the interspecific association between the species of plant communities.

Sorensen's species similarity index (SS) between the transects and the two sites. It gives greater "weight" to species that are common to the quadrats than to those found in only one quadrat. It uses presence/absence data and was calculated using following formula:

$$SS = 2a/(2a + b + c), \text{ where}$$

a = number of species common to both quadrats; b = number of species unique to the first quadrat; c = number of species unique to the second quadrat

SS usually is multiplied by 100% (i.e., SS = 67%), and may be represented in terms of dissimilarity (i.e., DS = 1.0 - SS).

Jaccard similarity index (SJ) between the transects and the two sites was calculated following formula: uses presence/absence data (i.e., ignores info about abundance)

$$SJ = a/(a + b + c), \text{ where,}$$

SJ = Jaccard similarity coefficient; a = number of species common to (shared by) quadrats; b = number of species unique to the first quadrat, and c = number of species unique to the second

To avoid individual variation, the degree of similarity is expressed mathematically on the basis of any quantitative character (Number of species in the present case). The indices of similarity of community coefficient (IS) between any two sample sites or communities is made by the formula of Sorensen (1948) as described by Muller- Dombois and Ellenberg (1974).

$$IS = (2C/A+B) \times 100$$

Where, A= Number of species in one stand / Community.

B= Number of species in another stand / Community.

C= Number of species common to both the communities.

Diversity indices

Basal area (m^2)	$(GBH)^2/4\pi$
Important Value Index (IVI)	R. density + R. frequency + R. basal area
Relative Density	No. of individuals of species A X 100 / Total no. of individuals
Relative frequency	No. of quadrats/plots having species A X 100 / Total no. of quadrats/plots sampled
Relative basal area	Basal area (m^2) of species A X 100 / Total basal area of all species

Shannon-Wiener Index (H') is the most commonly used index of diversity in ecological studies as it fairly sensitive to actual site differences. The values range from 0 to 5, usually ranging from 1.5 to 3.5. It is easily calculated using below equations:

$$H' = -\sum\left[\left(\frac{n_i}{N}\right)\times \ln\left(\frac{n_i}{N}\right)\right]$$

n_i = number of individuals or amount (e.g., biomass or density) of each species (the i^{th} species); N = total number of individuals (or amount) for the site, and ln = the natural log of the number.

Simpson's Index (λ) is a measure of dominance. Therefore, (1-λ) estimates species diversity. It gives the probability that any two individuals drawn at random from an infinitely large community belong to different species. It is less sensitive to species richness and heavily weighted towards the most abundant species. It is calculated using following equation

$$\lambda = \sum \frac{n(n-1)}{N(N-1)}$$

n_i = number of individuals or amount of each species (i.e., the number of individuals of the i^{th} species); N = total number of individuals for the site

Dominance concentration (CD) - Concentration of Dominance (Cd) of each stand will be calculated following the formula givenbelow by Simpson (1949).

$$Cd = (ni / N)^2$$

Where 'ni' is the IVI of individual species and 'N' is the total IVI of all the species.

Evenness Index (e)

Evenness Index (e) will be calculated according to Pielou (1966).

$$e = H / \overline{\log S}$$

Where, H = Shannon index and S = Number of species.

Species Richness Index (D)

Species Richness index (d) will be calculated according to Margalef (1958).

$$d = S-1 / \log N.$$

Where, S= Number of species, N = Importance Value and, d= Species richness.

Threatened status

The most critical aspect in the biodiversity conservation is the prioritisation of species as there may be number of species in need of immediate action. One of the ways to prioritise species especially plants is based on the threatened category the particular species belongs to. Apart from that how important the particular species is in the commercial trade market fetching more price value and also in great demand. In general, there is a RED data book published by the Botanical Survey of India with periodical updates while there is also an IUCN Red list of Threatened plants. In specific to medicinal plants, FRLHT has been organising number of Conservation Assessment and Management Prioritisation (CAMP) workshop at state level to conduct threat assessment for medicinal plants involving subject experts and taxonomists by following IUCN guidelines. The list of threatened medicinal plant species has been prepared for almost all states in India. Plant species that are listed as threatened species are given priority when it comes to undertaking any conservation actions.

Rapid assessment of threats to the medicinal plants of West Bengal was done through CAMP workshop held at state level. This workshop aimed at assigning the IUCN's qualitative Red List system to categorise each species to a degree of endangerment based on the estimates of the threats to the population and habitat. A total of 148 medicinal plant species was proposed for the assessment of which 43 species were assessed according to the IUCN Red List Criteria. Subject experts and taxonomists from West Bengal assessed their distribution and prepared the taxon sheets for each of 43 medicinal plant species priorised for conservation in West Bengal. The number of medicinal plant species across different threatened status categories are: 14 Vulnerable; 19 Endangered; 1 Near Threatened; 6 Critically Endangered. Among trees, there are 24 species in Vulnerable, 7 in Endangered and 3 in Near Threatened category. There are 6 trees and 4 climbers in Vulnerable category. Out of 15 herbs assessed, 8 species are in Endangered category. Out of 43 medicinal plant species having threatened status in West Bengal, 40 medicinal plant species are recorded in already established seven MPCAs.

Data analysis

Species diversity indices such as the Shannon, Simpson and Fisher's α (as in Magurran, 1988) were calculated. To understand a species' share in the plant community, the species importance value index (sum of the relative density (Rd), relative frequency (Rf) and relative dominance (Rdm) as per Cottom and Curtis, 1956) and family importance value index (sum of the relative diversity (Rdi), relative density (Rd) and relative dominance (Rdm) based on Mori et al. 1983) were calculated. The program EstimateS v.5 (Colwell, 1997) was used for raising species-area curves plotted as species increment with every quadrat placed. Spatial patterns of species (whether individuals of tree species are random/uniform/clumped in distribution), represented by >50 individuals in each site, were determined by the quadrat count method using standardized Morisita index (Krebs, 1989). A ratio of zero indicates random dispersion pattern, above zero clumped pattern and less than zero uniform pattern. This quantitative spatial pattern is not strongly influenced by species richness and sample size, although it is sensitive to the abundance of the most abundant species. The frequency distribution of plant size (gbh) classes between the MPCA sites was compared using Kolmogorov-Smirnov one-sample test (Zar, 1999).

Coefficient of variation (CV- standard deviation/mean for a species) was computed to identify whether there is an oligarchy in plant species. This would provide information on site differentiation with respect to species composition, whether species with a low CV regardless

of absolute density are equitably distributed, or those with a high CV show a large degree of variability in their distribution. To examine the species similarity among the ten sites an agglomerative hierarchical clustering analysis was performed, using Sorensen's index (Magurran, 1988) and unweighted paired group arithmetic average (UPGMA) using Biodiversity Pro (1997).

Details of field visits

The field work was conducted multiple times in 2015 onward. First visit was made between October and December months followed by January and March in 2016. There were other trips to site just prior to monsoon (April to June).

CHAPTER 3: QUANTITATIVE ASSESSMENT OF MEDICINAL PLANTS

Number of medicinal plants recorded

Table 5: Checklist of plant species: trees, shrubs and herbs recorded in the surveyed area.

Sl. No.	Species Name	Family	Local name
TREE SPECIES			
1	*Acer campbellii* Hook.f. & Thomson ex Hiern	Sapindaceae	Kapasi
2	*Acer sikkimense* Miq. Syn. Acer hookeri Miq.	Sapindaceae	Lahare Kapasi
3	*Alnus nepalensis* D.Don	Betulaceae	Uttis
4	*Aralia leschenaultii* (DC) J.Wen	Araliaceae	Chinde
5	*Betula alnoides* Buch.-Ham. ex D.Don	Betulaceae	Saur
6	*Betula utilis* D. Don	Betulaceae	Bhurjapatra
7	*Castanopsis hystrix* Miq.	Fagaceae	Dalnekatus
8	*Cryptomeria japonica (*Thunb. Ex L.f.) DDon	Cupressaceae	Dhuupi
9	*Daphniphyllum himalayense (*Benth) Mull.Arg.	Daphniphyllaceae	Lal Chandan
10	*Elaeocarpus sikkimensis Masters*	Elaeocarpaceae	Bhadrase
11	*Endospermum chinense*	Euphorbiaceae	Setikhat
12	*Enkianthus deflexus (*Griff.*)* C.K.Sch	Ericaceae	Firke Kath
13	*Eurya accuminata* DC.	Theaceae	Sanu Jhiganae
14	*Eurya japonica* Thunb.	Theaceae	Jhigini
15	*Evodia fraxinifolia*	Rutaceae	Khanakpa
16	*Evodia lunu-ankenda (*Gaertn.*)* Merr.	Rutaceae	Khanakpa

17	*Exbucklandia populnea* (R.Br. ex Griff.*)* R.W.Br.	Hamamelidaceae	Pipli
18	*Ilex Ficus neriifolia* J.E. Smith	Moraceae	Dudhilo
19	*sikkimensis Kurz*	Aquifoliaceae	
20	*Juglans regia* L.	Juglandaceae	
21	*Lithocarpus pachyphyllus (*Kurz*)* Rehder	Fagaceae	Bante/Sungre katus
22	*Litsea elongata (*Nees*)* Hook.f.	Lauraceae	
23	*Litsea javanica* Blume	Lauraceae	
24	*Lyonia ovalifolia (*Wallich*)* Drude	Ericaceae	Balu jhar
25	*Machilus edulis* King ex Hook.f.	Lauraceae	
26	*Machilus gamblei* King. ExHook. f.	Lauraceae	Kawla
27	*Machilus gammieana* King ex Hook.f.	Lauraceae	Chiple Kawlo
28	*Magnolia campbellii* Hook.f. & Thomson	Magnoliaceae	Ghoge Champ
29	*Magnolia doltsopa* (Buch.-Ham. ex DC.) Figlar	Magnoliaceae	Rani/Mithe Champ
30	*Meliosma pinnata* (Roxb.) Max.	Sabiaceae	Lekh Dabdabe
31	*Pentapanax leschenaulty* Seem.	Araliaceae	Chinde
32	*Photinia integrifolia* Lindl.	Rosaceae	Phalame
33	*Pinus patula Schiede* ex Schltdl. & Cham.	Pinaceae	Salla
34	*Pinus wallichiana* A. B. Jackson	Pinaceae	
35	*Piptanthus nepalensis* (Hook.) Sweet	Fabaceae	
36	*Populos glauca* Haines	Salicaceae	Lek Pipalpatey
37	*Prunus cerasoides* D. Don.	Rosaceae	

38	*Quercus lamellosa* Sm.	Fagaceae	Buk
39	*Quercus lineata* Blume	Fagaceae	Phalant
40	*Quercus pachyphylla* Kurz.	Fagaceae	
41	*Rhododendron arboreum* Sm.	Ericaceae	Lali Gurans
42	*Rhododendron barbatum* Wall. ex G.Don	Ericaceae	Lal Chimal/Junge Chimal
43	*Rhododendron falconeri* Hook.f.	Ericaceae	Pahenlo Korlinga
44	*Rhododendron grande* Wight	Ericaceae	Patle Korlinga
45	*Rhododendron griffithianum* Wight	Ericaceae	Seto Chimal
46	*Saurauia nepaulensis* DC.	Actinidiaceae	Gogun
47	*Schefflera elata* (Buch.-Ham.) Harms	Araliaceae	Gufla
48	*Schefflera rhododendrifolia* (Griff.) Frodin Syn. *Schefflera impressa* (C.B.Clarke) Harms	Araliaceae	Bhalu Chinde
49	*Sorbus foliolosa* (Wall. ex Hook.f.)	Rosaceae	Thulo Pasi
50	*Sorbus vestita* (G. Don*)* Lod.	Rosaceae	Tenga
51	*Symplocos glomerata* King ex C.B.Clarke	Symplocaceae	Kharane
52	*Symplocos lucida* (Thunb.) Zuccarini	Symplocaceae	Ghole/Kharane
53	*Symplocos racemosa* Roxb.	Symplocaceae	
54	*Taxus wallichiana* Zucc.	Taxaceae	Dhyangre Salla
55	*Tetradium fraxinifolium* (Hook.) T.G.Hartley	Rutaceae	Khanakpa
56	*Tsuga dumosa* (D. Don) Eichler	Pinaceae	Thingre Sall

57	*Zanthoxylum armatum* DC	Rutaceae	Bokey Timbur
SHRUBS AND CLIMBERS			
1	*Aconogonom molle* (D.Don)Hara	*Polygonaceae*	
2	*Agapetes serpens* (Wight) Sleumer	Ericaceae	
3	*Aristolochia griffithii* Hook.f. & Thomson ex Duch.	Aristolochiaceae	
4	*Berberis aristata* DC.	Berberidaceae	
5	*Berberis conccinna* Hook.f.	Berberidaceae	Tsema/Chutro
6	Berberis hookeri *Lem*.	Berberidaceae	
7	*Berberis insignis* J. D. Hooker & Thomson	Berberidaceae	Chutro
8	*Berberis thomsoniana* C.K.Schneid.	Berberidaceae	
9	*Cayratia trifolia* (L.) Domin	Vitaceae	
10	*Clematis buchananiana DC.*	Ranunculaceae	
11	*Clematis montana* Buch.-Ham. ex DC.	Ranunculaceae	
12	*Crawfurdia speciosa* Wall.	Gentinaceae	
13	*Dactylicapnos scandens* (D.Don) Hutch. Syn. *Dicentra scandens* (D.Don) Walp.	Papaveraceae	
14	*Daph Don ne bholua* Buch.-Ham. ex D.Don	Thymelaeaceae	
15	*Daphne papyracea* Wallich ex G. Don	Thymelaceae	
16	*Dicentra scandens (*D. Don*)* Walp.	Fumaricaceae	
17	*Euonymus frigidus* Wall.	Celastraceae	

18	*Eurya acuminata* DC.	Ericaceae	
19	*Eurya cerasifolia* (D.Don) Kobuski	Pentaphylacaceae	
20	*Gaultheria fragrantissima* Wall.	Ericaceae	
21	*Gaultheria nummulariodes* D.Don	Ericaceae	
22	*Helwingia himalaica* Hook.f. & Thomson ex C.B.Clarke	Helwingiaceae	Pipli
23	*Herpetospermum darjeelingense* (C.B.Clarke) H.Schaef & S.S.	Cucrbitaceae	
24	*Hydrangea anomala* D.Don	Hydrangeaceae	Jangli Hydrangea
25	*Hydrangea heteromala D.Don.*	Hydrangeaceae	Halonre
26	*Hypericum hookerianum* Wight & Arn.	Hypericaceae	Mehendi phul
27	*Hypericum oblongifolium* Choisy	Hypericaceae	
28	*Ilex dipyrena* Wall.	Aquifoliaceae	
29	*Jasminum dispermum* Wall.	Oleaceae	
30	*Laportea terminalis* Wight.	Urticaceae	Patle sisnu
31	*Lasianthus sikkimensis* Hook.f.	Fabaceae	
32	*Leucosceptrum canum* Sm.	Lamiaceae	
33	*Leycesteria gracilis* (Kurz) Shaw	C *Airy* aprifoliaceae	
34	*Leycesteria stipulta* Hook.f. & T Fr.	Cap.*)*rifoliaceae	Bherikuro
35	*Lonicera glabrata* Wall.	Caprifoliaceae	Honeysuckle
36	*Luculia gratissima* (Wall.) Sweet	Rubiaceae	
37	*Lyonia ovalifolia (*Wallich*)* Drude	Ericaceae	Lek Angeri
38	*Maesia montana* A.DC.	Myrsinaceae	Kalo Bilaunae

39	*Mahonia jap Thunb onica (.)* DC.	Berberidaceae	
40	*Mahonia nepalensis* DC. ex Dippel	Berberidaceae	Kesari/Chtro
41	*Myrsine semiserrata* Wall.	Primulaceae	Kalikath
42	*Naravelia zeylanica* (L.*)* DC.	Ranunculaceae	
43	*Neillia thyrsiflora D.*Don	Rosaceae	
44	*Neohymenopogon parasiticus (*Wall.*)* Bennet	Rubiaceae	Jhanti phul
45	*Ochna pumila* Buch.-Ham. ex D.Don	Ochnaceae	
46	*Osbeckia stellata var.* crinita (Benth. ex Naud.) C.Hansen	Melastomataceae	
47	*Pieris formosa* (Wall.) D.Don	Ericaceae	
48	*Piper suipigua Buch.*-Ham. ex D.	Piperac *Don* eae	
49	*Rhaphidophora calophylla* Schott	Araceae	
50	*Rhaphidophora glauca (*Wall.*)* Schott	Araceae	
51	*Rosa sericea Wall.ex Lindl.*	Rosaceae	Jangli Golap
52	*Rubia cordifolia L.*	Rubiaceae	
53	*Rubia manjith Roxb.*	Rubiaceae	
54	*Rubia sikkimensis Kurz*	Rubiaceae	
55	*Rubus ellipticus Sm.*	Rosaceae	Aselu
56	*Rubus hypargyrus* - (Wall. ex DDon.)Hara.	Rosaceae	
57	*Rubus moluccanus* L.	Rosaceae	
58	*Rubus rosifolius* Sm.	Rosaceae	Gempe Aselu
59	*Rubus wardii* Merr.	Rosaceae	Kanre Aselu
60	*Sabia campanulata* Wall.ex Roxb.	Sabiaceae	Simali Lahara

61	*Sarcococca wallichii* Stapf.	Euphorbiaceae	
62	*Schisandra grandiflora* (Wall.) Hook.f. & Thomson	Schisandraceae	
63	*Senecio scandens* Buchanan-Hamilton ex D. Don	Asteraceae	
64	*Smilax elegans* Wall. ex Kunth	Smilacaceae	
65	*Smilax myrtillus* A.DC.	Smilacaceae	Kare Kukurdaino
66	*Streptolirion volubile* Edgew.	Commelinaceae	
67	*Strobianthes capitata* Nees	Acanthaceae	Ankhle
68	*Strobilanthes helicta T.* Anderson	Acanthaceae	Ankle
69	*Tetrastigma serrulatum* (Roxb.) Planch.	Vitaceae	
70	*Thamnocalamus spathiflorus* (Trin.) Munro	Poaceae	Rato Nigalo
71	*Thunbergia lutea* T.Anderson	Acanthaceae	
72	*Viburnum erubescens* Wall. ex DC	Viburnaceae	Asare
73	*Viburnum mullaha* Buch.-Ham. Ex D.Don	Adoxaceae	Mulla Asare
74	*Yushania maling (*Gamble*)* R.B.Majumdar & Karthik.	Poaceae	
75	*Zanthoxylum oxyphyllum* Edgew.	Rutaceae	
HERBS SPECIES			
1	*Achyranthes bidentata* Blume	Amaranthaceae	
2	*Adiantum Adiantum edgeworthii* Hook.	Pteridaceae	
3	*Aeschynanthus hookeri* C.B.Clarke	Gesneriaceae	
4	*Agapetes hookeri (*C. B. Cl.*)* Sleum.	Ericaceae	

5	*Ageratum houstonianum* Miller	Asteraceae	
6	*Ainsliaea latifolia* (D. Don) Sch.Bip	Asteraceae	
7	*Anaphalis contorta (*D.Don*)* Hook.f.	Asteraceae	Bukiphul
8	*Anaphalis margaritacea (*L.*)* Benth. & Hook.f.	Asteraceae	
9	*Anaphalis royleana* DC.	Asteraceae	
10	*Anaphalis triplinervis (*Sims*)* C.B.Clarke	Asteraceae	Buki phool
11	*Anemone howellii* Jeffrey & W. W. Smith	Ranunculaceae	
12	*Anisomeles heyneana* Benth.	Lamiaceae	
13	*Anthogonium gracile* Wall. ex Lindl.	Orchidaceae	
14	*Arisaema concinnum* Schott	Araceae	Cobra lily/Gurbo
15	*Arisaema costatum* (Wall.) Mart.	Araceae	
16	*Arisaema erubescens* (Wall.) Schott	Araceae	
17	*Arisaema jacquemontii* Blume	Araceae	
18	*Arisaema speciosum (*Wall.*)* Mart.	Araceae	Gurbo
19	*Arisaema tortuosum (*Wall.*)* Schott	Araceae	
20	*Artemisia indica* Willd.	Asteraceae	
21	*Artemisia vulgaris* L.	Asteraceae	
22	*Arundinaria racemosa* Munro	Poaceae	
23	*Astilbe rivularis* Buch.-Ham. ex D.*Don*	Saxifragaceae	Buro Okhati
24	*Begonia aconitifolia* A.DC.	Begoniaceae	
25	*Begonia josephii* A.DC.	Begoniaceae	Magar kache
26	*Boenninghausenia albiflora (*Hooker*)*	Rutaceae	Dampate

	Reichenbach ex Meisner		
27	*Bosmania membranacea (*D.Don*)* Testo Syn. Microsorum *membranaceum (*D.Don*)* Ching	Polypodiaceae	
28	*Calanthe puberula* Lindl.	Orchidaceae	
29	*Calceolaria mexicana* Benth.	Calceolariaceae	
30	*Carex cruciata* Wahlenb.	Cyperaceae	
31	*Carex filicina* Nees	Cyperaceae	
32	*Carpesium abrotanoides* L.	Asteraceae	
33	*Cautleya gracilis (*Sm.*)* Dandy	Zingiberaceae	
34	*Cautleya gracilis var. robusta (*K.Schum.*)* Sanjappa	Zingiberaceae	
35	*Cautleya spicata (*Sm.*)* Baker	Zingiberaceae	
36	*Chlorophytum nepalense (*Lindl.*)* Baker	Asparagaceae	
37	*Cirsium falconeri (*Hook.f.*)* Petr.	Asteraceae	
38	*Clinopodium umbrosum (*M. Bieb.*)* C. Koch	Lamiaceae	
39	*Commelina sikkimensis* C.B.Clarke	Commelinaceae	
40	*Corydalis chaerophylla* DC.	Papaveraceae	
41	*Corydalis longipes* DC.	Papaveraceae	
42	*Craniotome furcata (*Link*)* Kuntze	Lamiaceae	
43	*Craterostigma nummulariifolium* (D.Don) Eb.Fisch., Schäferh. & Kai Müll.	Linderniaceae	
44	*Cyathula tomentosa (*Roth*)* Moq.	Amaranthaceae	
45	*Cynoglossum lanceolatum* Forssk.	Boraginaceae	

46	*Cynoglossum zeylanicum* (Lehm.)Brand	Boraginaceae	Kanike Kuro
47	*Dendrobium chryseum* Rolfe	Orchidaceae	
48	*Dendrobium longicornu* Lindl.	Orchidaceae	
49	*Deparia japonica (*Thunb.*)* M.Kato	Aspleniaceae	
50	*Didymocarpus aromatica* Wall ex D.Don	Gesneraceae	Kumkumpate/Ailo
51	*Didymocarpus punduanus var. pulcher (*C.B.Clarke*)* Su.Datta & B.K.Sinha Syn. *Didymocarpus pulcher* C.B.*Clarke*	Gesneriaceae	
52	*Diplazium japonicum (*Thunb.*)* Bedd.	Athyriaceae	
53	*Diplopterygium glaucum* (Thunb. ex Houtt.) Nakai	Gleicheniaceae	
54	*Drymaria cordata* (L.*)* Willd	Caryophyllaceae	
55	*Dryopteris chrysocoma* (Christ) C. Chr.	Dryopteridaceae	
56	*Elatostema monandrum (*Buch.-Ham ex D.Don*)*	Urticaceae	Gagleto
57	*Elatostema obtusum* Wedd.	Urticaceae	Gagleto
58	*Elatostema sessile* J.R.Forst. & G.Forst.	Urticaceae	Gagleto
59	*Elsholtzia blanda (*Benth.*)* Benth.	Lamiaceae	
60	*Elsholtzia fruticosa (*D. Don*)* Rehder	Lamiaceae	Sano Simal
61	*Elsholtzia strobilifera (*Benth.*)* Benth.	Lamiaceae	Ban Bawari
62	*Epilobium cylindricum* D.Don	Asteraceae	
63	*Epilobium wallichianum* Hausskn.	Onagraceae	
64	*Equisetum ramosissimum* Desf.	Equisetaceae	

65	*Eriocapitella vitifolia (*Buch.-Ham. ex DC.*)* Nakai	Ranunculaceae	
66	*Erythranthe nepalensis* (Benth.) G.L.Nesom	Phrymaceae	
67	*Fragaria nubicola* (Lindl. ex Hook.f.) Lacaita	Rosaceae	Bhuin Aselu
68	*Fragaria vesca* L	Rosaceae	Bhuin Aselu
69	*Galinsoga parv.iflora* Cavanilles	Asteraceae	Chitlange jhar
70	*Galium elegans Wall.*	Rubiaceae	Lahare Kuro
71	*Galium hoffmeisteri* (Klotzsch) *Ehrend. & Schönb.*-Tem. ex R.R.Mill	Rubiaceae	
72	*Gaultheria nummularioides* D.Don	Ericaceae	
73	*Gentiana capitata* Buch.-Ham. ex D. Don	Gentinaceae	
74	*Gentiana pedicellata (*D.Don) Griseb.	Gentianaceae	
75	*Geranium nepalense* Sweet	Geraniaceae	Chunitro ghans
76	*Geranium procurrens* Yeo	Geraniaceae	
77	*Girardinia diversifolia (*Link) Friis	Urticaceae	
78	*Gleichenia glauca (*Thunb. ex Houtt.) Hook.	Gleicheniaceae	
79	*Globba racemosa* Sm.	Zingiberaceae	
80	*Gonostegia triandra (*Syn. Pouzolzia hirta Hassk.	Urticaceae	
81	*Habenaria dentata (*Sw)Schltr	Orchidaceae	
82	*Hedychium thyrsiforme Sm.*	Zingiberaceae	
83	*Helichrysum luteoalbum* (L.*)* Rchb	Asteraceae	
84	*Hemiphragma heterophyllum* Wall.	Plantaginaceae	Lalgeri Jhar

85	*Henckelia pumila (*D.Don) A.Dietr.	Gesneriaceae	
86	*Henckelia urticifolia (*Buch.-Ham. ex D.Don*)* A.Dietr.	Gesneriaceae	
87	*Heracleum wallichii* DC.	Apiaceae	
88	*Herminium clavigerum (*Lindl.*)* X.H.Jin, Schuit., Raskoti & Lu *Q.Huang*	Orchidaceae	
89	*Houttuynia cordata* Thunb.	Saururaceae	
90	*Hydrangea febrifuga (*Lour.*)* Y.De Smet & Granados	Hydrangeaceae	
91	*Hydrocotyle himalaica* PK..Mukh.	Araliaceae	Athanejhar
92	*Hypericum choisyanum* Wall. ex N.Robson	Hypericaceae	
93	*Hypericum elodeoides* Choisy	Hypericaceae	
94	*Impatiens arguta* Hook.f. & Thomson	Balsaminaceae	
95	*Impatiens cathcartii* Hook.f.	Balsaminaceae	
96	*Impatiens discolor* DC.	Balsaminaceae	
97	*Impatiens drepanophora* Hook.f.	Balsaminaceae	
98	*Impatiens puberula DC.*	Balsminaceae	Bhende Ghans
99	*Impatiens racemosa* D.Don	Balsaminaceae	
100	*Impatiens radiata* Hook. f	Balsaminaceae	
101	*Impatiens radiata var. graciliflora (*Hook.f.*)* S.Akiyama Syn. *Impatiens graciliflora* Hook.f.	Balsaminaceae	
102	*Impatiens stenantha* Hook.f.	Balsaminaceae	
103	*Impatiens urticifolia* Wall.	Balsaminaceae	
104	*Isachne globosa (*Thunb.*)* Kuntze	Poaceae	

105	*Isachne sikkimensis* Bor	Poaceae	
106	*Isodon coetsa (*Buch.-Ham. ex D.Don*)* Kudô	Lamiaceae	
107	*Isodon lophanthoides (*Buch.-Ham. ex D.Don*)* H.Hara	Lamiaceae	
108	*Koenigia mollis* (D.Don*)* T.M.Schust. & Reveal Syn. *Polygonum molle* D. Don	Polygonaceae	
109	*Lactuca decipiens* Hook.f. & Thomson ex C.B.Clarke	Asteraceae	
110	*Lactuca dissecta* D.Don	Asteraceae	Dude jhar
111	*Lecanthus peduncularis (*Royle*)* Wedd.	Urticaceae	
112	*Liparis bootanensis* Griffith	Orchidaceae	
113	*Lobelia montana* Reinw. ex Blume	Campanulaceae	Eklebir
114	*Lobelia nummularia* Lam.	Campanulaceae	
115	*Lobelia seguinii* H.Lév. & Vaniot var. doniana (Skottsb.) Wimmer	Campanulaceae	
116	*Lycopodium clavatum* L.	Lycopodiaceae	
117	*Maianthemum fuscum* (Wall.) LaFrankie	Asparagaceae	
118	*Melanoseris decipiens var. multifida* (Hook.f.) Ghafoor, Qaiser & Roohi Bano *Kilian*	Asteraceae	
119	*Melanoseris graciliflora* (DC.) N.	Asteraceae	
120	*Miscanthus nepalensis* (Trin.) Hack.	Poaceae	
121	*Myriactis nepalensis* Less.	Asteraceae	Tuke phul
122	*Neanotis calycina* (Wall. ex Hook.f.) W.H.Lewis	Rubiaceae	

123	*Neillia thyrsiflora* D.Don	Rosaceae	
124	*Odontosoria chinensis* (L.) J.Sm.	Lindsaeaceae	
125	*Oenanthe thomsoni* C.B. .Clarke	Apiaceae	Water dropwort
126	*Oleandra pistillaris* (Sw.*)* C Chr.	Polypodiaceae	
127	*Ophiopogon intermedius* D.Don	Asparagaceae	Kaligeri
128	*Oplismenus burmanni* (Retz.) P.Beauv.	Poaceae	
129	*Oplismenus compositus* (L.) P.Beauv.	Poaceae	
130	*Osmunda claytoniana* L.	Osmundaceae	
131	*Oxalis corniculata* .L	Oxalidaceae	
132	*Panax pseudoginseng* Wall.	Araliaceae	Satpate
133	*Paris polyphylla* Sm.	Melanthiaceae	Satuwa
134	*Parochetus communis* D.Don	Fabaceae	
135	*Peperomia tetraphylla* (G.Forst.) Hook. & Arn.	Piperaceae	
136	*Persicaria canpanulate* (Hook.f.) Rons.	Polygonaceae	Thotne
137	*Persicaria hydropiper* (L.) Delarbre	Polygonaceae	
138	*Persicaria lapathifolia* (L.) Delarbre	Polygonaceae	
139		Polygonaceae	
140	*Persicaria wallichii* Greuter & Burdet	Polygonaceae	
141	*Phlomoides hamosa (Benth.)* Mathiesen Syn. *Notochaete hamosa* Benth.	Lamiaceae	Dalle Kuro
142	*Pilea bracteosa* Wedd.	Urticaceae	
143	*Pilea ternifolia Wedd.*	Urticaceae	
144	*Pilea umbrosa* Wedd. ex Blume	Urticaceae	

145	*Pimpinella diversifolia* DC.	Apiaceae	
146	*Plagiogyria pycnophylla (*Kunze*)* Mett. Syn. *Plagiogyria scandens* Mett.	Cyatheaceae	
147	*Plantago asiatica ssp.erosa (*Wall.*)* Z.Yu.Li	Plantaginaceae	Nasey jhar
148	*Plantago erosa* Wall.	Plantaginaceae	
149	*Pleione praecox (*Sm.*)* D.Don	Orachidaceae	
150	*Poa ludens* R.R.Stewart	Poaceae	
151	*Poa mairei* Hack. Syn. *Poa* ludens R.R.Stewart	Poaceae	
152	*Poa rajbhandarii* Noltie	Poaceae	
153	*Polygonatum brevistylum* Baker	Asparagaceae	
154	*Polygonatum oppositifolium (*Wall.*)* Royle	Asparagaceae	
155	*Polygonum chinense* L.	Polygonaceae	
156	*Polygonum runcinatum* Buchanan-Hamilton ex D. Don	Polygonaceae	
157	*Polystichum lentum* (D.Don) *T*Moore	P.olypodiaceae	
158	*Potentilla fruticosa* L.	Rosaceae	
159	*Potentilla lineata* Trevir.	Rosaceae	
160	*Pouzolzia zeylanica* (L.*)* Benn.	Urticaceae	
161	*Pratia montana (*Reinw. ex Blume*)* Hassk.	Campanulaceae	
162	*Prunella vulgaris* L.	Lamiaceae	
163	*Pseudognaphalium affine (*D.Don*)* Anderb.	Asteraceae	
164	*Pteridium revolutum* (Blume) Nakai	Dennstaedtiaceae	

	Syn. Pteris excelsa Blume		
165	*Pteris aspericaulis* Wall. ex J.Agardh	Pteridaceae	
166	*Pteris cretica* L.	Pteridaceae	
167	*Pteris excelsa* Gaud.	Pteridaceae	
168	*Pteris quadriaurita* Retz.	Pteridaceae	
169	*Ranunculus diffusus* DC.	Ranunculaceae	
170	*Rhynchospermum verticillatum* Reinw.	Asteraceae	
171	*Rohdea nepalensis (*Raf.*)* N.Tanaka Syn. *Tupistra aurantiaca (*Baker*)* Wall. ex Hook.f.	Asparagaceae	
172	*Rubia manjith* Roxb.ex Fleming	Rubiaceae	
173	*Rubus acuminatus* Sm.	Rosaceae	
174	*Rubus calycinus* Wall. ex D.Don	Rosaceae	Bhuin Aselu
175	*Rubus ellipticus* Sm.	Rosaceae	Aselu
176	*Rubus lineatus* Reinwardt	Rosaceae	Ghyampe Aselu
177	*Rubus rugosus* Sm.	Rosaceae	
178	*Rubus splendidissimus* H.Hara	Rosaceae	
179	*Rumex nepalensis* Spreng.	Polygonaceae	
180	*Scutellaria discolor* Wall. ex Benth.	Lamiaceae	
181	*Selliguea erythrocarpa (*Mett.*)* X.C.Zhang & L.J.He Syn. *Phymatodes erythrocarpa (*Mett.*)* Ching	Polypodiaceae	
182	*Senecio scandense* Buch.-Ham ex D.Don	Asteraceae	
183	*Senecio wightianus* DC.	Asteraceae	

184	*Stellaria media (*L.*)* Vill.	Caryophyllaceae	
185	*Stellaria sikkimensis* Hook. f.	Caryophyllaceae	
186	*Stenoseris graciliflora* (Wall. ex DC.) C.Shih	Asteraceae	
187	*Strobilanthes divaricata* (Nees) T.Anderson	Acanthaceae	
188	*Strobilanthes pentastemonoides (*Nees*)* T.Anderson	Acanthaceae	
189	*Strobilanthes pentastemonoides (*Nees*)* T.Anderson var. *dalhousieana* Kuntze	Acanthaceae	
190	*Swertia bimaculata* (Siebold & Zucc.) Hook.f. & Thomson ex C.B.Cla Karst rke	Gentianaceae	Bhale Chirowto
191	*Swertia chirayita (Roxb.)* H..	Gentinaceae	Chiroto
192	*Swertia purpurascens (*D.Don*)*	Gentianaceae	
193	*Synotis cappa (*Buch.-Ham. ex D.Don*)* *C.*Jeffrey & YL.Chen	Asteraceae	
194	*Synotis* sp	Asteraceae	
195	*Thalictrum chelidonii* DC.	Ranunculaceae	
196	*Thalictrum saniculiforme* DC.	Ranunculaceae	
197	*Thelypteris arida (*D.Don) Morton	Aspleniaceae	
198	*Trifolium pratense* L.	Fagaceae	
199	*Uraria lagopus var. neglecta* (Prain) H.Ohashi	Fabaceae	
200	*Urtica dioica* L.	Urticaceae	
201	*Valeriana hardwickei* Wall.	Rubiaceae	
202	*Viola pilosa* Blume	Violaceae	Bunufsa

203	Viola sikkimensis W.Becker	Violaceae	Ghatte

Table 5a : Summary of inventorization undertaken in Rachila Medicinal Plants Conservation Area (MPCA) in West Bengal

Tree species recorded	
# of species recorded	57
# of genera	37
# of families	25
# of threatened species	1
Shrub species recorded	
# of species recorded	75
# of genera	53
# of families	40
# of threatened species	1
Herb species and seedlings recorded	
# of species recorded	202
# of genera	130
# of families	54
# of threatened species	4

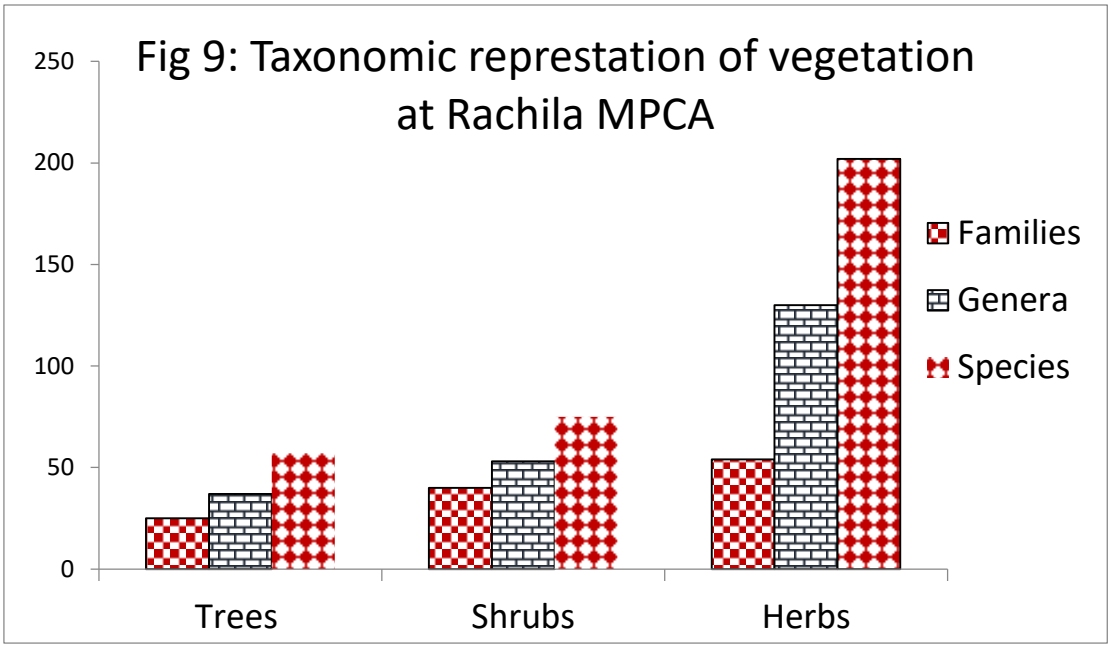


Fig 9: Taxonomic represtation of vegetation at Rachila MPCA
250
200
150
100
50
0
Trees
Shrubs
Herbs
Families
Genera
Species

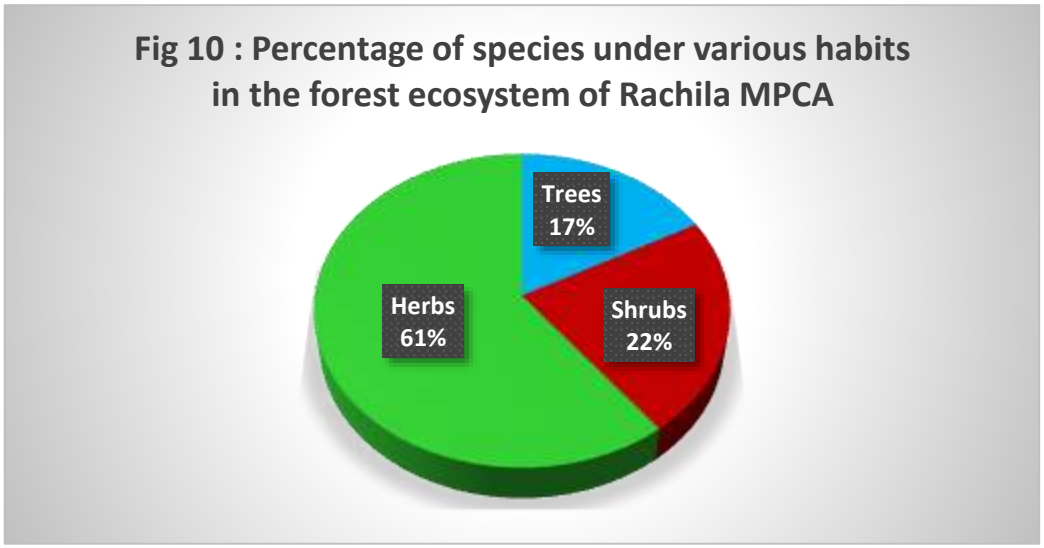


Fig 10 : Percentage of species under various habits in the forest ecosystem of Rachila MPCA
Trees 17%
Shrubs 22%
Herbs 61%

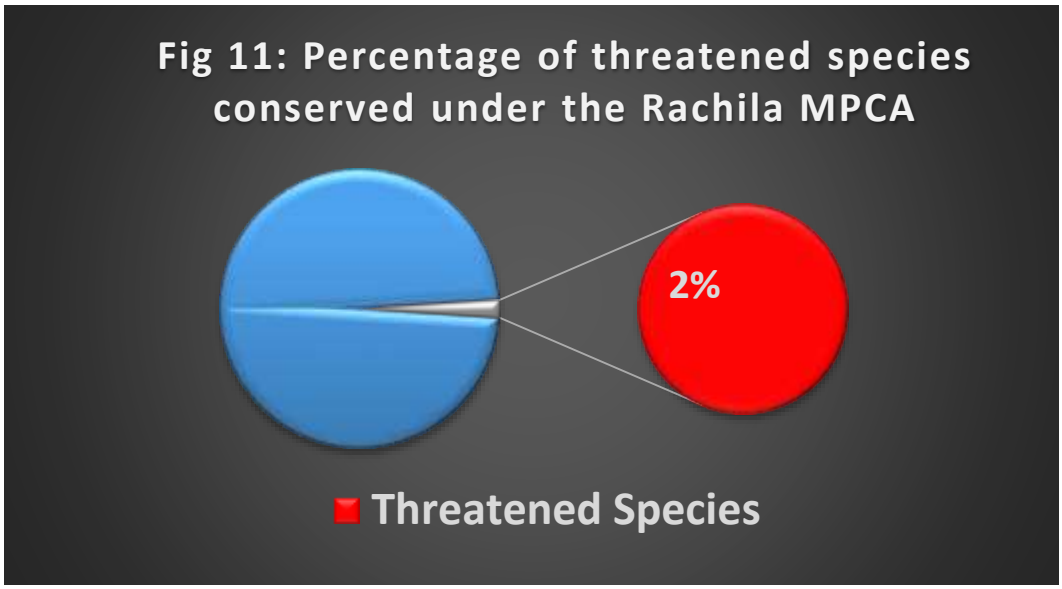


Fig 11: Percentage of threatened species conserved under the Rachila MPCA
2%
Threatened Species

Table 6 : An account of relative frequency, relative density and relative dominance of tree species recorded in the 20 x 20 m quadrats during the surveys held in October 2015

Sl. No.	Species Name	Density/ ha	Relative density	Relative frequency	Relative dominance	IVI
1	*Ilex sikkimensis* Kurz	60	19.12351	14.03509	17.27587	50.43446
2	*Quercus lamellosa* Sm.	25	7.968127	7.017544	7.5694	22.55507
3	*Quercus lineata* Blume	75	23.90438	15.78947	20.81671	60.51056
4	*Machilus edulis* King ex Hook.f.	37.5	11.95219	11.40351	10.87609	34.23179
5	*Evodia fraxinifolia*	2.5	0.796813	1.754386	0.856655	3.407853
6	*Symplocos theifolia (*Hayata*)* Hayata	36.25	11.55378	14.03509	12.25075	37.83962
7	*Taxus wallichiana* Zucc.	2.5	0.796813	1.754386	1.233583	3.784781
8	*Machilus gamblei* King.ExHook.f.	1.25	0.398406	0.877193	0.616791	1.892391
9	*Rhododendron griffithianum* Wight	1.25	0.398406	0.877193	0.616791	1.892391
10	*Magnolia campbellii* Hook.f.& Thomson	10	3.187251	5.263158	4.146208	12.59662
11	*Daphniphyllum himalayense* (Benth) Mull.Arg.	1.25	0.398406	0.877193	0.616791	1.892391
12	*Acer campbellii* Hook.f. & Thomson ex Hiern	3.75	1.195219	1.754386	1.462024	4.411629
13	*Rhododendron grande*	2.5	0.796813	0.877193	0.856655	2.53066
14	*Acer sikkimense* Miq	10	3.187251	4.385965	3.777847	11.35106
15	Quercus pachyphylla Kurz.	12.5	3.984064	6.140351	4.996009	15.12042
16	*Eurya japonica Thunb.*	1.25	0.398406	0.877193	0.616791	1.892391
17	Lyonia ovalifolia (Wallich) Drude	1.25	0.398406	0.877193	0.616791	1.892391
18	*Endospermum chinense*	3.75	1.195219	2.631579	1.850374	5.677172
19	*Prunus cerasoides* D. Don.	5	1.593625	3.508772	2.467165	7.569563
20	*Machilus gamblei* King. ExHook. f.	16.25	5.179283	3.508772	4.744548	13.4326
21	*Macaranga denticulata*	3.75	1.195219	0.877193	1.119362	3.191774
22	*Betula alnoides* Buch.-Ham. ex D.Don	1.25	0.398406	0.877193	0.616791	1.892391
	Total	**313.75**	**100**	**100**	**100**	**300**

Table 7: Results of species diversity indices (Shannon-Weiner index and Simpson index) analysed for tree species recorded in the 20 x 20 m quadrats during the surveys held in October 2015 and January 2016.

Sl. No.	Species Name	pi2	pilnpi
1	*Ilex sikkimensis* Kurz	0.036571	0.316351
2	*Quercus lamellosa* Sm.	0.006349	0.201571
3	*Quercus lineata* Blume	0.057142	0.342098
4	*Machilus edulis* King ex Hook.f.	0.014285	0.253895
5	*Evodia fraxinifolia*	6.35E-05	0.038504
6	*Symplocos theifolia* (Hayata) Hayata	0.013349	0.249349
7	*Taxus wallichiana* Zucc.	6.35E-05	0.038504
8	*Machilus gamblei* King.Ex.&Hook.f.	1.59E-05	0.022014
9	*Rhododendron griffithianum* Wight	1.59E-05	0.022014
10	*Magnolia campbellii* Hook.f Thomson	0.001016	0.109833
11	*Daphniphyllum himalayense* (Benth) Mull. Arg.	1.59E-05	0.022014
12	*Acer campbe*llii Hook.f. & Thomson ex Hiern	0.000143	0.05291
13	*Rhododendron grande* Wight	6.35E-05	0.038504
14	*Acer sikkimense* Miq	0.001016	0.109833
15	Quercus pachyphylla Kurz.	0.001587	0.128401
16	*Eurya japonica* Thunb.	1.59E-05	0.022014
17	Lyonia ovalifolia (Wallich) Drude	1.59E-05	0.022014
18	*Endospermum chinense*	0.000143	0.05291
19	*Prunus cerasoides* D. Don.	0.000254	0.065963
20	*Machilus gamblei* King. Ex Hook. f.	0.002682	0.153333
21	*Macaranga denticulate*	0.000143	0.05291
22	*Betula alnoides* Buch.-Ham. ex D.Don	1.59E-05	0.022014
	Total	0.134966	2.336954

Simpson index = 0.134966, i.e., concentration of dominance of tree species.

Shanon-weiner index = 2.336954, i.e., measure of tree species diversity

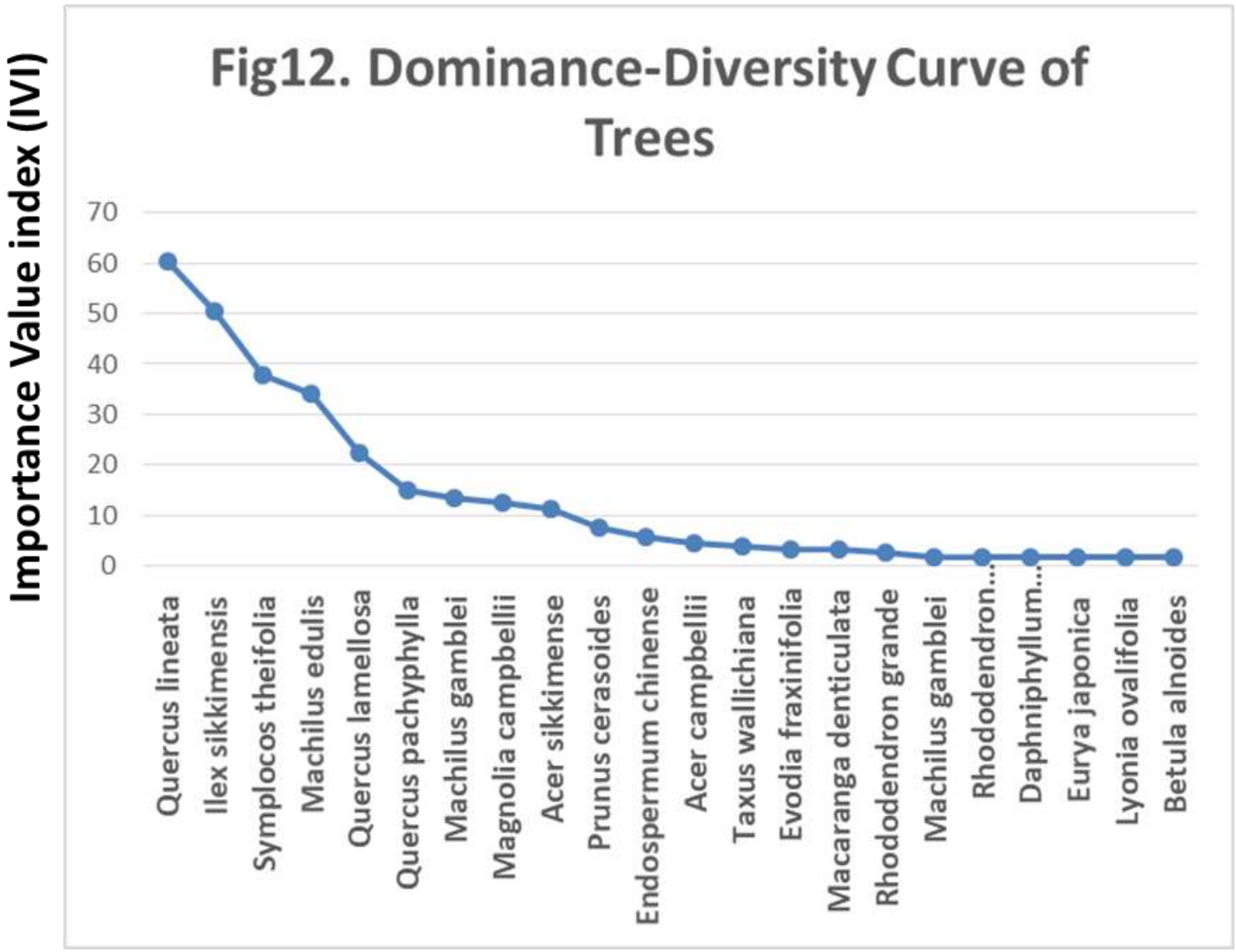


Fig12. Dominance-Diversity Curve of Trees
Importance Value index (IVI)
70
60
50
40
30
20
10
0
Quercus lineata
Ilex sikkimensis
Symplocos theifolia
Machilus edulis
Quercus lamellosa
Quercus pachyphylla
Machilus gamblei
Magnolia campbellii
Acer sikkimense
Prunus cerasoides
Endospermum chinense
Acer campbellii
Taxus wallichiana
Evodia fraxinifolia
Macaranga denticulata
Rhododendron grande
Machilus gamblei
Rhododendron...
Daphniphyllum...
Eurya japonica
Lyonia ovalifolia
Betula alnoides

Table 8: An account of relative frequency, relative density and relative area of shrub species and saplings recorded in the 5 x 5 m quadrats during the surveys held in October 2015.

Sl. No	Species Name	Density/ha	Relative density	Relative frequency	Relative abundance	IVI
1	*Aconogonom molle* (D.Don) Hara	0.04	1.927711	5.597015	2.51366	10.03839
2	*Viburnum erubescens* Wall. ex DC	0.055	2.650602	6.529851	2.962528	12.14298
3	*Berberis angulosa* Wall. ex Hook.f. & Thomson	0.0105	0.506024	1.865672	1.979507	4.351203
4	*Berberis aristata* DC.	0.02	0.963855	3.544776	1.984469	6.4931
5	*Rosa sericea* Lindl.	0.01	0.481928	2.238806	1.571038	4.291771
6	*Daphne bholua* Buch.-Ham. ex D.Don	0.1475	7.108434	3.731343	13.90368	24.74346
7	*Ilex dipyrena* Wall.	0.0205	0.987952	2.798507	2.576502	6.362961
8	*Hypericum choisyanum* Wall. ex N.Robson	0.06	2.891566	7.462687	2.827868	13.18212
9	*Yushania maling (Gamble) R.B. Majumdar*	1.38	66.50602	13.0597	37.16626	116.732
10	*Rubus calycinus* Wall. ex D.Don	0.0445	2.144578	7.835821	1.997462	11.97786
11	*Senecio scandens* Buchanan-Hamilton ex D. Don	0.055	2.650602	5.597015	3.456283	11.7039
12	*Ribes takare* D.Don Syn. *Ribes acuminatum* Wall. ex G.Don	0.0175	0.843373	3.731343	1.649589	6.224306
13	*Aristolochia griffithii* Hook.f. & Thomson ex Duch.	0.0115	0.554217	0.559701	7.226773	8.340691
14	*Rhododendron triflorum* Hook.f.	0.0215	1.036145	3.358209	2.251821	6.646174
15	*Rubus moluccanus* L.	0.03	1.445783	4.664179	2.262294	8.372256
16	*Rubus lineatus* Reinwardt	0.0225	1.084337	3.91791	2.019905	7.022153
17	*Smilax munita* S.C.Chen	0.0455	2.192771	7.835821	2.042349	12.07094
18	*Vitex altissima*	0.021	1.012048	4.664179	1.583606	7.259833
19	*Rubia cordifolia* L.	0.0225	1.084337	2.798507	2.827868	6.710713
20	*Clematis montana* Buch.-Ham.	0.015	0.722892	3.358209	1.571038	5.652138
21	*Mahonia nepalensis* DC. ex Dippel	0.0125	0.60241	2.425373	1.812736	4.840518
22	*Maesa chisia* Buch.-Ham. ex D. Don	0.0125	0.60241	2.425373	1.812736	4.840518
	Total	**2.075**	**100**	**100**	**100**	**300**

Table 9 : Results of species diversity indices (Shannon-Weiner index and Simpson index) analysed for shrub species and saplings recorded in the 5 x 5 m quadrats during the surveys held in October 2015.

Sl. No	Plant Name	pi2	pilnpi
1	*Aconogonom molle* (D.Don)Hara	0.000372	0.076122
2	*Viburnum erubescens* Wall. ex DC	0.000703	0.096227
3	*Berberis angulosa* Wall. ex Hook.f. & Thomson	2.56E-05	0.02675
4	*Berberis aristata* DC.	9.29E-05	0.044742
5	*Rosa sericea* Lindl.	2.32E-05	0.025711
6	*Daphne bholua* Buch.-Ham. ex D.Don	0.005053	0.187939
7	*Ilex dipyrena* Wall.	9.76E-05	0.045617
8	*Hypericum choisyanum* Wall. ex N.Robson	0.000836	0.102459
9	*Arundinaria racemosa* Munro	0.442305	0.271263
10	*Rubus calycinus* Wall. ex D.Don	0.00046	0.0824
11	*Senecio scandens* Buchanan-Hamilton ex D. Don	0.000703	0.096227
12	*Ribes takare* D.Don *Syn. Ribes acuminatum* Wall. ex G.Don	7.11E-05	0.040275
13	*Aristolochia griffithii* Hook.f. & Thomson ex Duch.	3.07E-05	0.028794
14	*Rhododendron triflorum* Hook.f.	0.000107	0.047348
15	*Rubus moluccanus* L.	0.000209	0.061251
16	*Rubus lineatus* Reinwardt	0.000118	0.049058
17	*Smilax munita* S.C.Chen	0.000481	0.083764
18	*Vitex altissima*	0.000102	0.046485
19	*Rubia cordifolia* L.	0.000118	0.049058
20	*Clematis montana* Buch.-Ham.	5.23E-05	0.035636
21	*Mahonia nepalensis* DC. ex Dippel	3.63E-05	0.030795
22	*Maesa chisia* Buch.-Ham. ex D. Don	3.63E-05	0.030795
	Total	**0.452032**	**1.558716**

Simpson index = **0.452032**, i.e., concentration of dominance of shrub species

Shanon-weiner index = **1.558716**, i.e., measure of shrub species diversity

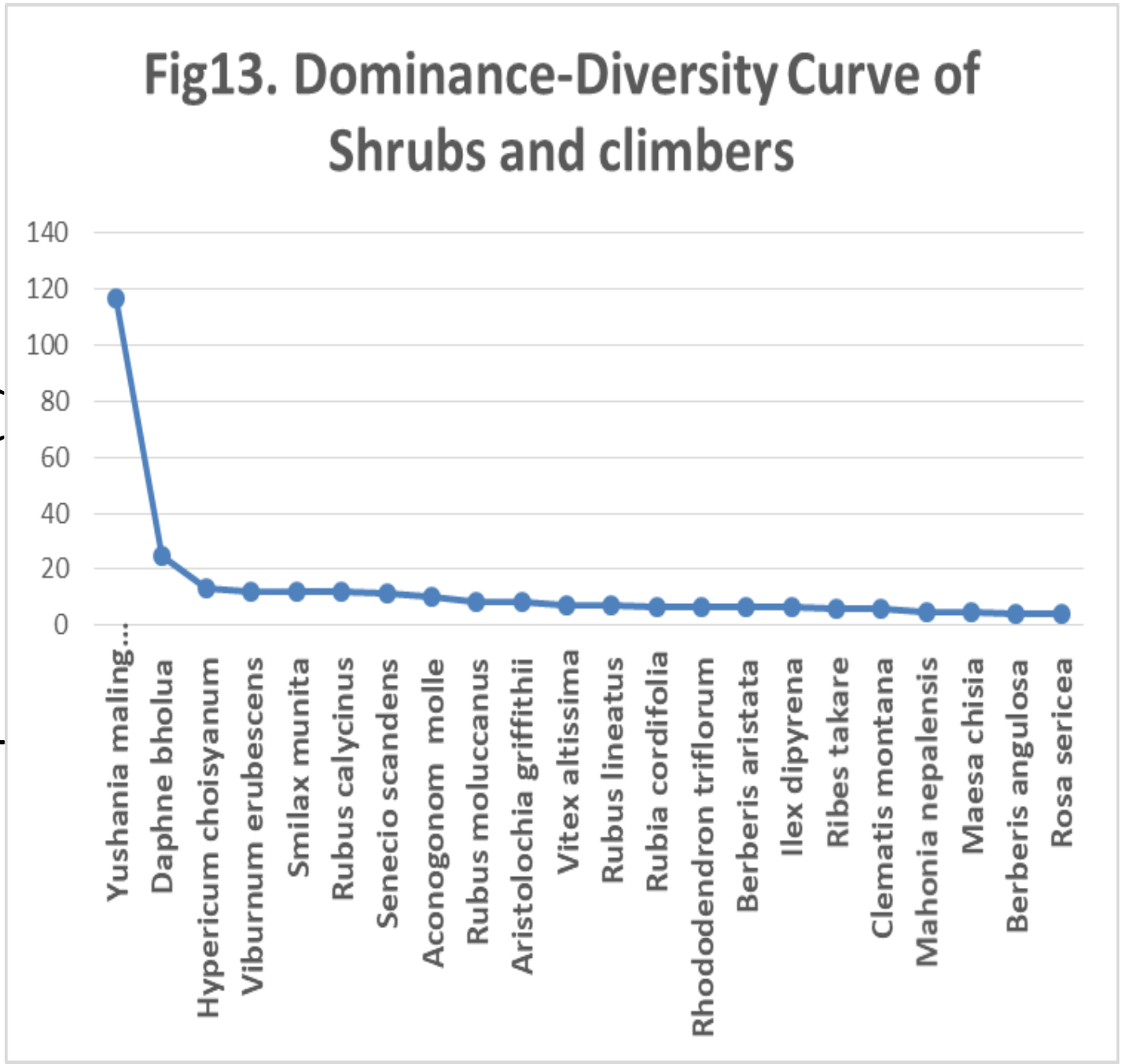


Fig13. Dominance-Diversity Curve of Shrubs and climbers
Importance Value index (IVI)
140
120
100
80
60
40
20
0
Yushania maling...
Daphne bholua
Hypericum choisyanum
Viburnum erubescens
Smilax munita
Rubus calycinus
Senecio scandens
Aconogonom molle
Rubus moluccanus
Aristolochia griffithii
Vitex altissima
Rubus lineatus
Rubia cordifolia
Rhododendron triflorum
Berberis aristata
Ilex dipyrena
Ribes takare
Clematis montana
Mahonia nepalensis
Maesa chisia
Berberis angulosa
Rosa sericea

Table 10 : An account of relative frequency, relative density and relative area of herbs/seedlings recorded in the 1 m x 1 m quadrats during the surveys held in October 2015.

Sl. No	Species Name	Density/ ha	Relative density	Relative frequency	Relative abundance	IVI
1	*Anaphalis contorta (D.Don) Hook.f.*	0.1	0.572082	0.746269	1.654042	2.972393
2	*Panax pseudoginseng Wall.*	0.33	1.887872	2.686567	1.516205	6.090644
3	*Polygonum chinense L.*	0.18	1.029748	1.044776	2.126626	4.20115
4	*Anaphalis triplinervis(Sims)Sims.ex C.B.Clarke.*	0.45	2.574371	2.686567	2.067553	7.328491
5	Polygonum runcinatum Buchanan-Hamilton ex D. Don	0.08	0.457666	0.447761	2.20539	3.110817
6	*Calanthe biloba Lindl.*	0.48	2.745995	2.985075	1.984851	7.715921
7	*CarexcruciataWahlenb.*	0.83	4.748284	1.19403	8.580344	14.52266
8	*Polygonatumbrevistylum Baker*	0.37	2.116705	0.447761	10.19993	12.76439
9	*Poa ludensR.R.Stewart*	0.52	2.974828	3.432836	1.869787	8.277451
10	*Dryopteris chrysocoma (Christ) C. Chr.*	0.03	0.171625	0.447761	0.827021	1.446407
11	*Polystichumlentum (D.Don) T.Moore*	0.77	4.405034	8.059701	1.179271	13.64401
12	*Fragaria nubicola (Lindl. ex Hook.f.) Lacaita*	0.13	0.743707	0.746269	2.150255	3.640231
13	*Habenaria dentata (Sw.) Schltr*	1.27	7.265446	1.940299	8.07936	17.2851
14	*Rohdea nepalensis (Raf.) N.Tanaka Syn. Tupistra aurantiaca (Baker) Wall. ex Hook.f.*	0.93	5.320366	1.940299	5.916382	13.17705
15	*Hemiphragmaheterophyllum Wall.*	0.68	3.89016	3.432836	2.445106	9.768102
16	*HydrocotylehimalaicaP.K.Mukh.*	0.43	2.459954	2.238806	2.370794	7.069554
17	*Hemiphragma heterophyllum*	1.15	6.578947	10	1.419514	17.99846
18	*Impatiens arguta*	0.03	0.171625	0.298507	1.240532	1.710664
19	Scutellaria discolor Wall. ex Benth.	0.15	0.858124	1.044776	1.772188	3.675088
20	*Primula denticuta Sm.*	0.2	1.144165	1.19403	2.067553	4.405747
21	*Myriactis nepelensis*	1.03	5.892449	9.402985	1.352114	16.64755
22	Pilea bracteosa Wedd.	1.07	6.121281	8.955224	1.474854	16.55136
23	*Pimpinella diversifolia*	0.13	0.743707	0.746269	2.150255	3.640231
24	*Persicaria canpanulate (Hook.f.) Rons.*	0.13	0.743707	1.19403	1.343909	3.281646
25	*Plantago erosa Wall.*	1.17	6.693364	10	1.444201	18.13756
26	*Polygonum runcinatum Buchanan-Hamilton ex D. Don*	0.13	0.743707	0.447761	3.583758	4.775226

27	*Potentilla lineata Trevir.*	1.12	6.407323	3.432836	4.027233	13.86739
28	*Ranunculus diffusus DC.*	0.23	1.315789	1.343284	2.113498	4.772571
29	*Rubia manjith Roxb.ex Fleming*	0.08	0.457666	0.447761	2.20539	3.110817
30	*Satyrium Satyrium nepalense D.Don*	0.08	0.457666	0.447761	2.20539	3.110817
31	*Selinum carvifolia (L.) L.*	0.12	0.686499	0.447761	3.308084	4.442344
32	*Smilacina racemosa (L.)*	0.33	1.887872	1.940299	2.099361	5.927532
33	*Swertia chirayita (Roxb.) H.Karst.*	0.42	2.402746	1.19403	4.341861	7.938637
34	*Viola pilosa Blume*	0.83	4.748284	4.029851	2.542324	11.32046
35	*Galium elegans Wall.*	0.7	4.004577	4.179104	2.067553	10.25123
36	*Elatostema sessile J.R.Forst. & G.Forst.*	0.8	4.576659	4.776119	2.067553	11.42033
	Total	**17.48**	**100**	**100**	**100**	**300**

Table 11 : Results of species diversity indices (Shannon-Weiner index and Simpson index) analysed for herb species and seedings recorded in the 1 m x 1 m quadrats during the surveys held in October 2015.

Sl. No	**Species Name**	**pi2**	**Pilnpi**
1	*Anaphalis contorta (D.Don) Hook.f.*	3.27E-05	0.02954
2	*Panax pseudoginseng Wall.*	0.000356	0.074943
3	*Polygonum chinense L.*	0.000106	0.04712
4	*Anaphalis triplinervis(Sims)Sims.ex C.B.Clarke.*	0.000663	0.094211
5	Polygonum runcinatum Buchanan-Hamilton ex D. Don	2.09E-05	0.024653
6	*Calanthe biloba Lindl.*	0.000754	0.098719
7	*CarexcruciataWahlenb.*	0.002255	0.144699
8	*Polygonatumbrevistylum Baker*	0.000448	0.081606
9	*Poa ludensR.R.Stewart*	0.000885	0.104565
10	*Dryopteris chrysocoma (Christ) C. Chr.*	2.95E-06	0.010928
11	*Polystichumlentum (D.Don) T.Moore*	0.00194	0.137544
12	*Fragaria nubicola (Lindl. ex Hook.f.) Lacaita*	5.53E-05	0.036451
13	*Habenaria dentata (Sw.) Schltr*	0.005279	0.190503
14	*Rohdea nepalensis (Raf.) N.Tanaka Syn. Tupistra aurantiaca (Baker) Wall. ex Hook.f.*	0.002831	0.15608

15	*Hemiphragmaheterophyllum Wall.*	0.001513	0.126303
16	*HydrocotylehimalaicaP.K.Mukh.*	0.000605	0.091142
17	*Hemiphragma heterophyllum*	0.004328	0.179033
18	*Impatiens arguta*	2.95E-06	0.010928
19	Scutellaria discolor Wall. ex Benth.	7.36E-05	0.040831
20	*Primula denticuta Sm.*	0.000131	0.05115
21	*Myriactis nepelensis*	0.003472	0.166845
22	Pilea bracteosa Wedd.	0.003747	0.170992
23	*Pimpinella diversifolia*	5.53E-05	0.036451
24	*Persicaria canpanulate (Hook.f.) Rons.*	5.53E-05	0.036451
25	*Plantago erosa Wall.*	0.00448	0.180992
26	*Polygonum runcinatum Buchanan-Hamilton ex D. Don*	5.53E-05	0.036451
27	*Potentilla lineata Trevir.*	0.004105	0.176056
28	*Ranunculus diffusus DC.*	0.000173	0.056983
29	*Rubia manjith Roxb.ex Fleming*	2.09E-05	0.024653
30	*Satyrium Satyrium nepalense D.Don*	2.09E-05	0.024653
31	*Selinum carvifolia (L.) L.*	4.71E-05	0.034197
32	*Smilacina racemosa (L.)*	0.000356	0.074943
33	*Swertia chirayita (Roxb.) H.Karst.*	0.000577	0.089588
34	*Viola pilosa Blume*	0.002255	0.144699
35	*Galium elegans Wall.*	0.001604	0.128857
36	*Elatostema sessile J.R.Forst. & G.Forst.*	0.002095	0.141153
	Total	**0.045402**	**3.254912**

Simpson index = **0.045402** i.e., concentration of dominance of herbs and seedlings

Shanon-weiner index = **3.254912** i.e., measure of herb species and seedlings diversity

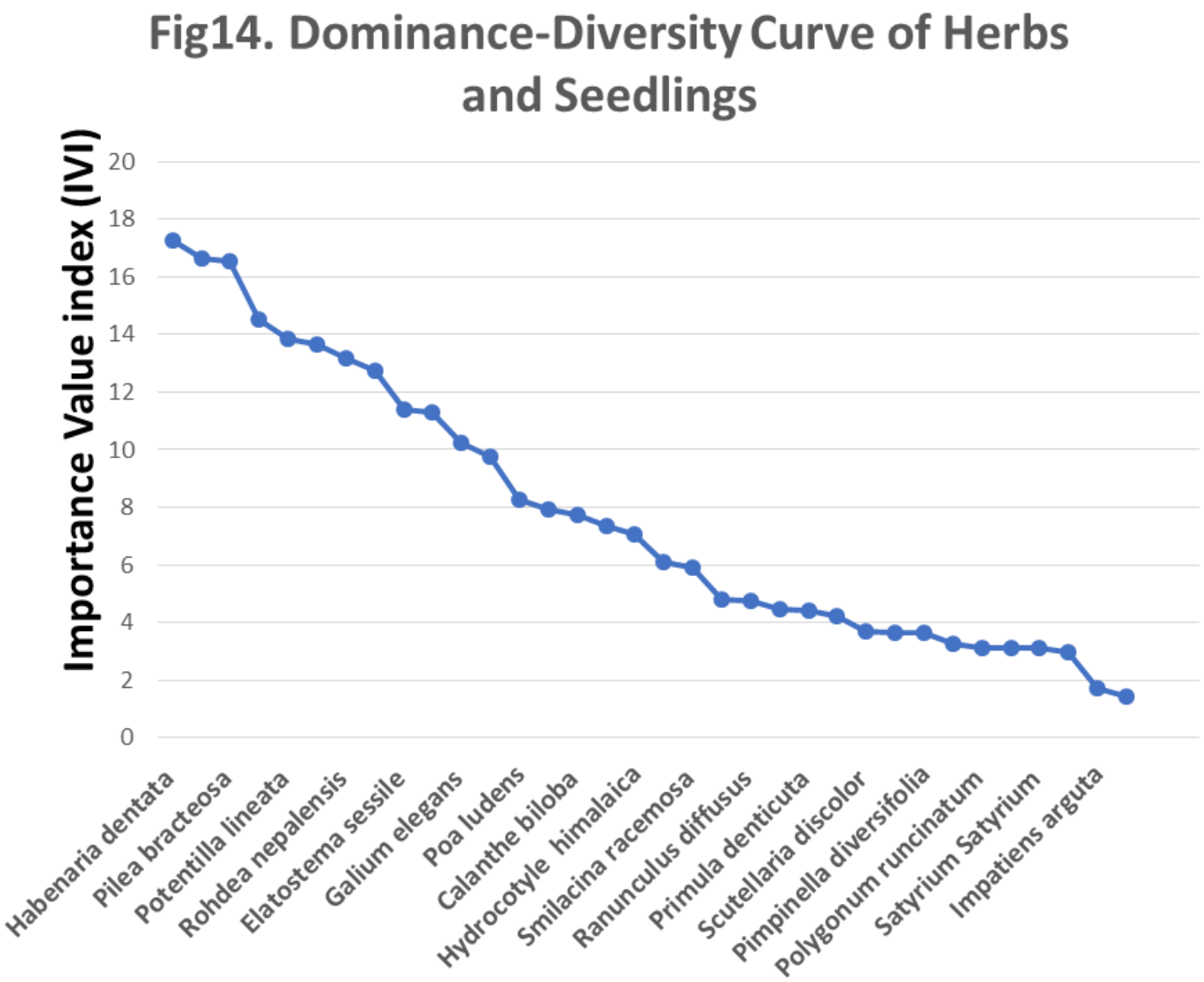


Fig14. Dominance-Diversity Curve of Herbs and Seedlings
Importance Value index (IVI)
20
18
16
14
12
10
8
6
4
2
0
Habenaria dentata
Pilea bracteosa
Potentilla lineata
Rohdea nepalensis
Elatostema sessile
Galium elegans
Poa ludens
Calanthe biloba
Hydrocotyle himalaica
Smilacina racemosa
Ranunculus diffusus
Primula denticuta
Scutellaria discolor
Pimpinella diversifolia
Polygonum runcinatum
Satyrium Satyrium
Impatiens arguta

Table 12 : An account of relative frequency, relative density and relative dominance of tree species recorded in the 20 x 20 m quadrats during the surveys held in January 2016

Sl. No.	Species Name	Density/ ha	Relative density	Relative frequency	Relative dominance	IVI
1	*Ilex sikkimensis* Kurz	60	19.12351	14.03509	17.27587	50.43446
2	*Quercus lamellosa* Sm.	25	7.968127	7.017544	7.5694	22.55507
3	*Quercus lineata* Blume	75	23.90438	15.78947	20.81671	60.51056
4	*Machilus edulis* King ex Hook.f.	37.5	11.95219	11.40351	10.87609	34.23179
5	*Evodia fraxinifolia*	2.5	0.796813	1.754386	0.856655	3.407853
6	*Symplocos theifolia* (Hayata) Hayata	36.25	11.55378	14.03509	12.25075	37.83962
7	*Taxus wallichiana* Zucc.	2.5	0.796813	1.754386	1.233583	3.784781
8	*Machilus gamblei* King. Ex Hook.f.	1.25	0.398406	0.877193	0.616791	1.892391
9	*Rhododendron griffithianum* Wight	1.25	0.398406	0.877193	0.616791	1.892391
10	*Magnolia campbellii* Hook.f.& Thomson	10	3.187251	5.263158	4.146208	12.59662
11	*Daphniphyllum himalayense* (Benth) Mull. Arg.	1.25	0.398406	0.877193	0.616791	1.892391
12	*Acer campbellii* Hook.f. & Thomson ex Hiern	3.75	1.195219	1.754386	1.462024	4.411629
13	*Rhododendron grande*	2.5	0.796813	0.877193	0.856655	2.53066
14	*Aster sikkimensis* Hook.f. & Thomson	10	3.187251	4.385965	3.777847	11.35106
15	Quercus pachyphylla Kurz.	12.5	3.984064	6.140351	4.996009	15.12042
16	*Eurya japonica* Thunb.	1.25	0.398406	0.877193	0.616791	1.892391
	Lyonia ovalifolia (Wallich) Drude	1.25	0.398406	0.877193	0.616791	1.892391
	Endospermum chinense	3.75	1.195219	2.631579	1.850374	5.677172
	Prunus cerasoides D. Don.	5	1.593625	3.508772	2.467165	7.569563
	Machilus gamblei King. ExHook. f.	16.25	5.179283	3.508772	4.744548	13.4326
	Macaranga denticulata	3.75	1.195219	0.877193	1.119362	3.191774
	Betula alnoides B.Don.	1.25	0.398406	0.877193	0.616791	1.892391
	Total	313.75	100	100	100	300

Table 13 : Results of species diversity indices (Shannon-Weiner index and Simpson index) analysed for tree species recorded in the 20 x 20 m quadrats during the surveys held in January 2016

Sl. No.	Species Name	pi2	pilnpi
1	*Ilex sikkimensis* Kurz	0.036571	0.316351
2	*Quercus lamellosa* Sm.	0.006349	0.201571
3	*Quercus lineata* Blume	0.057142	0.342098
4	*Machilus edulis* King ex Hook.f.	0.014285	0.253895
5	*Evodia fraxinifolia*	6.35E-05	0.038504
6	*Symplocos theifolia* (Hayata) Hayata	0.013349	0.249349
7	*Taxus wallichiana* Zucc.	6.35E-05	0.038504
8	*Machilus gamblei* King.ExHook.f.	1.59E-05	0.022014
9	*Rhododendron griffithianum* Wight	1.59E-05	0.022014
10	*Magnolia campbellii* Hook.f.& Thomson	0.001016	0.109833
11	*Daphniphyllum himalayense* (Benth) Mull. Arg.	1.59E-05	0.022014
12	*Acer campbellii* Hook.f. & Thomson ex Hiern	0.000143	0.05291
13	*Rhododendron grande*	6.35E-05	0.038504
14	*Aster sikkimensis* Hook.f. & Thomson	0.001016	0.109833
15	Quercus pachyphylla Kurz.	0.001587	0.128401
16	*Eurya japonica* Thunb.	1.59E-05	0.022014
17	Lyonia ovalifolia (Wallich) Drude	1.59E-05	0.022014
15	*Endospermum chinense*	0.000143	0.05291
19	*Prunus cerasoides* D. Don.	0.000254	0.065963
20	*Machilus gamblei* King. Ex Hook. f.	0.002682	0.153333
21	*Macaranga denticulata*	0.000143	0.05291
22	*Betula alnoides*	1.59E-05	0.022014
	Total	0.134966	2.336954

Simpson index = 0.134966, i.e., concentration of dominance of tree species.

Shanon-weiner index = 2.336954 i.e., measure of tree species diversity

Table 14 : An account of relative frequency, relative density and relative area of shrub species and saplings recorded in the 5 x 5 m quadrats during the surveys held in January 2016.

Sl. No	Species Name	Density/ha	Relative density	Relative frequency	Relative dominance	IVI
1	*Aconogonom molle* (D.Don)Hara	0.04	1.927711	5.597015	2.51366	10.03839
2	*Viburnum erubescens* Wall. ex DC	0.055	2.650602	6.529851	2.962528	12.14298
3	*Berberis angulosa* Wall. ex Hook.f. & Thomson	0.0105	0.506024	1.865672	1.979507	4.351203
4	*Berberis aristata* DC.	0.02	0.963855	3.544776	1.984469	6.4931
5	*Rosa sericea* Lindl.	0.01	0.481928	2.238806	1.571038	4.291771
6	*Daphne bholua Buch.-* Ham. ex D.Don	0.1475	7.108434	3.731343	13.90368	24.74346
7	*Ilex dipyrena* Wall.	0.0205	0.987952	2.798507	2.576502	6.362961
8	*Hypericum choisyanum* Wall. ex N.Robson	0.06	2.891566	7.462687	2.827868	13.18212
9	*Arundinaria racemosa* Munro	1.38	66.50602	13.0597	37.16626	116.732
10	*Rubus calycinus* Wall. ex D.Don	0.0445	2.144578	7.835821	1.997462	11.97786
11	*Senecio scandens Buchanan-Hamilton ex D. Don*	0.055	2.650602	5.597015	3.456283	11.7039
12	*Ribes takare D.Don Syn. Ribes acuminatum Wall. ex G.Don*	0.0175	0.843373	3.731343	1.649589	6.224306
13	*Aristolochia griffithii Hook.f. & Thomson ex Duch.*	0.0115	0.554217	0.559701	7.226773	8.340691
14	*Rhododendron triflorum Hook.f.*	0.0215	1.036145	3.358209	2.251821	6.646174
15	*Rubus moluccanus L.*	0.03	1.445783	4.664179	2.262294	8.372256
16	*Rubus lineatus Reinwardt*	0.0225	1.084337	3.91791	2.019905	7.022153
17	*Smilax munita S.C.Chen*	0.0455	2.192771	7.835821	2.042349	12.07094
18	*Vitex altissima*	0.021	1.012048	4.664179	1.583606	7.259833

19	*Rubia cordifolia L.*	0.0225	1.084337	2.798507	2.827868	6.710713
20	*Clematis montana Buch.-Ham.*	0.015	0.722892	3.358209	1.571038	5.652138
21	*Mahonia nepalensis DC. ex Dippel*	0.0125	0.60241	2.425373	1.812736	4.840518
22	*Maseia chisa*	0.0125	0.60241	2.425373	1.812736	4.840518
23		2.075	100	100	99.99997	300

Table 15 : Results of species diversity indices (Shannon-Weiner index and Simpson index) analysed for shrub species and saplings recorded in the 5 x 5 m quadrats during the surveys held in January 2016.

Sl. No	Species Name	pi2	Pilnpi
1	*Aconogonom molle* (D.Don)Hara	0.000372	0.076122
2	*Viburnum erubescens* Wall. ex DC	0.000703	0.096227
3	*Berberis angulosa* Wall. ex Hook.f. & Thomson	2.56E-05	0.02675
4	*Berberis aristata* DC.	9.29E-05	0.044742
5	*Rosa sericea* Lindl.	2.32E-05	0.025711
6	*Daphne bholua* Buch.-Ham. ex D.Don	0.005053	0.187939
7	*Ilex dipyrena* Wall.	9.76E-05	0.045617
8	*Hypericum choisyanum* Wall. ex N. Robson	0.000836	0.102459
9	*Arundinaria racemosa* Munro	0.442305	0.271263
10	*Rubus calycinus* Wall. ex D.Don	0.00046	0.0824
11	*Senecio scandens* Buchanan-Hamilton ex D. Don	0.000703	0.096227
12	*Ribes takare* D. Don Syn. *Ribes acuminatum* Wall. ex G.Don	7.11E-05	0.040275
13	*Aristolochia griffithii* Hook.f. & Thomson ex Duch	3.07E-05	0.028794
14	*Rhododendron triflorum* Hook.f.	0.000107	0.047348
15	*Rubus moluccanus* L.	0.000209	0.061251
16	*Rubus lineatus* Reinwardt	0.000118	0.049058
17	*Smilax munita S.C.*Chen	0.000481	0.083764
18	*Vitex altissima*	0.000102	0.046485

19	*Rubia cordifolia* L.	0.000118	0.049058
20	*Clematis montana* Buch.-Ham.	5.23E-05	0.035636
21	*Mahonia nepalensis* DC. ex Dippel	3.63E-05	0.030795
22	*Maseia chisa*	3.63E-05	0.030795
	Total	0.452032	1.558716

Simpson index = 0.452032 i.e., concentration of dominance of shrub species.

Shanon-weiner index = 1.558716 , i.e., measure of shrub species diversity

Table 16 : An account of relative frequency, relative density and relative area of herb species and seedlings recorded in the 1 m x 1 m quadrats during the surveys held in January 2016.

Sl. No	Plant Name	Density/ ha	Relative density	Relative frequency	Relative dominance	IVI
1	*Anaphalis contorta* (D.Don) Hook.f.	10	0.628931	0.770416	1.79372	3.193067
2	*Polygonum chinense* L.	18	1.132075	1.078582	2.306212	4.51687
3	*Anaphalis triplinervis* (Sims) Sims.ex C.B.Clarke.	30	1.886792	2.773498	1.494767	6.155057
4	Polygonum runcinatum Buchanan-Hamilton ex D. Don	8	0.503145	0.46225	2.391627	3.357021
5	*Calanthe biloba* Lindl.	20	1.257862	3.081664	0.89686	5.236386
6	*Carex cruciate* Wahlenb	83	5.220126	1.232666	9.304924	15.75772
7	*Polygonatum brevistylum* Baker	37	2.327044	0.46225	11.06128	13.85057
8	*Poa ludens* R.R.Stewart	52	3.27044	3.543914	2.027684	8.842038
9	*Dryopteris chrysocoma* (Christ) C. Chr.	3	0.188679	0.46225	0.89686	1.547789
10	*Polystichum lentum* (D.Don) T.Moore	77	4.842767	8.320493	1.278856	14.44212
11	*Fragaria nubicola* (Lindl. ex Hook.f.) Lacaita	13	0.81761	0.770416	2.331836	3.919863
12	*Habenaria dentata (*Sw.*)* Schltr	127	7.987421	2.003082	8.761634	18.75214

13	*Tupistra aurenticum*	93	5.849057	2.003082	6.416	14.26814
14	*Hemiphragmaheterophyllum* Wall.	68	4.27673	3.543914	2.651587	10.47223
15	*Hydrocotyle himalaica* P.K.Mukh Hydrocotyl	43	2.704403	2.311248	2.570999	7.58665
16	*Hymenophyllum* sp	115	7.232704	10.32357	1.539387	19.09567
17	*Impatiens arguta*	3	0.188679	0.308166	1.34529	1.842136
18	*Scutellaria discolor* Wall. *ex* Benth.	15	0.943396	1.078582	1.921843	3.943822
19	*Primula denticuta* Sm.	0	1.257862	1.232666	2.24215	4.732678
20	*Myriactis nepelensis*	60	3.773585	9.707242	0.854153	14.33498
21	Pilea bracteosa Wedd.	107	6.72956	9.244992	1.599401	17.57395
22	*Pimpi Plantago nella* diversifolia	13	0.81761	0.770416	2.331836	3.919863
23	*Persicaria canpanulate (*Hook.f.*)* Rons.	13	0.81761	1.232666	1.457398	3.507673
24	*Plantago erosa* Wall.	117	7.358491	10.32357	1.566159	19.24822
25	*Polygonum runcinatum* Buchanan-Hamilton ex D. Don	13	0.81761	0.46225	3.886394	5.166254
26	*Potentilla lineata* Trevir.	112	7.044025	3.543914	4.367319	14.95526
27	*Ranunculus diffusus* DC.	23	1.446541	1.386749	2.291976	5.125266
28	*Rubia manjith* Roxb.ex Fleming	8	0.503145	0.46225	2.391627	3.357021
29	*Selinum carvifolia (*L.*)* L.	12	0.754717	0.46225	3.587441	4.804407
30	*Smilacina racemosa* (L.)	33	2.075472	2.003082	2.276645	6.355198
31	*Swertia chirayita (*Roxb.*)* H.Karst	31	1.949686	1.232666	3.475333	6.657684
32	*Viola pilosa* Blume	83	5.220126	4.160247	2.757015	12.13739
33	*Galium elegans* Wall.	0	4.402516	4.31433	2.24215	10.959
34	*Elatostema sessile* J.R.Forst. & G.Forst.	60	3.773585	4.930663	1.681613	10.38586
	Total	**1500**	**100**	**100**	**100**	**300**

Table 17 : Results of species diversity indices (Shannon-Weiner index and Simpson index) analysed for herb species and seedlings recorded in the 1 m x 1 m quadrats during the surveys held in January 2016.

Sl. No	Plant Name	pi2	Pilnpi
1	*Anaphalis contorta (*D.Don*)* Hook.f.	3.96E-05	0.03188
2	*Polygonum chinense* L.	0.000128	0.05073
3	*Anaphalis triplinervis(*Sims*)*Sims.ex C.B.Clarke.	0.000356	0.074911
4	Polygonum runcinatum Buchanan-Hamilton ex D. Don	2.53E-05	0.026627
5	*Calanthe biloba Lindl.*	0.000158	0.055041
6	*Carex cruciate Wahlenb*	0.002725	0.154132
7	*Polygonatum brevistylum Baker*	0.000542	0.08751
8	*Poa ludens R.R.Stewart*	0.00107	0.111857
9	*Dryopteris chrysocoma (Christ) C. Chr.*	3.56E-06	0.011836
10	*Polystichum lentum (D.Don) T.Moore*	0.002345	0.146624
11	*Fragaria nubicola (Lindl. ex Hook.f.) Lacaita*	6.68E-05	0.039299
12	*Habenaria dentata (Sw.) Schltr*	0.00638	0.201866
13	*Tupistra aurenticum*	0.003421	0.166048
14	*Hemiphragmaheterophyllum Wall.*	0.001829	0.134802
15	*Hydrocotyle himalaica P.K.Mukh Hydrocotyl*	0.000731	0.097637
16	*Hymenophyllum sp*	0.005231	0.189971
17	*Impatiens arguta*	3.56E-06	0.011836
18	Scutellaria discolor Wall. ex Benth.	8.9E-05	0.043995
19	*Primula denticuta Sm.*	0.000158	0.055041
20	*Myriactis nepelensis*	0.001424	0.123666
21	Pilea bracteosa Wedd.	0.004529	0.181608
22	*Pimpinella diversifolia*	6.68E-05	0.039299
23	*Persicaria canpanulate (Hook.f.) Rons.*	6.68E-05	0.039299
24	*Plantago erosa Wall.*	0.005415	0.192006
25	*Polygonum runcinatum Buchanan-Hamilton ex D. Don*	6.68E-05	0.039299

26	*Potentilla lineata Trevir.*	0.004962	0.186877
27	*Ranunculus diffusus DC.*	0.000209	0.061275
28	*Rubia manjith Roxb.ex Fleming*	2.53E-05	0.026627
29	*Selinum carvifolia* (L.) L.	5.7E-05	0.03688
30	*Smilacina racemosa* (L.)	0.000431	0.080424
31	*Swertia chirayita (*Roxb.*)* H.Karst	0.00038	0.076769
32	*Viola pilosa* Blume	0.002725	0.154132
33	*Galium elegans* Wall.	0.001938	0.13749
34	*Elatostema sessile* J.R.Forst. & G.Forst.	0.001424	0.123666
	Total	0.049022	3.190958

Simpson index = 0.045402 i.e., concentration of dominance of herb species and seedlings

Shanon-weiner index = 3.254912, i.e., measure of herb species and seedlings diversity

Table 18 : Details of parameters analysed in the data such as dominance, species richness and diversity indices.

Layers	**Conc. of Dominance (D)**	**SDI (1-D)**	**RSI (1/D)**	**Mehnick index**	**Species diversity**
October 2015					
Trees	0.134966	0.865034	7.409273	1.388628	2.336954
Shrub & Climber	0.452032	0.547968	2.212234	0.341506	1.558716
Herbs	0.045402	0.954598	22.02546	0.861057	3.254912
January 2016					
Trees	0.134966	0.865034	7.409273	1.388628	2.336954
Shrub & Climber	0.452032	0.547968	2.212234	0.341506	1.558716
Herbs	0.045402	0.950978	20.399	0.852669	3.190958

Threatened plants of the MPCA

Table 19 : An account of plant species that are categorised as 'Threatened plants' and conservation conceren species recorded in Rachela MPCA.

Name of the species	Family	Habitat	Local Names	Status
Taxus wallichiana Zucc.	Taxaceae	1500-2800 m hill high montane forests	Dhyangre Salla	CR
Berberis aristata DC.	Berberidaceae	1500-2800 m hill high montane forests	Chutro	VU
Panax pseudoginseng Wall.	Araliaceae	1900-2800 msl	Salanay	CR
*Swertia chirayita (*Roxb.*)* H.Karst.	Gentianaceae	1500-2800 msl	Chiroto	CR
Valeriana hardwickei Wall.	Rubiaceae	1500-3400 msl	Bhale Jatamanshi	EN
Paris polyphylla Sm.	Melanthiaceae	1500-2800 msl	Satuwa	EN

Table 20 :Medicinal uses of important plants recorded in Rachela MPCA

Name of the species	Family	Parts Used	Local Name	Uses
Zanthoxylum armatum DC.Bokey	Rutaceae	Fruits	Timbur	To relieve stomach pain, toothache, fever
Zanthoxylum oxyphyllum Edgew.	Rutaceae	Stem barks, Fruits	Lahare Timbur	Skin diseases, rheumatism, varicose ulcers and varicose veins, leg pains
Rhododendron grande Wight	Ericaceae	Flower,	Gorus, Patle Korlinga	Gouty and rheumatic condition
Rubia manjith	Rubiaceae	Roots and stem bark	Manjith	Blood purifier, urinary disorder
Valeriana *hardwickei* Wall.	Rubiaceae	Roots	Bhale Jatamanshi	Rheumatism, joint pains, cardiac diseases, blood disorders, herpes and leprosy

Thalictrum spp.	Ranunculaceae	Roots	Chitrey	Detoxication, Swelling, dyspepsia,jaundice, skin disease
Taxus wallichiana Zucc.	Taxaceae	Leaves and barks	Dhyangre Salla	Anticancer, locally used in cold, cough, fever and pain
Berberis aristata DC.	Berberidaceae	Root, stem and leaves	Chutro	To treat eye disorders, skin disorders with itching, diabetes, urinary tract diseases; beneficial for patients of menorrhagia and leucorrhoea
Panax pseudoginseng Wall.	Araliaceae	Rootstock	Salanay	Diabetes, cancer, and heart disease; used as revitalizer
*Swertia chirayita (*Roxb.*)* H.Karst.	Gentianaceae	Whole plant	Chiroto	bitter tonic, carminative, anti-helmintic

CHAPTER 4: CONCLUSION AND RECOMMENDATIONS

Conclusion

One of the most critical issues of global, local and national agenda is the need to preserve biodiversity for future generations (Myers et al. 2000). Concurrently there is also a necessity to understand the biodiversity-associated indigenous knowledge base for sustainable resource management practices (Saha and Ved. 2014). The medicinal plant resources are getting depleted at an alarming rate. Around 90% of medicinal plants that are consumed domestically and exported are collected from the wild. Only 70 out of around 700 species in the trade are obtained purely from cultivated sources. The ever-increasing demand of herbal products has put the valuable plant resources under great stress and brought many medicinal plants at the verge of extinction (Goraya and Ved. 2017). In this regard the establishment of MPCAs and regular botanical survey at frequent intervals would help conserving medicinal plants in general and threatened plant species in specific (Ved et al., 2003).

In addition to this, other threats to the medicinal plants are deforestation, destructive harvesting because of the use of plant parts like root, stem, bark, wood and whole plant in case of herb, extensive industrialization, forest fire and climate change. Further, unsustainable collection and high voulume trade has brought many species on the verge of extinction (CITES .2017; Menon et al., 1994) It is estimated that in India about 246 plants species are threatened, a bulk of which are medicinal plants (IUCN 2011; Pollock et al., 2003). Of these, seven species are already extinct and 44 are critically endangered (IUCN 2011). Thus, there is an urgent need to conserve the wild populations of medicinal plant diversity (Shankar and Rawat. .2013).

This pioneering work of in-situ conservation programs initiated by the State Forest Departments across India with the support of the Foundation for Revitalisation of Local Health Traditions (FRLHT) through establishing the Medicinal Plants Conservation Areas (MPCAs) resulted in numerous significant conservation outcomes (Ved et al., 2003). Noteworthy among these is a notable shift in the conservation priorities of the forestry sector. After witnessing the novel conservation activities in the MPCAs, the Forest managers all over the country admit the need for broadening the conservation priorities in the forestry sector so as to cover the hitherto ignored medicinal plants. Thus, the MPCA program caused a significant change especially in the area of in-situ conservation principles in the entire forestry sector in the country (Saha et.al. 2022). The in-situ conservation program is focused on identifying habitats, which contain viable and breeding populations of prioritised taxa. Through this MPCA program, medicinal plant taxa that are in high volume trade and belong to endemic and threatened category could

be prioritised and conserved in-situ in their natural habitats (.Saha and Ved . 2014). Another interesting aspect of this program is that state forest departments implement this program in collaboration with (1) research institutes, who are capable of undertaking further research works including population studies, threat assessment, genetic and microbiome studies, etc., (2) local community institutions to develop alternate livelihood options for reducing the forest dependence of community members who dwell neighbouring MPCA areas.

Having realised the importance of conserving medicinal plants and traditional knowledge associated with them, the State Forest Department of West Bengal has been a pioneer in introducing a number of conservation activities especially making sure of conservation concern medicinal plants are well protected within their existing network of Protected Areas (PAs). As part of their conservation action initiatives, under the CF-II National Program on Promoting Conservation of Medicinal Plants and Traditional Knowledge for Enhancing Health and Livelihood Security, in the year between 2007 and 2009, the department established a network of seven Medicinal Plants Conservation Areas (MPCAs) across the state with the support of the FRLHT, Bengaluru. The selection of MPCA sites was primarily on the basis of inputs from the Conservation Assessment and Management Prioritisation (CAMP) workshop, which is an exercise to identify important medicinal plants areas for in-situ conservation of medicinal plants. Just after the establishment of MPCAs, the research institutions were involved to undertake plant taxonomical studies to develop a checklist of medicinal plants for each MPCA.

In this project, such floristic inventory with geo-referencing and diversity studies are expected to provide a greater understanding of species composition and the diversity status of forests, which also offer vital information for forest conservation. Further, geo-spatial tools would be useful in monitoring the land use and land cover changes in and around the MPCAs. MPCA areas, while ensuring the conservation of the medicinal plants, as part of contiguous forest landscapes, play a greater role in terms of ensuring overall biodiversity conservation and associated ecosystem services such as pollinator availability, recharging ground water, carbon sequestration, check soil erosion, etc.

The overarching outcome of this project is very promising in a way that the Rachila MPCA is proving to be a gene pool of medicinal plants of the state especially 6 number of conservation concern species with good and viable population.. MPCAs representing different forest ecosystems and landscapes of the state are found to be rich in medicinal plant diversity in terms of number of species, number of threatened species, etc. Through this project, the checklist of

plant species was updated and there are still more potential medicinal plants rich forest sites, which could be established as MPCAs.

The populations of these threatened plants were enumerated during the quadrat study and found to have good representation in all plant stages starting from adult (>30 cm gbh), sapling (≤30 cm gbh) and seedling stages (if they are trees and lianas), shrubs and herbs. It is proven that MPCAs are one such network of sites acting as refugia or natural repository of state medicinal plants being conserved in-situ. The addition of more potential forest areas would ensure the maintenance of viable population of all conservation concern medicinal plants within the MPCA network.

The current population survey and subsequently the analysis of the data has witness few important facts of the community structure in the MPCA area. Different ecological communities can be pretty diverse in terms of the types and numbers of species they cover. For example, the biotic communitiesin the polar region include just a few species, while some tropical rainforest communities have huge numbers of species packed into each cubic meter. One way to define this variance is to put forth the fact that the communities have different structures. Community structure is essentially the composition of a community, including the number of species in that community and their relative numbers. It can also be understood more broadly by attention towords all kinds of interaction between these different species.

The Phalut MPCA area, although demonstrates the dominance of species such as *Quercus pachyphylla, Tsuga dumosa, Quercus lineata, Symplocos theifolia, Taxus wallichiana, Rhododendron grande , Machilus edulis, Acer campbellii, Ilex sikkimensis, Betula alnoides* etc (Fig. 12), nevertheless the composition of the forest shows good diversity. The resource allocation in the community is reasonably homogenous in nature (Fig. 12, 13 &14). This resource allocation strategy of the community has allowed more species to establish and thrive enriching the overall diversity in the forest especially in the MPCA area

Local community people settled in the surroundings of MPCA are reported to have good knowledge and understanding of medicinal plants and their uses. Besides, they have the practice of using them for their health care needs on a regular basis. Such health traditions have to be recognised, preserved from being lost, while they have to be mainstreamed for the benefit of community members. During the questionnaire survey conducted among local community members, it was understood that there has been a regular practice of fuelwood extraction, medicinal plants collection, fodder collection, wood collection for charcoal making, etc. When

asked about the chances of implementing sustainable concepts for medicinal plants conservation, respondents informed about various opportunities available locally including (a) the cultivation of medicinal plants for commercial sale; (b) homestay business; (c) eco-tourism and the use of local craft skill; (d) improved agriculture with proper irrigation system as water scarcity is one of the emerging issues in the villages around MPCA areas; (e) women empowerment through involving them in decision making. It is also understood that there has been less awareness among local community members, irrespective of the distance of their settlements from MPCA, about the importance of MPCA in the conservation of medicinal plants. There has been no orientation given to them about the role they can play in the sustainable management of forest resources especially medicinal plants. The involvement of local community members in the resource management has to be made necessary.

The healthy status of MPCA is the proof of effective management of West Bengal Forest Department especially the role played by the frontline officers in making sure of protection of these forest patches. Though they are aware of the MPCA physically, however the importance and necessity of MPCA for medicinal plants conservation are not informed to them. It is critical that these frontline officers like watchers, guards and temporary workers in the state forest department are given proper orientation and training on the conservation of medicinal plants through establishing MPCAs across state (Ved et al., 2003; Biswash et al., 2017).

8.2 Recommendations

Further, in-situ conservation program of the MPCAs can be strengthened through collaboration among important stakeholders such as i) State Forest Department, ii) Local communities residing in the vicinity of MPCAs, iii) Research institutions and persons interested in research on medicinal plants, iv) Institutions undertaking medicinal plants related conservation education programme, v) Government departments/ organisations concerned with medicinal plants conservation, vi) Organisations like medicinal plants boards engaged in the work of conservation of medicinal plants, etc. As MPCA sites are the solely protected areas envisaged as hands off areas to provide long-term conservation of medicinal plant species, designing and implementing suitable management practices is very important. Some of the management interventions such as fire management, weed control and enrichment of native vegetation, soil and water conservation, maintenance of boundaries and paths are necessary in some of these MPCAs. Limited collection or removal of resources may be allowed for research and breeding purposes but the illicit removals, grazing and commercial harvest of any produce from MPCAs

should be strictly suspended. In addition, creating income generation activities for local dependent communities and educational programmes to promote conservation may help in better management of MPCAs. A definite role for local communities in management of MPCAs has to be built in the management scheme and the local communities need to be encouraged and facilitated in formation of local MPCA Management Committee. In all cases, the support of local communities for protection of Medicinal Plants Conservation Areas (MPCAs) is crucial.

Site specific Work Plan/Management Plan incorporating various management issues and prescriptions may be needed for each MPCA on simple formats for easy understanding in the field. The management of MPCAs, as per the Work Plan prescriptions, has to be the joint responsibility of the State Forest Department and the local communities through their local MPCA management committee. Watchers from the community may be engaged at some places to afford physical protection for MPCAs. The involvement of local community members has to be compensated with materials benefits in terms of reasonable wages in order to keep their spirits high during the activities. This will increase the morale and trust in forest management system especially at the time of less employment opportunities in the outside world. By way of providing remuneration, they would be discouraged to exploit the forest resources by making illegal wild collection of plant materials for petty cash during the employment lean period.

The local forest-dependent communities are closely associated with forest resources for their livelihoods, health security and cultural, religious and emotional bonding. They exert a lot of pressure and influence on the resources by way of collecting plant materials for medicine, fuel, etc., collecting or hunting small animals/insects, using other ecosystem services like water, pollinators, organic soil, etc. In that case, it is ideal to make them part of forest resource management system, thereby orienting them towards sustainable utilisation of resources. The complete banning of resource extraction has not shown to be successful conservation action in any landscape. Instead, the involvement of local institutions like JFMCs to create awareness and capacity building of community members on resource specific sustainable principles and methods to field implement. While making the community members to understand the implementation of sustainable wild collection through regular field trainings, the forest department may allow activities in forest fringe areas, JFMC forest areas, and to some extent into the buffer zone forest areas. Areas can be demarcated for undertaking the collection of forest resources, so that JFMCs and its members can only be allowed for such activities. These interventions like imparting the knowledge of medicinal plants and mainstreaming sustainable

resource use practices through institutional framework would ensure least anthropogenic pressures from villages neighbouring MPCAs and other protected areas.

The establishment of MPCA to conserve the medicinal plants in any natural habitats may be a new initiative for various stakeholders who get involved in this process. There is a need to sensitize different target groups to the need and approaches of conservation in general and of medicinal plants. With the proper education programmes, building the capacity to undertake conservation action programme is also very important. Some of the facilities which support education programme at MPCA sites may include i) set of signage, ii) appropriate educational materials, iii) nature trails, iv) demonstration gardens, v) interpretation centre. These facilities may be developed according to specific user needs in respect of a particular MPCA and there may not be necessary to have all these facilities and activities at all the MPCAs (Saha and Sundriyal. 2010; Saha et.al. 2022) . Therefore, the education programme should be site-specific and user-specific. After sensitizing the stakeholders about the conservation imperatives and their role in such initiatives through conservation education programmes, they need to be enabled to take up the responsibility of conservation action programmes (Saha and Sundriyal. 2012). In this case, building the capacity of various stakeholders involved in the process of establishment of conservation areas and its management is important.

Beside JFMCs, the other institutions like Self Help Groups (SHGs), constituted involving local women, can act as a good institutional machinery for carrying out number of Government schemes at local level such as laying of village roads, restoration of village ponds/lakes, tree planting, subsidies for agri/horti farming exercises, food processing, handicraft making, etc. These SHGs with the involvement of local women members can be instrumental in raising nurseries for medicinal plants, and also developing a number of value added, processed/semi-processed medicinal plant-based products. Some of the alternative livelihood options that can be offered to local community members are: (i) engagement of local community resource persons as trained tourist eco-guides with good knowledge of forest landscapes and its resources including medicinal plants found in MPCA and adjoining forest areas; (ii) developing homestay as a professional hospitality business model by introducing minimal standards and infrastructure and showcasing community's traditional lifestyle and food habits. Forest trails and nature walks in the buffer zone forest areas can be part of the homestay business model to cater to nature lovers and ecotourists; (iii) forming community clusters in the settlements near MPCAs to start activities like cultivation of medicinal plants, cash crops, plantation crops like cardamomum, ginger, etc. depending on the availability of local resources like water, soil

quality, etc. Prior to start cultivation practices, the chances of crop damages due to wildlife have to be checked, so that the choice of appropriate crops/plants can be made to avoid the crop losses; (iv) other livelihood options like honey beekeeping, value addition of locally available unique food items, drinks, etc.

In order to maintain the existing MPCAs and also to establish another set of MPCAs in the state, the West Bengal state forest department can avail funding from a number of sources. One of the most relevant funding bodies for MPCA related activities is the National Medicinal Plants Board (NMPB), Govt. of India. They have introduced Central Sector Scheme for supporting projects and activities related to conservation, development and sustainable management of medicinal plants in India. The above provided recommendations are converted into activities or projects that are eligible for fundings from the NMPB through Central Sector scheme. The projects listed in the table have to be proposed by the West Bengal State Forest Department as an implementing agency. These project proposals have to be prepared in the formats prescribed by the NMPB. The Forest department need a technical partner in terms of preparing proposals initially and executing the project with a coordination of field offices.

Summary of proposed medicinal plants and MPCA related activities for West Bengal state under various components given in the central sector scheme on Conservation, Development and Sustainable Management of Medicinal Plants called by the National Medicinal Plants Board (NMPB), Govt. of India.

Components of Central Sector Schemes	Proposed activities/projects
Conservation of medicinal plant through multi-pronged strategy	
In-situ Conservation - Medicinal Plants Conservation & Development Areas (MPCDAs)	
a. Setting up MPCDAs b. Revisiting/reviewing/documentation of existing MPCAs c. Mainstreaming medicinal plant management in management approaches	➢ Organising Conservation Assessment and Management Prioritisation (CAMP) workshop for identifying threatened medicinal plants and potential sites for MPCDAs ➢ Establishing a new network of MPCDAs in West Bengal in addition to existing 7 MPCAs ➢ Improving the status of existing 7 MPCAs in terms of upgradation, improving protection, geo-referencing, removal of exotic plants, fire management, etc. ➢ Mainstreaming medicinal plant conservation in management approaches
In-situ Resource augmentation	
Assisted Natural Regeneration (ANR) or Artificial regeneration (AR)	➢ Resource augmentation of selected RET and high traded medicinal plant species in selected forest divisions in West Bengal
Ex-situ Conservation	
Plantations of medicinal plants in lands outside of forests, in private lands	➢ Formation of a cluster of cultivators to raise selected medicinal plants in the private lands through buy back arrangements (Ideal MPCA sites are North Sevoke, Sursuti, North Rajabhatkhawa, Bonnie Camp and Tonglu)
Support to JFMCs/BMCs/Van Panchayats	
a. Creation of infrastructure facilities b. Providing packaging/handling/value addition equipment c. Buyer/seller meets, marketing support	➢ Implementation of sustainable wild collection, value addition, storage and marketing of selected medicinal plants with the involvement of JFMCs located near MPCAs in West Bengal

d. Training & capacity building e. Exposure visits, organic certifications, etc.	
Research & Development	
Population assessments and conservation biology	➢ Population assessment of selected conservation concern medicinal plants with specific reference to intrinsic and extrinsic threats to plant survival under natural conditions ➢ Developing species recovery plans for selected medicinal plants that are critically endangered and with highly commercial value ➢ Collection of germ plasm for research and propagation (in-situ and ex-situ methods)
Climate change impact studies	➢ Documenting and studying the impacts of different climate change scenarios on plant functional systems like phenotypic elements (leafing, flowering & fruiting), growth parameters (stem girth size), reproductive traits (germination, fruit maturity, delay/early arrival of pollinators, etc. ➢ Developing policy note on global warming and its impact plant growth and survival and various mitigation strategies for policy makers and general public
IEC & Training	
Awareness Building, Exposure Visits, Education and Capacity Building of Stakeholders through Information Education and Communication (IEC) strategy: a. Publicity through regular participation in Exhibitions/Fairs b. Setting up of Facilitation Centres c. Organizing Workshops/Seminars/Conferences/Arogya Fair d. Training and Capacity Building initiatives	➢ Division level Training of Trainers (ToT) or Master Trainers training program on conservation and sustainable use of medicinal plant resources in West Bengal ➢ JFMC level community training programme on conservation and sustainable use of medicinal plant resources in West Bengal ➢ State level consultation meeting on mainstreaming the conservation and sustainable use of medicinal plant resources ➢ Short-term training on state medicinal plants to forest frontline officers ➢ Developing brochures, pamphlets, other IEC materials on medicinal plants and MPCAs to create awareness among general public

	➢ Establishing interpretation centres in each MPCA to explain about medicinal plant diversity of the MPCA and also to share the importance of MPCA for medicinal plants conservation
Herbal Garden	
a. Home herbal garden b. School herbal garden c. Institutional garden	➢ Establishment of Home Herbal Gardens in the neighbourhoods of MPCA sites to improve the use of medicinal plants for daily healthcare needs at local households ➢ Establishment of School Herbal Gardens in the selected local panchayat schools that are located close to MPCA sites to create awareness about medicinal plants and its uses for daily healthcare needs at local households ➢ Establishment of institutional Gardens in the selected institution at forest division level to create general awareness about medicinal plants and its uses for daily healthcare needs
Marketing & trade	
Documenting trade practices	➢ Studying the supply value chain and demand and supply of medicinal plants that are sourced from and/or passed through West Bengal focussing Siliguri and Kolkata plant markets ➢ Assessment study on the socioeconomic aspects of trade nad marketing of medicinal plant materials on the livelihoods and income generation of local commununity members

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ANNEXURES

Annexure I

Threatened medicinal plants of West Bengal as per the Conservation Assessment and Management Prioritization (CAMP) exercise conducted applying *criteria and categories of IUCN* in West Bengal during 2007.

SI. No.	Botanical Name	Family	Synonym	Trade Name	Local Name	Habit	Parts traded	Threat
1.	*Abelmoschus moschatus* Medik	Malvaceae	*Hibiscus abelmoschus*	Muskdana, Lata kasturi	Lata Kasturi, Kal Kasturi,	Undershrub	Seeds	Near threatened
2.	*Aconitum bisma*	Ranunculaceae	*Aconitum palmatum*	--	Bikhma	Perennial -	Root	Endangered
3.	*Aconitum ferox*	Ranunculaceae	--	Atish meethi	Bish	Perennial-	Root	Endangered
4.	*Aconitum spicatum*	Ranunculaceae	*Aconitum ferox var.*	--	--	Perennial herb	Root	Endangered
5.	*Alpinia calcarata*	Zingiberaceae	--	--		Herb	Rhizome	Endangered
6.	*Ampelocissus barbata*	Vitaceae	*Vitis barbata*	--		Liana (Climber)	Stem	Critically Endangered
7.	*Aphanamixis polystachya* (Wall.) Parker	Meliaceae	*Aglaia polystachya, Amoora rohituka,*	Rohitak	Tiktaraj, Pittaraj, Harin-hara	Tree	Stem bark and seeds	Least concern
8.	*Aristolochia indica* Linn.	Aristolochiaceae	--	Ishwar mul	Ishwarmul, Sapsan,	Climber	Leaves and roots.	Vulnerable
9.	*Asparagus racemosus*	Liliaceae	--	Satawari	Satamuli, Shatawari	Shrub	Leaves	Endangered
10.	*Berberis aristata* DC.	Berberidaceae	*Barberis sikkimensis*	--	Chotra	Shrub	Branchlets, fruits,bark,	Vulnerable

SI.	Botanical Name	Family	Synonym	Trade Name	Local Name	Habit	Parts traded	Threat Status
11.	*Celastrus paniculatus* Willd.	Celastraceae	*Celastrus multiflorusC.mutans,C.rothiana Swertia paniculata*	Malkangni	Mulkangni, Jyostimati,Kujari	Climber	Seeds and	Endangered
12.	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	Lauraceae	*Laurus bejolghota, Cinnamomum obtusifolium*	Bejolghota	BhaleSinkohli, Tezpata	Tree	Leaves and bark	Vulnerable
13.	*Cinnamomum cecidodaphne* Meissn.	Lauraceae	--	--	Malagiri	Tree	Wood and seeds	Endangered
14.	*Desmodium motorium*	Fabaceae	*Desmodium gyrans*	Ban Chandal	Ban Chandal	Undershrub		Vulnerable
15.	*Dioscorea prazeri* Prain & Burkill	Dioscoreaceae	*Dioscorea clarkei, D.deltoideauar.sikkimensis*	Kukur, Tarul	Kukur, Tarul	Climber	Underground root tuber and bulbils	Endangered
16.	*Drosera burmannii*	Droseraceae	--	'Sun-dew'	Surija-sisir	Herb		Endangered
17.	*Gloriosa superba*	Liliaceae	--	Kali Hari	UlatChandal, Agnisikha	Tendril climber	Tubers	Vulnerable
18.	*Gymnema sylvestre* R.Br.	Asclepiadaceae	*Periplocoa sylvestris*	Gurmar	Gurmar, Mesh shringi,	Climber	Entire plant	Vulnerable
19.	*Gynocardia odorata*	Flacourtiaceae	--_	Chaulmoogra	Chaulmgra	Tree		Endangered
20.	*Helminthostachys zeylanica* (Linn.) Hook. F.	Ophioglossaceae	*Helminthostachys dulcis*	Ekbir	Ekbir	Rhizomatous herb	Whole Plant and	Endangered
21.	*Ipomoea mauritiana* Jacq.	Convolvulaceae	*Ipomoea digitata, I. paniculata, Convolvulus paniculata*	Bhumikumra, Bhumikus-	Bhumikumra, Bhumikushmanda	Climber	Roots and tubers	Near threatened

SI. No.	Botanical Name	Family	Synonym	Trade Name	Local Name	Habit	Parts traded	Threat Status
22.	*Litsaea glutinosa* (Lour.) Robinson	Lauraceae	*Sebifera glutinosa, Litsaea chinensis, L. Sebifera*	Maida Lakri, Maida Lakadi	Piplus, Kukur Chita, Maida Lakadi	Tree	Leaves, flower buds,	Least concern
23.	*Lumnitzera racemosa* Willd.	Combretaceae	--	--	Kripa	Small tree	Leaves, barks, fruits	Critically Endangered
24.	*Lycopodiella cernua* (Linn.) Pichli-Sermolli	Lycopodiaceae	*Lycopodium cernuum,*	Lycopodium	Nag beli	Herb (Perennial)	Whole plant	Endangered
25.	*Mesua ferrea* Linn.	Clusiaceae	--	Nagkesar	Nagkesar	Tree	Bark.	Endangered
26.	*Morinda citrifolia* Linn.	Rubiaceae	--	Noni	Ach, Chaili, Bartundi,Surangi, Aal	Small tree	Leaves, stems, fruits and roots	Vulnerable
27.	*Mucuna pruriens* (Linn.) DC.	Fabaceae	*Dolichos pruriens, Carpopogon pruriens, Mucuna prurita*	Kanso, Kuach	Kanso, Kuachi	Climber	Pod and seed	Endangered
28.	*Nipa fruticans*	Arecaceae	--	Golpata	Golpata	Tree	Leaves and fruits.	Vulnerable
29.	*Olax nana Wall.* ex	Olacaceae	--	Bhadu, Olax	Bhadu Shak, Merom Met	Undershrub	Leaves and	Vulnerable
30.	*Ophioglossum reticulatum* Linn.	Ophioglossaceae	*Ophioglossum cordifolium*	Adder's tongue/ Ektir	Ektir	Terrestrial Fern	Tuber	Endangered
31.	*Panaxpseudo ginseng* Wall.	Araliaceae	*Panax sikkimensis*	Ginseng	Jara-okhati, Mangan	Herb	Rhizome	Critically Endangered
32.	*Pericampylus glaucus* (Lamk.) Merr.	Menispermaceae	*Pericampylus incanus*	Pipal- pati	Pipal-pati, Lahara	Climber	Root tuber	Vulnerable

SI.	Botanical Name	Family	Synonym	Trade Name	Local Name	Habit	Parts traded	Threat Status
33.	*Perseaglaucescens* (Nees.) Long	Lauraceae	*Machilus villosa*	Kawla	Kawla, Atilo	Tree	Bark and wood.	Critically Endangered
34.	*Picrorhiza kurroa* Royle ex Benth.	Scrophulariaceae	*Picrorhiza kurrooa*	Kutki	Kutki, Kutaki	Perennial herb	Whole plant	Critically Endangered
35.	*Podophyllum hexandrum* Royle	Podopbyllaceae	*P. emodi, P. emodi var. Jaeschkei*	Ban kakri	Ban Kakri, Panchpatey	Perennial herb	Whole plant, fruit and root.	Critically Endangered
36.	*Pterocarpus marsupium* Roxb.	Fabaceae	--	Bijasal	Bijasal, Piyasal	Tree	Bark, wood and gum.	Vulnerable
37.	*Rauwolfia serpentina* (Linn.)Benth.	Apocynaceae	*Ophioxylon serpentinum*	Rauwolfia, Sarpagandha	Sarpagandha Chandra,	Shrub	Leaves, seeds, roots	Endangered
38.	*Sonneratia caseolaris* (Linn.) Engl.	Sonneratiacaeae	*Rhizophora caseolaris, Sonneratia acida*	Archa, Ora	Ochra, Archa, Archaka	Tree	Fruits and wood.	Endangered
39.	*Stereospermun colais*(Dillwyn) Mabb.	Bignoniaceae	*S. tetragonun, S. personatum*	Parao, Padri	Parania, Padri	Tree	Bark	Vulnerable
40.	*Swertia chirayita Roxb.*ex	Gentianaceae	*Gentiana chirayita, Ophelia chiraita*	Chirayata	Chireta, Chirayata	Herb	Whole plant	Critically Endangered
41.	*Taxus wallichiana* Zucc.	Taxaceae	*Taxus baccata sub. sp. Wallichiana*	Taxus	Dhengresalla	Tree	Leaf twigs and barks.	Critically Endangered
42.	*Thalictrum foliolosum* DC.	Ranunculaceae		Dampate	Dampate	Herb	Whole plant and root.	Vulnerable

43.	*Toona ciliate* Roem.	Meliaceae	*Cedrella toona*	Toon	Toon	Tree	Seed, bark and wood.	Vulnerable
SI.	**Botanical Name**	**Family**	**Synonym**	**Trade Name**	**Local Name**	**Habit**	**Parts traded**	**Threat**
44.	*Tylophora indica* (Burm. f.) Merr.	Asclepiadaceae	*Tylophora asthmatica, Cynanchum indicum*	Anantamul	Anantamul, Ananthamul	Perennial climber	Leaves and roots.	Near
45.	Viscum articulatum Burm. f.	Viscaceae	*Viscum nepalense*	Viscum	Bunda, Mandada	Shrub	Whole plant	Least
46.	*Xylocarpus granatum* Koer.	Meliaceae	*X.obovatus, Carallia obovata,*	Pussur	Pussur, Dhandul	Tree	Wood	Vulnerable

Annexure II

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Listed medicinal plants of India with their appendices (having various rules of international restrictions for trade)

Sl. No.	Species	Common Name	CITES	IUCN
1	*Cycas beddomei*	Beddome's Cycad	I	**EN**
2	*Vanda coerulea*	Blue Vanda	I	
3	*Saussurea costus*	Kuth	I	**CR**
4	*Paphiopedilium species*	Lady's slipper orchids	I	
5	*Nepenthes khasiana*	Pitcher Plant	I	**EN**
6	*Renathera mschootiana*	Red Vanda	I	
7	*Rauvolfia serpentina*	Sarpagandha	II	
8	*Ceropegia* spp.			
9	*Frerea indica*	Shindal Mankundi		
10	*Podophyllum hexandrum*	Indian Podophyllum	II	
11	*Cyatheaceae* species	Tree Ferns		
12	*Cycadaceae* species			
13	*Dioscorea deltoidea*	Elephant's Foot	II	
14	*Euphorbia* spp.	Euphorbias	II	
15	*Orchidaceae species*	Orchids		
16	*Pterocarpus santalinus*	Red Sanders	II	**NT**
17	*Taxus wallichiana*	Common Yew or Birmi	II	**EN**
18	*Aquilaria malaccensis*	Agarwood	II	**CR**
19	*Aconitum species*			
20	*Coptis teeta*			**EN**
21	*Coscinium fenestratum*	Calumba wood		**DD**
22	*Dactylorhiza hatagirea*	Wanpolagpa, Hathajodi,	II	**LC**
23	*Gentiana kurroo*	Kuru, Kutki		**CR**
24	*Gnetum* species			
25	*Kamphergia galenga*	Galangal, Chandramula		
26	*Nardostachys grandiflora*	Jatamansi	II	**CR**
27	*Panax pseudoginseng*	Ginseng	II	
28	*Picrorhiza kurrooa*	Kutki	II	
29	***Swertia chirata***	**Charayata**		

Annexure III

Estimated annual consumption of highly traded MAPs extracted from the wild (TRAFFIC- India)

Common Name	Scientific Name	Parts used	Estimated current annual consumption (Dry weight in mt)	IUCN Red list	FRLHT CAMP Red list
Jatamansi	*Nardostachys grandiflora*	Root (Rhizome)	500-1,000	Critically Endangered	Critically Endangered
Agarwood	*Aquilaria malaccensis*	Bark (Stem), Heart Wood	50-100	Critically Endangered	Critically Endangered
Queen Sago	*Cycas circinalis*	Flower, Pith	<10	Endangered	Critically Endangered
Himalayan Yew	***Taxus wallichiana***	**Leaf**	**100-200**	**Endangered**	**Critically Endangered**
Red Sanders	*Pterocarpus santalinus*	Wood	200-500	-	Critically Endangered
Ginseng	***Panax pseudoginseng***	**Root**	**<10**	**--**	**Critically Endangered**
Salampanja	*Dactylorhiza hataqirea*	Root (Tuber)	10-50	--	Critically Endangered
Kutki	***Picrorhiza kurrooa***	**Root (Tuber)**	**1,000-2,000**	**--**	**Critically Endangered**
Himalayan May apple	***Podophyllum hexandrum***	**Fruit, Root**	**10-50**	**--**	**Critically Endangered**
Elephant's Foot	*Dioscorea deltoidea*	Root	10-50	--	Endangered

Annexure IV

Sample data format

WORKING GRID-1				
TREE	(20X20)			
Quadrant	**Species**	**No.**	**BHG**	**Regeneration Status**
Q1/T1	Ilex spp.		0.7	
	Quercus lamellosa		95	
	Quercus lineata		0.4	
	Quercus lineata		0.6	
	Machilus eduliis Lapcha		0.9	
	Machilus eduliis Lapcha		0.87	
	Machilus eduliis Lapcha		0.83	
	Evodia fraxinifolia		0.4	
	Symplocus theifolia		0.23	
Q1/T2	*Machilus eduliis Lapcha*		01.5	
	Symplocus theifolia		0.33	
	Quercus lineata		1.15	
	Ilex sp		1.47	
Q1/T3	*Symplocus theifolia*		0.73	
	Quercus lamellosa		03.5	
	Quercus lineata		01.5	
	Quercus lineata		0.35	
	CI-CI (LOCAL NAME)		0.65	
Q1/T4	*Ilex spp*		0.2	
	Ilex spp		0.2	
	Quercus liineata		0.33	
	Quercus liineata		01.4	
	Quercus liineata		2.25	
	Michelia sp		03.1	

FLORAL INVENTORISATION				
WORKING GRID-27				
TREE (20X20)				
Quadrant	**Species**	**No.**	**BHG**	**Regeneration Status**
Q1/T1	*Quercus lamellosa*		0.81	
	Quercus lamellosa		0.4	
	Quercus lamellosa		1.43	
	Quercus lamellosa		2.12	
	Quercus lamellosa		02.1	
	Quercus lamellosa		02.4	
	Quercus lamellosa		1.71	
	Rhododendron grifithianum		0.4	
	Quercus lineata		01.2	
	Quercus lineata		0.85	
	Quercus lineata		0.7	
	Ilex sps		0.33	
	Magnolia campbelli		0.8	
	Daphni phullum		01.2	
Q1/T2	*Quercus lineata*		0.91	
	Quercus lineata		1.1	
	Quercus lineata		1.52	
	Quercus lineata		0.9	
	Quercus lineata		2.1	
	Quercus lineata		1.31	
	Quercus lineata		1.4	
	Symplocus theifolia		0.3	
	Quercus lamellosa		2.8	
	Quercus lamellosa		2.34	
	Quercus lamellosa		1.43	
	Quercus lamellosa		1.41	
	Magnolia campbelli		1.11	
	Magnolia campbelli		1.15	
Q1/T3	*Quercus lineata*		1.7	
	Quercus lineata		1.4	
	Quercus lineata		1.1	
	Quercus lineata		2.1	
	Ilex spp		0.9	
	Ilex spp		0.21	
	Ilex spp		0.6	
	Ilex spp		0.7	
	Ilex spp		0.61	
	Symplocus		0.53	
	Magnolia campbelli		2.5	
	Acer cambelli		0.8	
	Machillus edulis		0.61	

Plate 1: Images of Rachila Medicinal Plants Conservation Area (MPCA), Singalila N.P., West Bengal

Plate 2: Images of Rachila Medicinal Plants Conservation Area (MPCA), Singalila N.P., West Bengal

Plate 3: Images of *Taxus wallichiana,* a threatened medicinal plants of Rachila MPCA

Plate 4: Matured *Taxus wallichiana plant with profusely branched big bole* in the MPCA

Plate 5: Images of *Panax pseudoginseng* in Rachila MPCA

Plate 6: Images of *Mahonia nepalensis, an important medicinal plant of* Rachila MPCA

Plate 7: Images of *Swertia chirayita,* an important medicinal plant of Rachila MPCA

Plate 8: Images of *Zanthoxylum oxyphyllum* and *Yushania maling* in Phalut MPCA

Plate 9: Images of *Paris polyphylla*, a conservation concern medicinal plant in the MPCA

Plate 10: Images of *Valeriana hardwikii* a conservation concern medicinal plant in the MPCA

Plate 11: Images of *Rhododendron grande* a conservation concern medicinal plant in the MPCA

Plate 12: Vegetation survey to assess the population status of many threatened medicinal plants