Ethnobotanical applications of *Spathodea campanulata* P. Beauv. (Bignoniaceae) (African tulip tree) in Ghana

Maxwell Kwame Boakye, Alfred Ofori Agyemang, Richard Selase Gbadegbe, Mawuli Quashie, Bernard Kofi Turkson, Kekeli Kodjo Adanu and Edward Debrah Wiafe

Correspondence

Maxwell Kwame Boakye[1*], Alfred Ofori Agyemang[2], Richard Selase Gbadegbe[3], Mawuli Quashie[3], Bernard Kofi Turkson[4], Kekeli Kodjo Adanu[5] and Edward Debrah Wiafe[6]

[1]Department of Environmental Science, Ho Technical University, Ho, Ghana
[2]Institute of Traditional and Alternative Medicine, University of Health and Allied Sciences, Ho, Ghana
[3]Department of Industrial Art, Ho Technical University, Ho, Ghana
[4]Department of Herbal Medicine, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[5]Department of Surgery, School of Medicine, University of Health and Allied Sciences, Ho, Ghana
[6]School of Natural and Environmental Sciences, University of Environment and Sustainable Development, Somanya, Ghana

[*]Corresponding Author: mboakye@htu.edu.gh

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Research

Abstract

Background: *Spathodea campanulata* P. Beauv. (Bignoniaceae) is documented to have ethnobotanical potential worldwide, but knowledge about this useful tree to local communities is limited in Ghana. This study was aimed at evaluation of ethnobotanical knowledge of the utilization of *S. campanulata* among the local population in Ghana.

Methods: Data was collected through a semi-structured interviews with 193 participants in the Adaklu District of the Volta Region of Ghana. Ethnobotanical indices were used to quantitatively determine the most culturally important *S. campanulata* plant parts using the ethnobotanyR package.

Results: A total of 25 applications grouped into six use categories from seven *S. campanulata* parts were observed in this study. The primary use category was material, followed by fuel, medicine, environmental, food additive, and food. Anemia had the highest frequency of mentions, followed by firewood and dyeing of cloth, construction, furniture, and charcoal. The wood had the highest use reports (UR) and cultural importance (CI), while stem bark had the highest number of uses (NU) and cultural value index (CVe).

Conclusion: The study showed that the applications and use categories were influenced by the rural nature of communities and lack of availability of services. This study revealed a high-fidelity level for the *S. campanulata* stem bark to treat anemia, a common ailment in the study region. The study suggests increasing awareness for better promotion and valorization of *S. campanulata* in Ghana as a source of fuel wood and medicinal purposes.

Keywords: ethnobotany, Volta region, anemia, dyeing, construction, furniture, cultural importance

Background

Spathodea campanulata P. Beauv. commonly known as the African Tulip tree, is native to West Tropical Africa and introduced throughout South America, the Caribbean, and the Pacific Isles belongs to the family Bignoniaceae (Labrada & Medina 2009; Orwa et al. 2009; Rojas-Sandoval & Acevedo-Rodríguez 2013; Padhy 2021; Wagh *et al.* 2019, 2021; Świątek *et al.* 2022). It is a small-to-medium-sized tree species, up to a height of 25-35 m (Bosch 2002; Orwa *et al.* 2009; Rojas-Sandoval & Acevedo-Rodríguez 2013). The tree has a stout and sometimes buttressed trunk, with thick branches spotted with tiny white lenticels (Rojas-Sandoval & Acevedo-Rodríguez 2013). The leaves are oppositely arranged along the stems and are usually large, up to 50 cm long, compound with 7-17 leaflets that are oppositely arranged along the stems (Rojas-Sandoval & Acevedo-Rodríguez 2013; Wagh *et al.* 2019). The orange-red flowers are large. Horn-shaped silky buds filled with water emerge upside down at the end of the branch (Padhy 2021). The fruits are upstanding and usually 15-25 cm long, split on the ground into two boat-shaped valves, releasing many flat-winged seeds (Orwa *et al.* 2009).

The plant has tremendous ethnobotanical potential, with almost all of its parts used traditionally (Bosch 2002; Orwa *et al.* 2009; Rojas-Sandoval & Acevedo-Rodríguez 2013; Świątek *et al.* 2022). The African tulip tree has been shown traditionally to have potential medicinal properties for the treatment of various ailments (Bosch 2002; Orwa *et al.* 2009; Rojas-Sandoval & Acevedo-Rodríguez 2013; Wagh *et al.* 2021). In traditional medicine pharmacopeia, *S. campanulata* is reported to help treat ailments including fever, dysentery, stomach ulcers, wounds, constipation, malaria, diabetes, and urethritis (WAHP 2013; Babu *et al.* 2015; Padhy 2021). Natural dye has been extracted from *S. campanulata* to dye fabric (Lokesh & Swamy 2013; Amutha & Ramya 2021). It is used for purposes including ornamental, fodder, shade, and live fence (Gilman & Watson 1994; Bosch 2002; Labrada & Medina, 2009; Orwa *et al.* 2009; Rojas-Sandoval & Acevedo-Rodríguez 2013; Fongod *et al.*, 2014; Villanueva-Partida *et al.* 2019). The seeds are used as food, and a poison is derived from the tough central part of the fruit to kill animals (Orwa *et al.* 2009; Rojas-Sandoval & Acevedo-Rodríguez 2013). The wood is used for carving, carpentry and joinery, light construction, making drums, and fuelwood purposes (Bosch 2002; Orwa *et al.* 2009; Rojas-Sandoval & Acevedo-Rodríguez 2013; Villanueva-Partida *et al.* 2019).

In Ghana, the ethnopharmacological usefulness of *S. campanulata* in traditional medicine pharmacopeia (Agyare *et al.* 2009; Asase & Asafo-Agyei 2011; Komlaga *et al.* 2015; Appiah *et al.* 2018; Asafo-Agyei *et al.* 2019; Tetteh *et al.* 2020), and extraction of fiber for rope making (Quashie *et al.* 2021) have been documented. However, knowledge and exploitation of several products from *S. campanulata* still need to be improved and documented in the country, given its ethnobotanical potential worldwide. This study aims to ascertain the local people's knowledge of the uses of this species. This study's objective is to evaluate the ethnobotanical knowledge and cultural importance of *S. campanulata* to local communities in Ghana. This information will contribute to documenting indigenous knowledge systems that are fast eroding and pave the way for the better valorization of ethnobotanical purposes and sustainable management of the species.

Materials and Methods

Study area

The study was undertaken in the Adaklu District of the Volta Region of Ghana (Figure 1). The study area is located on Longitudes 06°41′1″N and 6.68361°N and Latitudes 00°20′1″E and 0.33361°E and shares boundaries to the east with Ho-West, North-Tongu District to the south, Agotime-Ziope District to the north, and the east with Akatsi-North District (Ghana Statistical Service 2014). The Adaklu District, which covers a total land area of 810 km^2 is wholly rural with no urban locality has a human population of 38,649 (Ghana Statistical Service 2021). The district's natural resources serve as livelihood and employment for most inhabitants (Adaklu District Assembly 2022). Agriculture, craft, and related trade workers constitute the dominant economic activity in the district (Ghana Statistical Service 2014). Rural communities actively interact with the biological diversity of the surrounding ecosystem, and it was anticipated that people in the study area would be knowledgeable about *S. campanulata*.

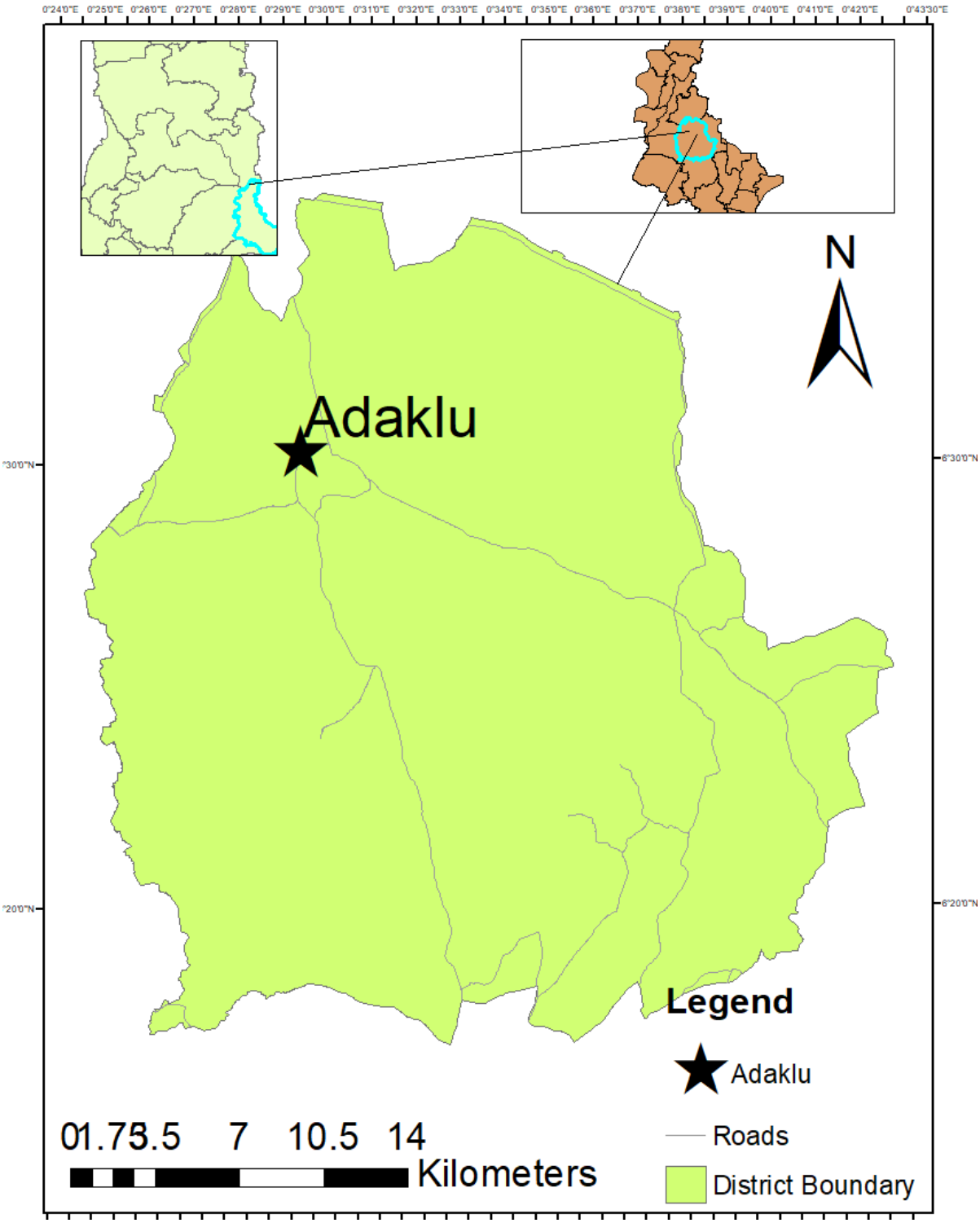

Figure 1. Map of Ghana indicating the Volta Region and Adaklu district

A previous survey conducted by MQ (Quashie *et al.* 2021) confirmed the occurrence of the species in the study area. A preliminary survey was conducted on 50 randomly sampled individuals in the study area. It was found that 43 individuals (p = 0.86) knew at least one use for the species. This information was used to calculate the sample size according to the formula of Dagnelie (1998):

$$n = \frac{U^2_{1-\alpha/2} \times p(1-p)}{d^2}$$

where $U_{1-\alpha/2}$ is the value of the Normal random variable corresponding to a probability value of $1-\alpha/2$. For a probability value of 0.975 (α = 0.05), $U_{1-\alpha/2} \approx 1.96$; d is the margin error of the estimation of any parameter to be computed, which was fixed at 5% (0.05). Under these assumptions, the sample size to use was established to be 185 people but was increased to 193 due to the cooperation of the study participants.

The data was collected between November and December 2022 using individual semi-structured interviews. Photographs were then shown to the respondents, who were asked to identify the species. Questionnaires focused on the local name and local uses of *S. campanulata.* To motivate and elicit information from the respondents, verbal prompts and probes, such as 'you did not mention this part (name of the plant part)' or 'you have never used it before?' were used. The most widely spoken language in the district is the Ewe language which many others have also adopted as a *lingua franca*, and interviews were conducted in this language. All the participants interviewed were fluent in the Ewe language. MQ was fluent in the Ewe language and did most of the Ewe translation. Also, most of the questions were structured to avoid loss of meaning through the translation. The local names mentioned by the respondents were matched with that in the available literature for plant species identification (Abbiw 1990; Irvine 1961). Plant material was collected and used to confirm their identification by comparison with voucher specimens by the curators at the Herbarium of the Department of Herbal Medicine, Faculty of Pharmacy and Pharmaceutical Sciences, Kwame Nkrumah University of Science and Technology (KNUST). The following voucher numbers were assigned to the leaves (KNUST/HM1/2012/L013), stem bark (KNUST/HM1/2019/SB008), and root (KNUST/HM1/2022/R001). The ailments mentioned were confirmed through a previous study of ethnobotanical inventory for therapeutic purposes in the Ho central market (Boakye *et al.* 2022) and local Traditional Medicine Practitioners associated with the Institute of Traditional and Alternative Medicine (ITAM), University of Health and Allied Sciences (UHAS).

Data analysis

Ethnobotanical analysis was performed using the ethnobotanyR package (Whitney 2020). The ethnobotanical indices determined included: Use report (UR), Cultural importance (CI), Frequency of citation (FC), Number of uses (NU), Relative Frequency of citation (RFC), Relative importance index (RI), cultural value of ethnospecies (CVe), and fidelity level (FL) per plant part.

The UR values per species count the number of informants who mention each use category for the species and the sum of all uses in each use category, whiles the number of uses (NU) per species is the sum of all categories considered useful for a species (Prance *et al.* 1987). The cultural importance (CI) index calculates the cultural importance index for each species in the data set (Tardío & Pardo de Santayana 2008). The frequency of citation (FC) per species is the sum of informants that cite a use for the species in the dataset (Prance *et al.* 1987). The relative frequency of citation (RFC) determines the significance of every species based on the number of informants who reported using it. The relative importance (RI) index calculates the relative importance of each species in the data set, considering only the use categories (Tardío & Pardo de Santayana 2008). The cultural value (CVe) calculates the cultural, practical, and economic dimensions (ethno) species importance (Reyes-Garcia *et al.* 2006). The fidelity level (FL) per species calculates the percentage of informants who use a plant for the same purpose compared to all plants' uses (Friedman *et al.* 1986).

Each use reported was assigned to one of Cook's (1995) use categories. A visualization of flows, i.e., weighted connections between *S. campanulata* parts used and their application, was presented in a Sankey diagram using Power BI.

Results

A total of 25 applications for *S. campanulata* were recorded, with anemia (local description of the ailment: eʋu manɔ ame si) having the highest frequency of mention, followed by firewood and dyeing of cloth (n = 193; each), construction (n = 192), and furniture and charcoal (n = 191; each) while the least number of mentions was recorded for diarrhoea (Figure 2). Based on Cook's (1995) use categories, the 25 applications were grouped into six (6) levels. The main category of use was material (n = 602), followed by fuel (n = 384), medicine (n = 341), environmental (n = 93), food additive (n = 75), and food (n = 5) (Figure 3). Concerning *S. campanulata* parts used, the wood, stem bark, whole plant, inner bark, root, young stem, and leaf were identified to be used by the respondents. The wood was mainly used in the material and fuel categories (n = 564 and 354, respectively), while the stem bark was the most dominant in the medicine category (n = 329). The whole plant was mainly used in the environmental (n = 93), food additive (n = 75), and food (n = 5) categories. The root and leaf were used under the medicine category (n =

11 and 1, respectively), while the inner bark was applied under the material category. The flow connections between *S. campanulata* parts and their use category are presented in Figure 4.

The medicinal application of *S. campanulata* parts revealed that the stem bark was used mainly for the treatment of anemia (n = 193), followed by stomach pain (n = 35), hernia (n = 19), to stop bleeding (n = 18), general wound (n = 14), to improve maternal blood (n = 12), vitality (n =10). The root was applied in the treatment of fever and headache (n = 3; each), general wound and appetizer (n = 2; each), and anemia (n = 1), while the leaf was used to treat stomach pain (n = 1). The contribution of the plant parts and the ailments used in treating is presented on a flow diagram in Figure 5.

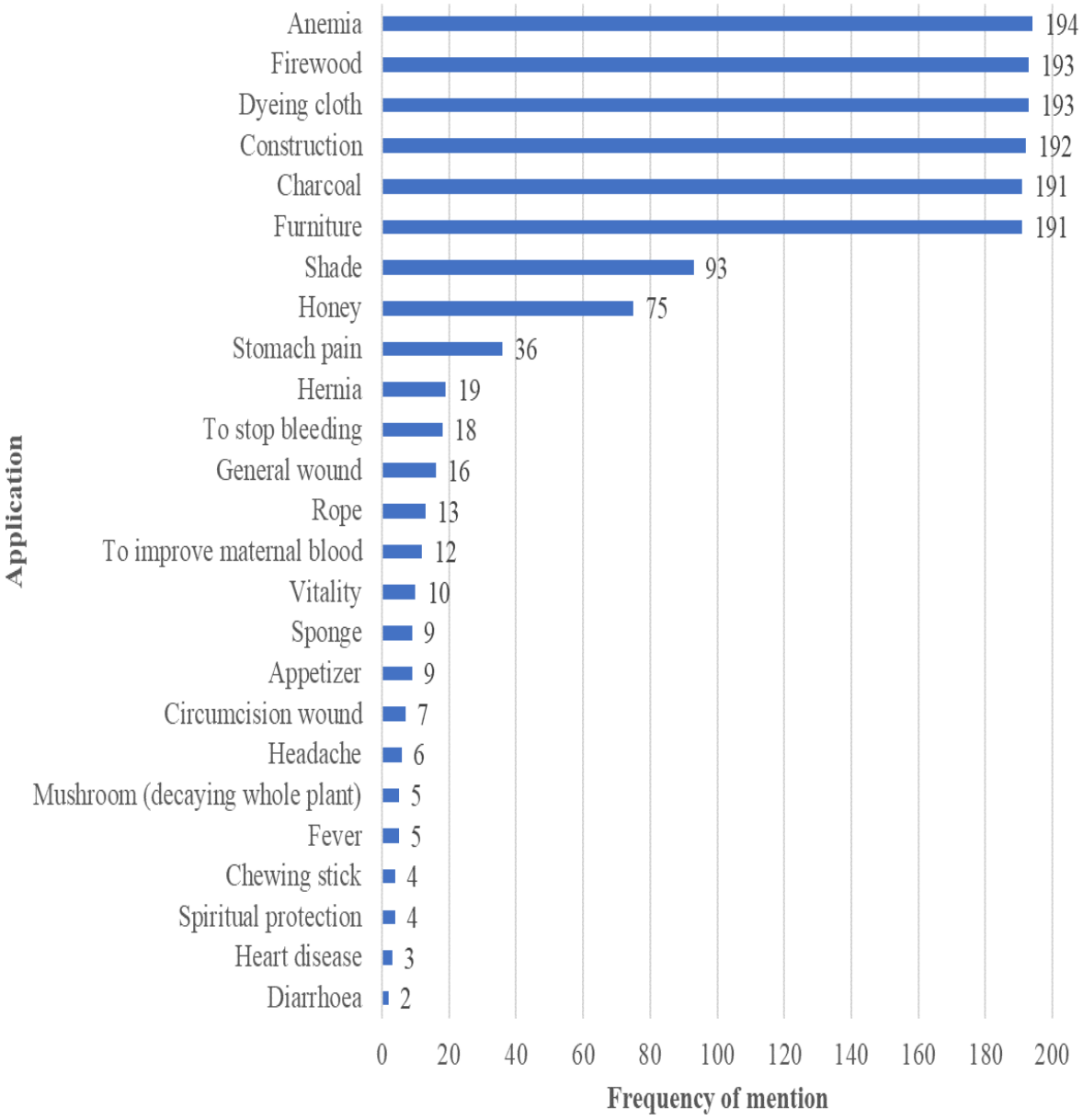

Figure 2. Ethnobotanical applications and frequency of mention of *S. campanulata*

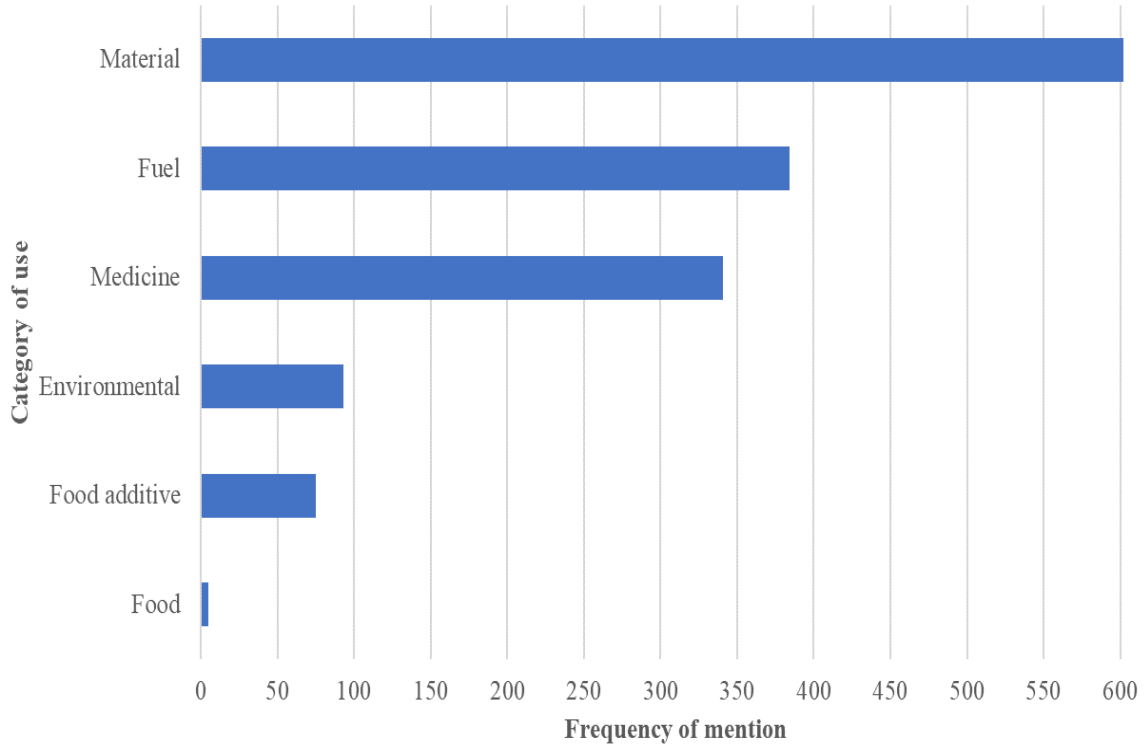

Figure 3. Category of use and frequency of mention by respondents

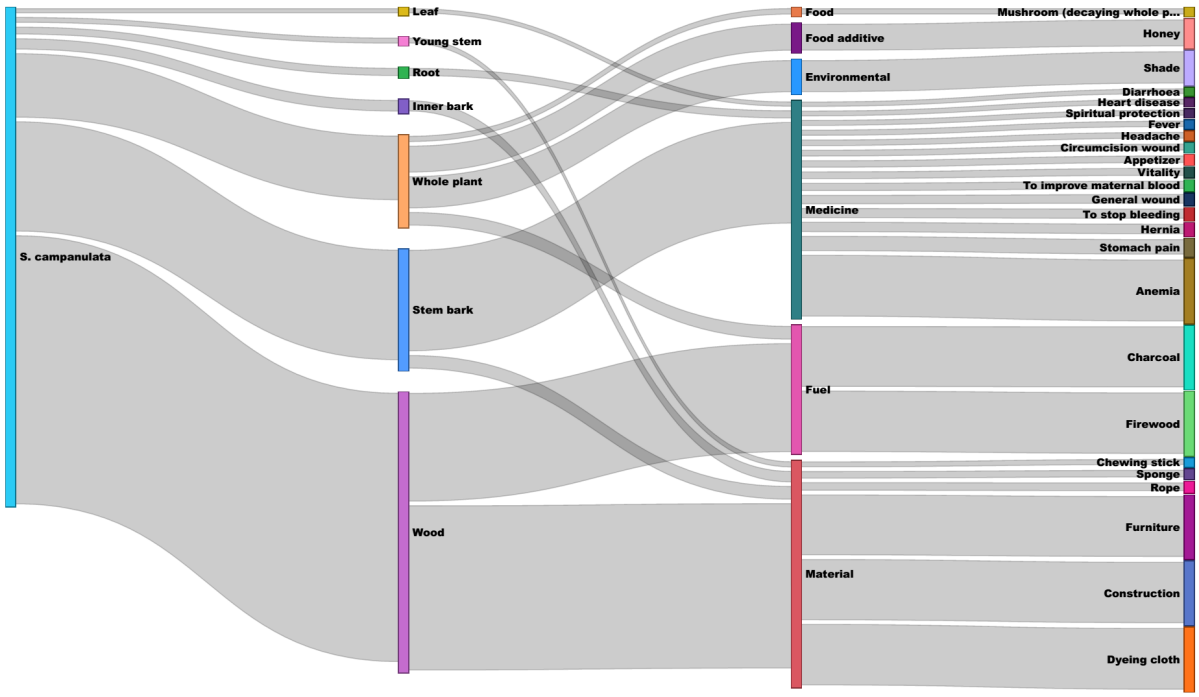

Figure 4. The flow connections between *S. campanulata* plant parts, category of use, and their applications

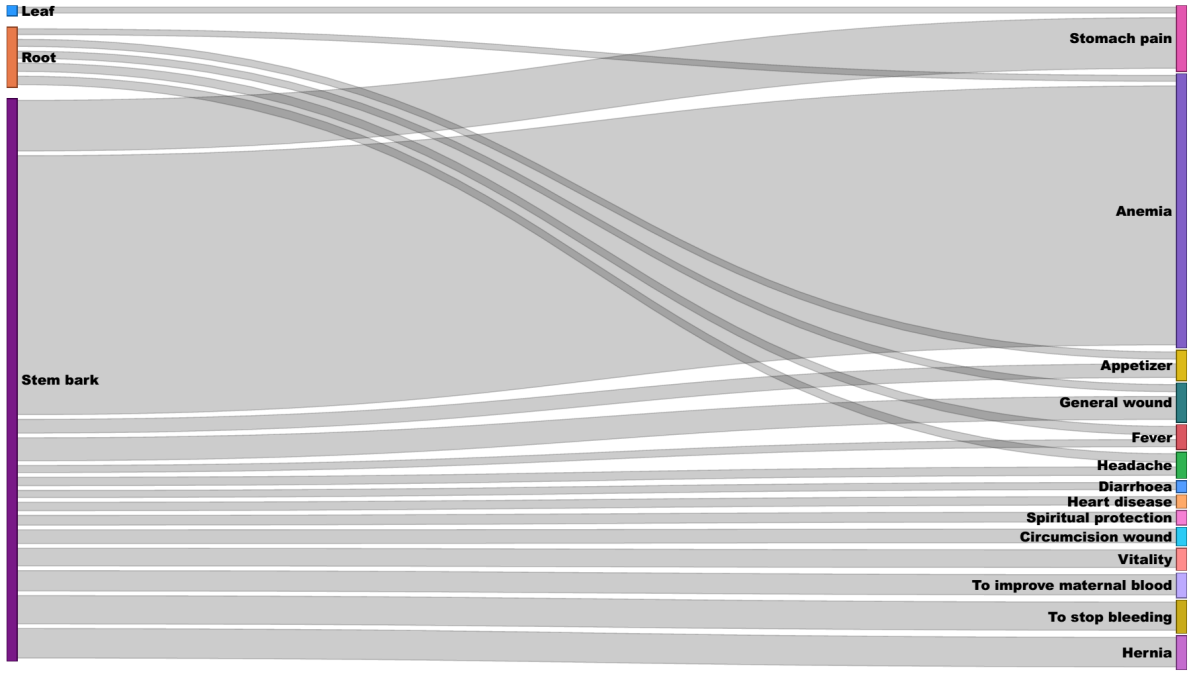

Figure 5. The flow connections between plant parts and the ailments used to treat

Ethnobotanical indices of the seven plant parts revealed that the highest use report (UR) was recorded for the wood (n = 900), stem bark (n = 359), whole plant (n = 203), inner bark (n = 22), root (n = 11), young stem (n = 4), and leaf (n = 1) (Table 1). The highest FC was recorded for the wood and the stem bark (n = 193; each), followed by the whole plant (n = 93), inner bark (n = 22), root (n = 11), young stem (n = 4) and leaf (n = 1). The number of uses (NU) for each plant part for the different categories of application was highest for stem bark (n = 15), while the wood and root had the same NU (n = 5; each), followed by the whole plant (n = 4), inner bark (n = 2), with young stem and leaf have the same NU (n = 1; each).

The wood and stem bark had the highest RFC value (1.000; each), followed by the whole plant (0.482), inner bark (0.114), root (0.057), young stem (0.021), and leaf (0.005) (Table 1). For the relative importance index (RI) of *S. campanulata* parts, the highest value was recorded for the stem bark (1.000), followed by the wood with RI value (0.667), whole plant (0.374), inner bark (0.124), root (0.195), young stem (0.044), and leaf (0.036). The highest cultural importance (CI) index was recorded for the wood (4.663), followed by the stem bark (1.860), whole plant (1.052), inner bark (0.114), root (0.057), young stem (0.021), and leaf (0.005). The cultural value revealed that the stem bark was the most culturally valued with (CVe) value (1.116), followed by the wood (0.933) and whole plant (0.081) (Table 1). Inner bark and root had the same CVe value (0.001; each) and the same CVe value (0.000; each) for young stem and bark.

Table 1. Ethnobotanical indices of African tulip tree parts application in Ghana

Plant part	UR	FC	NU	RFC	RI	CI	CVe
Wood	900	193	5	1.000	0.667	4.663	0.933
Stem bark	359	193	15	1.000	1.000	1.860	1.116
Whole plant	203	93	4	0.482	0.374	1.052	0.081
Inner bark	22	22	2	0.114	0.124	0.114	0.001
Root	11	11	5	0.057	0.195	0.057	0.001
Young stem	4	4	1	0.021	0.044	0.021	0.000
Leaf	1	1	1	0.005	0.036	0.005	0.000

Use report (UR), Frequency of citation (FC), Number of uses (NU), Relative frequency of citation (RFC), Relative importance (RI), Cultural importance (CI), Cultural value (CVe)

The plant parts and their particular applications are presented in Table 2. Based on the fidelity levels (FL), the wood was instrumental in descending order for firewood, construction, furniture, dyeing cloth, and charcoal. For the treatment of anemia, the stem bark was the most valuable *S. campanulata* part (Table 2). For shade and honey, the

whole plant was the most useful. Respondents that used young stem and leaf agreed on their application for chewing sticks and stomach pain, respectively.

Table 2. Fidelity level (FL) of applications of African tulip tree parts in Ghana

Plant part	Application	FL (%)
Wood	Firewood	100.00
	Construction	99.48
	Furniture	98.96
	Dyeing cloth	84.46
	Charcoal	83.42
Stem bark	Anemia	100.00
	Stomach pain	18.13
	Dyeing cloth	15.54
	Hernia	9.84
	To stop bleeding	9.33
	General wound	7.25
	To improve maternal blood	6.22
	Vitality	5.18
	Circumcision wound	3.63
	Appetizer	3.63
	Spiritual protection	2.07
	Headache	1.55
	Heart disease	1.55
	Fever	1.04
	Diarrhoea	1.04
Whole plant	Shade	100.00
	Honey	80.65
	Charcoal	32.26
	Mushroom (decaying whole plant)	5.38
Root	Fever	27.27
	Headache	27.27
	Appetizer	18.18
	General wound	18.18
	Anemia	9.09
Inner bark	Rope	59.09
	Sponge	40.91
Young stem	Chewing stick	100.00
Leaf	Stomach pain	100.00

Discussion

In general, communities with less access to modern services and commodities rely heavily on forest resources to sustain their material, fuel, and medicinal needs (De la Torre *et al*. 2012). Rural communities have been found to depend heavily on exploiting natural resources, mainly for material, fuel, and medicine (Osemeobo 2001; Bruschi *et al*. 2014; Miguéis *et al*. 2019; Kisangau *et al*. 2021). The dominant use categories of materials, fuel, and medicine in this study reflect a higher dependence of rural communities on natural resources. Mud brick and wood constitute over 60% of the primary construction material for the outer wall of a dwelling unit, while fuelwood and charcoal constitute over 90% of the primary source of cooking fuel in the study area (Ghana Statistical Service 2014). The suitability of *S. campanulata* wood for rough carpentry/joinery, crates, shuttering, and light construction and as fuelwood (Bosch 2002; Orwa *et al*. 2009; Rojas-Sandoval & Acevedo-Rodríguez 2013) may have influenced their high applications for material and fuel category in this study.

The name for the African tulip tree in the local Ewe language is *Adewudatsi* which translates to a plant for dyeing traditional hunting apparel (Quashie *et al*. 2014). Knowledge about *S. campanulata* wood for dyeing is embedded in the study area's traditional folklore, which may explain their high use report (UR). However, while the flowers and fruits were the main parts for dye extraction in India (Lokesh & Swamy 2013; Amutha & Ramya 2021), the wood

and stem bark were utilized for dyeing purposes. Natural dyes are available from various sources, including root, bark, heartwood, leaf, flower, fruit, and seed. The variation in *S. campanulata* part utilized for dyeing can be attributed to peculiarities in knowledge.

Miguéis *et al*. (2019) found cultural legacy and difficulty in access to healthcare facilities as facilitators for a high medicine use category for plant resources in rural communities. Inadequate healthcare facilities and the cultural acceptance of traditional medicine in Ghana may also explain the high frequency of mentions and dominance of the medicine use category. The study district has no hospital facility, and primary healthcare is delivered through health centers, Community-Based Health Planning and Services (CHPS), and traditional medicine practice (Adaklu District Assembly 2019). In Ghana, high cultural acceptance of traditional medicine use is established among rural and urban folks (Barimah 2016; Agyei-Baffour *et al*. 2017). The application *of S. campanulata* for shade purposes in this study was consistent with other studies in which it applied in the environmental use category (Gilman & Watson 1994; Bosch 2002; Labrada & Medina 2009; Orwa *et al*. 2009; Fongod *et al*. 2014). Limited use of wild edible species suggests a high tendency of abandonment or loss of knowledge in local communities as food resources (Bortolotto *et al*. 2015). The low food additive and food use categories were in line with Miguéis *et al*. (2019) and Bortolotto *et al*. (2015) findings and can be attributed to abandonment or loss of knowledge.

The medicinal application of stem bark of *S. campanulata* for wound healing was accordant with other studies in Ghana (Agyare *et al*. 2009; Appiah *et al*. 2018). Anemia prevalence in the study region is high (Adu-Amankwaah *et al*. 2018; Kofie *et al*. 2019; Dzando *et al*. 2022) and may explain their high frequency of mention. The versatility of the stem bark for ethnomedicinal applications is consistent with a review of medicinal applications of the African tulip tree by Padhy (2021). The widespread use of the stem bark may account for its high cultural value indices. One contrasting finding of this study was the application of the leaf for the treatment of stomach pain, which was applied for the treatment of malaria and wounds in previous studies in Ghana (Agyare *et al*. 2009; Asase & Asafo-Agyei 2011; Komlaga *et al*. 2015; Asafo-Agyei *et al*. 2019).

The findings of this study follow a pattern whereby few remedies are known to almost everyone, while most knowledge is idiosyncratic. The idiosyncratic distribution of traditional medicine knowledge in this study is supported by previous studies in Ghana (Boakye *et al*. 2021, 2019, 2015).. The study area's epidemiological profile shows a significant malaria prevalence (Ghana Statistical Service 2014). *S. campanulata* has demonstrated its potential for the treatment of malaria in traditional pharmacopeia in Ghana (Agyare *et al*. 2009; Asase & Asafo-Agyei 2011; Komlaga *et al*. 2015; Asafo-Agyei *et al*. 2019), other places (see Padhy 2021) and both *in vivo* and *in vitro* studies (Rangasamy *et al*. 2008; Padhy 2021). However, respondents did not mention it in this study to treat malaria. Boakye *et al*. (2022) found medicinal plants sold in markets in the study region to differ from other markets in Ghana and attributed the variation to peculiarities in the knowledge of the application of medicinal plants. Idiosyncrasy in knowledge may account for the variation in the use of *S. campanulata* plant parts to treat ailments that were unique to the study area compared to other regions in Ghana.

Conclusion

This study showed the paramount local importance of *S. campanulata* to local communities in Ghana, particularly the people of Adaklu district, providing them with goods and services such as food, medicine, materials for construction, dyeing, and furniture, and fuel for charcoal and firewood. The goods and services provided by the African tulip tree have a high potential to generate cash income for local communities and support poverty alleviation initiatives. This study confirms that traditional knowledge is closely linked to the rural nature of communities and their lack of availability of services. Therefore, ethnobotanical studies reporting on the knowledge distribution of plant species should account for the rural character of communities and the lack of availability of services in the study environment. Additional studies on the rurality and availability of services and the use of plant species are needed in Ghana to clarify this proposition. The study also suggests increasing awareness for better promotion and valorization of *S. campanulata* goods and services in Ghana.

Declarations

Ethics approval and consent to participate: This study was conducted according to the ethics guidelines of the International Society for Ethnobiology Code of Ethics All the participants provided prior informed consent before the interviews.

Consent for publication: Not applicable.

Competing interests: The authors declare no conflicting interests.

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Authors' contributions: MKB, AOA, RSG, MQ, BKT, KKA, and EDW conceived the research idea. AOA and MQ did the data collection. MKB, RSG, KKA, EDW and BKT analyzed and interpreted the data. MKB, RSG, MQ, RKT and AOA drafted the initial manuscript, and KKA and EDW revised and improved the manuscript. All the authors read, reviewed, and approved the final version of the manuscript.

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