

***Garcinia kola* Heckel, a multipurpose native tree extinct in the wild in Benin: threats, conservation challenges and domestication prospects**

Téléphore SODAHLON¹
Moustapha Arê mou KOLAWOLE²
Julien Gaudence DJEGO¹
Brice TENTÉ³

¹ University of Abomey-Calavi
Faculty of Agronomic Sciences
Laboratory of Applied Ecology
01 BP 526 Cotonou
Benin

² University of Abomey-Calavi
Faculty of Agronomic Sciences
Laboratory of Biomathematics
and Forest Estimation
04 BP 1525 Cotonou
Benin

³ University of Abomey-Calavi
Faculty of Human and Social Sciences
Laboratory of Biogeography
and Environmental Expertise
04 BP 1525 Cotonou
Benin

Auteur correspondant /
Corresponding author:
Téléphore SODAHLON –
sodahlontelephore@gmail.com

 ORCID : <https://orcid.org/0000-0002-5293-5196>



Photo 1.
Structured interviews conducted with local populations in Savi to assess their perceptions of *Garcinia kola*, Ouidah Municipality, Benin.
Photo G. Behanzin.

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RÉSUMÉ

***Garcinia kola* Heckel, un arbre indigène polyvalent disparu à l'état sauvage au Bénin : menaces, défis en matière de conservation et perspectives de domestication**

Garcinia kola Heckel est un arbre indigène polyvalent présent en Afrique centrale et occidentale, notamment en Angola, apprécié pour ses noix comestibles et ses usages médicinaux. Une exploitation intensive a entraîné l'extinction des populations sauvages dans tout le Bénin. Cette étude a évalué les perceptions des populations concernant (i) la connaissance de l'arbre *G. kola* et les menaces perçues, et (ii) la proposition de stratégies de conservation et de domestication. Des entretiens semi-structurés ont été menés auprès de 755 personnes dans 24 communes de quatre phytodistricts du Bénin. Des données ont été recueillies sur les caractéristiques sociodémographiques, les connaissances locales relatives au kola amer, la propriété, les pratiques de récolte, la culture, les méthodes de conservation et les menaces perçues pesant sur *G. kola*. La fréquence relative des mentions a été calculée. L'influence du sexe, de la profession et du phytodistrict sur les connaissances locales relatives au kola amer, ainsi que sur les pratiques de culture et de conservation, a été évaluée à l'aide de modèles linéaires généralisés binomiaux. Une régression logistique multinomiale a été appliquée pour évaluer l'influence du sexe et des phytodistricts sur les menaces perçues. Une analyse de correspondance a été réalisée pour explorer la relation entre les menaces perçues et les facteurs sociodémographiques. Les résultats ont révélé que 19,1 % des répondants ont déclaré connaître l'espèce. Le phytodistrict côtier comptait la plus forte proportion de répondants connaissant l'espèce (51,1 %), suivi de la vallée de l'Ouémé (21,1 %) et du Plateau (17,1 %). Le sexe, les phytodistricts et la profession ont influencé de manière significative les connaissances, les pratiques de culture et de conservation. Les principales menaces signalées étaient l'écorçage (54,2 %), le développement des infrastructures (43,8 %), la mutilation des arbres (17,4 %), les feux de végétation (11,8 %) et l'abattage anarchique (3,47 %). Les répondants du Plateau et de la Vallée de l'Ouémé, en particulier les hommes, ont identifié l'abattage anarchique comme la principale menace. Cette étude a fourni des informations précieuses pour la domestication et la gestion durable du kola amer au Bénin. Les efforts de domestication devraient être prioritaires dans les phytodistricts du Littoral et du Plateau, où l'espèce est bien documentée et cultivée. Les résultats de l'étude soulignent l'importance d'inclure les femmes dans les stratégies de gestion à long terme. Les recherches futures devraient se concentrer sur les techniques de culture du kola amer, car leur diffusion serait cruciale pour optimiser sa multiplication au Bénin.

Mots-clés : *Garcinia kola*, kola amer, savoirs locaux, menaces et défis, stratégie de domestication, sud du Bénin.

ABSTRACT

***Garcinia kola* Heckel, a multipurpose native tree extinct in the wild in Benin: threats, conservation challenges and domestication prospects**

Garcinia kola Heckel is a multi-purpose native tree found in Central and West Africa, including Angola, valued for its edible nuts and medicinal uses. Intensive harvesting has led to the extinction of wild populations throughout Benin. This study assessed local people's perceptions regarding (i) the knowledge of the *G. kola* tree and the perceived threats, and (ii) the proposal for conservation and domestication strategies. Semi-structured interviews were conducted with 755 respondents in 24 municipalities in four phytodistricts of Benin. Data were collected on socio-demographic characteristics, local knowledge on the bitter kola tree, ownership, harvesting practices, cultivation, conservation methods, and perceived threats to *G. kola*. The relative frequency of citations was calculated. The influence of gender, occupation, and phytodistrict on local knowledge of the bitter kola tree, as well as on cultivation and conservation practices, was assessed using binomial generalised linear models. Multinomial logistic regression was applied to evaluate the influence of gender and phytodistricts on perceived threats. Correspondence analysis was performed to explore the relationship between perceived threats and socio-demographic factors. Results revealed that 19.1% of respondents reported being familiar with the species. The Coastal phytodistrict had the highest proportion of respondents with knowledge of the species (51.1%), followed by the Valley of Ouémé (21.1%) and the Plateau (17.1%). Gender, phytodistricts and occupation significantly influenced knowledge, cultivation and conservation practices. The main reported threats were debarking (54.2%), infrastructure development (43.8%), tree mutilation (17.4%), vegetation fires (11.8%), and anarchic cutting (3.47%). Respondents from the Plateau and Valley of Ouémé, particularly the men, identified anarchic cutting as the primary threat. This study has provided valuable insights for the domestication and sustainable management of bitter kola in Benin. Domestication efforts should be prioritised in the Coastal and Plateau phytodistricts, where the species is well documented and cultivated. Results of the study highlight the importance of including women in long-term management strategies. Future research should prioritise the cultivation technique for bitter kola, as its dissemination would be crucial to optimise its multiplication in Benin.

Keywords: *Garcinia kola*, bitter kola, local knowledge, threat challenges, domestication strategy, South Benin.

RESUMEN

***Garcinia kola* Heckel, un árbol autóctono de múltiples usos extinto en estado silvestre en Benín: amenazas, retos de conservación y perspectivas de domesticación**

Garcinia kola Heckel es un árbol autóctono de múltiples usos presente en África Central y Occidental, incluida Angola, muy apreciado por sus frutos comestibles y sus usos medicinales. La recolección intensiva ha provocado la extinción de las poblaciones silvestres en todo Benín. Este estudio evaluó las percepciones de la población sobre (i) el conocimiento del árbol *G. kola* y las amenazas percibidas, y (ii) propuso estrategias de conservación y domesticación. Se realizaron entrevistas semiestructuradas a 755 encuestados en 24 municipios de cuatro fitodistritos de Benín. Se recopilaban datos sobre características sociodemográficas, conocimientos locales sobre el árbol de cola amarga, propiedad, prácticas de recolección, cultivo, métodos de conservación y amenazas percibidas para *G. kola*. Se calculó la frecuencia relativa de las menciones. Se evaluó la influencia del género, la ocupación y el fitodistrito en los conocimientos locales sobre el árbol de cola amarga, así como en las prácticas de cultivo y conservación, utilizando modelos lineales generalizados binomiales. Se aplicó una regresión logística multinomial para evaluar la influencia del género y los fitodistritos en las amenazas percibidas. Se realizó un análisis de correspondencias para explorar la relación entre las amenazas percibidas y los factores sociodemográficos. Los resultados revelaron que el 19,1 % de los encuestados declaró estar familiarizado con la especie. El fitodistrito costero presentó la mayor proporción de encuestados con conocimiento de la especie (51,1 %), seguido del valle del Ouémé (21,1 %) y la meseta (17,1 %). El género, los fitodistritos y la ocupación influyeron significativamente en el conocimiento y en las prácticas de cultivo y conservación. Las principales amenazas señaladas fueron el descortezado (54,2 %), el desarrollo de infraestructuras (43,8 %), la mutilación de árboles (17,4 %), los incendios de vegetación (11,8 %) y la tala anárquica (3,47 %). Los encuestados de la Meseta y el Valle del Ouémé, en particular los hombres, identificaron la tala anárquica como la principal amenaza. Este estudio ha proporcionado información valiosa para la domesticación y la gestión sostenible de la cola amarga en Benín. Se debe dar prioridad a los esfuerzos de domesticación en los fitodistritos Costero y de la Meseta, donde la especie está bien documentada y se cultiva. Los resultados del estudio destacan la importancia de incluir a las mujeres en las estrategias de gestión a largo plazo. Las investigaciones futuras deberían dar prioridad a las técnicas de cultivo de la cola amarga, ya que su difusión sería crucial para optimizar su multiplicación en Benín.

Palabras clave: *Garcinia kola*, cola amarga, conocimientos locales, amenazas y retos, estrategia de domesticación, sur de Benín.

Introduction

Garcinia kola Heckel (Clusiaceae) is a multipurpose indigenous tree, widely distributed from Central to West Africa, including Angola (POWO 2025). It is commonly known as bitter kola and is mainly found in home gardens and agroforests in the Guinean zone of Benin. It is a species with high medicinal, socio-cultural and economic potential (Ekene & Erhirhie 2014; Mañourová et al. 2019; Dogara et al. 2022). The seeds and bark of bitter kola are commonly used for their ability to prevent and treat gastrointestinal disorders and blood diseases (Durand et al. 2015; Dogara et al. 2022; Manourova et al. 2023). The leaves and roots can serve as alternative medicine to treat or prevent severe illnesses such as laryngitis, bronchitis, malaria, hepatitis, and immune-destructive diseases (Adegboye et al. 2008; Ijomone et al. 2012; Manourova et al. 2023). The kernels also play an important role in traditional ceremonies, e.g., the celebration of a childbirth, marriage, or chieftaincy (Durand et al. 2015). In Benin, the primary beneficiaries (producers) and other actors (wholesalers, semi-wholesalers, and retailers) in the bitter kola value chain can earn between 27.87 USD and 29.17 USD per equivalent of 25 kg of nuts (Durand et al. 2015). In Cameroon, the total volume of seed sales is estimated at 50 tonnes per year, with a market value of approximately 660,000 USD (Awono et al. 2016).

Despite the tree's economic and medicinal importance, bitter kola is declining due to overexploitation and urbanisation (Durand et al. 2015; Manourova et al. 2023), coupled with poor regeneration of the species. In the natural forest of southern Cameroon (van Dijk 1999) and in South-West Nigeria (Adebisi 2004), the density of bitter kola significantly decreased, with 1.10 to 0.40 trees per hectare and 0.50 to 0.33 trees per hectare, respectively. To reduce the negative effects of overexploitation and urbanisation on multipurpose indigenous trees, domestication has been recognised as a useful approach (Fondoun & Tiki Manga 2000; Leakey & Asaah 2011). Furthermore, the domestication of multipurpose indigenous trees that provide products and services (Simons & Leakey 2004) is crucial for biodiversity conservation, promotion, and valorisation, as well as for sustainable development (Guindé et al. 2025). However, bitter kola is still described as a species in the early stages of domestication (Mañourová et al. 2019). The species is retained or cultivated in agroforestry systems, home gardens, and natural forest stands (Dadjo et al. 2020; Manourova et al. 2023). It is listed among the top five priority species identified as candidates for domestication in West and Central Africa (Leakey 2012) and among the top ten priorities in Benin (Assogbadjo et al. 2017).

Consistent with Simons & Leakey (2004), tree domestication relies on how humans select, manage and propagate trees. Selection, management, and propagation of trees by humans involve socio-demographic factors such as age, education, occupation, gender, marital status, income, and household size, among others. The evaluation of socio-demographic characteristics and associated factors has thus become a major com-

ponent of the domestication process of multipurpose indigenous trees. Several studies have examined the socio-demographic factors influencing conservation and domestication decisions for multipurpose indigenous trees, such as *Vitex doniana* Sweet (N'Danikou et al. 2015; Guindé et al. 2025); *Uvaria chamae* P. Beauv. (Dai et al. 2025); *Borassus aethiopum* Mart. (Salako et al. 2018); *Strychnos spinosa* Lam. (Avakoudjo et al. 2020); and *Azelia africana* Sm. (Balima et al. 2018). It was found that socio-demographic characteristics such as age, ethnicity, education, occupation, marital status, and income, among others, influence local perceptions and knowledge, as well as the cultivation of multipurpose indigenous trees. However, those that examine the socio-demographic determinants of bitter kola domestication are few and disparate. For instance, Dadjo et al. (2020) showed that bitter kola ownership was positively correlated with age in Benin, with men and farmers being more likely to own, maintain and cultivate bitter kola. Similarly, Agwu et al. (2018) identified age, gender, marital status, education level, household size, and primary occupation as key explanatory variables influencing farmers' perceptions and cultivation practices in Nigeria. However, they also noted a prevailing reliance on inherited stands due to cultural beliefs that only a divine entity can make *G. kola* germinate. Furthermore, Yogom et al. (2020) revealed in Cameroon that ethnicity and agro-ecological zones profoundly influence use values and management strategies. Savanna communities exhibit more sustainable practices, such as fruit harvesting and active planting. While these studies collectively confirm the importance of socio-demographic context, they also highlight a significant knowledge gap regarding the relative importance and interaction of these factors across the species' entire geographic range. This knowledge gap emphasises the need for further study to improve our understanding of the relationship between socio-demographic factors and bitter kola ownership, knowledge, cultivation practices, conservation methods, and threats. The lack of such understanding limits deeper insights into the management and cultivation of bitter kola and its value across different communities. This kind of comprehension would lay the foundation for the species' sustainable utilisation, conservation, and on farm domestication. In the absence of this understanding, conservation and domestication initiatives compromise their ability to engage key demographic groups and may fail to account for the factors that motivate community adoption. Therefore, this study will provide the evidence needed for successful conservation and domestication interventions adapted to the specific needs of different communities.

The objectives of this study were to assess the relationship between gender, main occupation and phyto-districts with (i) *G. kola* tree knowledge; (ii) *G. kola* tree cultivation and conservation practices; and (iii) perceived threats to *G. kola*. Here, using data from 755 respondents in 24 municipalities and 4 phytodistricts on the occurrence of bitter kola in Benin, we tested two hypotheses: (i) whether

gender, occupation, and phytodistricts influence the knowledge, cultivation, conservation, and perceived threats; and (ii) whether people living in phytodistricts where bitter kola is abundant have greater knowledge of it than those living in phytodistricts where it is less common or rare.

Method

Study area

The study was conducted across 4 phytodistricts in Benin (figure 1, table I). These phytodistricts represent different bioclimatic zones (Adomou 2005; Assogbadjo 2006), characterised by significant variations in climate, precipitation, soil types, and vegetation. The phytodistricts exhibit highly variable human population densities (INSAE 2013). The Plateau phytodistrict is the most densely populated (table I), which could potentially lead to higher levels of anthropogenic pressure. The Coastal, Plateau and Valley of Ouémé phytodistricts host a great diversity of groups, including Adja, Fon, Yorouba, and Goun, among others. A common characteristic across these phytodistricts is a significant economic interest in forest products. Their livelihoods are complemented by activities such as selling firewood, charcoal, fruits, seeds, and other non-timber forest products.

Sampling and data collection

Twenty-four municipalities were randomly selected within the known distribution range of the species and were distributed across the four phytodistricts of the study area (table II). The municipalities were selected to maximise the diversity of social groups and capture as much knowledge as possible from local people (table II). In each municipality, 19 to 45 people aged at least 18 were randomly selected, for a total of 755 respondents.

The semi-structured interviews were conducted utilising highly specific questionnaires, encoded in the KoboCollect platform. The data collected included respondents' socio-demographic characteristics, knowledge about the bitter kola tree, ownership, harvesting practices, cultivation and conservation methods, and perceived threats to the bitter kola.

Data analysis

Local knowledge, ownership and harvesting of bitter kola

We calculated the Relative Frequency of Citation ($RFC = n \times 100 / N, \%$; where n = number of positive responses and N = sample size) for each criterion – knowledge about the bitter kola tree (Yes/No), ownership (Yes/No), and harvesting practices (Yes/No) – both per phytodistricts and overall. However, the RFC for ownership and harvesting practices was conducted exclusively among respondents who reported knowledge of the species ($n = 144$).



Photo 2.

Fruiting *Garcinia kola* tree in home gardens in Ouèdo, Abomey-Calavi Municipality, Benin.
 Photo G. Behanzin.

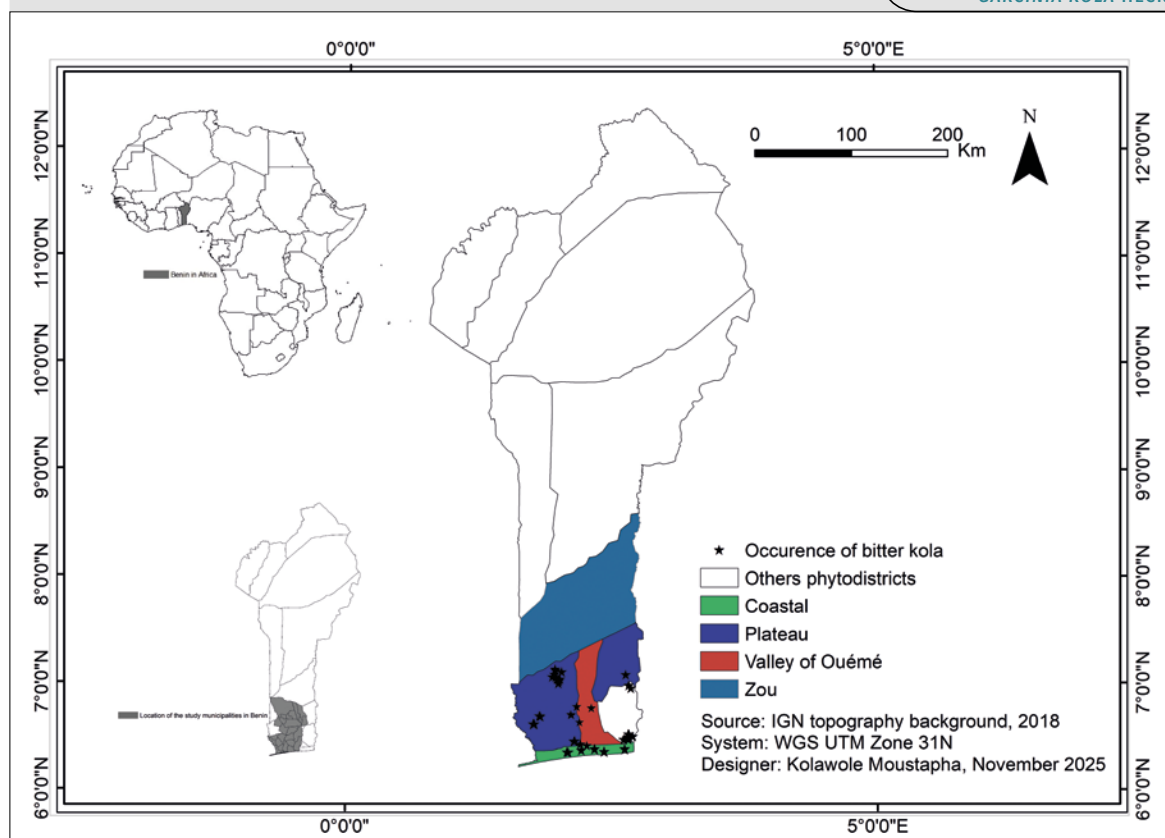


Figure 1.
Map showing the study area of *Garcinia kola* Heckel and the selected phytodistricts.

Table I.
Characteristics of the study areas.

Phytodistricts	Rainfall	Annual precipitation (mm)	Annual temperatures (°C)	Humidity index	Soil types	Vegetation	Population
Zou phytodistrict	Unimodal	1,100–1,200	21–32	2.8	Ferruginous	Dense dry forests (e.g., <i>Hildegardia barteri</i> (Mast.) Kosterm., <i>Diospyros mespiliformis</i> Hochst. ex A.DC.). Light woodlands of <i>Isobertinia doka</i> Craib & Stapf ex Holland. Gallery forests dominated by <i>Parinari congensis</i> Dirr., and <i>Berlinia grandiflora</i> (Vahl) Hutch. & Dalziel.	638,499
Coastal phytodistrict	Bimodal	900–1,300	25–29	5.2	Hydromorphic to halomorphie	Dense humid forests (e.g., <i>Dialium guineense</i> Willd., <i>Syzygium littorosum</i> Byng). Marsh forests (<i>Alstonia congensis</i> Engl., <i>Symphonia globulifera</i> L.f.). Mangrove ecosystems (<i>Rhizophora racemosa</i> G. Mey., <i>Avicennia germinans</i> (L.) L.). Savannas of <i>Mitragyna inermis</i> (Willd.) Kuntze.	1,121,383
Valley of Ouémé phytodistrict	Bimodal	1,100–1,300	25–29	4.9	Hydromorphic	Marsh forests dominated by <i>Xylopia rubescens</i> Oliv., and <i>Mitragyna ciliata</i> Aubrév. & Pellegr. Periodically flooded forests of <i>Dialium guineense</i> . Dense semi-deciduous forest (<i>Triplochiton scleroxylon</i> K. Schum., <i>Celtis zenkeri</i> Engl.).	1,110,445
Plateau phytodistrict	Bimodal	900–1,300	25–29	4.4	Ferralitic	Dense semi-deciduous forests dominated by <i>Triplochiton scleroxylon</i> K. Schum., and <i>Celtis zenkeri</i> Engl., with dry-climate specialists such as <i>Nesogordonia papaverifera</i> (A. Chev.) Capuron ex N. Hallé.	2,230,286

Using binomial generalised linear models (GLM), we evaluated the influence of socio-demographic factors (gender, occupation, and phytodistricts) on knowledge about the bitter kola tree (binary response: 1/0). For interpretation, we used the question package (Barnier et al. 2025) to obtain intuitive odds ratios (ORs) for socio-demographic factors.

Cultivation and conservation methods

For the subgroup with relevant knowledge (N = 144) on the bitter kola tree, we calculated the Relative Frequency of Citation (RFC = $n \times 100 / N$, %) for each criterion – cultivation (Yes/No), conservation actions (Yes/No), and conservation organs (Yes/No) – both per phytodistrict and overall.



Photo 3.

Garcinia kola tree growing in home gardens in Hounkanvié, Abomey-Calavi Municipality, Benin.
Photo G. Behanzin.

Table II.

List of district, municipalities, and number of respondents per municipality.

Phytodistricts	District	Municipality	Respondents
Coastal	Atlantique	Ouidah	24
	Mono	Grand-Popo	21
Plateau	Atlantique	Allada	30
		Kpomasse	30
		Toffo	32
		Tori-Bossito	29
	Couffo	Klouekanmey	19
		Lalo	36
	Mono	Athieme	43
		Bopa	45
		Comè	36
		Houeyogbe	37
		Lokossa	40
	Zou	Abomey	30
		Agbangnizoun	29
		Bohicon	30
		Ouinhi	30
		Zagnanado	31
		Zogbodomey	30
Valley of Ouémé	Atlantique	Abomey-Calavi	32
		Zè	31
	Zou	Cove	30
		Za-Kpota	30
Zou	Zou	Djidja	30
Total	4	24	755

To assess the influence of socio-demographic factors (gender, occupation, phytodistricts) on cultivation, conservation actions, and conservation organs (all binary responses: 1/0), we used binomial generalised linear models (GLMs). For interpretation, we used the 'questionr' package (Barnier et al. 2025) to derive intuitive odds ratios (ORs) for socio-demographic variables.

Perceived threats to bitter kola

We calculated the RFC for each perceived threat, both by phytodistricts and overall (N = 144). Then, we performed multinomial logistic regression (MLR) using the 'nnet' package (Ripley et al. 2016) to assess the influence of socio-demographic factors (gender and phytodistricts) on threat

perception. Furthermore, we used Correspondence Analysis (CA) to explore the associations between perceived threats and socio-demographic characteristics. To achieve this, respondents were then classified into distinct groups based on a combination of the three factors: phytodistrict (Coastal, Plateau, and Valley of Ouémé); gender (Male, Female); and occupation (Residents, Farmers, Nurserymen, Breeders, Planters, Public Servants, and Foresters). This approach resulted in 31 subgroups. For each subgroup, the RFC of the threats (anarchic cutting, debarking, vegetation fires, infrastructure, mutilation, and others) was calculated.

Results

Respondents' socio-demographic characteristics

As illustrated in table III, the proportion of female respondents in the study was 15.2%, while that of male respondents was 84.8%. The majority of respondents (33.6%) reported their principal occupation as residents (table III). The respondents' other occupations were as follows: farmers (31.5%), others (10.6%), nurserymen (10.1%), breeders (4.5%), planters (4%), public servants (2.9%), and foresters (2.8%). The majority of respondents (80.9%) reported not knowing *Garcinia kola* (table III).

Table III.

Socio-demographic characteristic of respondents.

	Modalities	Percentage (%)
Gender	Male	84.8
	Female	15.2
Occupation	Residents	33.6
	Farmers	31.5
	Others	10.6
	Nurserymen	10.1
	Breeders	4.5
	Planters	4
	Public servants	2.9
	Foresters	2.8
Knowledge	Known	19.1
	Unknown	80.9

Local knowledge of *Garcinia kola* and associated factors

Respondents had different levels of knowledge about the *G. kola* tree across the phytodistricts (figure 2). The majority of respondents (figure 2) in the Coastal phytodistricts (51.1%) knew the species, compared to other phytodistricts such as the Valley of Ouémé (21.1%) and the Plateau (17.1%). No respondents in the Zou phytodistrict (0%) knew the species. The estimated frequency of non-knowledge was 82.9%, 78.9%, 48.9% and 100% in the Plateau, Valley of Ouémé, Coastal and Zou phytodistricts, respectively (figure 2). In the study, 19.1% of respondents reported knowing the species, while 80.9% reported lacking knowledge.

The respondents from the Plateau and Valley of Ouémé phytodistricts demonstrated a notably lower level of knowledge regarding the *G. kola* tree, with 80% (OR = 0.20) and 74% (OR = 0.26) less likely to answer affirmatively than those from the Coastal phytodistricts (table IV). Male respondents had 1.13 times the odds of answering affirmatively compared with female respondents; however, this difference was not statistically significant ($p > 0.05$) (table IV). Foresters demonstrated a significantly higher probability of responding affirmatively than respondents from other occupational backgrounds, with a response rate 9.99 times higher. The findings of this study demonstrate that nurserymen (OR = 2.93, $p < 0.001$) possess significantly greater knowledge of the bitter kola tree than breeders, planters, individuals in other occupations, and residents. Residents demonstrated significantly lower knowledge of the species, with an odds ratio of 0.35 ($p < 0.001$), indicating a less than 0.35 probability of answering in the affirmative (table IV).

Ownership and harvesting of *Garcinia kola* and associated factors

A survey of the respondents revealed that only 1.4% of them possessed at least one tree of *G. kola* (figure 3.a). The study found that 4.35% of respondents were from the Coastal phytodistricts and 3.85% were from the Valley of Ouémé phytodistricts (figure 3.a). Notably, no respondent

Table IV.

Socio-demographic factors determining the knowledge of *Garcinia kola*: binomial generalised linear models.

Socio-demographic factors	Estimate	Standard error	OR	p-value
(Intercept)	-0.21	0.43	0.81	0.62
Phytodistricts - Plateau	-1.60	0.34	0.20	< 0.001
Phytodistricts - Valley of Ouémé	-1.34	0.42	0.26	< 0.01
Phytodistricts - Zou	-17.41	711.93	0.00	0.98
Gender - Male	0.12	0.30	1.13	0.68
Occupation - Others	0.62	0.33	1.85	0.06
Occupation - Breeders	0.13	0.49	1.14	0.78
Occupation - Public servants	0.92	0.50	2.51	0.07
Occupation - Foresters	2.30	0.50	9.99	< 0.001
Occupation - Nurserymen	1.07	0.30	2.93	< 0.001
Occupation - Planters	0.16	0.49	1.17	0.75
Occupation - Residents	-1.05	0.31	0.35	< 0.001

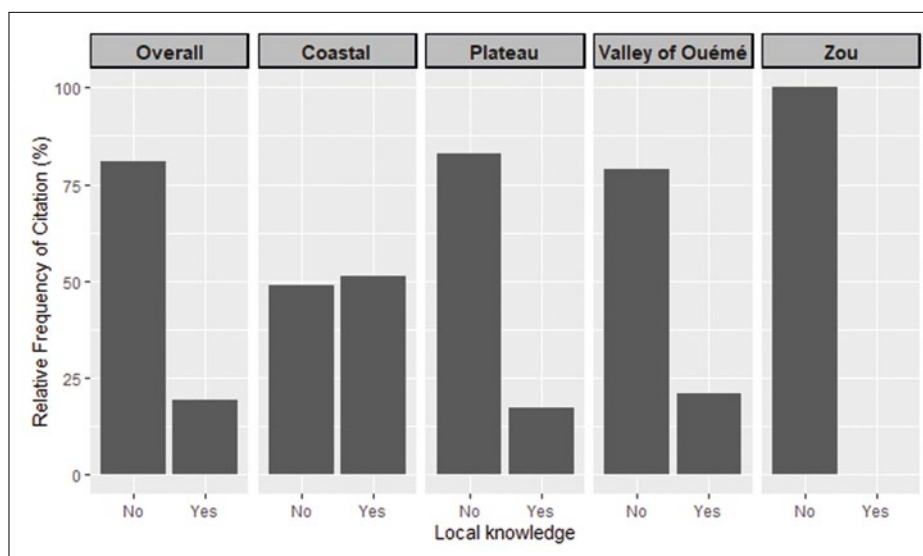
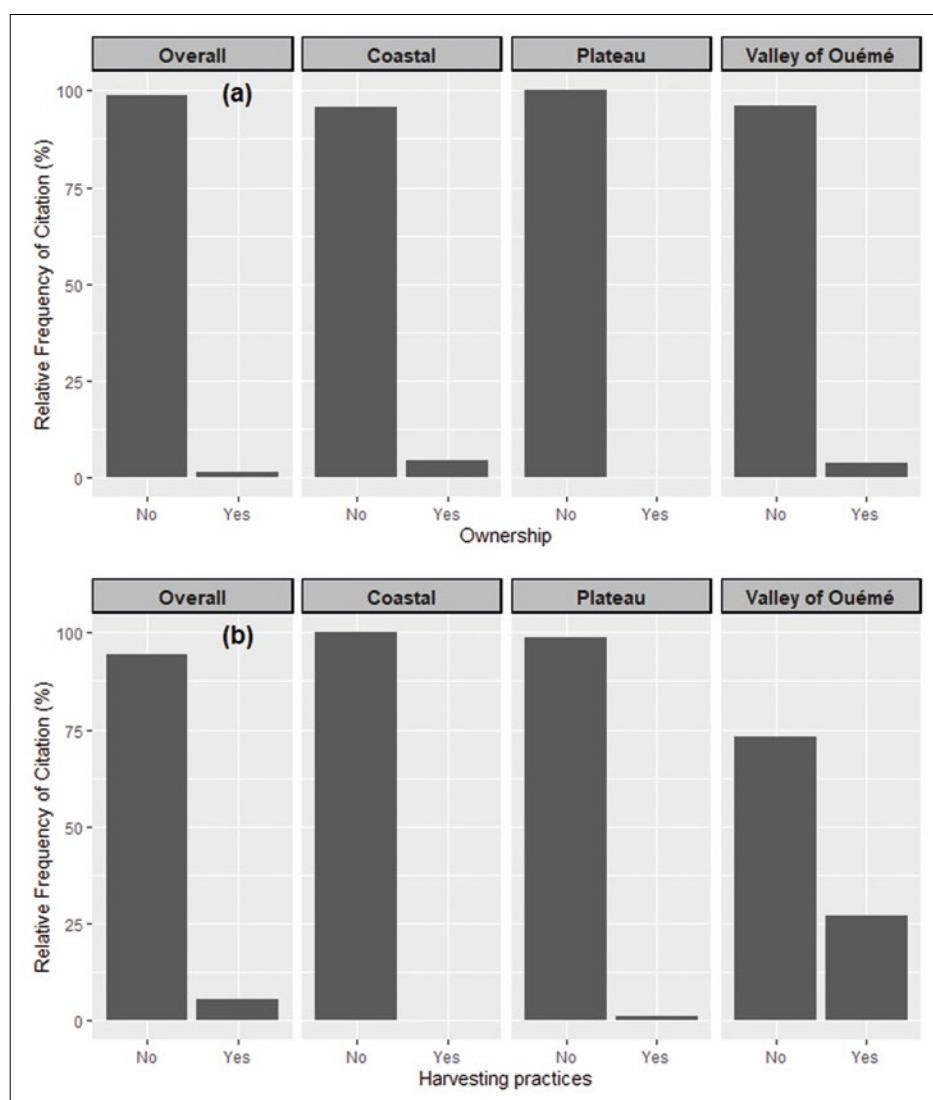


Figure 2.

Relative Frequency of Citation (RFC) of local knowledge on *Garcinia kola* Heckel, global and per phytodistrict.

possesses at least one tree in the Plateau phytodistricts (figure 3.a).

A significant proportion of respondents (94.4%) reported that trees were not harvested in their phytodistrict, while only 5.6% reported that trees were harvested (figure 3.b). The exploitation of trees is predominantly concentrated in the Valley of Ouémé phytodistrict, accounting for 26.39% of the total, with a comparatively smaller percentage, 1.05%, being recorded in the Plateau phytodistrict (figure 3.b). The tree is more conserved in the Coastal phytodistrict, where exploitation is presumed unlikely.



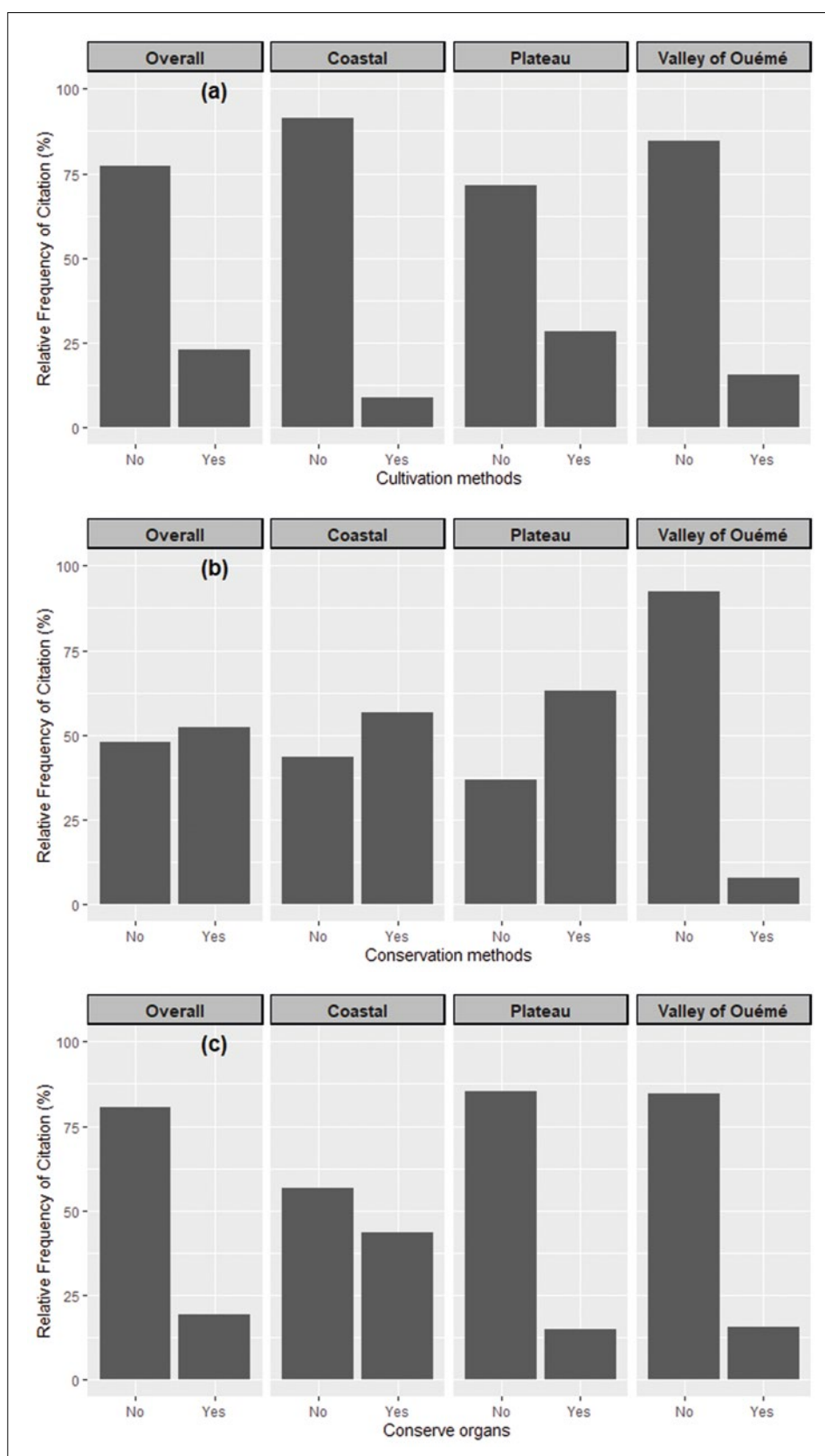
Figures 3. Relative Frequency of Citation (RFC) of ownership (a) and harvesting practices (b) on *Garcinia kola* Heckel, global and per phytodistrict. No respondents from the Zou phytodistrict (0%) reported knowledge of the species. Consequently, no data was collected on ownership, and harvesting practices within that specific phytodistrict.

Cultivation and conservation of *Garcinia kola* and associated factors

In response to the question regarding the cultivation of *G. kola* trees (figure 4.a), 22.9% of respondents indicated that they engage in this practice, in contrast to the 77.1%. A survey in the Plateau phytodistricts revealed that 28.4% of respondents had engaged in cultivation, with 15.4% cultivating in the Valley of Ouémé and 8.7% in the Coastal phytodistricts (figure 4.a). Phytodistricts and occupation significantly affect cultivation (table V). Planters and nurserymen were significantly more likely to have planted *G. kola* trees than respondents from other occupational groups, with odds ratios of 8.00 and 2.88, respectively (table V). Respondents from the Plateau phytodistrict were significantly more likely

to have planted *G. kola* trees than those from other phytodistricts, with an odds ratio of 6.68 (table V). Although not statistically significant, males were 4.90 times more likely than females to have planted a *G. kola* tree (table V).

The present study found that 52.1% of respondents engage in conservation activities, compared with 47.9% who do not (figure 4.b). It is further revealed that respondents in the Plateau phytodistrict are undertaking a greater number of conservation actions (63.2%), followed by those in the Coastal phytodistrict (56.5%), and only 7.69% in the Valley of Ouémé phytodistrict (figure 4.b). The conservation actions in question are generally practised in plantations and home gardens, as well as in sacred forests, based on endogenous prohibitions. Phytodistricts and gender have been identified as socio-demographic factors influencing



Figures 4.

Relative Frequency of Citation (RFC) of cultivation methods (a), conservation methods (b) and conserve organs (c) on *Garcinia kola* Heckel, global and per phytodistrict. No respondents from the Zou phytodistrict (0%) reported knowledge of the species. Consequently, no data was collected on cultivation methods, conservation methods, and conserve organs within that specific phytodistrict.

Table V.

Socio-demographic factors determining the cultivation, conservation actions, and organ-part conservation of *Garcinia kola*: binomial generalised linear models.

Socio-demographic factors	Estimate	Standard error	OR	p-value
Cultivation				
(Intercept)	-4.42	1.45	0.01	< 0.01
Phytodistricts - Plateau	1.9	0.91	6.68	< 0.05
Phytodistricts - Valley of Ouémé	0.57	1.06	1.77	0.59
Gender - Male	1.59	1.12	4.9	0.16
Occupation - Others	-0.62	0.76	0.54	0.41
Occupation - Breeders	-15.81	1,380.76	0	0.99
Occupation - Public servants	0.56	0.98	1.76	0.56
Occupation - Foresters	0.66	0.77	1.93	0.39
Occupation - Nurserymen	1.06	0.59	2.88	0.07
Occupation - Planters	2.08	1.02	8.02	< 0.05
Occupation - Residents	-1.19	1.13	0.31	0.29
Conservation actions				
(Intercept)	-0.792	0.816	0.453	0.33
Phytodistricts -Plateau	-0.202	0.576	0.82	0.73
Phytodistricts Valley of Ouémé	-3.72	0.955	0.03	< 0.001
Gender - Male	1.86	0.643	6.42	< 0.001
Occupation - Others	-0.507	0.603	0.6	0.4
Occupation - Breeders	1.964	1.271	7.13	0.12
Occupation - Public servants	-1.696	0.948	0.19	0.07
Occupation - Foresters	0.875	0.814	2.4	0.28
Occupation - Nurserymen	0.35	0.641	1.42	0.58
Occupation - Planters	-0.664	0.878	0.52	0.75
Occupation - Residents	-0.398	0.701	0.67	0.57
Organ part conserve				
(Intercept)	0.59	0.79	1.81	0.45
Phytodistricts - Plateau	-1.61	0.57	0.2	< 0.01
Phytodistricts - Valley of Ouémé	-1.4	0.77	0.25	0.07
Gender - Male	-0.48	0.61	0.62	0.44
Occupation - Others	-0.72	0.78	0.49	0.36
Occupation - Breeders	-0.2	1.02	0.82	0.85
Occupation - Public servants	-0.47	0.99	0.63	0.64
Occupation - Foresters	0.27	0.74	1.31	0.72
Occupation - Nurserymen	-1.07	0.74	0.34	0.15
Occupation - Planters	-1.21	1.23	0.3	0.32
Occupation - Residents	-0.54	0.79	0.58	0.5

the conservation of *G. kola* (table V). In the Valley of Ouémé phytodistrict, the probability that respondents had not taken measures to conserve the species was 97%, compared with 18% in the Plateau phytodistrict. The results of this study indicate that men were 6.4 times more likely than women to have engaged in conservation actions.

Garcinia kola organs that have been preserved are the bark, leaves, roots, and seeds. The survey revealed that 19.4% of respondents conserve these organs, with 43.5%, 15.4% and 14.7% of respondents, respectively, in the Coastal, Valley of Ouémé and Plateau phytodistricts (figure 4.c). The conservation of *G. kola* tree organs is influenced by the phytodistricts (table V). The results of the study indicate that, compared with respondents from the Coastal phytodistrict, those from the Plateau and Valley of Ouémé phytodistricts were, respectively, 80% and 75% less likely to conserve the species' organs (table V). Furthermore, men exhibited a 38% lower probability of preserving *G. kola* organs than women (table V). Finally, foresters were found to be 1.31 times more likely to possess *G. kola* organs than individuals in other occupations.

Perceived threats to *Garcinia kola* and associated factors

The most prevalent threats cited by respondents (figure 5) were debarking (54.2%), infrastructure (43.8%), tree mutilation (17.4%), vegetation fires (11.8%), anarchic cutting (3.47%), and others (18.1%). The most frequently cited threats in Coastal phytodistricts were debarking (39.1%), infrastructure (39.1%), and mutilation (30.4%). In the Plateau phytodistricts, debarking (55.8%) and infrastructure (51.6%) were the most commonly cited threats (figure 5). In the Valley of Ouémé phytodistrict, respondents frequently cited (figure 5) debarking (61.5%) and mutilation (34.6%) as threats to *G. kola*, followed by infrastructure (19.2%) and vegetation fires (19.2%).

Multinomial logistic regression analysis (table VI) shows that respondents from the Plateau and Valley of Ouémé phytodistricts, as well as male respondents, significantly perceive anarchic cutting as the main threat to the species.

The results of the correspondence analysis (figure 6) showed that 59.9% of the variances were explained by the first two dimensions, which is sufficient for interpreting the results. Axis 1 distinguished vegetation fires that exhibited a strong correlation with the CMEle (Coastal phytodistricts | Male | Breeders) and VFPeP (Valley of Ouémé | Female | Nurserymen) subgroups (figure 6 and table VI). Axis 2 also distinguishes threats named 'others', with a strong correlation to PMFor (Plateau | Male | Foresters) and CMRes (Plateau | Male | Residents) (figure 6 and table VI).

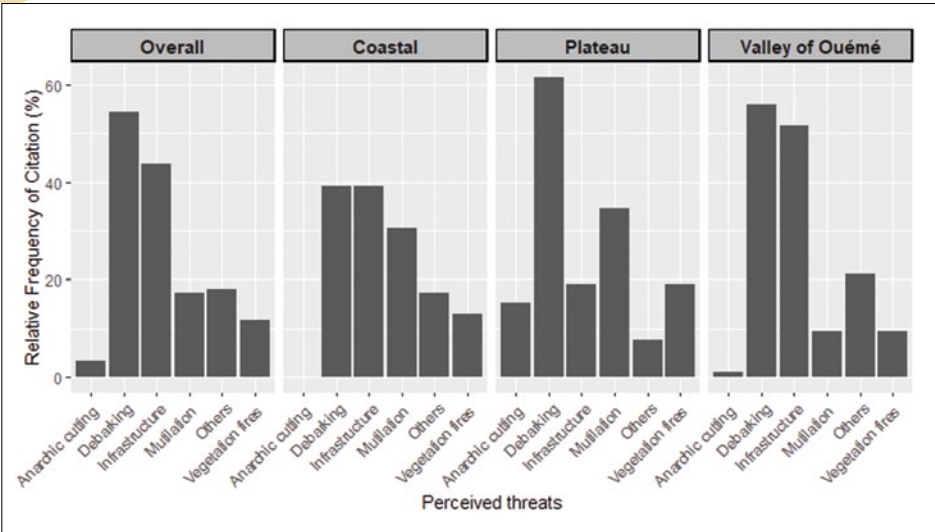


Figure 5. Relative frequency of citing threats on *Garcinia kola* Heckel according to phytodistricts. No respondents from the Zou phytodistrict (0%) reported knowledge of the species. Consequently, no data was collected on perceived threats within that specific phytodistrict.

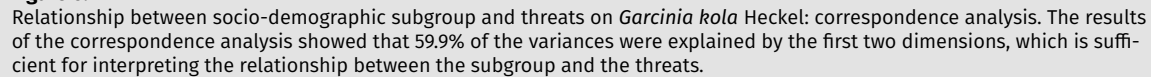
Table VI. Socio-demographic factors determining threats of *Garcinia kola*: multinomial logistic regression.

Parameters	Estimate	Standard error	z-score	p-value
Anarchic cutting - Intercept	-28.41	0.27	-105.63	< 0.001
Anarchic cutting - Phytodistricts Plateau	13.83	0.71	19.56	< 0.001
Anarchic cutting - Phytodistricts Valley of Ouémé	17.39	0.66	26.25	< 0.001
Anarchic cutting - Gender Male	11.74	0.27	43.63	< 0.001
Debarking - Intercept	0.86	0.75	1.14	0.25
Debarking - Phytodistricts Plateau	0.17	0.66	0.26	0.79
Debarking - Phytodistricts Valley of Ouémé	1.29	0.98	1.32	0.19
Debarking - Gender Male	-0.07	0.65	-0.11	0.91
Vegetation fires - Intercept	-0.03	0.96	-0.04	0.97
Vegetation fires - Phytodistricts Plateau	-0.45	0.88	-0.51	0.61
Vegetation fires - Phytodistricts Valley of Ouémé	1.32	1.17	1.13	0.26
Vegetation fires - Gender Male	-0.38	0.87	-0.44	0.66
Infrastructure - Intercept	1.00	0.75	1.34	0.18
Infrastructure - Phytodistricts Plateau	0.13	0.67	0.20	0.84
Infrastructure - Phytodistricts Valley of Ouémé	0.19	1.05	0.18	0.86
Infrastructure - Gender Male	-0.28	0.64	-0.44	0.66
Mutilation - Intercept	0.88	0.81	1.08	0.28
Mutilation - Phytodistricts Plateau	-1.27	0.76	-1.68	0.09
Mutilation - Phytodistricts Valley of Ouémé	1.10	1.03	1.07	0.29
Mutilation - Gender Male	-0.49	0.78	-0.63	0.53

Discussion

Tree abundance, phytodistrict, and occupation affect traditional knowledge of the bitter kola tree

The conservation and sustainable management of multipurpose indigenous trees are best achieved through the knowledge and participation of local communities in the domestication process (Vodouhe & Dansi 2012). Bitter kola is restricted to the Guinean zone of Benin (Akoègninou et al. 2006), with confirmed presence in the Coastal, Valley of Ouémé, and Plateau phytodistricts (figure 1). The findings of this study indicate that among respondents in the Zou phytodistrict, there was a total lack of knowledge regarding the species (0%), which strongly suggests the species' absence or ecological unsuitability in this phytodistrict. Respondents from the Plateau and Valley of Ouémé phytodistricts demonstrated a notably lower level of knowledge regarding the bitter kola tree. They were 80% (OR = 0.20) and 74% (OR = 0.26) less likely, respectively, to answer affirmatively compared with those from the Coastal phytodistricts (figure 1 and table IV). Our results are consistent with the hypothesis that individuals residing in regions where a species is abundant are more familiar with it than those residing in areas where it is rare (Albuquerque et al. 2006; Gaoue et al. 2017). Our study showed that phytodistricts and occupation are mainly factors driving knowledge of bitter kola in Benin. This aligns with the age, gender, and dynamics of knowledge hypothesis (Gaoue et al. 2017), which suggests that socio-demographic factors drove knowledge dynamics in communities. This result is similar to that of Salako et al. (2018), who found that the traditional knowledge of *Borassus aethiopum* was significantly associated with age, categories, gender, local abundance, and region. In addition, this finding corroborates Dai et al. (2025), who reported that traditional knowledge of *Uvaria chamae* varies across climatic zones, professional activities, gender, sociolinguistic groups, and respondent age. Foresters (OR = 9.99, $p < 0.001$) and nurserymen (OR = 2.93, $p < 0.001$) had a significantly higher probability of responding affirmatively than respondents from other occupational backgrounds. This could be attributed to their occupations, which are more focused on the management of natural and forest resources.



Cultivation of multipurpose species is an important strategy for conservation and sustainable management. Cultivation, conservation practices and conservation of the organ parts of *G. kola* are influenced by the phytodistricts. Respondents expressed their willingness to cultivate the species primarily due to its multiple benefits, including medicinal uses, cultural value, and income generation. This willingness represents a significant opportunity for both national and international organisations to collaborate to ensure the conservation and domestication of species in Benin. The respondents from the Plateau phytodistrict are predominantly engaged in cultivation (28.4%) and conservation actions (63.2%), a finding attributable to the principal occupation of most respondents in this phytodistrict being planting or nursery production. Respondents (77.1%) who do not cultivate the species cited the tree's taboo, the absence of seeds, and a lack of knowledge of nursery techniques.

**Photo 4.**

Garcinia kola tree cultivated in home gardens in Savi, Ouidah Municipality, Benin.
Photo G. Behanzin.

Furthermore, the majority of respondents assert that bitter kola is mystical and that young people are not permitted to cultivate it. According to belief, any young person who cultivates this species will die prematurely before the tree reaches the fructification stage. These myths have negative implications for the domestication and conservation of taboo species (Balima et al. 2018). The main conservation actions are generally protected by plantations and in home gardens, as well as in sacred forests, based on endogenous prohibitions. The latter conservation action is taboo, as a conservation strategy hypothesis suggests that certain plant and animal species are made taboo to protect them from overexploitation and extinction (Gaoe et al. 2017). *Afzelia africana* is one of the multi-purpose species whose conservation is supported by its sacred or taboo status (Balima et al. 2018). According to Dadjo et al. (2020), the conservation of bitter kola in plantations and home gardens would indicate that it is extinct in the wild in Benin. In southern Cameroon, farmers implemented traditional conservation approaches to conserve bitter kola, such as selective clearing during land preparation for cropping, sustainable bark harvesting of stands in wild populations, transplan-

tation of wildlings, artificial propagation and recognition of individual property ownership on certain wild stands of bitter kola (Fondoun & Tiki Manga 2000). Conservation actions reported for important multipurpose trees such as *Balanites aegyptiaca* (L.) Delile (Akakpo et al. 2024) and *Vitex doniana* (Guindé et al. 2025) could be adapted for bitter kola, with specific adjustments to its ecology and traditional uses. The conservation of bitter kola is largely the domain of men, as they possess the most expertise in the domains of planting and nursery production. This finding corroborates the study by Dadjo et al. (2020), who reported that gender influenced the conservation of bitter kola. The bitter kola organs that have been preserved in Benin are the bark, leaves, roots, and seeds. However, men exhibited a 38% lower probability of preserving *G. kola* organs than women. This could be attributed to the role of women in rural communities, where various preserved tree parts are used both as a source of income and for the treatment of various illnesses (Durand et al. 2015). This finding aligns with the observations reported by Vodouhe & Dansi (2012), who noted a strong preference among women for domesticating plants for medicinal and culinary purposes.



Photo 5.

Fruits and seeds of *Garcinia kola* collected from home gardens in Savi, Ouidah Municipality, Benin.
 Photo G. Behanzin.

Anarchic cutting represents a key threat to bitter kola

Despite the initiation of certain conservation efforts, respondents indicated that bitter kola faces significant threats, including debarking (54.2%), infrastructure (43.8%), mutilation of the tree (17.4%), vegetation fires (11.8%), anarchic cutting (3.47%), and other factors (18.1%). Previous studies have identified a threat to the species in Benin (Durand et al. 2015; Dadjo et al. 2020) and Cameroon (Fondoun & Tiki Manga 2000; Yogom et al. 2020; Manourova et al. 2023). These findings corroborate previous studies (Avakoudjo et al. 2020; Biao et al. 2023; Dai et al. 2025), indicating that multipurpose indigenous trees face intensive harvesting pressure from local populations for livelihoods. These threats, coupled with the low level of the local communities' involvement in cultivation, highlight the urgent need for its domestication in West and Central Africa (Leakey 2012; Assogbadjo et al. 2017). Respondents from the Plateau and Valley of Ouémé phytodistricts, as well as male respondents, significantly perceive anarchic cutting as the main threat to the species. Training farmers in the sustainable harvesting of tree products has

been suggested as a potential solution to preserve bitter kola (Manourova et al. 2023). It is therefore essential that targeted training programmes be implemented to establish resilience-building strategies and sustainable management protocols to mitigate the effects of anthropogenic pressures and conserve bitter kola.

Implications for domestication and sustainable management

The results of this study provide valuable insights for the domestication and sustainable management of bitter kola in Benin. The findings underscore the influence of socio-demographic factors and phytodistricts on local knowledge about the bitter kola tree, cultivation practices, conservation efforts, and perceived threats to the species. These elements must be carefully considered to design suitable conservation and sustainable management interventions.

The variation in knowledge of the bitter kola tree, cultivation practices, and perceived threats across phytodistricts indicates that domestication efforts should be prioritised in

the Coastal and Plateau phytodistricts, where the species is already well-known and cultivated. The higher level of engagement in cultivation observed among planters and nurserymen suggests that these occupational groups are key stakeholders in domestication programmes. It is imperative that training and resources are allocated to these stakeholders to optimise propagation efforts. Despite the current predominance of males in cultivation activities, the potential contribution of females should not be underestimated, as they preserve bitter kola organs more than males. Our results highlight the importance of engaging both genders in long-term management strategies, i.e., gender-inclusive participation. Traditional practices, such as the protection of sacred forests and home gardens, must be reinforced and incorporated into formal management strategies. Including traditional leaders in the governance of bitter kola resources could improve best practices in conservation regulations and sustainable utilisation. Conversely, the respondent from the Valley of Ouémé phytodistricts exhibits minimal conservation efforts, underscoring the necessity for targeted awareness campaigns and phytodistrict-based initiatives. In order to address the most significant threats to bitter kola, namely debarking, infrastructure, and mutilation of the tree, it is essential to implement specific solutions at a phytodistrict level. Therefore, the implementation of phytodistrict-based monitoring and enforcement of existing prohibitions could assist in the reduction of overexploitation, particularly in the Plateau and Valley of Ouémé phytodistricts, where anarchic cutting is perceived as a major threat. Future studies should prioritise the investigation of the factors that limit bitter kola cultivation, as well as the potential for assisted cultivation trials in the phytodistricts. Moreover, the programme could provide training to the local population in various cultivation techniques and raise awareness of the taboo surrounding the death of cultivation, particularly targeting younger generations to encourage long-term conservation efforts.

Conclusion

The study, conducted in 24 municipalities across four phytodistricts in Benin, assessed local knowledge, conservation practices and perceived threats concerning *Garcinia kola*. These multipurpose species are now extinct in the wild in the country. We showed that only 19.1% of the 755 respondents were aware of the species, with significantly higher awareness in the Coastal phytodistrict (51.1%), followed by the Ouémé valleys (21.1%) and the Plateau (17.1%). Awareness was mainly influenced by phytodistrict and occupation, with nursery owners and foresters being 3 and 10 times more likely to be knowledgeable, respectively, while gender showed a comparatively weaker effect. The major threats identified are debarking (54.2%), infrastructure (43.8%) and anarchic cutting (3.5%), the latter being perceived as particularly critical in the Plateau and Ouémé Valley phytodistricts. Although 22.9% of respondents cultivate *G. kola*, cultivation remains limited by persistent

taboos and a lack of technical knowledge, particularly among younger generations. Conservation efforts, largely driven by men (who are 6.4 times more involved than women), are mainly centred on plantations, home gardens and sacred forests. These findings highlight the urgent need to develop participatory management strategies, prioritising the Coastal and Plateau phytodistricts for domestication, whilst involving women in long-term management. It is crucial to strengthen training in cultivation and propagation techniques, to promote indigenous knowledge (such as cultural taboos), and to adapt conservation policies to local specificities, particularly to combat unregulated logging and overexploitation. Domestication programmes should target nursery operators and foresters, identified as key stakeholders (up to 10 times more likely to possess knowledge of the species). An inclusive approach that involves both men and women — the latter playing a central role in the preservation of plant organs — is essential. Finally, targeted awareness campaigns, particularly in the Ouémé Valley, where conservation efforts are minimal, could promote the sustainable management of this resource, which has high medicinal, cultural, and economic value.

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Access to data

The datasets generated during this study have been deposited in Zenodo (<https://doi.org/10.5281/zenodo.19719522>).

Ethics and professional conduct

All participants gave their voluntary consent to be included in the study. They remain anonymous. The manuscript complied with the regulations governing experimentation in Benin where the experiment was conducted, and/or has been approved by the appropriate ethics committee and therefore has been carried out in accordance with the ethical standards set out in the 1964 Declaration of Helsinki and its subsequent amendments.

Artificial Intelligence

Artificial intelligence has been employed to enhance and rectify the written English language, with a particular focus on its scientific and technical aspects.

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Sodahlon et al. – Credit authorship contribution statement

Contributor role	Contributor names
Conceptualisation	T. Sodahlon, M. A. Kolawole, J. G. Djego
Data Curation	M. A. Kolawole
Formal analysis	M. A. Kolawole
Funding Acquisition	T. Sodahlon
Inquiry and investigation	T. Sodahlon
Methodology	T. Sodahlon, M. A. Kolawole
Project management	T. Sodahlon, J. G. Djego, B. Tenté
Supervision	J. G. Djego, B. Tenté
Validation	T. Sodahlon, M. A. Kolawole, J. G. Djego, B. Tenté
Visualisation	M. A. Kolawole
Writing – Original Draft Preparation	T. Sodahlon, M. A. Kolawole
Writing – Review & Editing	T. Sodahlon, M. A. Kolawole, J. G. Djego, B. Tenté

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Cirad - Campus international de Baillarguet,
34398 Montpellier Cedex 5, France
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