Journal of Medicinal Plants Studies

www.PlantsJournal.com

ISSN (E): 2320-3862
ISSN (P): 2394-0530
www.plantsjournal.com
JMPS 2022; 10(1): 98-106

Received: 09-11-2021
Accepted: 13-12-2021

Authors Details Given Below

Availability of medicinal forest plant species used as adjuvant in COVID-19 treatment in the periphery of the Deng-Deng forest, Cameroon

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DOI: https://doi.org/10.22271/plants.2022.v10.i1b.1367

Abstract

Since the advent of the Coronavirus pandemic (COVID-19) in 2019, medicinal forest plant species (MFPS) have played a primordial role as an adjuvant in the treatment/prevention of this pandemic. Today, the availability of MFPS could be adversely impacted in the future due to high demand. It was within this backdrop that this study assessed the current status of the main MFPS used by local people against COVID-19 symptoms in Deng-Deng forest community in Cameroon. The methodological approach involved the administration of questionnaires to 405 respondents including naturopaths, healers and heads of households; and botanical inventories of the main MFPS in transects of 2000mx20m (40ha). For 40% of the respondents, the demand for MFPS has increased since the advent of COVID-19; with 16% of the respondents affirming that the availability of MFPS has reduced. For 60%, the availability of MFPS would decrease in the near future. Total density of the 12 main MFPS was 30.14±2.86 stems/ha in 8 land forest cover types found. Understanding these medicinal adjuvant plant species variation is a crucial step in achieving their sustainable management.

Keywords: COVID-19, Availability, Medicinal plant species, Sustainable management, Land cover type, Deng-Deng forest; Cameroon

Introduction

COVID-19 was detected for the first time in Wuhan – China in December 2019 and as of 5th December 2021, there has been nearly 265 million confirmed cases and over 5.2 million deaths globally [1]. COVID-19 is caused by the SARS-CoV-2 virus [1]. Cold, fever, cough, difficulty in breathing and tiredness are some of the most common symptoms [2-4]. It continuous to spread worldwide; and causing death and panic in many countries [5]. Since it outbreak, approved drugs are still lacking and the world is seeking effective treatment; nevertheless, some vaccines (e.g. SINOPHRAM, Astrazeneca, Pfizer, Johnson & Johnson) are available today. However, none of them guarantees an absolute protection against COVID-19 due to the current emergence of different strains of SARS-CoV-2 virus like Omicron. This explains why in many countries especially in lower incomes countries traditional medicine is preferred by local people to guard against this pandemic. Seeing that it has no secondary effects, easily accessible and also these traditional drugs contribute to boost the immune system [6].

Traditional medicine is used by 80% of the world's population and most rely on natural plant products for their health [6]. Its efficiency is unquestionable as far as treating COVID-19 is concerned and this has been supported by the WHO which has welcomed traditional medicine in its strategy to fight the pandemic [7]. Internationally, some traditional medicine was put in place as adjuvants for the treatment of COVID-19. This was the case of COVID-Organics (CVO) of Madagascar. In the same vein, the Ministry in charge of Health in Cameroon gave the go ahead for the commercialization over the national territory of four validated improved

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traditional medicinal therapies used as adjuvant for the treatment of COVID-19. These traditional remedies were put together by independent researchers and naturopaths working in the area of medicinal plant research.

Traditional medicinal therapies require raw biological material (e.g. barks, leaves, root of trees etc.) for which the habitat is essentially the forest [4]. Since the turn of the new millennium, forests provide several goods and ecosystem services that are essential to the wellbeing of rural households in developing countries, especially for people living in and around the forests [8]. Taking the case of Deng-Deng forest area where this study was undertaken, [9] found that it is very rich in biological diversity. Since the advent of the COVID-19 pandemic and the long duration being taken for its complete control and eradication, there is inevitably high demand for medicinal plants capable of treating the disease, which may pose a long term threat to the survival of these plants as the stems and barks of these medicinal tree species are being harvested at an alarming rate. Taking for example the case of Cameroon, the level of exploitation of medicinal plants used against COVID-19 symptoms have increased and also with the approved medicinal plants in Cameroon, the collection of raw biological material which in most cases was unsustainable will increase. It is therefore important to evaluate the current status of availability of MFPS in the areas where medicinal plants play a primordial role like the communities in and around the Deng-Deng forest.

In a study carried out on the Deng-Deng forest, [4] focusing on the most common symptoms of COVID-19, identified 46 medicinal plants with 12 of them being the main medicinal forest plant species (MFPS) according to frequency of citation. Presently, based on the fact that local people are mainly using traditional medicine to cure various disease symptoms including COVID-19 symptoms such as fever, headache, cough, diarrhea, and nasal discharge [4], the question of current availability of these plant species remains pressing especially when we seek to conserve these MFPS for the future. Information on their distribution is a crucial step in enhancing their conservation and sustainable use [10]. This study aims to: (1) assess the perception of local population on the current and future status of availability of medicinal plant species used by the local people against COVID-19 symptoms; and (2) assess the density of stems of medicinal plants used as adjuvant against COVID-19 by communities in and around the Deng-Deng national park.

Material and methods

Study area

This study was carried out from April to August 2021 in the Deng-Deng forest more precisely in the periphery of the Deng-Deng National Park (DDNP) located in the East Region of Cameroon. The average altitude of the study area varies between 600 to 800 m and it is characterized by the presence of several low-lying areas and few hills. The climate in this area is typically the Equatorial Guinean, with four unevenly distributed seasons: a short dry season from July to August, a long dry season from mid-October to mid-March, a long rainy season from mid-March to June and finally a short rainy season from September to mid-October. The average rainfall is 1600 mm/year and average annual temperature varies between 23 °C and 25 °C. The hydrographic network is very dense and characterized by the presence of several tributaries. The soils are essentially lateritic with some hydrographic soil found especially in swamp areas and flood plains. The vegetation is the semi-deciduous moist forest with dominance of Cannabaceae and Malvaceae [11]. According to [11], the vegetation belongs phytogeographicaly to the Guinean-Congolese domain. The main activities are logging, shifting cultivation, poaching and the collection of non-timber forest products (NTFPs). These common activities contribute to the degradation of the periphery of DDNP. For the local people living around the DDNP, traditional medicine is the main form of medicine used for the treatment of ailments [4].

Data collection

The methodological approach included surveys in communities in and around the DDNP and a botanical inventory in this forest area starting in Mbaki 1 which is the community closest to DDNP (Figure 1).

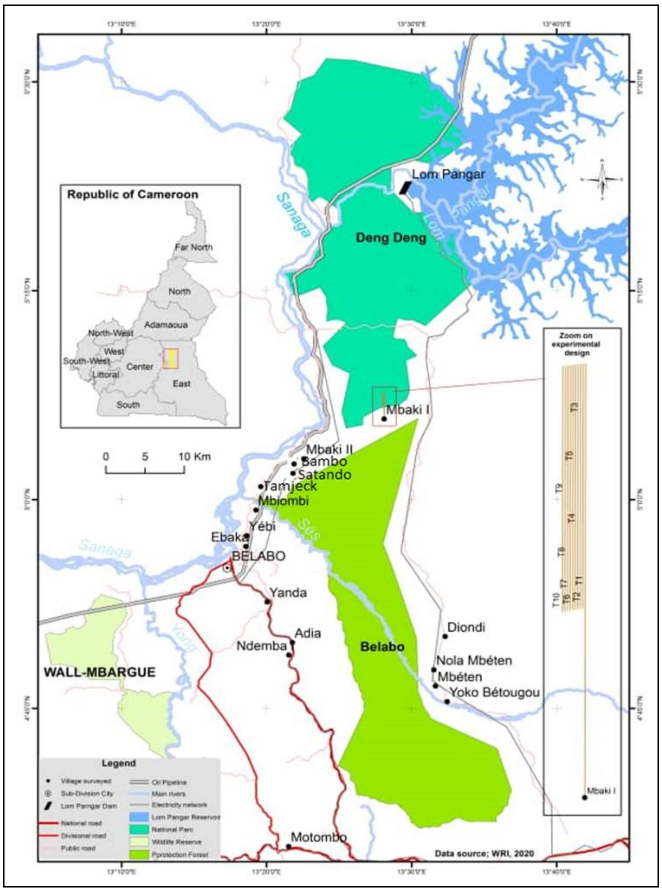

Fig 1: Map of study area and sampling design for botanical inventory

Ethnobotanical Surveys

Concerning the survey approach, it was done through the administration of questionnaires to 405 households in 22 villages surrounding the Deng-Deng forest massif (see some surveys village in figure 1). Questionnaires were administered to respondents made up of healers, naturopaths, and heads of households (men and/or women) who use traditional medicine to treat members of their household, relatives and non-family members. These questionnaire was framed to examine their perceptions of the availability of MFPS used against COVID-19 symptoms; with emphasis on: the parts use of different species, the actual level of availability, the current level of demand compared to the time before COVID-19, the future trend (in the next 5 years) of availability.

Botanical inventory

Botanical inventory concerned the 12 main MFPS in DDNP. These were the most used by the local people of Deng-Deng massif forest against COVID-19 as reported in the same study area by [4], and for which the citation frequency was ≥10%. These plant species in decreasing order according to their frequency citation were: *Alstonia boonei, Annickia chlorantha, Picralima nitida, Pycnanthus angolensis, Milicia excelsa, Trichoscypha acuminate, Voacanga africana, Musanga cecropioides, Myrianthus arboreus, Garcinia kola, Allanblackia floribunda* and *Rauvolfia vomitoria.*

Mbaki 1 village was chosen as the transect base line (see figure 1) because it is the closest village to the DDNP and where medicinal plants are predominant. The Botanical inventory was done in the DDNP and followed the centrifugal orientation from periphery to the center of the forest. As recommended by [10], 10 linear transects of 2000 m x 20 m each were established for a total transect surface area of 40 hectares. Then, on each transect, all Land Forest Covers Type (LFCT) present were recorded with the help of GPS, where the start and end point of each were collected and helped us to estimate the total length/area of each LFCT identified within the 40 ha area. Concerning the target MFPS, the stems density of all individual target species with diameter ≥10 cm were collected for each LFCT. According to [10], the land cover type identified in the context of this study can be considered as a habitat of these medicinal plant species sampled.

Data analysis

Data were imputed into Excel where ethnobotanical data were used to compute percentages. For each land cover type and for each transect, the proportion and total area were obtained by calculating the ratio of the transect area occupied by each land cover type to the total area. Area correspond to the length of one transect multiplied by 20 m.

For density of each target plant species in each land cover type, the following formulae was used:

$D = \frac{n_i}{S}$; where: D = stems density (ha); ni = number of individuals of each target species in each land cover type; S = total sampling area.

R software was used for statistical data analysis. With data that follow a normal distribution, parametric test like analysis of variance (ANOVA) and Turkeys test were performed to examine whether target species densities varied according to land cover type and target MFPS.

Results

The respondents living around the Deng-Deng forest were 71% male; 71% of them were over 30 years old and 80% of them were married. Regarding the level of education, 20% had no schooling, 59% and 20% had primary and secondary schooling respectively; only 1% had higher education. 94% of the respondents had acquired knowledge of traditional medicine from their parents (inheritance); 6% had trained with naturopaths or healers in the village.

Perceptions of local people on the target medicinal plant species level.

Here we appreciated the perceptions of households living around the Deng-Deng forest concerning the availability of MFPS used as adjuvant in the treatment/prevention of COVID-19 symptoms. 45% of the respondents perceived that, MFPS used to take care of COVID-19 symptoms are available (current status); however, 19% of respondents perceived that MFPS are currently disappearing. 18% and 18%, respectively of the respondents perceived that these MFPS are threatened and rare in the study area. Even though 67% of the respondents perceived that MFPS are available (i.e. concerning the current quantity), 49% perceive that, the demand of these plant species remain low; while 39% perceive that their demand has increased. Nevertheless, 30% of respondents perceived that the rate of use of MFPS remains low in spite of the COVID-19 pandemic; whereas, 19% and 51% perceived that it is high and constant, respectively. Concerning respondents' perception of the future trend of the availability of MFPS, 60% perceive that it will be decrease, while 30% and 10% perceive that it will remain constant and increase, respectively (Table 1).

Table 1: Respondents' perception of the availability and future trend of medicinal forest plant species used in the treatment/prevention COVID-19

1. What is the current status of medicinal forest plants used in your locality against COVID-19 treatment/prevention?			
Available	Disappearing	threatened	Rare
45%	18%	18%	19%
2. How do you find the demand for medicinal forest plant species used in COVID-19 treatment/prevention in your locality?			
Very low	Low	High	Very high
10%	49%	39%	1%
3. How do you assess the quantity of medicinal forest plant species used in COVID-19 treatment/prevention in your locality?			
Not available	less available	available	highly available
1%	16%	67%	16%
4. What do you think of the rate of use of medicinal forest plant species used in the treatment/prevention COVID-19 in your locality in the midst of the COVID-19 pandemic compared to the past?			
Constant	Low	high	
51%	30%	19%	
5. What do you think will happen to the medicinal forest plant species used in the treatment/prevention COVID-19 in your locality in the near future (in the next 5 years)?			
Constant	Increasing	decreasing	
30%	10%	60%	

In terms of the parts of medicinal plants used, the results obtained indicated that the bark is the principal part used of all these main MFPS collected. For 67% (8 species) of these MFPS, only the bark is the part collected. Bark+seed (*Garcinia kola*), bark+sap (*Milicia excelsa*), bark+fruit (*Picralima nitida*) and bark+leaf (*Rauvolfia vomitoria*) represent each 8% (one species each). 17% (2 species: *G. kola* and *A. floribunda*) of these MPFS are threatened according to the red list of the IUCN (Table 2).

Table 2: Medicinal plant species sampled and parts used

Target plant species	Family	IUCN status	Part used	Authors who have confirmed medicinal properties of these MFPS
Alstonia boonei De Wild.	Apocynaceae	LC	Bark	[3, 12, 13, 14, 15]
Annickia chlorantha (Oliv.) Setten & Maas	Annonaceae	LC	Bark	[14, 15, 16]
Picralima nitida (Stapf) Th. & H. Durand	Apocynaceae	LC	Bark, fruit	[2, 3, 14, 15, 17]
Pycnanthus angolensis (Welw.) Exell	Myristicaceae	LC	Bark	[14, 15]
Milicia excelsa (Welw.) C.C. Berg	Moraceae	LC	Bark, sap	[14, 15, 18]
Trichoscypha acuminata Engl.	Anacardiaceae	LC	Bark	[14, 15]
Voacanga africana Stapf ex Scott-Elliot	Apocynaceae	LC	Bark	[19]
Musanga cecropioides R. Br. apud Tedlie	Urticaceae	LC	Bark	[15]
Myrianthus arboreus Beauv.	Urticaceae	LC	Bark	-
Garcinia kola Heckel	Clusiaceae	Vu	Bark, seed	[3, 12, 18, 20]
Allanblackia floribunda Oliv.	Clusiaceae	Vu	Bark	[21]
Rauvolfia vomitoria Afzel.	Apocynaceae	LC	Bark, leaves	[19]

Land cover type diversity identified

Out of the 8 LFCT identified in the 40 ha transect, the MFPS were found in 7 of them. The Old Secondary Forest (OSF) was the most LFCT identified which represent 83.8% (33.2 ha out of the 40 ha); it is followed by Young Secondary Forest (YSF) with 8% (3.2 ha). The Periodically Flooded Swamps (PFS), Old Fallows (OF), shrub savannah (SA), young Fallow (YF), Agroforest (AF) and Raphia swamps (RSW) represent 5%(2 ha), 1.6% (0.6 ha), 1.3% (0.5 ha), 0.5% (0.2 ha), 0.4% (0.2ha) and 0.2% (0.1 ha), respectively (Table 3).

Table 3: Diversity of land cover type types in the transect

Land forest cover type (LCFT)	Distance (m)	Area (m²)	Area (ha)	Percentage (%)
Old Secondary Forest (OSF)	16619	332380	33.2	83.8
Young Secondary Forest (YSF)	1603	32060	3.2	8.0
Periodically Flooded Swamps (PFS)	994	19880	2.0	5,0
Old Fallows (OFA),	314	6280	0.6	1,6
shrubs' savannah (SAV),	260	5200	0.5	1,3
young Fallow (YFA),	100	2000	0.2	0,5
Agroforest (AFO)	80	1600	0.2	0,4
Raphia swamps (RSW)	30	600	0.1	0,2
Total area sampled	20000	400000	40	100

Stems density of target MFPS by LFCT

The results showed major differences in stem densities of main target species used by the local population of the DDNP against COVID-19 symptoms across LFCT (Table 3). In the context of this study, LFCT are considered as the habitat of these plant species. Then, for the 12 forest plant species, the average stem densities are evaluated at 30.14±2.86 stem/ha, and OSF were the LFCT with highest stem density and RSW with low stem densities. AFO, YFA and RSW were the LFCT with less than 1 stem/ha. None of these species were found in shrubs savannah. With respect to the priority of species according to citation frequency [4], results concerning stem density of each species are presented in Table 4.

Alstonia boonei which is the most used MFPS against COVID-19 symptoms, with an average stems density of 1.88±0.90 stem/ha, was found in 5 LFCT. The highest number of individual stems of *A. booneii* was found in OSF (1.55 stem/ha). In other LFCT (YSF, YFA, OFA, PFS) it was found that stems density was lower than 1 stem/ha.

Annickia chlorantha with stem densities of 4.58±1.60 stem/ha was found in 4 LFCT. It was not found in fallow (YFA and OFA) and RSW. The highest stems density of *A. chlorantha* were found in OSF (4.28 stem/ha), and 0.3 stem/ha were found in the 3 other LFCT (AFO, YSF and OFS).

Picralima nitida with a stem density of 0.93±0.31stem/ha, were the most concentrated in OSF (0.83 stem/ha). This plant species was only found in AFO, OSF and YSF.

Pycnanthus angolensis was found in all LFCT except in fallow (YFA and OFA) and RSW. It was the species which had the highest stem density in the study area estimated at an average of 8.45±2.23 stem/ha. *P. angolensis* was higher in OSF with a density of 4.83 stem/ha than the 3 other LFCT (AFO, YSF and PFS) which had a density less than 1 stem/ha.

Milicia excelsa was found only in OSF and YSF with average stem densities of 0.05 and 0.03, respectively. The average stem densities of *M. excelsa* was 0.08±0.02 stem/ha.

Trichoscypha acuminata was found in 3 LFCT (OSF, YSF and PFS). The average stems density was 1.20±0.42 stem/ha.

Voacanga africana with an average stem density of 0.88±0.28 stems/ha, was found only in OSF and YSF.

Musanga cecropioides was found in all the LFCT except in AFO. The highest stem densities were found in OSF and YSF with 5.43 and 1.43 stem/ha, respectively. The average stem density was 8.45±1.99 stems/ha.

Myrianthus arboreus was found in 4 LFCT. The highest stem density was found in OSF with 2.15 stems/ha and the lowest density in YSF and RSW. The average stem density of *M. arboreus* in the study area was 2.33±0.80 stems/ha.

Garcinia kola was found only in 2 OFS with mean stems densities of 0.48 and 0.03 stem/ha respectively. The average stems densities of *G. kola* is 0.51±0.18 stems/ha

Rauvolfia vomitoria was found in 4 LFCT. It was not found in AFO, YFA and RSW. Its average stem density was 0.60±0.16 stems/ha and was more concentrated in OSF (0.43 stems/ha).

Allanblackia floribunda was found only in OSF and YSF with mean stem density of 0.23 and 0.05 stems/ha, respectively. The average stems density of *A. floribunda* is 0.28±0.08 stems/ha.

Table 4: Stem density of medicinal plant species in relation to land cover type

Species (main MFPS)	AFO	OSF	YSF	YFA	PFS	RSW	OFA	Total density
Allanblackia floribunda	0.00	0.23	0.05	0.00	0.00	0.00	0.00	0.28±0.08 c
Alstonia boonei	0.00	1.55	0.15	0.05	0.10	0.00	0.03	1.88±0.57 bc
Annickia chlorantha	0.05	4.28	0.20	0.00	0.05	0.00	0.00	4.58±1.60 ab
Garcinia kola	0.00	0.48	0.00	0.00	0.03	0.00	0.00	0.51±0.18 c
Milicia excelsa	0.00	0.05	0.03	0.00	0.00	0.00	0.00	0.08±0.02 c
Musanga cecropioides	0.00	5.43	1.43	0.10	0.28	0.03	1.20	8.45±1.99 a
Myrianthus arboreus	0.00	2.15	0.03	0.00	0.13	0.03	0.00	2.33±0.80 b
Picralima nitida	0.05	0.83	0.05	0.00	0.00	0.00	0.00	0.93±0.31c
Pycnanthus angolensis	0.05	7.60	0.23	0.00	0.58	0.00	0.00	8.45±2.83 a
Rauvolfia vomitoria	0.00	0.43	0.13	0.00	0.03	0.00	0.03	0.60±0.16 c
Trichoscypha acuminata	0.00	1.13	0.03	0.00	0.05	0.00	0.00	1.20±0.42 bc
Voacanga africana	0.00	0.75	0.13	0.00	0.00	0.00	0.00	0.88±0.28 bc
Total density	0.15±0.02c	24.88±2.41a	2.43±0.39 b	0.15±0.03 c	1.23±0.17 bc	0.05±0.01 c	1.25±0.06 c	30.14±2.86

Discussion

Cameroon's strategy to improve the contribution of forests in poverty alleviation lays emphasis on the development of solutions required to improve the livelihood of forest dependent communities while ensuring forest conservation and sustainable management. It is why in this study, focused on DDNP, we firstly analyze the perception of local people on the current and future availability of MFPS used in the treatment of COVID-19 symptoms; and secondly undertake a botanical inventory of the target MFPS considering the lacuna of knowledge with respect to their distribution, population status; and the poor policy to manage them.

Local people's perception regarding availability of medicinal plants used for COVID-19 treatment

For the future trend, local people living in and around the Deng-Deng forest massif believe that according to the current demand for MFPS (perceived by 39% as high) used for the treatment of COVID-19, the availability will decrease in the next 5 years (reported by 60% of respondents). Although some respondents reported the sustainable exploitation of these MFPS, the real problem lies elsewhere; and these include illegal logging, conversion of forest areas to agricultural land and non-ecological collection method [3, 9, 22]. This is for example the case of species like *Alstonia boonei*, *Milicia excelsa* and *Pycnanthus angolensis*, for which despite their medicinal role, they are a preferential timber species in the study area [22]; and their industrial exploitation (logging) contributes to reduce their availability in the forest. The conversion of forest areas into agricultural land also has a significant impact on the density of medicinal plant species especially in the periphery of DDNP. This can explain the low density found in AFO land. [23] found that the conversion of forest covers into agricultural land contributes to the reduction of forest cover and therefore reduce species diversity, density and their availability.

From the non-ecological harvesting point of view, the populations reported for example that species like *G. kola* have become rare in the area, because in addition to its medicinal value, its bark is widely used as an additive for palm wine. Thus, when a member of the community has identified a stem of *G. kola*, it is felled and all of its bark is collected in order to ensure that there are reserves during periods of shortage. Moreover, it is a plant species which is on the red list of IUCN (Vulnerable) and also its seed which is a key element for natural regeneration is collected by people or eaten by some wild animals. 10% and 30% of the respondents affirmed that the availability of these species would increase and remain constant, respectively within the next 5 years. The reason given by the latter was that there is sustainable harvesting and that despite the increase in demand, these are naturally regenerating species that will continue to be available for future generations [24]. Specifically, the species cited as being available such as *Musanga cecropioides*, *Myrianthus arboeus*, *Voacanga africana* are species that easily regenerate in addition to their characteristic rapid growth rate [25], which can justify the high availability of pioneer species in the study area. In addition, they have a high regeneration rate and it is not counted as a timber tree species [15]. Thus, human influence on this species is limited seeing that it is not a timber tree species. These justify its availability.

Typology of vegetation cover

Based on the methodological approach of [10], the line transects installed had the azimuth of the periphery of the DDNP closest to the Mbaki 1 locality; thus following an orientation from the periphery towards the forest center. The reason why we identified agroforestry and fallow FLCT only on the first transect; thereafter, only natural ecosystems were identified due to the consecutive 500 m interval between transects. It is due to the fact that agriculture is not intensively carried out by the local people of surroundings DDNP. That being said, the study area is a permanent forest domain where the activities of the population detrimental to the conservation of the forest area (like agriculture) are forbidden. Thus, for some residents, despite the awareness campaigns of the authorities in charge of the management of the forest, the population say that they do not know the limits of the permanent forest domains; others say that these are areas that their ancestors bequeath to them, and they should therefore continue to exploit them in order to provide for their daily needs. However, given that most of them already know the permanent nature of the forest areas, they practice their agricultural activities elsewhere; which explains the small surface area occupied by agricultural activities in the sampled site.

The presence of savannahs in the forest environment is not new in the study area [26]. It is a natural phenomenon where savannahs can be observed in the middle of forests. [26, 27] made the same observation respectively in the Dja Wildlife Reserve belonging to the evergreen forest domain and in the teaching and research forest of the University of Dschang located near our study site and belonging to the semi-deciduous forest. [11] described them as savannahs included; however, their surface area remains small, as of the 40 ha sampled, they represented only 0.5 ha.

Density of medicinal plant species in Deng-Deng forest massif

From the results of the target species inventory, it appears that the density of these medicinal species varies significantly not only between them but also according to LFCT. Regarding LFCT, the highest density was observed in OSF; which is the most important LFCT sampled (84%), and also can be considered as a natural habitat of these species [15]. Indeed, according to these authors, these species inventoried are essentially forest species of *terra firme*; this does not exclude their ability to develop in other types of natural environment such as swamps, raffia, etc. [9]. This could also explain the total absence of these species in the savannahs identified in the sampled area. However, some specifications were observed within the MFTS went they are considered separately.

Concerning the stem density of *Milicia excelsa* for example, it has a very low density of stems in the study area (0.08±0.02 stems/ha). It is true that it is a medicinal species recognized in the treatment of several diseases including COVID-19 symptoms in the area [3,4]; but it is a very sought-after timber species by the local community in their multiple construction and craft works [15]. Moreover, given that it has a low regeneration rate, its availability remains low. The same is true for medicinal species such as *P. angolensis*, but with the only difference that it has a high regeneration rate. In the case of *G. kola* on the other hand, even if it is not considered as timber, the threat to it is rather high which would explain its low density. Indeed, in the study area, it is a species highly prized in the area (bark) as a palm wine additive, and because of its scarcity, local people once they have identified a *G. kola* plant, prefer to cut it down to collect its bark, and given that it has a low regeneration rate (coupled with competition with animals which eat its seeds), we therefore have a low density of the latter.

In the case of *M. Cecropioides*, with its pioneer characteristic [15, 25], one would expect a high density earlier in the fallows; however, it is rather in the OSF that its density was high. This could be explained by the fact that it was essentially in areas of windfall (either natural or due to tree felling) observed, the light that arrives directly to the ground favors the development of this species not only the surface area.

A density of 2.33±0.80 stems/ha was found for M. *arboreus* in the study area with the highest density in OSF. In fact, *M. arboreus* is a forest tree of semi-deciduous and evergreen forest (Munier *et al.* 2015). Even though it is not a timber tree, this intermediate density compared to others MFPS for example can be explained by the fact that, it possess a degree of seed dormancy which is crucial for regeneration [28]. In fact, seeds in general are normally a key element for the success or failure of natural regeneration [29]. On its part, *Voacanga africana* is rather present in OSF where it was the most abundant. It is a plant species not exploitable like timber [30]; and it is abundant in the undergrowth forest stratum of semi-deciduous forest [31].

Taking the case of *G. kola*, it is a plant species with a low density in the study area; *G. kola* was become rare in the area because it is a plant species highly sought-after by the local people for their bark and seed not only for their medicinal value. In fact, the bark is collected in an unsustainable fashion which is at the origin of the dead of these tree species in the forest. In addition, the seed is a key element for regeneration [29]; but with it high value for the local people, during the flowering season, these fruits/seeds are collected by the local people, and for those left in the forest, wild animals equally feed on them. This limits its regeneration. According to the IUCN red list, this species is threatened and requires the putting in place of strategies which can promote its sustainable management in order to increase its aavailability. Farmers' desire to keep the tree in their fields could also justify the presence of these trees in their agroforests and even in the fallow lands. In fact, during the establishment of open fields (conversion of forest areas into agricultural areas), some trees are kept because of the goods and services they provide (medicinal, food, shade for crops, etc.) [10] and the diversity can be enriched later by fruit species including indigenous plants like *Trichoscypha acumunata* [15]; and in most cases exotic species depending on the choice of the farmer [32, 33]. This is for example the case of medicinal and food plant resources such as *G. kola*, *M. arboreus* and *A. boonei* which despite their presence in AFO and fallow lands are at low densities because in addition to selective felling, local people rather enrich the sites with fruit trees hence the low density of forest trees. We can note also the fact that low stem density in AFO and fallows where we found herbaceous invasion are a factor responsible to the poor regeneration of degraded forests [10].

Importance of the exploitation of medicinal plants for the well-being of the population and involvement in the conservation of biodiversity

Forests are known to play an important role in meeting the health needs of forest peoples all over the world [7]. Traditional medicine supported today by the WHO is a preferred option chosen by people in lower income countries because the traditional therapies present in many cases no secondary/after effects, it is easily accessible and also contributes to boost their immune system [6]. In the face of the current risk of unsustainable management of the Deng-Deng forest, conservation of these medicinal plants and forest biodiversity must be a central focus. In fact, seeing the current demand and overexploitation of MFPS and also poor exploitation methods that in most cases includes the felling of trees in order to collect barks, leaves and flowers, biodiversity conservation is seriously affected especially for medicinal trees/plant species concerned by these poor collection techniques. To ensure that medicinal plants can continue to provide different ecosystem services now and for future generations, best conservation measures for medicinal plants will be required. In this respect, to ensure the sustainability of local natural ecosystems into the future, it is necessary to provide information that will help in developing scientifically-informed strategies for conservation of medicinal resources and sustainable measures that can help to inform policy-makers' policy choices.

Conclusions

Understanding the perceptions of local people in the Deng-Deng forest massif pertaining to the availability of MFPS used to treat or prevent COVID-19 symptoms, their distribution and density is a crucial step in achieving their sustainable use and management; Essentially in the context where 37% of local people perceived that the MFPS are today rare and/or disappear due to increasing demand (39%) and also where perception of local people (60%) predict a reduction of this resource in the near future. Concerning density distribution of these medicinal plants, their high density in OSF, justified their natural character. The low density of species like *G. kola* is due to unsustainable exploitation practices as the species is highly sought-after by the local people which has made it threatened according to the red list of IUCN. It is therefore urgent to develop conservations measures to limit forest conversions into other land uses which contributes to forest degradation. This will go a long way to ensure the sustainable management and the long-term availability of medicinal plant as well as forest biodiversity conservation. Globally, the results of this study can help towards effectively ensuring the future sustainability of the Deng-Deng forest ecosystems that harbors medicinal plants. This will depend upon conservation and management approaches that value the involvement of local communities in the management of the forest.

Acknowledgements
Our gratitude to the Conservation Action Research Network (CARN) which provided the financial assistance for the accomplishment of this study. We express our gratitude to Conservation and Sustainable Natural Resources Management Network (CSNRM-Net) who for their expertise on the field during socio-economic survey. We also express our gratitude to respondents for their hospitality and availability to answer the questionnaires.

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