

## Importance of Preserved Medicinal Plants in Cocoa Agroforestry Systems for Health Security of Cocoa Producers in West Center, Côte d'Ivoire

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Received: 18/12/2025

Accepted: 20/04/2026

Available online: 24/04/2026



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**Abstract:** In Côte d'Ivoire, the historical cocoa farming expansion has significantly contributed to the forest conversion into agricultural land, resulting in biodiversity loss. Agroforestry systems based on cocoa trees, established following deforestation, contain plant biodiversity that includes medicinal plants. The recent intensification of cocoa production tends to reduce this plant diversity, even as producers continue to rely on traditional medicine. In the context of health crisis and promotion of a global solution like the One health, this study aims to link human health, agricultural practices, and the conservation of medicinal resources. It was conducted in Gonaté region, a major cocoa-producing area in West-central Côte d'Ivoire. An ethnobotanical survey was carried out with 60 producers aged 20 to 80. The data collected concerned the symptoms of diseases encountered during the previous twelve months and the plants used to treat them. Botanical specimens were identified using reference catalogs, and citation frequencies were used to prioritize symptoms of diseases and species. The results revealed fourteen symptoms of diseases, dominated by malaria (86.7%), general tiredness (71.7%), and gastric ulcers (35%). The most frequent pathologies were concentrated in the active age groups [20–40] and [40–60], while persons that had an age up to 60 years presented osteoarticular and anemic symptoms. Twenty-four medicinal species, distributed among 23 genera and 17 families were identified. *Vernonia amygdalina*, *Moringa oleifera*, *Alchornea cordifolia*, and *Passiflora foetida* were related to the most impactful symptoms of diseases. These results highlight the strategic importance of agroforestry as reservoirs of medicinal plants essential to the health of cocoa producers, and call for sustainable management programs that reconcile productivity, food safety and biodiversity conservation.

**Keywords:** Agroforestry; Cocoa; Ethnobotany; Phytotherapy; Producer Health.

### INTRODUCTION

Solving the health problems facing the world today promotes an integrated and interdisciplinary understanding of health according to the concept 'One Health'. Plants constitute a major biological resource for human societies, providing timber, food, and therapeutic substances. In many

countries of the world, traditional medicine remains an essential resource: the World Health Organization estimates that approximately 80% of the population uses it for primary healthcare (WHO, 2002). Numerous studies in West Africa have highlighted the medicinal value of plant species used in treating everyday symptoms of diseases (Koulibaly, 2008, Piba et al., 2011; Dro et al., 2021). The

sustainability of the plant biodiversity is now severely threatened. The dynamics of global change and, more specifically, the conversion of forests into agricultural land, are major drivers of biological erosion in West Africa (Koulibaly et al. 2010, Jagoret et al., 2020). In Côte d'Ivoire, the rapid and historic expansion of cocoa farming has led to the massive forest loss, making the world's leading cocoa producer country, also a country with a large cost of biodiversity loss.

In this context, cocoa-based agroforestry systems occupy a paradoxical position. Their establishment often results from deforestation, but producers maintain a variable plant diversity, preserved or introduced to provide shade, materials, food resources, or medicinal plants. However, the recent intensification of cocoa cultivation is progressively reducing this diversity, particularly the diversity of medicinal plants in these agroforestry systems (Konan et al. 2011; Koulibaly, 2019, Diomandé et al. 2023), while interest in traditional medicine increases, particularly due to the accessibility of traditional healers and the low cost of care (Piba et al., 2011; Boko et al., 2020). However, in Côte d'Ivoire, more than 1,500 medicinal species have been inventoried by key botanical and ethnopharmacological studies, notably N'Guessan (2009), Koulibaly et al. (2010) and Timité et al. (2019). Several species have also been subject of phytochemical and pharmacological studies highlighting bioactive compounds (Coulbaly et al., 2020). Ethnobotanical studies are addressed through inventories of medicinal species, methods of making potions and the pharmacological potential of the species. The need for medicinal agroforestry phytodiversity of agricultural populations is not assessed, whereas an impoverished flora could impact on their health as it is known that most of the cocoa producers live below the poverty line, according to recent economic reports (World Bank, 2019). Also, the WHO (World Health Organization) promotes a holistic view of health, stating that it goes beyond the absence of disease to include physical, mental and social well-being. Here, we propose to evaluate the health problems of producers through their symptoms of diseases in order to use it as a tool for identifying the medicinal flora of interest to be preserved.

Within this context, the present study aims to contribute to the conservation of medicinal resources in cocoa agroforestry systems. The aim is (i) to characterize the socio-demographic profile of producers, (ii) to detect dominant symptoms of diseases and the most vulnerable groups, and (iii) to identify the medicinal species used for their treatment. This approach will help to promote medicinal plants as a functional component of agroforestry systems and support their integration into sustainable management strategies.

## MATERIALS AND METHODS

### Study Area

The present study was conducted in the Haut-Sassandra region, located in West-central Côte d'Ivoire. Its

administrative capital, the city of Daloa, lies between 6°53' N latitude and 6°27' W longitude, approximately 141 km from Yamoussoukro, the political capital of the country (MPD, 2015). The target investigation site was the sub-prefecture of Gonaté, situated 22 km north of Daloa. This locality extends approximately between 06°90'–06°24' N and 06°54'–06°14' W and has a population of 36,938 inhabitants, according to the most recent national investigation (INS, 2014).

Gonaté is located within a transitional ecological zone between the tropical domain with two seasons and the subequatorial domain with four seasons. The climate is hot and humid, with a mean annual temperature of 26°C and high relative humidity (Koffié-Bikpo & Kra, 2013). The topography is weakly contrasted and consists of tabular plateaus ranging from 200 to 400 m in elevation. From a phytogeographical perspective, the region belongs to the mesophilic sector and is characterized by a mosaic of semi-deciduous moist dense forest, mesophilic forests, and savannas (Guillaumet & Adjanohoun, 1971). These forests host characteristic woody species such as *Cola lorougnonis* (Malvaceae), *Drypetes singroboensis* (Putranjivaceae), and *Leptactina involucrata* (Rubiaceae). However, extensive or shifting cultivation practices (coffee, rubber, oil palm, and cocoa), combined with uncontrolled timber exploitation, have led to a significant reduction in regional forest cover (Sangaré et al., 2009).

### Justification for Site Selection

The selection of Gonaté was based on multiple socioeconomic, health-related, and environmental considerations. Gonaté is identified as one of the principal cocoa bean production zones in Côte d'Ivoire (N'Guessan et al., 2014), a context that has favored the expansion of cocoa-based agroforestry systems. The area is described as presenting a high health risk for rural populations (Esso, 2009). Traditional pharmacopoeia plays a central role in plant use; it constitutes the second most common form of plant resource utilization after food (Dro et al., 2021). Medicinal species are sourced predominantly from cultivated fields, particularly from cocoa agroforestry systems (Kouadio et al., 2022). Thus, Gonaté represents a strategic location for assessing the diversity and availability of medicinal plants in agroforestry contexts, as well as their role in local health management strategies.

### Ethnobotanical Survey

A semi-structured ethnobotanical survey was conducted among 60 cocoa farmers in Gonaté, using a standardized individual questionnaire (Figure 3). Two criteria guided respondent selection: (i) being the owner of a cocoa plantation, and (ii) being at least 20 years old, regardless of sex or ethnicity.

The information collected focused on health disorders encountered during the previous twelve months. The questions focused on health issues as they are known and expressed, and medicinal plants used for treatments.

### Species Identification

Botanical samples collected were identified using the

reference catalogues and classified according to Cronquist (1981) nomenclature. Biological types were assigned following Raunkiaer's (1934) classification. Phytogeographical affinities were determined with reference to Lebrun (1981).

**Data Analysis**

Citation frequency (CF) was calculated to assess the recurrence of reported symptoms of diseases and the level of use of medicinal plants by producers. Citation frequency was determined according to Ladoh-Yemeda et al. (2016), using the formula:

$$CF = \frac{n}{N} \times 100$$

where n represents the number of citations of symptoms of diseases or species, and N represents the total number of respondents.

Symptoms of diseases were then classified into three frequency levels:

CF < 15%: less frequent symptoms of diseases (AMF)

15% ≤ CF ≤ 30%: moderately frequent symptoms of diseases (AMoF)

CF > 30%: frequent symptoms of diseases (APF)

To explore the relationship between farmers' age and reported symptoms of diseases, a Correspondence Factor Analysis (CFA), coupled with a Hierarchical Ascending Classification (HAC), was applied. This multidimensional descriptive factorial method groups individuals according to similarity profiles. All statistical analyses were performed using R (version 4.0.2).

**RESULTS**

**Socio-demographic characteristics of cocoa producers**

The age of the cocoa farmers surveyed ranged from 20 to 80 years, with a mean of 47.2 years (Figure 1). The 40–60 age group contained the largest proportion of producers (40%), whereas the lowest proportion (23.33%) was recorded among those older than 60 years.

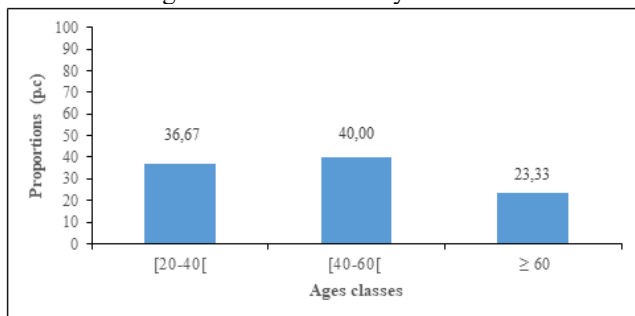


Figure 1. Age groups of producers in the Gonaté Region

**Health disorders reported by cocoa producers**

Health surveys indicate that producers in Gonaté are exposed to a wide range of medical constraints. In total, fourteen (14) distinct symptoms of diseases were recorded (Figure 2). Among these, three symptoms of diseases clearly dominate the overall health status of the producers population. Malaria, reported by 86.67% cases, constitutes the major symptom of diseases. General tiredness, which reflects a weakened physical state linked to intense agricultural labour was cited by 71.67%. then gastric ulcer,

reported by 35%, may be associated with metabolic, dietary, or psychosocial factors.

At an intermediate level, prevalence symptoms of diseases was likely associated with work posture, hygiene, or common infections. These include lower-back pain (28.35%), hemorrhoids (16.67%), typhoid fever (16.67%), and joint pain (15%).

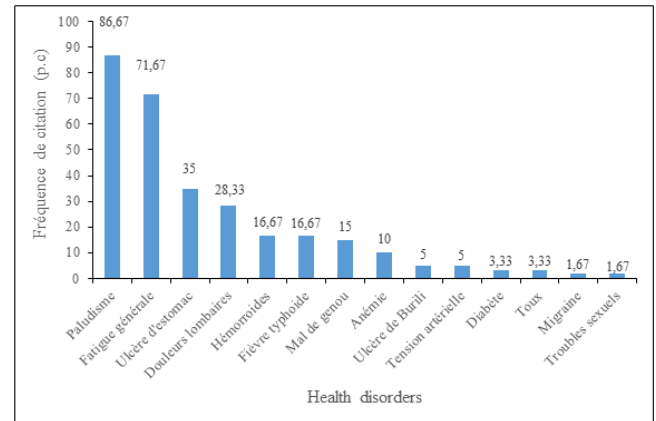


Figure 2. Health disorders reported by cocoa producers

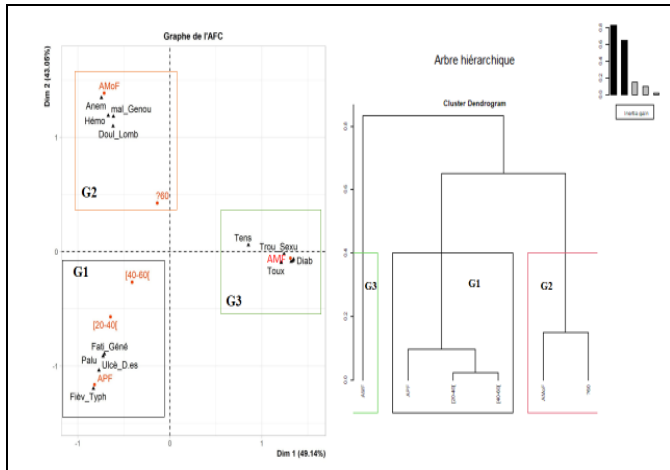
**Health profile of Producer**

The first two factorial axes of the Correspondence Factor Analysis (CFA) accounted for 92.19% of the total variability, ensuring a robust representation of the relationships among variables. Interpretation of the results allowed the identification of three characteristic symptoms of diseases groups (Figure 3).

Group 1 (G1) comprises the most frequent symptoms, concentrated mainly among young and adult producers aged 20–40 and 40–60 years. This group includes malaria, general tiredness, gastric ulcer, and typhoid fever, indicating heightened vulnerability among individuals in their peak productive years.

Group 2 (G2) brings together moderately frequent symptoms, observed predominantly among producers aged up to 60 years. These symptoms are essentially age-related or linked to chronic tiredness, such as anemia, knee pain, hemorrhoids, and lower-back pain.

Group 3 (G3) encompasses less frequent symptoms, including cough, sexual dysfunction, diabetes, and hypertension, with no clear statistical association with any specific age class, suggesting a sporadic distribution.



**Figure 3.** Correlations between producing populations and health disorders

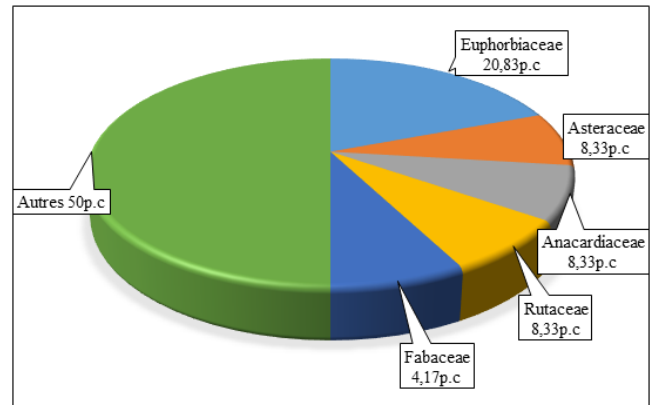
Table I. Grouping of symptoms of diseases by age class

Group	Code
G1	APF: Most Frequent Disorders; Palu: Malaria; Fati_géné: General fatigue; Ulc_d’es: Gastric ulcer; Fièv_typh: Typhoid fever
G2	AMoF: Moderately Frequent Disorders; Anem: Anaemia; Mal_genou: Knee pain; Hémo: Haemorrhoids; DouL_lomb: Lower-back pain
G3	AMF: Least Frequent Disorders; Trou_sexu: Sexual disorders; Diab: Diabetes; Tens: Hypertension

**Medicinal plants used in treating disorders**

The medicinal flora used by cocoa producers in Gonaé comprises twenty-four (24) medicinal plant species distributed across twenty-three (23) genera and seventeen (17) botanical families (Table 1). Among these species, *Vernonia amygdalina* is the most widely used (FC = 26.67%). *Carica papaya* (FC = 16.67%), *Musa paradisiaca* (FC = 15%), *Tectona grandis* (FC = 13.33%), *Moringa oleifera* (FC = 13.33%), *Mangifera indica* (FC = 10%), *Citrus limon* (FC = 10%), *Alchornea cordifolia* (FC = 10%), *Azadirachta indica* (FC = 8.33%), *Senna siamea* (FC = 8.33%), and *Alstonia boonei* (FC = 6.67%) constitute the moderately used medicinal flora for treating the symptoms of diseases encountered by producers.

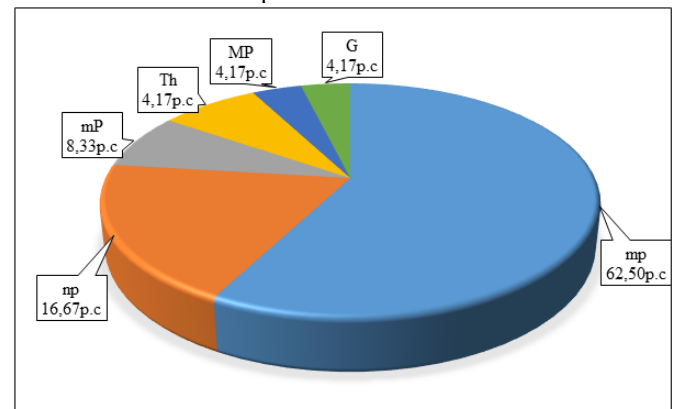
Botanical families are dominated by the Euphorbiaceae (19.23%), accounting for five medicinal species (Figure 4). These are followed by Asteraceae, Anacardiaceae, Rutaceae and Fabaceae (7.69% each).



**Figure 4.** Botanical families of medicinal plants

**Distribution of species by biological type**

The inventoried species cover six biological types (Figure 5). Microphanerophytes overwhelmingly dominate the pharmacopoeia, representing 57.69% of species (15 plants), indicating a predominance of small trees and shrubs—the most accessible life forms in fallows, plantations, and hedgerows. They are followed by the Nanophanerophytes (19.23%). Megaphanerophytes, Mesophanerophytes, Therophytes, and Geophytes are only marginally represented, confirming the limited use of annual or subterranean plants.

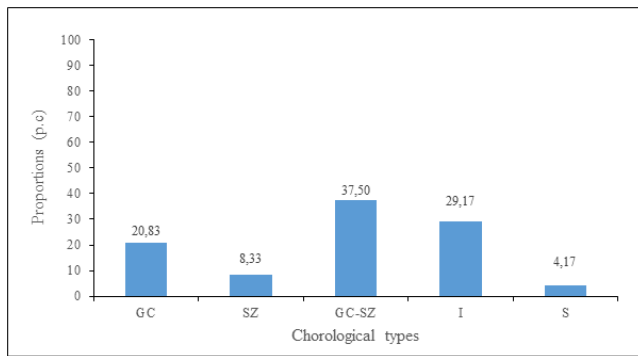


**Figure 5.** Biological types of medicinal plants

MP: Megaphanerophyte; mP: Mesophanerophyte; mp: Microphanerophyte; np: Nanophanerophyte; Th: Therophyte; G: Geophyte

**Phytogeographical distribution of medicinal species**

The 24 medicinal species recorded are distributed across five major phytogeographical regions (Figure 6). Taxa from the Guineo-Congolian/Sudano-Zambeian transition zone form the largest contingent (37.50%). Introduced or cultivated species represent 29.17%, reflecting horticultural and agro-ecological integration of non-native medicinal plants. Strictly Guineo-Congolian taxa account for 20.83%, whereas Sudano-Zambeian and Sudanian regions represent 8.33% and 4.17%, respectively.



**Figure 6.** Phytogeographical distribution of medicinal species

GC: Guineo-Congolian; SZ: Sudano-Zambezian; GC-SZ: Transition between Guineo-Congolian and Sudano-Zambezian; I: Introduced/cultivated; S: Sudanian

### Medicinal plants involved in treating disorders affecting the most vulnerable producers

Of the 24 plants inventoried, 16 are specifically associated with treating the most prevalent disorders affecting the most vulnerable groups. Among them, several species stand out for the diversity of their therapeutic indications. *Vernonia amygdalina* is indicated for the treatment of malaria, gastric ulcer, and typhoid fever, confirming its central role in the local pharmacopoeia. *Alchornea cordifolia* is used to treat gastric ulcer and typhoid fever, indicating a locally recognised gastro-protective effect. *Moringa oleifera* and *Passiflora foetida* are used for treating malaria and combating general fatigue, as these species are reputed for their tonic properties.

## DISCUSSION

### Socio-demographic profile of producers

The socio-demographic profile of cocoa producers in Gonaï indicates an age range of 20 to 80 years, with a mean of 47.2 years, confirming the predominance of relatively young producers. This pattern reflects the physical strength and work capacity required for labor-intensive agricultural tasks. Similar age structures have been documented in other cocoa-producing localities of the Daloa department (Diomandé et al., 2023; Oyoua, 2020) as well as nationwide (Assi et al., 2009), where mean ages typically range between 45 and 46 years.

### Disease exposure and age-differentiated vulnerability

Producers in Gonaï report fourteen major symptoms of diseases, dominated by malaria (86.67%), general tiredness (71.67%), and gastric ulcer (35%). The predominance of malaria is consistent with its endemicity in hot and humid inter-tropical environments (N'Guessan et al., 2009) and with observations from several ethnobotanical surveys in Côte d'Ivoire (Koulily et al., 2016; Gnagne et al., 2017; Dro et al., 2021). General tiredness and gastric ulcers may reflect strenuous physical activity and precarious living conditions.

Ordination methods linking symptoms of diseases to age classes distinguished three health groups. One groupe

comprised the most frequent symptoms affecting young and middle-aged producers ([20–40[ and [40–60[), notably malaria, general tiredness and gastric ulcer—conditions consistent with active labor participation. Another group included older individuals (up to 60 years) presenting moderately frequent symptoms. Hemorrhoids may reflect dietary constraints associated with rural living (Monian, 2016), whereas lower-back and knee pain derive from musculoskeletal degeneration associated with ageing (Jaeger, 2018). The last group included less frequent symptoms (sexual dysfunction, diabetes, hypertension) without clear age associations, instead reflecting stress, poverty and environmental exposure).

### Medicinal plant diversity and local pharmacopoeia

The medicinal flora cited by producers comprises 24 species distributed across 23 genera and 17 families, with Euphorbiaceae dominant. The most frequently cited species is *Vernonia amygdalina* (26.67%). Most medicinal taxa are shrubs (microphanerophytes) originating from ecotonal vegetation between forest and savanna (Guineo-Congolian/Sudano-Zambezian transition zone). The number of medicinal species aligns with inventories reported in Daloa by Boko et al. (2020) but remains lower than the 44 species reported by Dro et al. (2021) in Gonaï—a difference likely attributable to sample size and spatial coverage.

The prominence of *Vernonia amygdalina* may reflect socio-cultural familiarity with its therapeutic properties; highly familiar taxa receive higher citation frequencies. The dominance of Euphorbiaceae may relate to the accessibility and abundance of its representatives (Malan, 2008), including *Manihot esculenta*, *Phyllanthus amarus* and *Jatropha gossypifolia*. The reliance on shrubs from transitional zones likely reflects the scarcity of large woody species under increasing forest loss, while also demonstrating the ecological knowledge carried by migrant communities. The recurrent use of *V. amygdalina*, *Alchornea cordifolia*, *Moringa oleifera* and *Passiflora foetida* suggests inter-generational transmission of ethnotherapeutic knowledge.

## CONCLUSION

The productive population is confronted to fourteen major symptoms of diseases and reveal a health disorder due to the most frequent symptoms like malaria, general tiredness and gastric ulcer affect primarily young and middle-aged adults (20–40 and 40–60 years). This population could use a medicinal phytodiversity of 24 species for treatment, preserved in cacao agroforestry systems in the Gonaï region. This flora used is largely composed of shrubs (generally fruit trees) confirming the importance of small-stature species readily accessible in plantations. Among the most polyvalent taxa, *Vernonia amygdalina*, *Alchornea cordifolia*, *Moringa oleifera* and *Passiflora foetida* are used in the treatment of at least two symptoms of diseases and could be specially recommended as plant for health interest in this agricultural region.

Health constraints represent a major challenge for the sustainability of cocoa production. These results highlight the need to integrate medicinal plants into agricultural-planning policies to prevent the erosion of useful Phytodiversity, particularly in the context of woody-species decline and land pressure.

Also, in the context of the One health approach. It seems important to identify the source of pathogens and the interactions between factors involved in agricultural environments.

Finally, this approach combining agroforestry and One health could ensure environmental stability, health and well-being of agricultural populations.

### Acknowledgement

Authors are thankful to the "Groupe de Recherche InterDisciplinaire en Agroforestry (GRIDA)" for support and technical assistance.

### Conflict of Interest

There are no conflicts of interest declared by the authors.

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