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ORIGINAL ARTICLE

Medicinal plant sources and traditional healthcare practices of forest-dependent communities in and around Chunati Wildlife Sanctuary in southeastern Bangladesh

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Abstract

Bangladesh's forest-dependent people rely on medicinal plants for traditional healthcare practices, as plant-based medicines are easily available and cost-effective. This study evaluated and documented ethnomedicinal practices for, and traditional knowledge of, utilising plants to cure ailments. Ethnobotanical indices quantified the use value (UV), frequency of citation, relative frequency of citation (RFC) and the informant consensus factor. Using a semi-structured questionnaire, the study interviewed 231 respondents from 18 villages in and around Chunati Wildlife Sanctuary (CWS). The study documented 134 medicinal plant species from 60 families; tree species were dominant (37.31%). Malvaceae (seven species), Rutaceae and Lamiaceae (six species each) families covered more species. Nearly half of the species (46.02%) were collected from CWS. Both above-ground and below-ground plant parts treated 71 types of ailments under 21 categories, with leaves (66 species) being the most widely used plant part. In total 33 species were used to treat dysentery, 25 species each for fever and jaundice, and 24 species for cuts and wounds. The average UV value was 0.24 and RFC value was 0.47%. Communities were found to utilise medicinal plants more at home than to sell at markets, substantially relying on medicinal plants to meet their domestic needs. Plants used for healthcare and cultural and religious beliefs have a strong connection that plays a vital role in plant conservation. This study identified 42 medicinal plant species that could be considered to treat COVID-19 patients in Bangladesh. The findings suggest that community awareness of sustainable harvesting and commercial cultivation could lead to conservation and use of these invaluable plant species for healthcare, new drugs discovery and sustainable forest management.

Keywords Medicinal plants · Traditional knowledge · Ailments · Medicine preparation · Cultural and traditional beliefs · COVID-19

Introduction

Billions of people worldwide depend partly or entirely on more than 70,000 medicinal plants (Alamgir 2017), with this as a provisioning ecosystem service as mentioned in the United Nations (UN) Millennium Ecosystem Assessment (WHO 2005). Medicinal plants used in popular and traditional medicine and developing pharmaceuticals also provide cultural and economic value to local people (Kaky and Gilbert 2016; Jamshidi-Kia et al. 2018). Growing scientific and commercial interest is evident for medicinal plants as raw materials for herbal pharmaceutical companies growing in importance and increasing greatly due to global demand (Bieski et al. 2015). According to the World Health Organization (WHO), 70–95% people in developing countries still largely rely on medicinal plants for their primary healthcare purposes. The worldwide market value for medicinal plant products (made from plant extracts containing phytochemicals) was approximately US$60 billion in 2017 and is expected to reach more than US$129 billion by 2023 (Market Research Future 2018). Yet only 15% of medicinal plants globally have been evaluated to determine their phytochemical and phytopharmacological potential (De Luca et al. 2012).

Southeast Asia and South Asia are hotspots for medicinal plants used for traditional healthcare practices. Bangladesh, a South Asian country in which about 75% of the

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country's total population lives in rural areas, has almost 80% of its population reliant on plant-based ethnomedicine for their primary healthcare purposes, such as treating fever, coughs and colds, diarrhoea and dysentery (Ahmed 2009; FAO 2010). Bangladesh is thought to be home to about 6500 plants, of which more than 500 species have medicinal value, with 250 regularly used in preparing medicines for healthcare purposes (Ahmed et al. 2009). In the country's rural areas, knowledge of medicinal plant use has historically originated from forest-dependent communities across the country, particularly in the central (Islam et al. 2014); northeastern (Khan et al. 2011); southwestern (Mollik et al. 2009); and southeastern regions (Faruque et al. 2018). The traditional knowledge of these communities also significantly contributes to the origin and evolution of many effective herbal medicines, including those for treatments of cancer and cardiovascular diseases (Chowdhury and Koike 2010). According to Bangladesh's Directorate General of Drug Administration (available at www.dgda.gov.bd/), the number of plant-based medicine manufacturers is 528 (Unani 272, Ayurvedic 201 and herbal 55), with their registered medicines totalling 11,290 (Unani 6630, Ayurvedic 4110 and herbal 550). No restrictions apply to the sale of medicinal plant products in Bangladesh, with the quality of these medicines lagging due to various bottlenecks and stakeholders' lack of goodwill.

Bangladesh's traditional ethnomedicine sector has long been established in an important position in rural and forest-dependent communities' socio-cultural, spiritual, economic, and healthcare arenas (Chowdhury and Koike 2010). Plant-based herbal medicines are easily available and cost-effective for these communities (Faruque et al. 2018). Over the last two decades, medicinal plants and ethnomedicinal studies have been carried out in different parts of Bangladesh, receiving significant attention from the government and pharmaceuticals sector. At the same time, medicinal plants are rarely commercially farmed in Bangladesh and are mostly used when gathered from the wild. However, the growing demand for herbal products has led to a quantum leap in the volume of plant materials traded within and across the country (Shahidullah and Haque 2010). In Bangladesh, the rural people conserve their traditional ethnomedicinal knowledge through their experience and practice from generation to generation, handed down orally with no documentation (Bregum 2010; Rahman 2013). Motaleb and Khan (2012) reported that the age-old practice of traditional ethnomedicine is highly threatened by deforestation, land-use change and unsustainable harvesting. In contrast, the growing demand for medicinal products incentivises further over-exploitation. Other studies (e.g., Khan et al. 2011; Rahman et al. 2011a; Rahman 2013) indicated that this invaluable traditional knowledge is now under threat of extinction due to its limited inter-generational transfer and inadequate documentation.

Additionally, the coronavirus disease (COVID-19) pandemic, caused by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) has spread to 226 countries and territories worldwide since December 2019 and is now the topmost global public health concern. As of 14 April 2022, there have been 500,186,525 confirmed cases of COVID-19, including 6,190,349 deaths (WHO 2022). Several studies (e.g., Adeleye et al. 2021; Ang et al. 2020a, b; Benarba and Pandiella 2020; Deng et al. 2020; El Alami et al. 2020; Jahan and Onay 2020; Khadka et al. 2021; Lee et al. 2020; Luo et al. 2020a, b; Runfeng et al. 2020; Shawky et al. 2020; Silveira et al. 2020; Vardanjani et al. 2020; Weng 2020; Zhou et al. 2020; Zhuang et al. 2020) have suggested that ethnomedicine from traditional Chinese, Indian and Persian medicine could be considered as rich sources of ingredients to be used in drug discovery to combat COVID-19. These studies confirmed that China, South Korea and India have widely used medicinal plants for COVID-19 treatment, with several clinical practice results showing significant roles. Moreover, studies conducted in Bangladesh (e.g., Ahmed et al. 2020; Azam et al. 2020; Bhuiyan et al. 2020; Bachar et al. 2021; Dutta et al. 2021; Islam et al. 2021; Shahriar et al. 2022) have reported more than 30–149 plant species that have been found useful for COVID-19 treatment as home remedies by Bangladeshi COVID-19 patients. These shreds of evidence support the effective use of these plants and their products in preventing and managing COVID-19 symptoms.

Scientific studies on Bangladesh have claimed that one of the best ways to conserve medicinal plants and the related traditional knowledge is through documentation and stimulating traditional practices involving local people. However, documentation has not previously been undertaken of traditional healthcare knowledge in study area of present study, Chunati Wildlife Sanctuary (CWS), located in southeastern Bangladesh. Despite its many unique features, the flora diversity of CWS and, more specifically, of plants used by local people to treat various ailments remains unexplored. Regarding the natural growth of medicinal plants in the CWS wilderness, the ethnobotanical knowledge of forest-dependent communities in and around CWS must be documented and conserved. The objectives of this study were:

(i) to evaluate and document the plant-based ethnomedicinal practices and traditional knowledge of the utilisation of plants for curing ailments, using this to construct a database of medicinal plants and their traditional uses in and around CWS.
(ii) to perform quantitative analysis of the documented data using quantitative ethnobotanical indices.

(iii) to evaluate the role of cultural and traditional beliefs regarding medicinal plant conservation across these poorly studied communities.
(iv) to record the available medicinal plant species in CWS potential for use in COVID-19 treatment as home remedies by Bangladeshi COVID-19 patients.

This pioneering attempt to conduct a quantitative ethnomedicinal study in and around CWS aims to provide a useful guideline for further phytochemical and phytopharmacological investigations to discover new drugs. We hope that the documentation in the present study of the traditional knowledge and practices associated with these plant resources will form part of an important strategy linked to the ex situ and in situ conservation of medicinal plants, sustainable management of CWS, and improvement in the quality of life of poor forest-dependent communities. Furthermore, this study's findings are intended to be helpful for Bangladesh's Forest Department and non-governmental organisations (NGOs) when working in and around CWS on community-based medicinal plant cultivation, management and commercialisation.

Materials and methods

Description of Chunati Wildlife Sanctuary

The CWS is located at 21° 40′ N and 92° 07′ E in the Chattogram Division of southeastern Bangladesh (Fig. 1). With an area of 7764 hectares (ha), CWS was established in 1986 to reduce the rate of deforestation and forest degradation and to conserve the habitat of the Asian elephant (*Elephas maximus*). It comprises two Forest Ranges and seven Forest Beats (the lowest forest administration unit) (Mollah et al. 2004). The physiography of CWS is generally hilly (average elevation is 30–90 m above sea level [m asl]). Inside the sanctuary, many places are traversed by numerous creeks with beds of gravel or stone. These creeks provide a good drainage facility, supplying water within the sanctuary for wildlife, people and irrigation in agricultural fields (GIZ 2011).

The CWS enjoys a tropical moist climate (temperature ranges from 14 to 32 °C) characterised by frequent rainfall (annual precipitation is 3000 mm) from April to September. The original semi-evergreen forests have been degraded due to heavy anthropogenic interferences, including cultivating betel leaf (*Piper betle*, Piperaceae family) inside the sanctuary. A little natural forest area exists in CWS, with only a few scattered patches of *Dipterocarpus* spp. For management purposes, CWS is divided into five designated habitat types, namely, scattered grasslands and bamboo patches; cultivated lands; patches of secondary forests, wetlands and water bodies; and short and long rotation plantations (BFD 2015).

The CWS is the remaining vital habitat in Bangladesh of the globally threatened *E. maximus*. Therefore, CWS has experienced more research activity and positive attention from donors since its establishment than any protected forests in Bangladesh. Habitat fragmentation and degradation caused by anthropogenic forest use activities have increased conflict between humans and *E. maximus*. The major damaged areas are paddy fields, homestead forests, vegetable gardens and settlements (Sarker and Røskaft 2010; Kabir 2013).

This sanctuary harbours diverse flora resources, namely, 691 plant species comprising 240 tree species (96 of which are exotic tree species), 102 shrub species, 211 herb species, 106 climber species, 19 epiphyte species, 7 parasite species and 6 fern species (Hossain and Hossain 2014). The average tree density per ha is only 239 trees, and seedling density per ha is 77,000, with more than 60% of the trees being exotic tree species that have been planted (GIZ 2011). The status of the CWS's carbon stock is low, at only 136.48 CO_2 Mg ha^1, indicating the degraded condition of this sanctuary (Fakir et al. 2015).

Local community members' livelihoods in and around the sanctuary

About 57,000 people from 10,200 households live in and around CWS in 69 registered forest villages (locally called *para*) (BFD 2015). Over 50% of the population is dependent on forest resources for their livelihoods (GIZ 2011), with nearly 65% living on the poverty line. About 48% of the villages are located inside and at the edge of CWS, while the remaining villages are located outside but adjacent to and near the sanctuary. The only indigenous community living in CWS is called *Mog* (Hoque 2009).

Nearly 50% of the population is engaged in agriculture, 10% in fishing, 20% are day labourers, and the remaining 20% are involved in other occupations (BFD 2015). The women are housewives and involved in poultry, duck and cattle rearing to generate extra household income (Tamima 2016). The collection of forest resources, such as timber and non-timber forest products (NTFPs), by both men and women is considered a secondary occupation in and around CWS, which plays a vital role in income generation (BFD 2015). About 80% of households depend on NTFPs (e.g., fuelwood, bamboo, medicinal plants, *Imperata cylindrica* and wild fruits). Unfortunately, over-exploitation of these NTFPs has resulted in the degradation of CWS resources.

People have encroached on and used forestland to expand settlements, agricultural farming, vegetable gardening, fish cultivation, betel leaf cultivation and cattle grazing. Landless poor people usually lease land (from

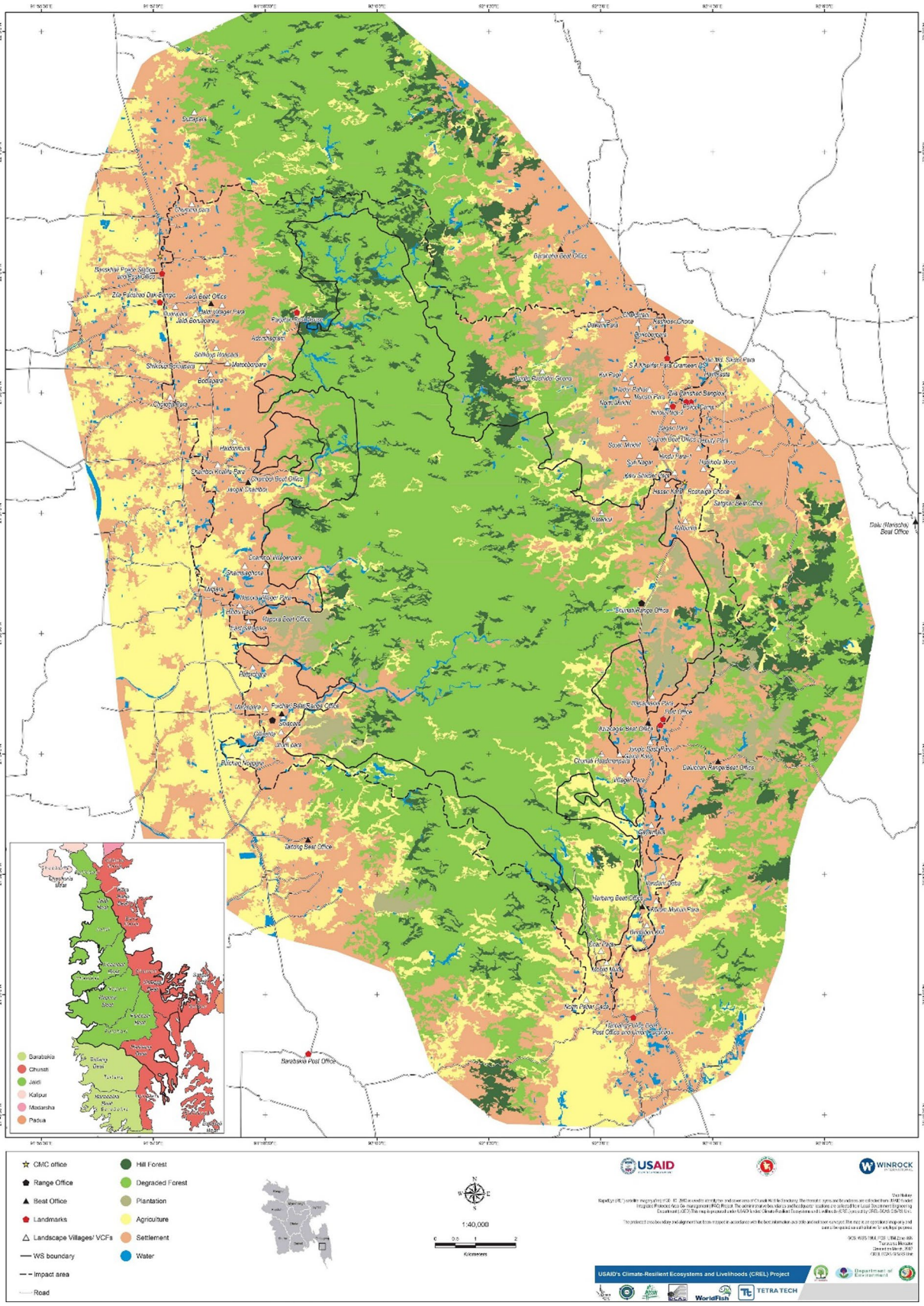

Fig. 1 Location map of Chunati Wildlife Sanctuary in southeastern Bangladesh (source: http://nishorgo.org/project/)

local elites who lease the forestland from local forest offices) for agricultural farming for their consumption and to sell farm produce at the market for subsistence income (GIZ 2011). Agricultural labourers find work for 6 months in a year but have no income-earning work for the remaining 6 months. They are engaged in illegal harvesting of timber and NTFPs and selling these products at the nearest market to generate income during the unemployed period (BFD 2015). Consequently, conflict arises between local people and the Forest Department. The former use the forestland for their livelihood, and the latter seek to restrict the forestland's use for biodiversity conservation (Rahman et al. 2017a).

The CWS is one of the pilot sites in Bangladesh for co-management project implementation with financial and technical assistance from the United States Agency for International Development (USAID), in partnership with the Forest Department (Rahman 2013). Between 2004 and 2018, three co-management projects have been implemented in this sanctuary, aiming to restore, protect and conserve the remaining forest biodiversity, undertake sustainable use of forest resources and reduce forest dependency among forest-dependent communities through alternative income-generating (AIG) activities (Rahman et al. 2017a, b). Furthermore, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)-funded Management of Natural Resources and Community Forestry (MNRCF)-Chunati project (2009–2015) implemented pilot reforestation and sustainable forest management measures in CWS based on cooperation between local co-management organisations and the Forest Department. This project further strengthened co-management structures through different non-forestry income-generating, cultural and awareness-raising activities (GIZ 2015; Rahman et al. 2017a, b).

The co-management projects increased households' average monthly non-forestry income by US$140 and decreased their average monthly forest income by US$25 (Rahman et al. 2017a). At the end of these co-management projects, Islam et al. (2019) assessed that people were still entering the CWS to collect forest products with a total estimated market value of about US$1856 a day. The local people were still practising betel leaf farming inside the sanctuary.

Villagers have no legal rights to collect forest resources and use forestland for settlements, farming and fishing. The co-management and participatory social forestry schemes evolved to give forest-dependent people ownership and a stake in managing forest resources, incentivise them to protect forest resources, and involve them in non-forest-related livelihood options. However, forest use rights for the sustainable harvest of both timber and NTFPs are granted to local communities involved in protection activities through Participatory Benefit Sharing Agreements (PBSAs) in the buffer zone (an area of 4615 ha) (BFD 2015).

Study methods

Conceptual framework of the study

Forest-dependent communities have used plants, plant parts and plant-derived products for healthcare purposes in Bangladesh since time immemorial. Unfortunately, detailed plant information and complete inventories on these plants often do not exist. Moreover, studies that combine the investigation of the traditional use of medicinal plants and their quantitative values are also minimal. Moreover, the 2050 vision of the Convention on Biological Diversity (CBD 2010) and the 2020 Aichi Biodiversity's Target 14 call for increased efforts to conserve, restore, and safeguard those areas that 'contribute to health, livelihoods, and well-being' and 'deliver benefits essential for all people' (CBD 2010). To meet these goals, a necessary first step is to document and accurately quantify the ecosystem services for conservation and sustainable management (Mitchell et al. 2021). Consequently, this study aims to identify and record the CWS-dependent communities' traditional ethnomedicinal knowledge that contributes to their health, livelihoods and well-being. Every one of these communities has unique styles for preparing medicine from plants.

Therefore, in this study, we evaluate the traditional mode of medicine preparation and utilisation of these plants for curing ailments. Due to the importance of the plant conservation, we identified the sources of medicinal plants and evaluated the cultural and traditional beliefs regarding the conservation of medicinal plants. Finally, we analyse the medicinal plant use data by employing different quantitative ethnobotanical indices. From the existing literature (e.g., Vandebroek et al. 2020), we learn that medicinal plants have been used globally to treat the novel coronavirus disease (COVID-19). In this paper, we record medicinal plants from the literature similar to those already listed in this study. Pharmaceutical companies could find these plants useful for phytochemical and phytopharmacological evaluation for effective drug preparation for COVID-19 treatments. Considering the present situation and future needs, the present study results could be useful for medicinal plants' conservation and sustainable management, particularly in CWS and other protected forests in Bangladesh.

Reconnaissance survey

Prior to data collection, a reconnaissance survey was carried out in June 2013 in the study area to gain some basic ideas about the CWS's medicinal plants through personal

discussion with staff from the Forest Department, the MNRCF-Chunati project and the Climate-Resilient Ecosystems and Livelihoods (CREL) project, as well as with local herbal practitioners (called *Kabiraj*). A complete list of villages in and around CWS was collected from the MNRCF-Chunati project. A draft household questionnaire was pre-tested with five forest-dependent people during that time. With their input, some questions were added, with some deleted, to finalise the questionnaire for the field survey. A *Kabiraj* was also hired and contracted for work on the final field survey.

Data collection procedures

The primary data for the study were collected through a household questionnaire survey (HQS), key informant interviews (KIIs) and focus group discussions (FGDs). Informal discussions were also conducted in tea stalls where local people gathered for refreshment, conversation and social interaction from morning to night. Secondary data were collected from published books, journal articles, and pamphlets of the Forest Department and the MNRCF-Chunati and CREL projects. Two Forestry Master's graduates were employed in this research to help the researchers during data collection from July to October 2013.

Household questionnaire survey

A household-level ethnobotanical survey was conducted using a semi-structured questionnaire. The study applied a purposive sampling technique (e.g., village → household → respondent) to select households for survey interviews. The survey was deliberately targeted toward experienced people, mostly of older age, who attempted to identify the medicinal plants used by local people, documenting their traditional knowledge and perceptions of medicinal plant use and tracing the patterns (if any) in the harvesting and management of particular medicinal plant species.

HQS were conducted in all seven Forest Beats inside the CWS. From the 69 villages, 18 (26%) villages were selected randomly for data collection from respondents. From these 18 villages, 231 respondents (both male and female) from 231 households (covering 26% of households) were randomly selected and interviewed for the study (see details in Online Resource 1).

A semi-structured questionnaire was designed to collect information from respondents about what medicinal plant species and which plant parts they used, what ailments were treated, what usage patterns were followed, the collection sources for plants, the reasons for conservation of specific plants, etc. Interviews were conducted in each respondent's home using the native language (Bangla), sometimes with more than one respondent participating simultaneously, with everyone's opinion recorded for the study. The researchers and the research assistants both conducted the HQS. When needed, local dialects were interpreted by the *Kabiraj*.

Key informant interviews

In total, 18 KIIs (one KII from each village) were conducted using a checklist (Online Resource 1). These interviews helped to obtain more candid or in-depth answers about the CWS's medicinal plants. The selected key informants were the local *Kabiraj*, herbal businessmen, nursery owners and members of the Co-Management Committee (CMC) and Village Common Forest (VCF). All KIIs were conducted by the researchers.

Focus group discussion (FGD)

In total, 18 FGDs (one FGD from each village) were conducted using a guideline (Online Resource 1). Some FGDs were conducted in the local markets, inside houses and some at the front of house-yards. For FGDs conducted at tea stalls in the market, male participants were usually dominant. In the inside house and house-yard FGDs, female participants were dominant but male participants also responded. In some cases, respondents interviewed for HQSs were also FGD participants. On average, each FGD involved participation by 10 participants. The FGDs only involved those who were knowledgeable about medicinal plant resources and the uses of medicinal plants for healthcare purposes. The FGDs were facilitated by the research assistants and moderated by the researchers. Questions in the FGDs were particularly focused on sustainable harvesting and conservation of the CWS's medicinal plants. During the FGDs, data from the HQSs and KIIs were verified, cross-checked and validated.

Data analysis

During the field survey, the name of each medicinal plant was first recorded by its local name. Subsequently, local names were cross-referenced with the established Bangla names from the *Encyclopaedia of Flora and Fauna of Bangladesh* published by the Asiatic Society of Bangladesh. The species' scientific name was recorded from the same source (see Siddique et al. 2007, 2008; Ahmed et al. 2008a, b, c, 2009, 2010). Finally, each species' scientific name and family name were verified with "The Plant List" website (available at: www.theplantlist.org).

Quantitative status

Descriptive statistics were used to quantitatively describe or summarise the features of the data, using suitable tables and figures whenever possible. The use value (UV) score of plant

species and values for the frequency of citation (FC), relative frequency of citation (RFC) and informant consensus factor (ICF) indices were also calculated using the specific equations provided below:

Use value

The UV score was calculated for individual plant species using the following equation, as explained by Phillips et al. (1994), to provide a quantitative and objective measure of its relative importance to informants:

$$UV = \frac{\Sigma Ui}{N} \quad (1)$$

where UV refers to the use value of a species; U_i refers to the number of uses reported by each informant for that plant species; and N refers to the total number of informants in the survey. A high UV score for a plant species indicated that it received many use reports (i.e., it was most frequently indicated), while a low score indicated that informants cited fewer use reports (Islam et al. 2014; Umair et al. 2017; Faruque et al. 2018).

Informant consensus factor

Before calculating the ICF value, ailments were broadly categorised into different ailment categories (Heinrich et al. 1998). The ICF values ranged from 0.00 to 1.00. The maximum ICF value, that is, a value close to 1, indicated that a well-known species was used by a large proportion of informants due to its authenticity in the treatment of ailments. However, a low ICF index value close to 0 specified that informants used this species randomly to treat reported ailments (Heinrich et al. 1998). The ICF value was calculated using the following equation:

$$ICF = \frac{(Nur - Nt)}{(Nur - 1)} \quad (2)$$

where N_{ur} referred to the total number of use reports for a particular ailment category, and N_t referred to the total number of species used for that ailment category.

Frequency of citation and relative frequency of citation indices

The FC index score was calculated using the following equation:

$$FC = \frac{Ns}{Nt} \quad (3)$$

where N_s referred to the number of times a particular species was mentioned and N_t referred to the total number of times all species were mentioned.

The RFC index score was determined by dividing the FC index score by the total number of informants in the survey (N). The RFC index scores ranged from 0 when no one referred to a plant as useful to 1 when all informants referred to a plant as useful. The RFC index score was calculated using the following equation, as described by Tardío and Pardo-De-Santayana (2008):

$$RFC = \frac{FC}{N} (0 < RFC < 1) \quad (4)$$

Results

Demographic profile of surveyed respondents

Of the surveyed 231 respondents, about 55.41% were female. The highest number of respondents (45.89%) were 41–50 years old. Regarding educational qualifications, 62.77% of respondents completed primary education, with about one-quarter (24.68%) illiterate or only able to sign their name. As female respondents were the majority in this survey, most surveyed respondents (53.68%) cited 'housewife' as their occupation, followed by farmers (29.87%). About 70.13% of respondents were highly dependent on CWS to support their livelihoods. In all, 73.16% respondents reported that they collected medicinal plants from CWS, with the highest collection frequency being 1–2 times per month (62.13%) (Table 1).

Medicinal plant resources in CWS

From the household survey, the study documented 134 species of medicinal plants with curative values that were traditionally used by forest-dependent communities in and around CWS for their daily healthcare purposes (Table 2). Of the documented species, 37.31% species were trees, 28.36% species were herbs, and 20.15% species were shrubs (Fig. 2). Table 2 lists the botanical description of each species recorded, the plant parts used, the ailments treated, the usage pattern and the UV, FC and RFC values.

The 134 species recorded belong to 60 families. The highest number of species belonged to the Malvaceae family with seven species; followed by the Lamiaceae and Rutaceae families (six species each); the Moraceae, Solanaceae and Asteraceae families (five species each); and the Apocynaceae, Convolvulaceae, Cucurbitaceae, Euphorbiaceae, Fabaceae, Myrtaceae, Poaceae, Rubiaceae and Zingiberaceae families (four species each) (Fig. 3 and Online Resource 2).

Table 1 Basic demographic features of surveyed 231 respondents living in and around Chunati Wildlife Sanctuary

Parameter	Categories	Number of respondents	Percentage of respondents
Sex	Male	103	44.59
	Female	128	55.41
Age class (year)	30–40	71	30.74
	41–50	106	45.89
	51–60	41	17.75
	> 60	13	5.63
Educational qualification	Illiterate/can sign	567	24.68
	Primary	145	62.77
	Junior	22	9.52
	Secondary	4	1.73
	Higher Secondary	3	1.30
Occupation	Housewife	124	53.68
	Farmer	69	29.87
	Day labour	15	6.49
	Businessmen	10	4.33
	Others	13	5.63
Forest dependency	High	162	70.13
	Medium	61	26.41
	Low	8	3.46
Collection of medicinal plants from forest	Yes	169	73.16
	No	62	26.84
Frequency of medicinal plants collection from forest	1–2 times per month	105	62.13
	2–3 times per month	41	24.26
	3–4 times per month	23	13.61

Sources and mode of preparation and utilisation of recorded medicinal plants

About half the medicinal plant species (46.02%) were collected from CWS, as reported by respondents, followed by 34.07% plant species from their homestead forest (Fig. 4). People harvested medicinal plants from CWS throughout the year but mostly in the winter and summer seasons and less in monsoon. Due to heavy rainfall and the chance of landslides, it was extremely difficult to enter CWS in the monsoon season for medicinal plant harvesting. Both the above-ground and below-ground plant parts were used to prepare medicine from plants. In most cases, different plant parts from the same plant were used to prepare medicine to treat different ailments in respondents' everyday healthcare. In other cases, similar or different parts of more than one plant were mixed to prepare medicine to treat a single ailment. Based on the field survey, leaves from 66 medicinal plant species were used to prepare medicine. These also comprised fruits from 33 species, roots from 18 species, bark from 13 species, and seeds from 11 species (Fig. 5).

Generally, respondents made juice after processing, with this involving pasting, squeezing and blending leaves, rhizomes, bark and roots to use as medicine, while fresh and ripened fruits (*Mangifera indica, Spondias pinnata, Ammona squamosa, Phoenix dactylifera, Averrhoa carambola, Ananas comosus, Carica papaya,* etc.) were eaten. Sometimes plant parts (*Bombax ceiba, Terminalia bellirica, T. chebula, Plantago ovata, Phyllanthus emblica, Hyptis suaveolens, Ocimum sanctum, Swertia chirata*, etc.) were soaked in water either for the person to drink on an empty stomach in the morning or to soften the skin before being eaten. Most plant parts were consumed orally or were used by rubbing or burning; some were taken raw after being soaked or boiled in water; while some were eaten after being cooked as vegetables, particularly the herbs (*Alternanthera philoxeroides, Diplazium esculentum, Polycarpon prostratum,* etc.), shrubs (*Colocasia affinis, C. esculenta, Cajanus cajan,* etc.) and climbers (*Ipomoea aquatic, I. balatus, Momordica charantia, Lagenaria siceraria,* etc.). Medicines prepared from plant parts were sometimes applied externally to wounded or sore body parts to treat cuts and wounds, scabies, pain or skin diseases. Fresh plant parts were used to prepare medicine; dried parts were also used when fresh was not available. In some cases, dried fruits and seeds (*T. belerica,*

Table 2 Details of 134 recorded medicinal plant species used by forest-dependent communities in and around Chunati Wildlife Sanctuary, Bangladesh

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
Acanthaceae	Bashok	*Adhatoda vasica* Nees	Shrub	Forest, homestead forest, roadside	Leaf	Cough and cold, asthma, piles, pneumonia, malarial fever	Juice extracted by crushing leaves and heated slightly then drunk with honey	0.31	1.78	0.61
	Kalomegh	*Andrographis paniculata* (Burm.f.) Nees	Herb	Forest	Whole plant	Fever, worms, dysentery, astringent, piles, physical weakness	Juice is made from plant parts and drunk	0.24	1.36	0.47
Actinidiaceae	Bhola kadam	*Saurauia roxburghii* Wall	Tree	Forest	Leaf	Skin diseases	To treat boils, leaf infusion is used in baths	0.08	0.48	0.16
Alangiaceae	Akarkanta	*Alangium salvifolium* (L.f.) Wangerin	Tree	Forest	Fruit	Hair fall, dandruff	Paste made from leaves is rubbed on head for hair fall and dandruff problems	0.07	0.39	0.13
Amaranthaceae	Apang	*Achyranthes aspera* L.	Herb	Forest, homestead forest	Whole plant	Dysentery, piles, skin diseases, rheumatism, stop bleeding, cough and cold, fever, snake bite	Juice made from leaves and roots and drunk	0.29	1.63	0.56
	Helencha	*Alternanthera philoxeroides* (Mart.) Griseb	Herb	Fallow land	Leaf	Dysentery, eye diseases, liver problems, jaundice	Leaves are cook and eaten as vegetables	0.32	1.84	0.64
	Kanta mali	*Amaranthus spinosus* L.	Herb	Forest, fallow land	Leaf, root	Stomach pain	Leaves and roots are crushed, made juice and drunk	0.13	0.76	0.26
Amaryllidaceae	Piaj	*Allium cepa* L.	Herb	Homestead forest	Whole plant	Stomach pain, cough and cold, hair fall, dandruff	Rhizome are eaten as raw with salt; whole plant is used with curry	0.35	2.01	0.70
	Rashun	*Allium sativum* L.	Herb	Homestead forest	Whole plant	Stomach pain, teeth ache, heart diseases, urinal problem, snake bite	Rhizome are eaten as raw with salt; whole plant is used with curry	0.36	2.03	0.70

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
Anacardiaceae	Aam	*Mangifera indica* L.	Tree	Forest, homestead forest, roadside	Leaf, fruit, tender twig	Fat burning, teeth ache, cut and wounds, diabetes, dysentery, jaundice, asthma, piles, diarrhoea, cough and cold	Tender leaves are cook and eaten as vegetables; tender leaves are eaten mixing with salt; green and ripe fruits are eaten; tender twig used as toothbrush; paste made from leaves used on wounded place	0.37	2.08	0.72
	Amra	*Spondias pinnata* (L.f.) Kurz	Tree	Forest, homestead forest	Fruit, bark	Fever, skin diseases, vitamin deficiencies, taste increaser	Green and ripe fruits are eaten; juice made from bark used on skin	0.29	1.65	0.57
	Lota aam	*Mangifera sylvatica* Roxb	Tree	Forest	Bark	Cough and cold, fever	Powder made from dry bark and mixed with honey	0.15	0.88	0.30
Annonaceae	Ata	*Annona squamosa* L.	Tree	Forest, homestead forest	Leaf, fruit	Worms, vomiting	Juice of leaves are feed to children; ripe fruits are eaten	0.27	1.54	0.53
Apiaceae	Dhonia pata	*Coriandrum sativum* L.	Herb	Homestead forest	Leaf, seed, root	Stomach pain, digestive problem	Roots are crushed and eaten raw with sugar; seeds and leaves are used in curry	0.34	1.94	0.67
	Thankuni	*Centella asiatica* (L.) Urban	Herb	Forest, homestead forest, fallow land	Whole plant	Diarrhoea, dysentery, gastritis, piles, tonic, hypertension	Whole plant is blended and eaten; green leaves are eaten as vegetables; green leaves also cooked and eaten as vegetables	0.37	2.11	0.73
Apocynaceae	Chatim	*Alstonia scholaris* (L.) R.Br	Tree	Forest, roadside	Leaf, bark	Stimulate lactation, jaundice, malarial fever, snake bite	Juice made from crushing bark and leaves; bark exudates for snake bite	0.27	1.51	0.52

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
	Kurchi	*Holarrhena antidysenterica* (L.) Wall. ex A. DC	Tree	Forest, fallow land	Whole plant	Dysentery, asthma, skin diseases, cut and wounds, fever, worms	Boiling with water and mixing with honey or sugar; bark and seeds paste are used in skin diseases; paste made from leaves are used on wounded place	0.23	1.31	0.45
	Rupatola	*Tabernaemontana recurva* Roxb. ex Lindl	Shrub	Forest	Root	Snake bite	Paste made from roots and placed around the place	0.09	0.49	0.17
	Akanda	*Calotropis gigantea* (L.) Dryand	Shrub	Forest, homestead forest, roadside	Leaf, latex	Cut and wounds, arthritis	Leaves are heated and placed on pain place; latex are placed on injured place	0.36	2.05	0.71
Araceae	Kachu	*Colocasia esculenta* (L.) Schott	Shrub	Forest, homestead forest, fallow land	Whole plant	Eye diseases, anaemia, cut and wounds, stop bleeding, constipation, earache, mouth blow	Whole plant (leaves and rhizome) is used as vegetable; latex is placed on wounded place	0.32	1.84	0.64
	Mankachu	*Colocasia affinis* Schott	Shrub	Forest, homestead forest, fallow land	Whole plant	Gout pain, constipation, rheumatism	Leaves are heated on fire and place in the affected area; leaves and rhizome are eaten as vegetable	0.28	1.59	0.55
Arecaceae	Khejur	*Phoenix dactylifera* L.	Tree	Forest, homestead forest, roadside	Fruit, root	Worms, jaundice, constipation,	Juice is made by crushing roots and drunk; ripe fruits are eaten	0.24	1.39	0.48
	Narikel	*Cocos nucifera* L.	Tree	Homestead forest	Fruit, root	Worms, jaundice, diarrhoea, hair fall, dandruff, burn, dysentery, physical weakness, skin diseases	Fleshy part of the fruit is mixed with water and sugar and taken in every morning; water of green coconut is drunk; oil made from fruits used in hair; paste made from roots used in the burnt places	0.34	1.91	0.66

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
	Supari	*Areca catechu* L.	Tree	Homestead forest, roadside	Root, seed	Worms, vomiting, sex stimulant, astringent, heart diseases, digestive problems	Roots are crushed and drunk mixing with sugar; raw and dried seeds are chew and eaten with betel leaf	0.36	2.06	0.71
Asparagaceae	Shatomuli	*Asparagus racemosus* Willd	Climber	Forest	Leaf, root	Sexual weakness, sex stimulant, fever, dysentery	Juice made from roots and leaves are drunk regularly	0.25	1.44	0.50
Asteraceae	Assam lata	*Mikania cordata* (Burm.f.) B.L.Rob	Climber	Forest, homestead forest, roadside, fallow land	Whole plant	Cut and wounds, stop bleeding	Whole plant is squeezed and the juice is used externally on the wounded places	0.37	2.08	0.72
	Assam pata	*Chromolaena odorata* (L.) R.M.King & H.Rob	Shrub	Forest, homestead forest, roadside, fallow land	Leaf	Cut and wounds, stop bleeding	Whole plant is squeezed and the juice is used externally on the wounded places	0.35	2.01	0.70
	Gendha ful	*Tagetes erecta* L.	Herb	Homestead forest	Leaf	Cut and wounds	Juice is made from leaves and placed over the wounded spot	0.14	0.80	0.28
	Shillata	*Vernonia cinerea* (L.) Less	Climber	Forest	Stem	Gastritis	Juice made from stem and drunk	0.13	0.74	0.26
	Tora gash	*Blumea clarkei* Hook. f	Herb	Forest	Leaf	Jaundice, bone fracture	To treat bone fracture, paste of leaves of these plants is applied to affected areas and bandaged tightly with a piece of coarse cloth for several days. To treat jaundice, pills prepared from the leaf paste are taken thrice daily	0.09	0.49	0.17
Athyriaceae	Dhai sak	*Diplazium esculentum* (Retz.) Sw	Herb	Forest, fallow land	Leaf	Gastritis, eye diseases, stomach pain	Tender leaves are cooked and eaten as vegetables	0.30	1.69	0.58
Bignoniaceae	Thona	*Oroxylum indicum* (L.) Benth. ex Kurz	Tree	Forest	Bark, stem, seed	Jaundice, diarrhoea, scabies	Juice made and drunk directly	0.11	0.60	0.21

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
Bromeliaceae	Anarosh	*Ananas comosus* (L.) Merr	Herb	Homestead forest	Leaf, fruit	Worms, stomach pain, jaundice	Green and ripe fruits are eaten; tender leaves are crushed then feed to children	0.30	1.73	0.60
Cactaceae	Cactus	*Cactus* spp.	Cactus	Forest	Leaf	Blood pressure	Boiled water of leaves is drunk with sugar	0.04	0.24	0.08
Caesalpiniaceae	Daud pata	*Cassia alata* L.	Tree	Forest	Leaf	Scabies, eczema	Leaves are crushed, mixing with salt and kerosene and rubbed on wounded places	0.07	0.39	0.13
	Sonalu	*Cassia fistula* (L.) Gaertn	Tree	Forest	Leaf	Ulcer, cut and wounds	Powder made from dry leaves and rubbed on wounded places; leaves are soaked in water and drunk for ulcer treatment	0.23	1.31	0.45
Caricaceae	Pepe	*Carica papaya* L.	Shrub	Homestead forest	Fruit	Worms, dysentery, jaundice, stomach pain	Green ad ripe fruits are eaten; green fruits are cooked as vegetables	0.36	2.05	0.71
Caryophyllaceae	Ghima	*Polycarpon prostratum* (Forssk.) Asch. & Schweinf	Herb	Homestead forest, fallow land	Whole plant	Diarrhoea, dysentery, fever, gastritis, earache	Leaves are eaten as vegetables; juice made from whole plant is drunk; paste made from leaves used for earache	0.33	1.88	0.65
Combretaceae	Arjun	*Terminalia arjuna* (Roxb. *ex* DC.) Wight & Arn	Tree	Forest, homestead forest	Bark	Diabetes, stomach pain, taste increaser, fever, heart diseases, asthma, dysentery, digestive problem, hypertension, cough and cold, piles, burn	Boiled water of bark is drunk; keeping bark into water for 1 night then drunk; powder made from dry bark and mixing with honey	0.38	2.14	0.74
	Bohera	*Terminalia bellirica* (Gaertn.) Roxb	Tree	Forest	Fruit, bark	Astringent, piles, constipation, gastritis, stomach pain, fever, jaundice, asthma, heart diseases	Fruits and bark are kept in water and drunk in every morning; made powder after crushing dried fruits	0.34	1.93	0.67

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
	Horitoki	*Terminalia chebula* Retz	Tree	Forest	Fruit	Astringent, piles, constipation, gastritis, stomach pain, fever, cough and cold, anaemia, dysentery, eye diseases, rheumatism, asthma	Fruits are kept in water and drunk in every morning	0.34	1.91	0.66
Convolvulaceae	Kalmi sak	*Ipomoea aquatica* Forssk	Climber	Homestead forest, fallow land	Whole plant	Asthma, constipation, eye diseases	Eaten as vegetable; paste made from dry leaves	0.37	2.11	0.73
	Misti alu	*Ipomea batatus* (L.) Lam	Climber	Homestead forest	Leaf, rhizome	Urinal problem, jaundice, rheumatism	Leaves are eaten as vegetable; rhizome also eaten raw	0.31	1.79	0.62
	Swarno lata	*Cuscuta reflexa* Roxb	Climber	Forest, homestead forest	Whole plant	Cough and cold, gastritis	Whole plants are crushed and feed cow; juice feed to children	0.23	1.30	0.45
	Voi kumra	*Ipomoea mauritiana* Jacq	Climber	Forest	Root	Cough and cold, tonic, alterative, demulcent, digestive problem	Juice made from root	0.16	0.89	0.31
Crassulaceae	Pathorkuci	*Bryophyllum pinnatum* (Lam.) Oken	Herb	Forest, homestead forest	Leaf	Cough and cold	Juice made from tender twig are feed to the children for cold ailments	0.25	1.40	0.48
Cucurbitaceae	Korolla	*Momordica charantia* L.	Climber	Homestead forest	Leaf, fruit	Arthritis, digestive problem, constipation, blood purification	Eaten as vegetables; leaves are crushed and placed on wounded place	0.35	2.01	0.70
	Lau	*Lagenaria siceraria* (Molina) Standl	Climber	Homestead forest	Whole plant	Diarrhoea, worms, constipation	Fruits and leaves are used as vegetable; juice made from roots are taken for worm diseases	0.35	2.01	0.70
	Misti kumra	*Cucurbita moschata* Duchesne ex Poir	Climber	Homestead forest	Whole plant	Worms, skin diseases	Fruits and leaves are used as vegetable; juice made from roots are taken for worm diseases	0.35	2.01	0.70

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
	Telakucha	*Coccinia cordifolia* (L.) Cogn	Climber	Forest, homestead forest, roadside	Leaf	Cough and cold, diabetes, hair fall, dandruff	Taken as vegetables after cooking; leaves are crashed and placed in head skin	0.22	1.26	0.44
Dilleniaceae	Chalta	*Dillenia indica* L.	Tree	Forest, homestead forest	Leaf, fruit	Sex stimulant	Juice obtained from crushed leaves is taken once daily; fruits cooked as curry	0.27	1.53	0.53
Dipterocarpaceae	Garjan	*Dipterocarpus turbinatus* C.F. Gaertn	Tree	Forest	Latex	Diarrhoea	Latex is eaten with honey	0.14	0.79	0.27
Ebenaceae	Deshi gab	*Diospyros peregrina* (Gaertn.) Gürke	Tree	Forest, homestead forest	Fruit	Dysentery	Fruits are squeezed and taken with sugar; ripe fruits are eaten	0.29	1.63	0.56
Elaeocarpaceae	Jalpai	*Elaeocarpus robustus* Roxb	Tree	Forest, homestead forest	Fruit	Vitamin deficiencies, cough and cold, taste increaser	Raw fruits are eaten with salt; also used in curry	0.33	1.89	0.65
Euphorbiaceae	Bon morich	*Croton bonplandianus* Baill	Shrub	Forest, roadside, fallow land	Leaf, flower	Anti-allergic, teeth ache, headache, asthma, skin diseases	Paste made from flower and leaves placed over affected place; juice made from leaves sometimes used for head pain with coconut oil	0.22	1.25	0.43
	Gundi gach	*Mallotus roxburghianus* Muell. Arg	Tree	Forest	Leaf, root	Dysentery, jaundice	Fruits are boiled and taken as vegetables; paste made from leaves	0.09	0.51	0.18
	Patabahar	*Cobiaeum variegatum* (L.) A.Juss	Shrub	Homestead forest	Leaf	Cut and wounds	Juice made from leaves	0.16	0.90	0.31
	Pitali	*Trewia nudiflora* L.	Tree	Forest	Leaf	Cut and wounds	Juice made from leaves	0.20	1.15	0.40
Fabaceae	Arol	*Cajanus cajan* (L). Millsp.	Shrub	Forest, homestead forest	Leaf, seed	Jaundice, gout pain	Juice made from leaves; leaves are heated and rubbed on affected place; seeds cooked as vegetables	0.27	1.54	0.53

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
	Mandar	*Erythrina variegata* L.	Tree	Forest, homestead forest	Bark	Worms, gastritis, sexual weakness, jaundice, stimulate lactation	Bark are crashed and juice is also used	0.19	1.08	0.37
	Shim	*Phaseolus vulgaris* L.	Climber	Homestead forest	Leaf, seed	Scabies, earache	Dried seeds are crushed and made paste with water then applied on wounded place; the decoction of leaves and roots are heated slightly, and the warm liquid is poured into the ear in case of ear pain	0.35	2.01	0.70
	Sisoo	*Dalbergia sissoo* DC	Tree	Forest, roadside	Leaf	Cut and wounds	Tender leaves are squeezed and juice placed in affected area	0.13	0.71	0.25
Gentianaceae	Cirota	*Swertia chirata* Buch.-Ham. *ex* Wall	Herb	Forest	Branch	Fever, taste increaser, physical weakness, stomach pain, blood poisoning, malarial fever	Branches are cut into small pieces and soaked on water for drinking in the morning	0.33	1.89	0.65
Lamiaceae	Dondokolos	*Leucas aspera* Link	Herb	Forest	Leaf	Pneumonia	Extracted juice from leaves	0.20	1.15	0.40
	Pudina pata	*Mentha piperita* L.	Herb	Homestead forest	Leaf	Dysentery, tonic	Leaves are crushed and taken with rice as vegetables	0.25	1.40	0.48
	Gamar	*Gmelina arborea* (Roxb.) *ex* Sm	Tree	Forest, homestead forest	Leaf	Hair fall, dandruff	Juice is extracted by blending leaves then rubbed on hair	0.10	0.58	0.20
	Vatpata	*Clerodendrum viscosum* Vent	Shrub	Forest, homestead forest, roadside	Leaf, branch, root	Stomach pain, vomiting, earache, fever	Tender leaves, branches and roots are squeezed and juice taken with sugar	0.26	1.50	0.52
	Tukma	*Hyptis suaveolens* (L.) Poit	Herb	Forest, homestead forest	Seed	Urinary problem, stomach pain, constipation, sexual weakness, fever	Seeds are soaked in water and taken in the morning	0.33	1.89	0.65

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
	Tulsi	*Ocimum sanctum* L.	Herb	Forest, homestead forest	Leaf, seed	Cough and cold, cut and wounds, constipation, antiseptic	Leaves are squeezed and taken with honey after heating; juice of leaves are placed on wounded place; seeds are soaked in water and taken in the morning	0.36	2.03	0.70
Lecyphidaceae	Hizol	*Barringtonia acutangula* Gaertn	Tree	Forest	Bark	Physical weakness	Juice is made after boiling with water	0.08	0.44	0.15
Leguminosae	Tetul	*Tamarindus indica* L.	Tree	Forest, homestead forest	Leaf, fruit	Cough and cold, fever, loss of appetite, dysentery, lethargy to food	Water of boiled leaves is drunk; green and ripe fruits are eaten with salt	0.34	1.94	0.67
	Minijiri	*Senna siamea* (Lamk.) Irwin & Barneby	Tree	Forest, homestead forest	Flower	Diabetes	Flowers are baked and eaten with rice	0.22	1.23	0.42
	Lozzabati	*Mimosa pudica* L.	Herb	Forest, roadside	Whole plant	Scabies, teeth ache, chicken pox, jaundice, sexual weakness	Leaves are crashed and paste is placed on wounded place, roots are used in sexual weakness and teeth ache	0.35	2.01	0.70
Loranthaceae	Orsallu	*Macrosolen cochinchinensis* (Lour.) Teigh	Tree	Forest	Leaf	Jaundice	Fresh leaf juice is taken twice daily to treat jaundice	0.06	0.36	0.13
	Parula	*Scurrula parasitica* L.	Shrub	Forest	Stem	Teeth ache	Cutting into small pieces, boiled and used for mouth wash	0.06	0.35	0.12
Lythraceae	Mehendi	*Lawsonia inermis* L.	Shrub	Homestead forest	Leaf	Sexual weakness, sex stimulant, urinal problem, skin diseases, dandruff, hair fall, hair and beard colour, colouring nails and palm	Dry leaves are crushed and taken with water; paste made from leaves used in hair and skin	0.34	1.95	0.68
	Dalim	*Punica granatum* L.	Shrub	Homestead forest	Fruit	Increase in red blood cell count	Ripe fruits are eaten and juice made by crushing it to drunk	0.32	1.81	0.63

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
Malvaceae	Chatehata	*Sida mysorensis* Wight & Arn	Herb	Forest	Root	Piles, jaundice, malarial fever, diarrhoea	Juice after crushing root	0.21	1.18	0.41
	Joba	*Hibiscus rosa-sinensis* L.	Shrub	Homestead forest	Leaf, flower	Dysentery, cut and wounds	Flowers are squeezed and taken with sugar; paste is made from young leaf	0.22	1.28	0.44
	Shimul	*Bombax ceiba* L.	Tree	Forest, homestead forest	Leaf, root	Worms, sexual weakness, sex stimulant	Juice made from roots and drunk. Leaves and roots are soaked in water overnight followed by drinking the water early in the morning	0.22	1.24	0.43
	Udal	*Sterculia villosa* Roxb	Tree	Forest	Leaf, tender twig	Dysentery, jaundice, rheumatism	Leaves are cut into small pieces and soaked into water; to treat rheumatism, water extract of petioles is given to drink with sugar	0.23	1.30	0.45
	Ulat kambal	*Abroma augusta* L.	Shrub	Forest	Bark, root	Dysmenorrhoeal, sexual weakness	Bark and roots are soaked into water and drunk	0.15	0.88	0.30
	Asar	*Grewia paniculata* Roxb	Shrub	Forest	Leaf	Cut and wounds	Paste made from leaves and rubbed on the wounded area	0.15	0.86	0.30
	Pisla	*Grewia nervosa* (L.) G.Panigrahi	Shrub	Forest	Latex	Diarrhoea, dysentery	Latex is taken with honey	0.13	0.74	0.26
Melastomataceae	Bontej pata	*Melastoma malabathricum* L.	Shrub	Forest, roadside, fallow land	Leaf, fruit, bark, flower	Dysentery, diarrhoea, skin diseases	Leaves, flowers, barks and fruits are cut and crushed for making paste and juice	0.22	1.26	0.44
Meliaceae	Neem	*Azadirachta indica* A. Juss	Tree	Forest, homestead forest	Leaf, tender twig, bark	Chicken pox, teeth ache, fever, asthma, worms, skin diseases, antiseptic, rheumatism	Bath with boiled leaves water; teeth are brushed with twigs; dry leaves and bark are eaten with honey after making powder	0.39	2.21	0.77

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
Menispermaceae	Gulanci lata	*Tinospora cordifolia* Miers	Climber	Forest	Leaf, tender twig	Arthritis, fever	Boiling with water	0.13	0.76	0.26
Moraceae	Dumur	*Ficus roxburghii* Wall. ex Steud	Tree	Forest, homestead forest	Fruit	Dysentery, diabetes	Fruits are eaten as vegetables	0.25	1.43	0.49
	Fala	*Ficus racemosa* L.	Tree	Forest	Root	Tonsillitis	Juice made from root and eaten with rice	0.06	0.31	0.11
	Kanthal	*Artocarpus heterophyllus* Lamk	Tree	Forest, homestead forest	Fruit, latex, seed	Skin diseases, eczema, constipation, stomach pain	Latex is placed on wounded place; fruits are eaten as raw; seeds are eaten after baked	0.38	2.15	0.74
	Khaiz bichi	*Ficus religiosa* L.	Tree	Forest	Leaf	Tonsillitis	Paste made from leaves and roots then place on wounded place	0.05	0.30	0.10
	Shewra	*Streblus asper* Lour	Tree	Forest, homestead forest, roadside	Leaf, latex	Scabies, dysentery, skin diseases, arthritis, female sexual disorders	Paste made from leaves are placed on wounded place; latex of leaves is eaten with honey; juice made from leaves is drunk for dysentery	0.29	1.64	0.57
Moringaceae	Sojina	*Moringa oleifera* Lamk	Tree	Homestead forest	Leaf, fruit	Dysentery, malarial fever, arthritis, sexual weakness	Leaves and fruits are eaten as vegetable, juice from leaves is drunk	0.33	1.89	0.65
Musaceae	Kola	*Musa sapientum* L.	Shrub	Forest, homestead forest	Whole plant	Dysentery, cut and wounds, anaemia	Inner part of bark is eaten as vegetables; fruits are eaten raw; roots are crushed and given on wounded place	0.37	2.09	0.72
Myrtaceae	Eucalyptus	*Eucalyptus camaldulensis* Dehnh	Tree	Forest, homestead forest, roadside	Leaf, bark	Malarial fever, hair fall, dandruff	Soaked on water for a night then eaten with honey; oil from leaves used in hair	0.07	0.41	0.14

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
	Guava	*Psidium guajava* L.	Tree	Forest, homestead forest	Leaf, fruit	Stomach pain, vitamin deficiencies, dysentery, diarrhoea, fever, cut and wounds	Juice made from tender leaves are taken; fruits are eaten for deficiency of vitamin C, juice made from young leaves are placed on wounded place	0.39	2.23	0.77
	Jam	*Syzygium cumini* (L.) Skeels	Tree	Forest, homestead forest	Fruit, seed	Typhoid, diabetes, blood purification	Fruits are eaten raw; powder made from dry seeds and mixed with honey	0.32	1.83	0.63
	Puti jam	*Syzygium fruticosum* DC	Tree	Forest	Fruit	Fever	Eaten raw	0.26	1.49	0.52
Oxalidaceae	Kamranga	*Averrhoa carambola* L.	Tree	Forest, homestead forest	Fruit	Jaundice, hair fall, Datura poisoning, physical weakness, constipation, diarrhoea, vitamin deficiencies	Green and ripe fruits are eaten; juice made from fruits and drunk	0.31	1.78	0.61
Papveraceae	Shial kanta	*Argemone mexicana* L.	Herb	Forest, roadside, fallow land	Leaf	Dysentery, cut and wounds	Leaves are eaten as vegetables	0.09	0.51	0.18
Phyllanthaceae	Lotkon	*Baccaurea ramiflora* Lour	Tree	Forest	Fruit	Headache, stomach pain	Ripe fruits are eaten; fruits washed water is drunk for stomach problem	0.23	1.33	0.46
	Amloki	*Phyllanthus emblica* L.	Tree	Forest, homestead forest	Leaf, fruit	Astringent, constipation, gastritis, stomach pain, fever, jaundice, skin diseases, hair fall, digestive problem	Fruits and leaves are kept in water and drunk in every morning	0.34	1.94	0.67
Piperaceae	Paan	*Piper betle* L.	Climber	Forest	Tender twig	Cut and wounds, loss of appetite, dysentery, indigestion, stomach pain, sex stimulant	Leaves are crushed and applied in wounded area; green leaves are eaten with betel nut	0.38	2.16	0.75
Plantaginaceae	Isopgul	*Plantago ovata* Forssk	Herb	Homestead forest	Seed	Constipation	Seeds are kept in water then drunk in the morning	0.34	1.95	0.68

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
	Brahmmi sak	*Bacopa monniera* (L.) Pennell	Herb	Forest, homestead forest, roadside, fallow land	Leaf, seed	Cough and cold, fever, asthma, mental depression, heart diseases	Juice from leaves for drunk; green leaves cooked as vegetables; seeds are used in curry	0.25	1.44	0.50
Poaceae	Akh	*Saccharum bengalense* Retz	Shrub	Homestead forest	Stem	Jaundice	Stem is eaten and made juice by crushing it to drunk	0.31	1.76	0.61
	Durba grass	*Cynodon dactylon* (L.) Pers	Grass	Forest, homestead forest, roadside, fallow land	Whole plant	Cut and wounds, stop bleeding, diabetes, teeth ache	The paste made from whole plant is placed in the wounded places	0.40	2.29	0.79
	Goicha	*Paspalum scrobiculatum* L.	Herb	Forest	Leaf	Skin diseases	Leaves are squeezed and given between fingers of toe	0.07	0.43	0.15
	Bansh	*Bambusa* spp.	Grass	Forest, homestead forest	Leaf, bark	Teeth ache, cut and wounds, stop bleeding	Boiled water of leaves are used for teeth ache; green portion of bark is used for stopping bleeding	0.25	1.41	0.49
Polygonaceae	Bon palong	*Rumex dentatus* L.	Herb	Forest, fallow land	Leaf, stem	Anti-allergic, fever, scabies	Soup is made from leaves and used to prevent fever; leaves also used for scabies; stem is used as anti-allergic	0.17	0.99	0.34
Rhamnaceae	Boroi	*Zizyphus mauritiana* Lamk	Tree	Forest, homestead forest	Fruit	Fever, cough and cold, digestive problem	Green and ripe fruits are eaten	0.34	1.94	0.67
Rubiaceae	Bishma	*Hydyotis scandens* Roxb	Herb	Forest	Leaf	Stomach pain	Infusion of leaves is taken 2–3 times a day to treat stomach pain	0.07	0.40	0.14

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
	Haru lodi	*Tarenna campaniflora* (Hook. f.) N.P. Balak	Tree	Forest, homestead forest	Leaf, fruit, root	Eczema, diarrhoea, fever, scabies	Leaves extract is applied externally in the affected area to treat eczema; root extract is given to drink to treat abdominal pain caused by diarrhoea; root extract is given to drink to treat fever; leaf infusion is used for bathing to treat scabies	0.21	1.20	0.42
	Kodom ful	*Anthocephalus chinensis* (Lamk.) A. Rich. *ex* Walp	Tree	Forest, homestead forest, roadside	Leaf	Arthritis, cut and wounds, skin diseases	Paste made from leaves are placed on the affected area	0.21	1.21	0.42
	Gandha bhaduli	*Paederia foetida* L.	Herb	Forest, roadside	Tender twig; rhizome	Arthritis, fever	Twigs are boiling with water and used externally; rhizome is eaten raw with salt	0.20	1.16	0.40
Rutaceae	Baruna shak	*Zanthoxylum budrunga* DC	Herb	Forest, homestead forest	Whole plant	Jaundice	Cooked and eaten as vegetables	0.23	1.30	0.45
	Batabi lebu	*Citrus maxima* (Burm.) Merr	Shrub	Homestead forest	Fruit	Cough and cold, vitamin deficiencies	Ripe fruits are eaten; juice made from fruits to drunk	0.24	1.38	0.48
	Bel	*Aegle marmelos* (L.) Correa *ex* Roxb	Tree	Forest, homestead forest	Leaf, fruit	Dysentery, stomach pain, worms, diarrhoea, physical weakness, constipation,	Fleshy soft part of ripe fruit is eaten; young leaves are eaten	0.34	1.93	0.67
	Jambura	*Citrus grandis* (L.) Osb	Shrub	Homestead forest	Fruit	Dysentery, fever, jaundice, lethargy to food, vitamin deficiencies	Ripe fruits are eaten; juice made from fruits to drunk	0.31	1.76	0.61

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
	Lebu	*Citrus limon* (L.) Burm. f	Shrub	Forest, homestead forest	Leaf, fruit	Vitamin deficiencies, cut and wounds, liver problems, snake bite, lethargy to food, physical weakness	Green and ripe fruits are eaten; juice made from fruits to drunk; green leaves are eaten; green leaves also used in curry	0.32	1.81	0.63
	Motkila pata	*Glycosmis pentaphylla* (Retz.) A. DC	Herb	Forest	Leaf	Jaundice, cough and cold, cut and wounds	Juice made from leaves are used for jaundice and cough and cold; paste is used on cut and wounded place	0.23	1.31	0.45
Smilacaceae	Kumarilata	*Smilax macrophylla* Poepp. ex A.DC	Climber	Forest	Leaf	Sexual weakness, sex stimulant	Juice from top tender leaves are eaten raw	0.22	1.26	0.44
Solanaceae	Dhutura	*Datura innoxia* Mill	Herb	Forest	Leaf, seed, fruit	Gout pain, dog bite, diarrhoea, dysentery, mental depression	Leaves and fruit are heated on fire and place on affected place; seeds are eaten with betel leaf; grinding to make juice	0.21	1.19	0.41
	Kanta morich	*Solanum surattense* Burm.f	Herb	Forest, fallow land	Leaf, root	Gastritis, worms, dysentery, bee sting	Juice made from leaves and roots are used for gastritis and worms; leaves also eaten as vegetables	0.13	0.76	0.26
	Kantakari	*Solanum xanthocarpum* Schrad. & Wendl	Herb	Forest	Leaf, tender twig	Sexual weakness, hair fall, dandruff	Plant parts are boiled for drunk; fresh juice of leaves applied on head to prevent hair fall and removes dandruff	0.09	0.50	0.17
	Morich	*Capsicum annuum* L.	Herb	Homestead forest	Fruit	Mouth blow, eye disease, bee sting	Green and ripe fruits are eaten and sued in curry; dried fruits are used in curry also made powder after crushing	0.39	2.20	0.76
	Tit begun	*Solanum violaceum* Ortega	Shrub	Forest, fallow land	Fruit	Dysentery	Fruits are cooked and eaten as vegetables	0.25	1.40	0.48

Table 2 (continued)

Family	Local name	Scientific name	Life form	Habit	Plant parts used	Treating ailments	Mode of preparation and utilisation	UV	FC (%)	RFC (%)
Theaceae	Cha gach	*Camellia sinensis* O. Kuntze	Shrub	Forest	Leaf	Teeth ache	Green leaves are chewed for tooth ache; green leaves are mixed with smashed potato and eaten as vegetables	0.13	0.71	0.25
Verbenaceae	Lantana	*Lantana camara* L.	Shrub	Homestead forest, roadside, fallow land	Leaf, stem	Antiseptic, arthritis, skin diseases, stop bleeding	Leaves are used for antiseptic and skin diseases; crushed leaves and stems are used for arthritis and stop bleeding	0.25	1.41	0.49
Vitaceae	Harzora lata	*Cissus quadrangularis* Linn	Climber	Forest	Stem	Bone fracture, blood pressure	Paste made of blended climbers is placed on broken place and bandaged	0.28	1.56	0.54
Zingiberaceae	Ada	*Zingiber officinale* Roscoe	Herb	Homestead forest	Rhizome	Gastritis, stomach pain, cough and cold, tonsillitis, vomiting, teeth ache, cut and wounds, hypertension	Rhizome eaten raw with salt; rhizome paste used in curry	0.36	2.04	0.71
	Bhulchengi	*lpinia nigra* (Gaertn.) B.L.Burtt	Herb	Forest	Root	Jaundice, gastritis	Roots extract is taken thrice daily to treat jaundice; for gastritis, decoction of roots is taken twice daily	0.07	0.40	0.14
	Go-ada	*Zingiber zerumbet* (L.) Sm	Herb	Forest, fallow land	Rhizome	Gastritis, diarrhoea, dysentery	Rhizome eaten raw with salt; rhizome paste used in curry	0.15	0.84	0.29
	Holud	*Curcuma longa* L.	Herb	Homestead forest	Rhizome	Blood purification, skin diseases, gastritis	Rhizome crushed and eaten; rhizome paste used in curry; rhizome paste mixed with milk and drunk	0.36	2.04	0.71

UV use value, *FC* frequency of citation, *RFC* relative frequency of citation

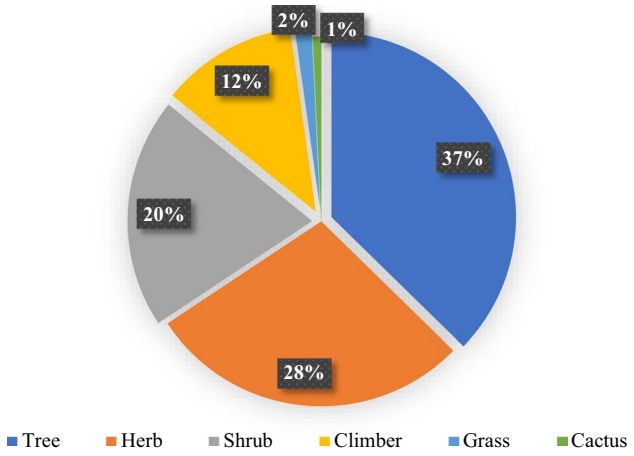

Fig. 2 Life form categorisation of recorded medicinal plant from Chunati Wildlife Sanctuary

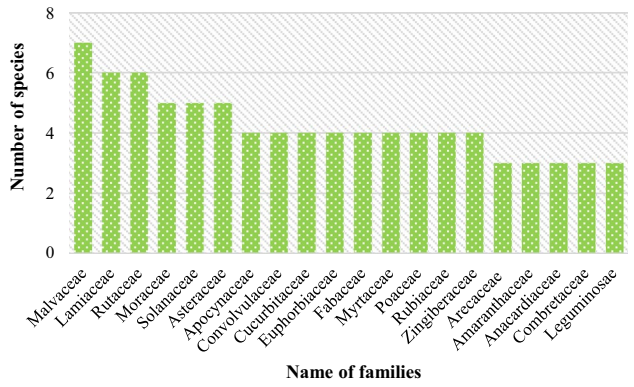

Fig. 3 Dominant families of recorded medicinal plant species

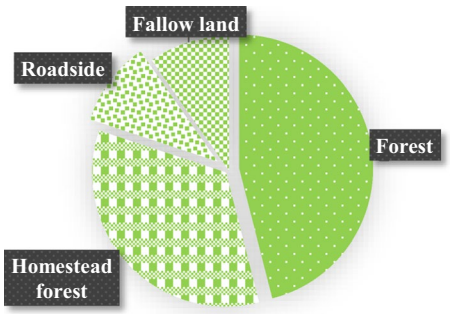

Fig. 4 Sources of recorded medicinal plant species

Areca catechu, Phaseolus vulgaris, Capsicum annuum, etc.) were used to prepare medicine (Table 2). However, the dosage pattern varied with the age of the patient, severity of the ailment and mode of medicine preparation by the practitioner.

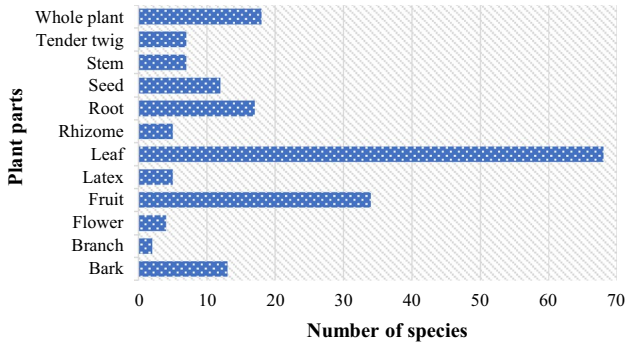

Fig. 5 Distribution of plant parts used for preparing medicine from recorded medicinal plant species

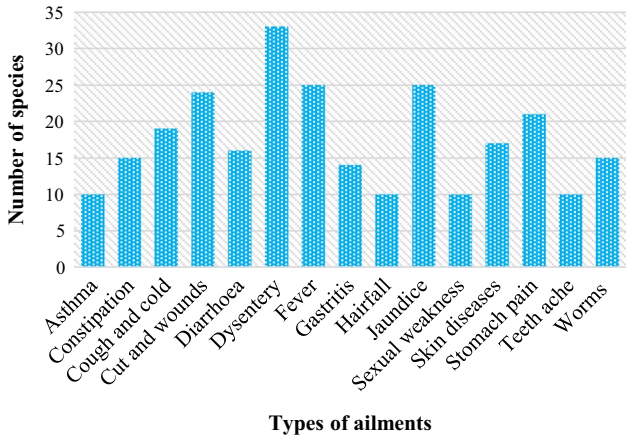

Fig. 6 Dominant uses of recorded medicinal plant species for treating different ailments

Traditional uses of medicinal plant species for curing ailments

Figure 6 shows the traditional uses of plant species for treating 71 types of ailments. In summary, respondents cited a total of 454 times in which they treated 71 ailments. Trees were dominant (44.71%) for treating ailments, followed by herbs (27.97%), shrubs (15.20%), climbers (10.35%), grasses (1.54%) and cacti (0.22%) (Online Resource 3). Among the recorded species, 33 species were used to treat dysentery, 25 each for fever and jaundice, 24 for cuts and wounds, 21 for stomach pain, 19 for coughs and colds, 17 for skin diseases, 16 for diarrhoea and 15 each for constipation and worms. One species was used to treat each of the following 14 ailments: as an alterative, increase in red blood cell count, blood poisoning, colouring nails and palm, *Datura* poisoning, as a demulcent, dog bite, dysmenorrhoea, fat burning, female sexual disorders, hair and beard colour, indigestion, typhoid and ulcers. Furthermore, more than one species was used to treat the remaining 57 ailments (Online Resource 3).

Cultural and traditional beliefs regarding medicinal plants' conservation

Input from the FGDs on cultural and traditional beliefs regarding medicinal plant conservation was evaluated. Participants stated that some important medicinal plant species, such as *Aegle marmelos*, *A. indica*, *Cocos nucifera, Hibiscus rosa-sinensis, Hyptis suaveolens, Lawsonia inermis*, *M. indica*, *M. sapientum, O. sanctum*, *P. betle*, *P. ovata, Punica granatum, Tagetes erecta* and *Zizyphus mauritiana* were regarded as culturally significant and traditionally sacred plants by the Hindu and Muslim religious communities in the studied forest-dependent villages. Hindu communities used parts of some of these plants, such as *Anthocephalus chinensis, A. marmelos, C. nucifera, Colacasia esculenta, H. rosa-chinenesis, M. indica, M. sapientum, O. sanctum, P. betle* and *P granatum* during their worship; consequently, they planted and conserved these specific species in their homestead forest. Moreover, worship by members of the Hindu community involved the whole *O. sanctum* plant every morning and evening, with the earth around the base of this species kept neat and clean, with regular mud paste added by older women. The Muslim community used the leaves of the *Z. mauritiana* species to shower the dead body before its burial.

The FGD participants also advised that the orange colour from the paste of the leaves of *L. inermis* was often used to colour the palms of the hands of both the bride and groom and of women and children on cultural, ceremonial and religious occasions in Muslim, Hindu and Christian religious communities. People in Bangladesh, including in the study area, used paste made from leaves to colour hair and fingernails (for both men and women) and men's beards. The yellow paste made from the *Curcuma longa* rhizome was used to colour the whole body of both the bride and groom in Muslim, Hindu and Christian communities. During the entire wedding ceremony (from pre- to post-ceremony), a plate (*dala*) was decorated nicely with colourful patterns containing grains from *Areca catechu, C. dactylon, P. betle, C. longa* and *Oryza sativa* as a sign of purity and piousness. It was presented with a flaming light as everybody blessed the bridal couple.

Findings from the FGDs also revealed that most people planted some species with valuable medicinal properties, such as *Areca catechu*, *A. indica*, *Citrus grandis*, *C. limon*, *C. nucifera*, *Elaeocarpus robustus, Lawsonia inermis*, *M. indica* and *O. sanctum*, in their homestead forests. *A. indica*, in particular, was usually planted on the southern side of homesteads, purifying the air from the south side with its foliage. *A. marmelos, Bambusa* spp., *C. nucifera, Ricinus communis, Streblus asper* and *Tamarindus indica* were planted on the periphery of homestead forests, based on the belief that evil spirits take shelter in tree foliage. Some species, such as *Kalanchoe pinnata, Cobiaeum variegatum, H. rosa-chinenesis* and *Tagetes erecta*, serving both beautification and medicinal purposes, were grown and maintained in front of dwelling houses. People also created living fences by planting *H. rosa-chinenesis* surrounding their homesteads. *A. indica* and *C. papaya* were planted in homestead forests to prevent ailments from entering. Similar beliefs were also reported by people in other areas of Bangladesh, as mentioned by Chowdhury et al. (2009) and Rahman (2013).

Quantitative status of recorded medicinal plants

Use value and relative frequency of citation

The average UV score in the present study was 0.24 and ranging between 0.04 and 0.40. Based on UV scores, the ethnomedicinal plant species most commonly used was *Cynodon dactylon* (UV 0.40); followed by *A. indica, C. annuum* and *Psidium guajava* (UV 0.39 each); *Piper betle*, *Artocarpus heterophyllus* and *T. arjuna* (UV 0.38 each); and *I. aquatic*, *Centella asiatica*, *Musa sapientum, M. indica* and *Mikania cordata* (UV 0.37 each) (Table 2). The least used species were *Ficus racemosa* (UV 0.06), *F. religiosa* (UV 0.05) and *Cactus* spp. (UV 0.04). Most species with higher UV scores were used for diverse purposes, including treating cuts and wounds; diarrhoea; dysentery; fever; coughs and colds; stomach pain; toothache; vitamin deficiencies; to stop bleeding; diabetes; chicken pox; worms; heart diseases; digestive problems; hypertension; constipation; asthma; skin diseases, etc. The three species with the lowest UV scores were solely used to treat tonsillitis and blood pressure.

On the other hand, the average RFC value in this study was found 0.47%, with this score ranging from 0.08 to 0.79%. The highest RFC value was recorded for *C. dactylon* (0.79%); followed by *P. guajava* and *A. indica* (0.77% each); *C. annuum* (0.76%); *P. betle* (0.75%); *A. heterophyllus* and *T. arjuna* (0.74% each); *I. aquatic* and *C. asiatica* (0.73% each); and *M. sapientum, M. indica* and *M. cordata* (0.72% each) (Table 2).

Informant consensus factor

The reported ailments were first classified into 21 different ailment categories based on their use reports to calculate the ICF, with the recorded plant species distributed according to these categories. The average ICF value for all categories was 0.99 (ranging from 0.99 to 1.00). The highest ICF values were found for female sexual disorders, heart diseases, lactation, mental disorders, and urinary and rectal diseases

Table 3 Ailments grouped by major ailment categories, ICF values and medicinal plants used to treat these major ailments

Ailment categories	Common ailments and features	No. of species	ICF[a]	Most frequently cited plants
Dental care	Teeth ache and decay, mouth blow, bad breath, mouth sores	12 (2.67)	0.99	*Cynodon dactylon, Azadirachta indica*
Dermatological problems	Cut and wounds, burn, scabies, chickenpox, eczema, itching, allergic, astringent, prickly heat	63 (14.03)	0.99	*Cynodon dactylon, Psidium guajava*
Ear nose throat problems	Earache, tonsillitis	6 (1.34)	0.99	*Zingiber officinale, Phaseolus vulgaris*
Endocrinal disorders	Diabetes	7 (1.56)	0.99	*Cynodon dactylon, Terminalia arjuna*
Female sexual disorders	Dysmenorrhoeal, excessive vaginal discharge, severe bleeding in vagina	2 (0.45)	1.00	*Streblus asper*
Fever	Fever, malarial fever, typhoid	33 (7.35)	0.99	*Psidium guajava, Azadirachta indica*
Gastrointestinal disorders	Gastric irritation and disorders, ulcer and peptic ulcer, constipation, diarrhoea, dysentery, digestive problem, dysentery, indigestion, vomiting, piles, lethargy to food	102 (22.72)	0.99	*Psidium guajava, Piper betle, Terminalia chebula*
General health	High blood pressure, hypertension, blood purification, headache, fat burning	11 (2.45)	0.99	*Terminalia arjuna, Centella asiatica*
Hair growth	Hair colour, hair fall or loss, dandruff	19 (4.23)	0.99	*Allium cepa, Lawsonia inermis*
Heart diseases	Abnormal heartbeats, heart failure, heart attack	5 (1.11)	0.99	*Terminalia arjuna, Areca catechu*
Helminthiasis	Ringworm, tapeworm, roundworm	15 (3.34)	0.99	*Azadirachta indica, Areca catechu*
Inflammation and pain	Arthritis, alterative, stomach pain, gout pain, rheumatism, demulcent, stop bleeding, bone fracture	49 (10.91)	0.99	*Psidium guajava, Azadirachta indica*
Lactation	Enhance milk secretion	2 (0.45)	1.00	*Alstonia scholaris*
Liver disorders	Jaundice, abdominal pain and swelling, loss of appetite	29 (6.46)	0.99	*Piper betle, Mangifera indica*
Mental disorders	Depression, anxiety, nervous illness	2 (0.45)	1.00	*Bacopa monniera*
Nutritional deficiencies	Anaemia, tonic, vitamin deficiencies, blood increaser, physical weakness, taste increaser	25 (5.57)	0.99	*Psidium guajava, Terminalia arjuna*
Respiratory complaints	Cough and cold, tuberculosis, asthma, bronchitis, pneumonia, influenza, nasal catarrh	31 (6.90)	0.99	*Azadirachta indica, Terminalia arjuna*
Sexual disorders	Sexual weakness, sex stimulant	17 (4.01)	0.99	*Piper betle, Areca catechu*
Toxicity complaints	Snake bite, blood poisoning, bee sting, dog bite, Dhatura	10 (2.23)	0.99	*Allium sativum*, *Capsicum annuum*
Urinary and rectal diseases	Urine colour and odour, burning with urination, blood in the urine, kidney disorders	3 (0.67)	1.00	*Allium sativum*
Vision problems	Eye pain, hazy, blurred or double vision, night blindness, glaucoma	5 (1.11)	0.99	*Ipomoea aquatica, Terminalia chebula*

Parentheses shows the percentage values

[a]Informant Consensus Factor (ICF)

(1.00 each) (Table 3). This may be due to the small number of species (ranging from only one to four species) used to treat these ailment categories.

Among the five major ailment categories, gastrointestinal disorders were dominant with 102 (22.72%) plant species used, followed by dermatological problems (63 species, 14.03%), inflammation and pain (49 species, 10.91%), fever (33 species, 7.35%) and respiratory complaints (31 species, 6.46%). *P. guajava*, *T. chebula* (UV 0.34) and *P. betle* were the plant species most frequently used to treat gastrointestinal disorders. *C. dactylon* and *P. guajava* were the plant species most frequently used to treat dermatological problems. *A. indica* and *P. guajava* were also the plant species most frequently used to treat inflammation and pain. *P. guajava* and *A. indica* were the most frequently used plant species to treat fever. To treat respiratory complaints, *A. indica* and *T. arjuna* were the most frequently used plant species. To treat these ailments, *P. guajava, C. dactylon, A. indica* and *T. arjuna* were the most frequently used medicinal plants (Table 3). These findings indicate that gastrointestinal disorders and dermatological, inflammation and pain, fever and respiratory complaints were prevalent in the study area.

Potential of medicinal plant species for COVID-19 treatment

Considering the existing literature, such as Ahmed et al. (2020), Azam et al. (2020), Dutta et al. (2021), Islam et al. (2021), Bachar et al. (2021), and Shahriar et al. (2022) we identified the following 42 medicinal plant species (i.e., *Adhatoda vasica*, *A. marmelos*, *Allium sativum*, *A. cepa*, *A. comosus*, *Andrographis paniculate*, *A. carambola*, *Azadirachta indica*, *Bacopa monniera*, *B. ceiba, Bryophyllum pinnatum*, *C. annuum*, *C. sinensis*, *Cassia fistula*, *C. asiatica*, *Citrus* spp., *Cocos nucifera*, *C. longa*, *Calotropis gigantea*, *Camellia sinensis*, *Coriandrum sativum*, *Elaeocarpus robustus*, *Eucalyptus* spp., *H. rosa-sinensis*, *Ipomoea mauritiana*, *Mentha piperita*, *Moringa oleifera, O. sanctum*, *P. emblica*, *P. granatum*, *Polycarpon prostratum*, *P. guajava*, *P. dactylifera, Solanum* spp., *S. pinnata*, *Swertia chirata*, *Syzygium* spp., *T. indica*, *Terminalia* spp., *Tinospora cordifolia*, *Zizyphus mauritiana*, and *Zingiber officinale*) are using by the CWS-dependent communities that could be favourably considered for the treatment of COVID-19 patients in Bangladesh.

Discussion

Medicinal plants for traditional healthcare practices

As shown in the present study's findings, the use of plant species indicated that local people had good ethnobotanical knowledge about the specific plants and plant parts to use for their daily healthcare purposes. Other studies in Bangladesh have found similar findings. For example, Faruque et al. (2018) listed 159 plants from 62 families in the hilly Bandarban District; Islam et al. (2014) documented 78 plants from 45 families in the Madhupur forest area; and Rahman and Roy (2014) found 43 invasive medicinal plant species belonging to 28 families in two forest-protected areas (FPAs). Similarly, Khan et al. (2011) recorded 39 invasive medicinal plants belonging to 29 families in two FPAs in north-eastern Bangladesh; Rahman et al. (2011b) listed 50 plant species from 42 families in Khadimnagar National Park; and Chowdhury and Koike (2010) recorded 44 plant species belonging to 28 families in Rema-Kalenga Wildlife Sanctuary. Similar to the present study's 50 tree species, Rahman and Hossain (2002) recorded 55 medicinal tree species from 26 families in CWS.

In addition, several similar studies conducted in protected areas in other parts of the world indicated the following: da Silva et al. (2019) documented 167 medicinal plant species in the Araripe National Forest of Brazil; de Brito et al. (2017) enlisted 71 local medicinal plant species in the Tambaba Environmental Protected Area of north-east Brazil; while Flavien et al. (2016) reported 195 medicinal plant species around a traditional protected area in the Democratic Republic of the Congo. Furthermore, Kala (2005) documented 60 threatened medicinal plant species in protected areas of the Indian Himalayas; Betti (2004) recorded 102 medicinal plants in Dja Biosphere Reserve in Cameroon; and Dzerefos and Witkowski (2001) reported 51 species in Abe Bailey Nature Reserve of South Africa. Moreover, Gumisiriza et al. (2019) recorded 211 medicinal plant species in southwestern Uganda; Umair et al. (2017) found 85 plants belonging to 34 families in Punjab in Pakistan; and Ahmad et al. (2016) recorded 217 plant species belonging to 69 families in different districts of Pakistan.

In the present study, survey data and field observation confirmed that older family members were knowledgeable and experienced in ethnomedicinal plant species (e.g., which species have which medicinal value and which species are used to treat which ailments), with these family members generally preparing the medicine for treating ailments. The survey also found that people shared plant parts and produced medicine with friends and neighbours, enabling everybody to easily meet their needs, especially when medicinal plant resources were scarce. Similar findings were also noticed by Chowdhury et al. (2009) and Rahman (2013) in rural areas of Bangladesh.

Quantitative importance of medicinal plants for traditional healthcare

The UV scores of plant species show the relative importance of medicinal plant species and plant families for a specific population (Islam et al. 2014; Umair et al. 2017; Faruque et al. 2018). In the present study, the species with high UV scores in CWS need specific medicinal plant conservation measures to maintain forest biodiversity. Similarly, the ethnomedicinal plant species with high RFC values indicate specific species that are widely distributed and easily accessible and plant species about which the communities have widespread knowledge (Umair et al. 2017; Faruque et al. 2018; Dixit and Tiwari 2020). Therefore, the medicinal plants with high UV scores and RFC values should be further evaluated for their phytochemically and phytopharmacologically important substances to identify their active constituents for discovering new drugs (Vitalini et al. 2009; Ahmad et al. 2016).

Furthermore, the ICF value calculation helped us identify homogeneity in the users' ethnobotanical evidence (Faruque et al. 2018). The higher the ICF value, higher the number of healthcare services provided by a specific species, with most species in our study scoring a higher ICF value (0.99). Islam et al. (2014) found a higher ICF value for mental disorders in central Bangladesh. Rahman and Roy (2014) found the highest ICF values for gastrointestinal disorders and respiratory complaints in northeastern Bangladesh. High ICF

values were found for sexual disorders and respiratory complaints by Rana et al. (2010) in Bangladesh. In north-eastern Bangladesh, Chowdhury and Koike (2010) found the highest ICF values for respiratory complaints, liver disorders, and urinary and rectal ailments. Other studies found higher ICF values for digestive disorders, general health and unspecified disorders in Uganda (Gumisiriza et al. 2019), and nervous system disorders and skin diseases in India (Dhakal et al. 2020).

As in the present study, other studies reported that more species were used to treat gastrointestinal diseases than other ailments (Chowdhury and Koike 2010; Kadir et al. 2012; Singh et al. 2012; Islam et al. 2014; Umair et al. 2017). Conversely, Faruque et al. (2018) recorded the second-highest number of species for the treatment of inflammation and pain; Chowdhury and Koike (2010) for treating respiratory complaints; and Rahman and Roy (2014) for the treatment of dermatological problems.

Sustainable harvesting, commercialisation and conservation of medicinal plants

The plant species diversity of CWS has been deteriorating day by day due to local people's significant dependency on daily resource collection for their livelihoods (Rahman et al. 2017a, b). From our FGDs and KIIs, the present study identified the following major problems for medicinal plant conservation in CWS: extensive plantations of exotic tree species, especially *Acacia* and *Eucalyptus* spp., with plantations inside the sanctuary; forest area encroached upon and slash-burned for betel leaf (*P. betle*) cultivation; overharvesting of important medicinal plants; lack of awareness-raising programs on medicinal plants; no recorded documentation of medicinal plants; no income-generating activity from medicinal plants; and no organised marketing channel for commercialisation of medicinal plants and herbal medicine products (Online Resource 4). Key informants stated that, although no restrictions have been placed on harvesting medicinal plants from the sanctuary for individual use, the Forest Department has placed restrictions on unsustainable harvesting for commercial purposes. The local Co-Management Committee through the volunteer Community Patrol Group (CPG) plays a significant role in guarding and monitoring forest resources.

In response to these problems, key informants advised that the Forest Department and NGOs had undertaken some initiatives, such as distributing seedlings of different medicinal and fruit tree species, such as *T. arjuna, P. emblica, T. chebula, T. belerica* and *C. papaya*; provided support for the cultivation of medicinal plants in homestead forests as well as inside the sanctuary; distributed seeds of different seasonal vegetables for immediate cash returns; and formed a committee through the Village Conservation Forum to protect these plantations. Moreover, the following suggestions, abridged from the FGD and KII input, could further improve the situation: massive plantations of native fruit trees and medicinal plant species on denuded and degraded hills; minimisation of the land tenure problem for tree plantations; controlling the overharvesting of important medicinal plant species; raising awareness about the curative value of medicinal plants, especially among the young generation; provision of financial aid, seedlings and training to develop nurseries for the conservation of medicinal plants; documentation of traditional and cultural beliefs of local communities on plant utilisation; and commercialisation of local medicinal plant resources, with linkages formed with the pharmaceutical industry (Online Resource 4).

Cultural and religious beliefs have a strong connection with plant species conservation, especially with the conservation of specific plant species believed to bring good health and fortune into people's lives (Anderson et al. 2005). For example, the *Mising* tribal community of Assam (India) uses 30 plant species for their religious purposes and the treatment of different ailments (Sharma and Pegu 2011). As in the present study's findings, Cartwright-Jones (2006) found that paste made from *L. inermis* leaves was popular as an integral part of weddings and other cultural and religious festivals in South Asia, the Middle East and Africa. Interestingly, Chowdhury et al. (2009) mentioned that young girls sometimes put blood from their fingers at the base of this plant when planting, hoping for its long life and darker leaf colour.

Phytochemical and phytopharmacological evaluation of medicinal plants

Bangladesh is suffering from the continual decline of medicinal plant availability from forest and non-forest sources, the decline in the number of traditional practitioners, the loss of their ethnomedicinal knowledge, and the lack of interest in knowledge transfer to the young generation. Several published studies in Bangladesh, such as Rahman et al. (2001), Ghani (2003), Mazumder and Rahman (2008), Rahmatullah et al. (2010), Kaisar et al. (2011), Haque et al. (2013), Islam et al. (2016), Ghosh et al. (2018), Mohiuddin (2019) and others, have discovered the lead compounds (phytochemical, phytopharmacological, biological, toxicological and other medicinal properties) of important medicinal plants in Bangladesh, which can lead to better drug preparation for healthcare purposes. These scientific studies have suggested that all the documented medicinal plant species in Bangladesh could be a promising source of new drug discovery to treat many ailments, with even a single species able to be used to treat multiple ailments. Therefore, medicinal plant species used for traditional healthcare in and around CWS should be evaluated for essential lead compounds, showing

economic, industrial and environmental importance of these species for ex-situ and in-situ conservation.

Role of ethnomedicine in COVID-19 treatment

Deng et al. (2020) recommended 'cheap kitchen medicine', such as *A. sativum*, *A. cepa*, *Cliteria ternatia, Morus alba, Solanum melongena* and *Z. officinale* to fight against COVID-19. Shawky et al. (2020) suggested the following medicinal plants such as *Anastatica hierochuntica*, *Cichorium intybus*, *Chrysanthemum coronarium*, *Epilobium hirsutum, Euphorbia* spp., *Glycyrrhiza glabra*, *Hibiscus sabdariffa*, *Nigella sativa* and *P. guajava* to mitigate COVID-19. Jahan and Onay (2020) documented more than 40 medicinal plants for possible treatment of COVID-19 such as *C. sinensis*, *C. annuum*, *Citrus spp.*, *C. longa*, *Mentha longifolia*, *Olea europaea*, *Phoenix hanceana*, *Eucalyptus* spp., etc.

Silveira et al. (2020) identified 39 herbal medicines among five species (i.e., *Althaea officinalis, Commiphora molmol, Glycyrrhiza glabra, Hedera helix and Sambucus nigra*) were found to have a positive effect on the COVID-19 patient; 10 species were found to be promising (*A. sativum, Andrographis paniculata, Echinacea angustifolia, Echinacea purpurea, Eucalyptus globulus, Justicia pectoralis, Magnolia officinalis, Pelargonium sidoides, Salix* sp. and *Z. officinale*), while the remainder were continuing to be tested.

A mixture of 11 medicinal plant species called *'Lianhuaqingwen'* was used in China for the COVID-19 treatment (Runfeng et al. 2020). Luo et al. (2020a, b) reported that *Astragalus mongholicus*, *Atractylodes lancea, A. macrocephala, Forsythia suspensa*, *Glycyrrhiza glabra*, *Lonicera japonica* and *Saposhnikovia divaricate* were found to be the most frequently used in China. Furthermore, Ang et al. (2020a) and Weng (2020) recorded the widely used medicinal plants in China: *Agastache rugosa*, *Alisma plantago-aquatica*, *Armeniacae semen, A. Amarum*, *Asarum sieboldii*, *Aster tataricus*, *A Rhizoma*, *A. macrocephala*, *Bupleurum chinense*, *Cinnamomum cassia*, *Citrus aurantium*, *Dioscorea polystachya*, *Ephedra sinica*, *Forsythiae fructus*, *Glycyrrhizae Radix* et Rhizoma (comprising 20 species of Fabaceae family), *Iris domestica*, Lepidii seu Descurainiae Semen (seeds of inauthentic plant species), *Pinellia ternate*, *Polyporus umbellatus*, *Prunus armeniaca*, *Radix scutellariae*, *Scutellaria baicalensis*, *Tussilago farfara* and *Wolfiporia extensa*.

Furthermore, the following medicinal plants have already been reported for the treatment and management of COVID-19 in previous studies and were found to be used for treating different ailments in CWS: *Achyranthes aspera*, *A. sativum*, *A. indica*, *C. longa*, *M. oleifera*, *P. guajava*, *Z. officinale* in Africa (Adeleye et al. 2021). *Adhatoda* spp., *A. sativum*, *A. indica*, *A. marmelos*, *B. ceiba*, *C. longa, Citurs* spp., and *Z. officinale* (Bachar et al. 2021) and *Calotropis gigantea* in Bangladesh (Dutta et al. 2021). *Allium cepa, A. sativum, A. indica, A. carambola, A. marmelos, C. asiatica, C. sativum, C. papaya, C. annuum, C. sinensis, Ficus religiosa, M. piperita, P. guajava, P. emblica, T. bellirica, Terminalia chebula, T. cordifolia, Syzygium cumini* and *Z. officinale* in Nepal (Khadka et al. 2021). *A. sativum, Citrus limon, C. sinensis, O. sanctum* and *Z. officinale* in Bangladesh (Ahmed et al. 2020). *A. Sativum, A. cepa, E. globulus, P. dactylifera* and *Z. officinale* in Morocco (El Alami et al. 2020). *C. limon, O. sanctum* and *Z. officinale* in Bangladesh (Azam et al. 2020). *A. cepa, A. comosus, A. indica, A. sativum, C. annuum, C. sativum, C. sinensis, M. piperita, O. sanctum, P. emblica, P. granatum, P. guajava, S. pinnata* and *Z. officinale* in Bangladesh (Islam et al. 2021). *A. cepa, A. sativum, A. paniculate, A. indica, C. sinensis, Cassia fistula, C. nucifera, C. longa, P. granatum, M. oleifera, O. sanctum, T. indica, T. chebula, T. cordifolia, Z. officinale* in Bangladesh (Shahriar et al. 2022). *A. sativum, E. globulus* and *Z. officinale* in Peru (Villena-Tejada et al. 2021). *A. cepa, A. sativum, A. comosus, C. sinensis, C. annuum, C. limon, C. nucifera, Colocasia esculenta, C. longa, Dalbergia sissoo, E. globulus, Ficus* spp., *M. indica, Mentha* spp., *M. cordata, M. oleifera, Musa* spp., *P. dactylifera*, *Syzygium* spp., and *Zingiber officinale,* etc. are common medicinal plants used in China, Italy, Spain, USA, Brazil, Jamaica, Bolivia, Romania, Belarus, Lithuania, Poland, Georgia, Turkey, Pakistan, Cambodia, and South Africa (Pieroni et al. 2020).

The above studies suggested that plant-based drugs could be used alone or in combination as alternative medicines to treat/prevent COVID-19. While these plants will not cure or prevent COVID-19, they may improve the well-being of patients, offering an opportunity to personalise the therapeutic approaches taken. However, standard clinical trials should be carried out to prove the efficacy of these medicinal plant species.

Conclusion

Our exhaustive survey of medicinal plants and traditional healthcare practices revealed that CWS-dependent communities rely exclusively on plant-based ethnomedicine for their daily healthcare purposes. The quantitative assessment indicates that each species has been used to treat multiple ailments. This study also proposes standard clinical trials by pharmaceutical companies to prove the efficacy of locally available medicinal plant species for treating COVID-19 patients in Bangladesh. The results suggest that community awareness of sustainable harvesting and cultivation at the homestead forests and commercial level could lead to sustainable conservation of these invaluable plant species for healthcare use, increased income and dietary quality of communities, and sustainable forest management by

involving them. The study findings can potentially lead to the development of new therapeutic uses and may represent novel bioresources for phytochemical and pharmacological studies. The preservation, propagation and conservation of vulnerable but commercially important plant species are further essential research areas. The collaboration between universities, research organisations, pharmaceutical companies and Forest Department could boost the country's medicinal plant production and use. Finally, medicinal plant conservation and sustainable forest management are essential for meeting the rural sustainable development in Bangladesh.

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Declarations

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

Ethical approval The survey and data collection permission were approved by the authority.

Consent to participate Verbal consent to participate in the survey was obtained from all respondents.

References

Adeleye OA, Femi-Oyewo MN, Bamiro OA, Bakre LG, Alabi A, Ashidi JS, Balogun-Agbaje OA, Hassan OM, Fakoya G (2021) Ethnomedicinal herbs in African traditional medicine with potential activity for the prevention, treatment, and management of Coronavirus Disease 2019. Future J Pharm Sci 7:72. https://doi.org/10.1186/s43094-021-00223-5

Ahmad M, Khan MPZ, Mukhtar A, Zafar M, Sultana S, Jahan S (2016) Ethnopharmacological survey on medicinal plants used in herbal drinks among the traditional communities of Pakistan. J Ethnopharmacol 184:154–186. https://doi.org/10.1016/j.jep.2016.02.039

Ahmed FU (2009) Production, processing and marketing of medicinal plants in Bangladesh. Arannayk Foundation, Dhaka

Ahmed ZU, Begum ZNT, Hassan MA, Khondker M, Kabir SMH, Ahmad M, Ahmed ATA, Rahman AKA, Haque EU (eds) (2008a) Encyclopaedia of flora and fauna of Bangladesh, volume 6. Angiosperms: Dicotyledons (Acanthaceae-Asteraceae). Asiatic Society of Bangladesh, Dhaka

Ahmed ZU, Hassan MA, Begum ZNT, Khondker M, Kabir SMH, Ahmad M, Ahmed ATA, Rahman AKA, Haque EU (eds) (2008b) Encyclopaedia of flora and fauna of Bangladesh, volume 12. Angiosperms: Monocotyledons (Orchidaceae-Zingiberaceae). Asiatic Society of Bangladesh, Dhaka

Ahmed ZU, Hassan MA, Begum ZNT, Khondker M, Kabir SMH, Ahmad M, Ahmed ATA, Rahman AKA, Haque EU (eds) (2008c) Encyclopaedia of flora and fauna of Bangladesh, volume 7. Angiosperms: Dicotyledons (Balsaminaceae-Euphorbiaceae). Asiatic Society of Bangladesh, Dhaka

Ahmed ZU, Hassan MA, Begum ZNT, Khondker M, Kabir SMH, Ahmad M, Ahmed ATA (eds) (2009) Encyclopaedia of flora and fauna of Bangladesh, volume 9. Angiosperms: Dicotyledons (Magnoliaceae-Ponicaceae). Asiatic Society of Bangladesh, Dhaka

Ahmed ZU, Hassan MA, Begum ZNT, Khondker M, Kabir SMH, Ahmad M, Ahmed ATA, Rahman AKA, Haque EU (eds) (2009) Encyclopaedia of flora and fauna of Bangladesh, volume 8. Angiosperms: Dicotyledons (Fabaceae-Lythraceae). Asiatic Society of Bangladesh, Dhaka

Ahmed ZU, Begum ZNT, Hassan MA, Khondker M, Kabir SMH, Ahmad M, Ahmed ATA, Rahman AKA, Haque EU (eds) (2009) Encyclopaedia of flora and fauna of Bangladesh: cumulative index volume-Flora, vol 13. Asiatic Society of Bangladesh, Dhaka

Ahmed ZU, Hassan MA, Begum ZNT, Khondker M, Kabir SMH, Ahmad M, Ahmed ATA (eds) (2010) Encyclopaedia of flora and fauna of Bangladesh, volume 10. Angiosperms: Dicotyledons (Ranunculaceae-Zygophyllaceae). Asiatic Society of Bangladesh, Dhaka

Ahmed I, Hasan M, Akter R, Sarkar BK, Rahman M, Sarker MS, Samad MA (2020) Behavioral preventive measures and the use of medicines and herbal products among the public in response to COVID-19 in Bangladesh: a cross-sectional study. PLoS One 15(12):e0243706. https://doi.org/10.1371/journal.pone.0243706

Alamgir ANM (2017) Therapeutic use of medicinal plants and their extracts: Volume 1 (Pharmacognosy). Springer, Berlin. https://doi.org/10.1007/978-3-319-63862-1

Anderson DM, Salick J, Moseley RK, Ou XK (2005) Conserving the sacred medicine mountains: a vegetation analysis of Tibetan sacred sites in Northwest Yunnan. Biodivers Conserv 14(13):3065–3091. https://doi.org/10.1007/s10531-004-0316-9

Ang L, Lee HW, Choi JY, Zhang J, Lee MS (2020a) Herbal medicine and pattern identification for treating COVID-19: a rapid review of guidelines. Integr Med Res 9:100407. https://doi.org/10.1016/j.imr.2020.100407

Ang L, Lee HW, Kim A, Lee MS (2020b) Herbal medicine for the management of COVID-19 during the medical observation period: a review of guidelines. Integr Med Res 9:100465. https://doi.org/10.1016/j.imr.2020.100465

Azam MNK, Mahamud RA, Hasan A, Jahan R, Rahmatullah M (2020) Some home remedies used for treatment of COVID-19 in Bangladesh. J Med Plants Stud 8(4):27–32

Bachar SC, Mazumder K, Bachar R, Aktar A, Al Mahtab M (2021) A review of medicinal plants with antiviral activity available in Bangladesh and mechanistic insight into their bioactive metabolites on SARS-CoV-2, HIV and HBV. Front Pharmacol 12:732891. https://doi.org/10.3389/fphar.2021.732891

Benarba B, Pandiella A (2020) Medicinal plants as sources of active molecules against COVID-19. Front Pharmacol 11:1189. https://doi.org/10.3389/fphar.2020.01189

Betti JL (2004) An ethnobotanical study of medicinal plants among the Baka Pygmies in the Dja Biosphere Reserve. Cameroon Afr Study Monogr 25(1):1–27. https://doi.org/10.14989/68229

BFD (2015) Management plan for Chunati Wildlife Sanctuary. Climate-Resilient Ecosystems and Livelihoods (CREL) Project. Bangladesh Forest Department, Dhaka

Bhuiyan FR, Howlader S, Raihan T, Hasan M (2020) Plants metabolites: possibility of natural therapeutics against the COVID-19 pandemic. Front Med 7:444. https://doi.org/10.3389/fmed.2020.00444

Bieski IGC, Leonti M, Arnason JT, Ferrier J, Rapinski M, Violante IMP et al (2015) Ethnobotanical study of medicinal plants by population of Valley of Juruena Region, Legal Amazon, Mato Grosso, Brazil. J Ethnopharmacol 173:383–423. https://doi.org/10.1016/j.jep.2015.07.025

Bregum F (2010) The present status of medicinal plants in Bangladesh. Iran J Pharm Res 3(Supplement 2):34–34. https://doi.org/10.22037/ijpr.2010.394

Cartwright-Jones C (2006) Developing guidelines on henna: a geographical approach. TapDancing Lizard Publishing, Ohio

CBD (Convention on Biological Diversity) (2010) Strategic plan for biodiversity 2011–2020, including Aichi Biodiversity Targets (https://www.cbd.int/sp/)

Chowdhury MSH, Koike M (2010) Therapeutic use of plants by local communities in and around Rema-Kalenga Wildlife Sanctuary: implications for protected area management in Bangladesh. Agrofor Syst 80:241–257. https://doi.org/10.1007/s10457-010-9316-9

Chowdhury MSH, Koike M, Muhammed N, Halim MA, Saha N, Kobayashi H (2009) Use of plants in healthcare: a traditional ethnomedicinal practice in rural areas of southeastern Bangladesh. Int J Biodivers Sci Ecosyst Serv Manag 5(1):41–51. https://doi.org/10.1080/17451590902771342

da Silva NF, Hanazaki N, Albuquerque UP, Campos JLA, Feitosa IS, Araújo EL (2019) Local knowledge and conservation priorities of medicinal plants near a protected area in Brazil. Evid Based Complement Alternat Med. https://doi.org/10.1155/2019/8275084

de Brito MFM, Marín EA, da Cruz DD (2017) Medicinal plants in rural settlements of a protected area in the litoral of northeast Brazil. Ambient Soc XX(1):83–104. https://doi.org/10.1590/1809-4422asoc20150034r2v2012017

De Luca V, Salim V, Atsumi SM, Yu F (2012) Mining the biodiversity of plants: a revolution in the making. Science 336(6089):1658–1661. https://doi.org/10.1126/science.1217410

Deng J, Hou X, Zhang T, Bai G, Hao E, Chu JJH, Wattanathorn J, Sirisa-ard P, Ee CS, Low J, Liu C (2020) Carry forward advantages of traditional medicines in prevention and control of outbreak of COVID 19 pandemic. Chin Herb Med 12:207–213. https://doi.org/10.1016/j.chmed.2020.05.003

Dhakal P, Chettri B, Lepcha S, Acharya BK (2020) Rich yet undocumented ethnozoological practices of socio-culturally diverse indigenous communities of Sikkim Himalaya. India J Ethnopharmacol 249:112386. https://doi.org/10.1016/j.jep.2019.112386

Dixit S, Tiwari S (2020) Investigation of anti-diabetic plants used among the ethnic communities of Kanpur division. India J Ethnopharmacol 253:112639. https://doi.org/10.1016/j.jep.2020.112639

Dutta M, Nezam M, Chowdhury S, Rakib A, Paul A, Sami SA, Uddin MZ, Rana MS, Hossain S, Effendi Y, Idroes R, Tallei T, Alqahtani AM, Emran TB (2021) Appraisals of the Bangladeshi medicinal plant *Calotropis gigantea* used by folk medicine practitioners in the management of COVID-19: a biochemical and computational approach. Front Mol Biosci 8:625391. https://doi.org/10.3389/fmolb.2021.625391

Dzerefos CM, Witkowski ETF (2001) Density and potential utilization of medicinal grassland plants from Abe Bailey Nature Reserve, South Africa. Biodivers Conserv 10:1875–1896. https://doi.org/10.1023/A:1013177628331

El Alami A, Fattah A, Chait A (2020) Medicinal plants used for the prevention purposes during the COVID-19 pandemic in Morocco. J Anal Sci Appl Biotechnol 2(1):4–11

Fakir MAL, Consultant NM, Banik H, Chowdhury RM (2015) Forest carbon inventory 2014 at eight protected areas in Bangladesh. Bangladesh Forest Department and Winrock International, Dhaka

FAO (Food and Agriculture Organization of the United Nations) (2010) State of the world's forests 2009. Rome, Italy

Faruque MO, Uddin SB, Barlow JW, Hu S, Dong S, Cai Q, Li X, Hu X (2018) Quantitative ethnobotany of medicinal plants used by indigenous communities in the Bandarban District of Bangladesh. Front Pharmacol 9:40. https://doi.org/10.3389/fphar.2018.00040

Flavien NB, Vanhove W, Termote C, Van PD (2016) Importance of traditional protected areas for the collection of medicinal plants, Kongo-Central (DRC). Afr J Ecol 54(4):479–487. https://doi.org/10.1111/aje.12307Ci

Ghani A (2003) Medicinal plants of Bangladesh with chemical constituents and uses. Asiatic Society of Bangladesh, Dhaka

Ghosh MK, Kumar A, Barman RK, Wahed MII (2018) Current status of phytochemical and phytopharmacological study of some medicinal plants used by the tribes in Bangladesh: a review. J Pharmacogn Phytochem 7(5):1089–1095

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) (2011) Baseline survey report for management of natural resources and community forestry in Chunati Wildlife Sanctuary project. Dhaka, Bangladesh

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) (2015) Final report of the final survey of indicators of "Management of Natural Resources and Community Forestry Project (MNRCF-Chunati)" in Chunati Wildlife Sanctuary (CWS), Chittagong, Bangladesh. Dhaka, Bangladesh

Gumisiriza H, Birungi G, Olet EA, Sesaazi CD (2019) Medicinal plant species used by local communities around Queen Elizabeth National Park, Maramagambo Central Forest Reserve and Ihimbo Central Forest Reserve, Southwestern Uganda. J Ethnopharmacol 239:111926. https://doi.org/10.1016/j.jep.2019.111926

Haque MM, Ahsan MA, Akbor MA, Rashid MM, Sultana N (2013) Phytochemical screening of some Bangladeshi medicinal plants. Bangladesh J Sci Ind Res 48(3):193–196

Heinrich M, Ankli A, Frei B, Weimann C, Sticher O (1998) Medicinal plants in Mexico: Healers' consensus and cultural importance. Soc Sci Med 47:1859–1871. https://doi.org/10.1016/S0277-9536(98)00181-6

Hoque ME (2009) Evaluating co-management as a tool for the reduction of poverty and inequality in Chunati Wildlife Sanctuary. In: Fox J, Mustafa MG, Quazi SA, Miles WB, Cunninghum EJ, Chassels M (eds) Connecting communities and conservation: collaborative management of protected areas in Bangladesh. Nishorgo Support Project, Bangladesh Forest Department, Dhaka, pp 227–246

Hossain MK, Hossain MA (2014) Biodiversity of Chunati Wildlife Sanctuary: Flora. Arannayk Foundation, Dhaka

Islam MK, Saha S, Mahmud I, Mohamad K, Awang K, Uddin SJ, Rahman MM, Shilpi JA (2014) An ethnobotanical study of medicinal plants used by tribal and native people of Madhupur forest area, Bangladesh. J Ethnopharmacol 151:921–930. https://doi.org/10.1016/j.jep.2013.11.056

Islam MT, Mamun MAA, Rahman MH, Rahman MA, Akter MM, Ashraf MS (2016) Qualitative and quantitative analysis of phytochemicals in some medicinal plants in Bangladesh. J Chem Biol Phys Sci A 6(2):530–540

Islam K, Nath TK, Jashimuddin M, Rahman MF (2019) Forest dependency, co-management and improvement of peoples' livelihood capital: evidence from Chunati Wildlife Sanctuary. Bangladesh Environ Dev 32:100456. https://doi.org/10.1016/j.envdev.2019.100456

Islam ATMR, Ferdousi J, Shahinozzaman M (2021) Previously published ethno-pharmacological reports reveal the potentiality of plants and plant-derived products used as traditional home remedies by Bangladeshi COVID-19 patients to combat SARS-CoV-2. Saudi J Biol Sci 28(11):6653–6673. https://doi.org/10.1016/j.sjbs.2021.07.036

Jahan I, Onay A (2020) Potentials of plant-based substance to inhabit and probable cure for the COVID-19. Turk J Biol 44:228–241. https://doi.org/10.3906/biy-2005-114

Jamshidi-Kia F, Lorigooini Z, Amini-Khoei H (2018) Medicinal plants: past history and future perspective. J HerbMed Pharmacol 7(1):1–7. https://doi.org/10.15171/jhp.2018.01

Kabir MJ (2013) Elephant habitat and human-elephant conflict: a case study in Chunati Wildlife Sanctuary. In: Fox J, Mustafa MG, Bushley BR, Brennan SM, Durand L (eds) Connecting communities and conservation: co-management initiatives implemented by IPAC in wetlands and forests of Bangladesh. Integrated Protected Area Co-management Project, Bangladesh Forest Department, Dhaka, pp 159–176

Kadir MF, Sayeed MSB, Mia M (2012) Ethnopharmacological survey of medicinal plants used by indigenous and tribal people in Rangamati, Bangladesh. J Ethnopharmacol 144:627–637. https://doi.org/10.1016/j.jep.2012.10.003

Kaisar MA, Rahman MS, Rahman MZ, Hasan CM, Rashid MA (2011) A review on phytochemicals from some medicinal plants of Bangladesh. J Pharm Nutr Sci 1:87–95

Kaky E, Gilbert F (2016) Using species distribution models to assess the importance of Egypt's protected areas for the conservation of medicinal plants. J Arid Environ 135:140–146. https://doi.org/10.1016/j.jaridenv.2016.09.001

Kala CP (2005) Indigenous uses, population density, and conservation of threatened medicinal plants in protected areas of the Indian Himalayas. Conserv Biol 19(2):368–378. http://www.jstor.org/stable/3591249.

Khadka D, Dhamala MK, Li F, Aryal PC, Magar PR, Bhatta S, Thakur MS, Basnet A, Cui D, Shi S (2021) The use of medicinal plants to prevent COVID-19 in Nepal. J Ethnobiol Ethnomed 17:26. https://doi.org/10.1186/s13002-021-00449-w

Khan MASA, Sultana F, Rahman MH, Roy B, Anik SI (2011) Status and ethnomedicinal usage of invasive plants in traditional healthcare practices: a case study from northeastern Bangladesh. J for Res 22(4):649–658. https://doi.org/10.1007/s11676-011-0174-8

Lee B-J, Lee JA, Kim K, Choi J-Y, Jung H-J (2020) A consensus guideline of herbal medicine for coronavirus disease 2019. Integr Med Res 9:100470. https://doi.org/10.1016/j.imr.2020.100470

Luo CH, Ma L, Liu H, Liao W, Chun XR, Zhi-Min C, Jun-Zhi L, Li H, Zhang D (2020a) Research progress on main symptoms of novel coronavirus pneumonia improved by traditional Chinese medicine. Front Pharmacol 11:556885. https://doi.org/10.3389/fphar.2020.556885

Luo H, Tang QL, Shang YX, Liang SB, Yang M, Robinson N, Liu J-P (2020b) Can Chinese medicine be used for prevention of Corona virus disease 2019 (COVID-19)? A review of historical classics, research evidence and current prevention programs. Chin J Integr Med 26(4):243–250. https://doi.org/10.1007/s11655-020-3192-6

Market Research Future (2018) Herbal medicine market report—forecast 2018–2023. WantStats Research and Media Pvt. Ltd., Maharashtra

Mazumder MEH, Rahman S (2008) Pharmacological evaluation of Bangladeshi medicinal plants for antioxidant activity. Pharm Biol 46(10–11):704–709. https://doi.org/10.1080/13880200802215735

Mitchell MGE, Schuster R, Jacob AL, Hanna DEL, Dallaire CO, Raudsepp-Hearne C, Bennett EM, Lehner B, Chan KMA (2021) Identifying key ecosystem service providing areas to inform national-scale conservation planning. Environ Res Lett 16:014038. https://doi.org/10.1088/1748-9326/abc121

Mohiuddin AK (2019) A brief review of traditional plants as sources of pharmacological interests. Open J Plant Sci 4(1):001–008. https://doi.org/10.17352/ojps.000015

Mollah AR, Rahman MM, Rahman MS (2004) Site-level field appraisal for protected area co-management: Chunati Wildlife Sanctuary. Nishorgo Support Project, Bangladesh Forest Department, Dhaka

Mollik MAH, Faruque MR, Badruddaza M, Chowdhury A, Rahman MS (2009) Medicinal plants from Sundarbans used for the prevention of cardiovascular diseases: a pragmatic randomized ethnobotanical survey in Khulna division of Bangladesh. Eur J Integr Med 1(4):231–232. https://doi.org/10.1016/j.eujim.2009.08.018

Motaleb MA, Khan NA (2012) Community-based conservation of medicinal plants and traditional herbal practice and knowledge: sharing a Bangladeshi experience. Int J for Usufructs Manag 13(2):53–65

Phillips O, Gentry AH, Reynel C, Wilkin P, Galvez-Durand BC (1994) Quantitative ethnobotany and Amazonian conservation. Conserv Biol 8(1):225–248. https://doi.org/10.1046/j.1523-1739.1994.08010225.x

Pieroni A, Vandebroek I, Prakofjewa J, Bussmann RW, Paniagua-Zambrana NY, Maroyi A, Torri L, Zocchi DM, Dam ATK, Khan SM, Ahmad H, Yeşil Y, Huish R, Pardo-de-Santayana M, Mocan A, Hu X, Boscolo O, Sõukand R (2020). Taming the pandemic? The importance of homemade plant-based foods and beverages as community responses to COVID-19. J Ethnobiol Ethnomed 16:75. https://doi.org/10.1186/s13002-020-004269

Rahman MH (2013) A study on exploration of ethnobotanical knowledge of rural community in Bangladesh: basis for biodiversity conservation. ISRN Biodivers. https://doi.org/10.1155/2013/369138

Rahman ML, Hossain MK (2002) Distribution pattern of medicinal tree species in Chunati Wildlife Sanctuary of Chittagong. Trop J Med Plants 3(1):65–72

Rahman MH, Roy B (2014) Population structure and curative uses of invasive plants in and around the protected forests of Bangladesh: a means of utilization of potential invasive species. J Ecosyst. https://doi.org/10.1155/2014/249807

Rahman S, Hasnat A, Hasan CM, Rashid MA, Ilias M (2001) Pharmacological evaluation of Bangladeshi medicinal plants—a review. Pharm Biol 39(1):1–6. https://doi.org/10.1076/phbi.39.1.1.5939

Rahman MH, Fardusi MJ, Reza MS (2011a) Traditional knowledge and use of medicinal plants by the *Patra* tribe community in the north-eastern region of Bangladesh. Proc Pak Acad Sci 48(3):159–167

Rahman MH, Rahman M, Islam MM, Reza MS (2011b) The importance of forests to protect medicinal plants: a case study of Khadimnagar National Park, Bangladesh. Int J Biodivers Sci Ecosyst Serv Manag 7(4):283–294. https://doi.org/10.1080/21513732.2011.645071

Rahman MM, Mahmud MAA, Ahmed FU (2017a) Restoration of degraded forest ecosystem through non-forestry livelihood supports: experience from the Chunati Wildlife Sanctuary in Bangladesh. For Sci Tech 13:109–115. https://doi.org/10.1080/21580103.2017.1349003

Rahman MM, Mahmud MAA, Ahmed FU, Deb R (2017b) Developing alternative income generation activities reduces forest dependency of the poor and enhances their livelihoods: the case of the Chunati Wildlife Sanctuary. Bangladesh for Trees Livelihoods 26(4):256–270. https://doi.org/10.1080/14728028.2017.1320590

Rahmatullah M, Rahman MA, Hossan MS, Taufiq-Ur-Rahman M, Jahan R, Mollik MAH (2010) A pharmacological and phytochemical evaluation of medicinal plants used by the Harbang Clan of the Tripura tribal community of Mirsharai area,

Chittagong District. Bangladesh J Altern Complement Med 16(7):769–785. https://doi.org/10.1089/acm.2009.0497
Rana MP, Sohel MSI, Akhter S, Islam MJ (2010) Ethnomedicinal plants use by the Manipuri tribal community in Bangladesh. J for Res 21(1):85–92. https://doi.org/10.1007/s11676-010-0015-1
Runfeng L, Yunlong H, Jicheng H, Weiqi P, Qinhai M, Yongxia S, Chufang L, Jin Z, Zhenhua J, Haiming J, Kui Z, Shuxiang H, Jun D, Xiaobo L, Xiaotao H, Lin W, Nanshan Z, Zifeng Y (2020) Lianhuaqingwen exerts anti-viral and anti-inflammatory activity against novel coronavirus (SARS-CoV-2). Pharmacol Res 156:104761. https://doi.org/10.1016/j.phrs.2020.104761
Sarker AHMR, Røskaft E (2010) Human–wildlife conflicts and management options in Bangladesh, with special reference to Asian elephants (*Elephas maximus*). Int J Biodivers Sci Ecosyst Serv Manag 6(3–4):164–175. https://doi.org/10.1080/21513732.2011.554867
Shahidullah AKM, Haque CE (2010) Linking medicinal plant production with livelihood enhancement in Bangladesh: implications of a vertically integrated value chain. J Transdiscipl Environ Stud 9(2):1–18
Shahriar S, Sarker MMR, Soma MA, Jannat T, Mina ST, Rahman R, Rahman MS, Rashid MA (2022) Potential of prospective medicinal plants of Bangladesh for the complementary management of COVID-19. Bangladesh Pharma J 25(1):89–114. https://doi.org/10.3329/bpj.v25i1.57845
Sharma UK, Pegu S (2011) Ethnobotany of religious and supernatural beliefs of the Mising tribes of Assam with special reference to the 'Dobur Uie.' J Ethnobiol Ethnomed 7:16. https://doi.org/10.1186/1746-4269-7-16
Shawky E, Nada AA, Ibrahim RS (2020) Potential role of medicinal plants and their constituents in the mitigation of SARS-CoV-2: identifying related therapeutic targets using network pharmacology and molecular docking analyses. RSC Adv 10:27961. https://doi.org/10.1039/D0RA05126H
Siddiqui KU, Islam MA, Ahmed ZU, Begum ZNT, Hassan MA, Khondker M, Rahman MM, Kabir SMH, Ahmad M, Ahmed ATA, Rahman AKA, Haque EU (eds) (2007) Encyclopaedia of flora and fauna of Bangladesh, volume 11: angiosperms: Monocotyledons (Agavaceae-Najadaceae). Asiatic Society of Bangladesh, Dhaka
Siddiqui KU, Islam MA, Ahmed ZU, Begum ZNT, Hassan MA, Khondker M, Rahman MM, Kabir SMH, Ahmad M, Ahmed ATA, Rahman AKA, Haque EU (eds) (2008) Encyclopaedia of flora and fauna of Bangladesh, volume 5: bryophytes, pteridophytes, gymnosperm. Asiatic Society of Bangladesh, Dhaka
Silveira D, Prieto-Garcia JM, Boylan F, Estrada O, Fonseca-Bazzo YM, Jamal CM, Magalhães PO, Oliveira E, Tomczyk M, Heinrich M (2020) COVID-19: is there evidence for the use of herbal medicines as adjuvant symptomatic therapy? Front Pharmacol 11:581840. https://doi.org/10.3389/fphar.2020.581840
Singh AG, Kumar A, Tewari DD (2012) An ethnobotanical survey of medicinal plants used in Terai forest of western Nepal. J Ethnobiol Ethnomed 8:19. https://doi.org/10.1186/1746-4269-8-19
Tamima U (2016) Performance evaluation of forest co-management: a case study of Chunati Wildlife Sanctuary, Bangladesh. J for Res 27:853–861. https://doi.org/10.1007/s11676-015-0198-6
Tardío J, Pardo-De-Santayana M (2008) Cultural importance indices: a comparative analysis based on the useful wild plants of Southern Cantabria (Northern Spain). Econ Bot 62(1):24–39. https://doi.org/10.1007/s12231-007-9004-5
Umair M, Altaf M, Abbasi AM (2017) An ethnobotanical survey of indigenous medicinal plants in Hafizabad district, Punjab-Pakistan. PLoS One 12(6):e0177912. https://doi.org/10.1371/journal.pone.0177912
Vandebroek I, Pieroni A, Stepp JR, Hanazaki N, Ladio A, Alves RRN, Picking D, Delgoda R, Maroyi A, van Andel T, Quave CL, Paniagua-Zambrana NY, Bussmann RW, Odonne G, Abbasi AM, Albuquerque UP, Baker J, Kutz S, Timsina S, Shigeta M, Oliveira TPR, Hurrell JA, Arenas PM, Puentes JP, Hugé J, Yeşil Y, Pierre LJ, Olango TM, Dahdouh-Guebas F (2020) Reshaping the future of ethnobiology research after the COVID-19 pandemic. Nat Plants 6:723–730. https://doi.org/10.1038/s41477-020-0691-6
Vardanjani HM, Heydari ST, Dowran B, Pasalar M (2020) A cross-sectional study of Persian medicine and the COVID-19 pandemic in Iran: rumors and recommendations. Integr Med Res 9:100482. https://doi.org/10.1016/j.imr.2020.100482
Villena-Tejada M, Vera-Ferchau I, Cardona-Rivero A, Zamalloa-Cornejo R, Quispe- Florez M, Frisancho-Triveño Z, Abarca-Meléndez RC, Alvarez-Sucari SG, Mejia CR, Yañez JA (2021). Use of medicinal plants for COVID-19 prevention and respiratory symptom treatment during the pandemic in Cusco, Peru: a cross sectional survey. PLoS ONE 16(9):e0257165. https://doi.org/10.1371/journal.pone.0257165
Vitalini S, Tomè F, Fico G (2009) Traditional uses of medicinal plants in Valvestino (Italy). J Ethnopharmacol 121:106–116. https://doi.org/10.1016/j.jep.2008.10.005
Weng J-K (2020) Plant solutions for the COVID-19 pandemic and beyond: historical reflections and future perspectives. Mol Plant 13:803–807. https://doi.org/10.1016/j.molp.2020.05.014
WHO (World Health Organization) (2005) Ecosystems and human well-being: Health synthesis: a report of the Millennium Ecosystem Assessment. WHO, Geneva
WHO (World Health Organization) (2022) WHO Coronavirus (COVID-19) dashboard. https://covid19.who.int/
Zhou Z, Gao N, Meng WY, Chang P, Tong Y, Fu S (2020) Clinical studies on the treatment of novel coronavirus pneumonia with traditional Chinese medicine—a literature analysis. Front Pharmacol 11:560448. https://doi.org/10.3389/fphar.2020.560448
Zhuang W, Fan Z, Chu Y, Wang H, Yang Y, Wu L, Sun N, Sun G, Shen Y, Lin X, Guo G, Xi S (2020) Chinese patent medicines in the treatment of Coronavirus Disease 2019 (COVID-19) in China. Front Pharmacol 11:1066. https://doi.org/10.3389/fphar.2020.01066

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