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Systematic Review

Systematic Review of the Agro-Ecological, Nutritional, and Medicinal Properties of the Neglected and Underutilized Plant Species *Tylosema fassoglense*

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Abstract: Neglected and Under-utilized plant Species (NUS) can contribute to food system transformation in Sub-Saharan Africa, but many are understudied. Here, we conducted a systematic review of 37 empirical studies to synthesize the evidence from Sub-Saharan Africa about the agro-ecological characteristics, nutritional properties, and medicinal properties of the NUS *Tylosema fassoglense*. Overall, the evidence is highly fragmented and lacks a comprehensive description of the species characteristics, properties, and benefits. Most reviewed studies focus on the eastern part of Africa and a few on the southern part, suggesting its limited geographic distribution. Studies on agro-ecological properties, and especially on morphological characteristics, indicate that the species' long tuberous roots and large vegetative systems help it adapt to harsh climatic conditions. The species is also utilized for medicinal and nutrition purposes by different communities across its range due to its phytochemical, macro-, and micronutrient content, along with its favorable physico-chemical properties. In particular, the seeds contain many different amino acids, while their calcium, magnesium, phosphorus, zinc, and carbohydrate content is comparable to *Tylosema esculuntum*, the better studied species in the *Tylosema* genus. These demonstrate the species' potential to contribute to nutrition and food security. Furthermore, parts of the plant contain many phytochemicals, such as phenolics, alkaloids, flavonoid, terpenoids, and tannins (mainly in the roots), and for this reason local communities use it to treat various conditions. Overall, our systematic review suggests that although *Tylosema fassoglense* has some potential to contribute towards food security, nutrition, health, and livelihoods, there are many remaining knowledge gaps that constrain its effective integration into agricultural production systems and possible contribution to food system transformation in the region.

Keywords: Neglected and Under-utilized plant species; orphan crops; nutrition; food security; medicinal properties; agro-ecological characteristics; Sub-Saharan Africa

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1. Introduction

Sub-Saharan Africa is among the most food insecure region of the world, with several hundreds of millions of people living below the poverty line and/or being chronically malnourished [1]. Rapid urbanization and economic transformation is radically changing diets, with the growing urban and rural populations increasingly relying on unsustainable and unhealthy diets [2]. Climate change, population growth, and agrarian transformation are all expected to put further strain on local and regional food systems that are already struggling to deliver safe, nutritious, and sufficient food to consumers, as well as adequate livelihoods to producers [3]. Unless there are radical food system transformations (particularly in crop production systems), there are fears that large fractions of the urban and rural population across the region will remain trapped in this cycle of food insecurity, disease, poverty, and the triple burden of malnutrition [4,5].

One of the underlying factors hindering food system transformation has been the overdependence of the prevailing crop production systems across the region on just a few staple crops (e.g., maize, rice, wheat, beans), which can be particularly vulnerable to the changing climate [6]. This has resulted in low levels of agro-diversity within crop production systems, which has in turn been linked to increased vulnerability to climatic and socioeconomic shocks and negative impacts on local ecosystems [7]. Increasingly, there are calls that food system transformations should embrace agro-diversity as a means of producing diverse, nutritious, and sustainable food products to improve food security and livelihoods [4].

One of the possible ways to facilitate the transformation of crop production systems is through the introduction and increased production of indigenous Neglected and Underutilized plant Species (NUS) [8,9]. There are several promising NUS species growing throughout Sub-Saharan Africa that can provide products with diverse socio-cultural, medicinal, and economic value, which have been associated with multidimensional benefits such as resilience to climate change, improved nutrition, food security, environmental sustainability, and livelihood improvement [10,11]. For example, the database of the African Orphan Crop Consortium (AOCC) lists more than 100 such plant species that collectively have huge potential to cater for multiple human needs, such as food, medicine, and raw materials [12]. In reality, there are many more NUS that local communities throughout the region have used for centuries to meet diverse human needs [13]. This points to both the huge available agro-diversity in the continent and the benefits it can offer for food system transformation.

One promising example of NUS are some species within the *Tylosema* genus. The genus contains four perennial legume species, namely *Tylosema esculentum*, *Tylosema fassoglense*, *Tylosema argentea*, and *Tylosema humifusa* [14]. These species are native to Africa and are distributed across most of the eastern and southern part of the continent, from Sudan southwards to South Africa [15]. Plant of the genus can be found growing in a wide range of landscapes, including wooded grassland, grassland, bushland, and open bushland sandy plains, as well as on limestone/sandy soils in arid regions, and occasionally near water courses [15]. Although the species within the genus could be broadly characterized as semi-woody viniferous plants, they are quite variable. Past studies have shown variation of up to 85%, which has resulted in many synonyms for the species within the genus, and especially within *Tylosema esculentum* and *Tylosema fassoglense* [15].

Of the four species within the genus, *Tylosema esculentum* (also known as gemsbok bean, marama bean, or morama bean) has been the most widely studied, as it is an important food source for people in the Kalahari Desert [16]. Several studies have focused on *Tylosema esculentum* genome sequencing [17,18], engineering properties [19], agronomy [20], commercial viability [21], and climate adaptation and mitigation potential [22], among other topics. However, there are also other species within the *Tylosema* genus, such as *Tylosema fassoglense*, which can have promising agro-ecological characteristics and nutritional and medicinal properties, holding potential for supporting food security, human health, and livelihoods in communities across the region.

Tylosema fassoglense is a savanna plant with an extensive range in southern Africa and eastern Africa [23]. The botanical system of the species is as follows: genus—*Tylosema*, family—Fabaceae, order—Fabales, subclass—Magnoliidae, class—Equisetopsida, phylum—Streptophyta [15]. It has notable intraspecific morphological variation [14], as well as longer vines, longer functional tendrils, rusty pubescence on young growths and on the veins of leaves, longer petioles, shallowly bilobed leaves, and larger, flatter fruit pods that are distinctly woody compared to the better studied *Tylosema esculentum* [14]. *Tylosema fassoglense* is also characterized by a large underground tuber that has high water storage and retention capacity [14]. Figure 1 shows different parts of *Tylosema fassoglense*.

Figure 1. Flower (**a**), leaves (**b**), pods (**c**), tuber (**d**), and seeds (**e**) of *Tylosema fassoglense*. Note: In panel (**e**) *Tylosema fassoglense* seeds are in the left-hand side and *Tylosema esculentum* seeds on the right-hand side. Source: Authors (Credit: Ndiko Ludidi).

These morphological characteristics can potentially offer *Tylosema fassoglense* several nutritional, medicinal, and environmental benefits. There is an emerging, yet relatively modest, literature about the characteristics and properties of the species. For example, studies have revealed that the seeds, tubers, and leaves contain many micro- and macronutrients, which makes the species a potentially attractive domestication option for food production [14]. Studies have indicated that the protein, moisture, crude fiber, and ash content of *Tylosema fassoglense* is higher than in *Tylosema Esculentum* [24]. Laboratory studies have also assessed its phytochemical content, identifying the presence of phenolics, tannins, flavonoids, saponins, terpenoids, and alkaloids in the roots of the plant, which indicate the species' possible medicinal properties [25]. Ethnobotanical surveys have shown that some local communities use the species for antenatal care for pregnant women [26,27]. Similarly, laboratory studies have indicated the potential antimicrobial properties of root extracts [28]. An inventory of medicinal plants in South Africa mentions that the species has medicinal value and is used for craftwork among the "*Vhavenda*" people [29]. Laboratory studies have also demonstrated that *Tylosema fassoglense* seeds contain oil with favorable acid value, peroxide value, refractive index, and saponification value and are comparable to most other popular oil crops and point to its commercial potential [30]. Surveys of ethnoveterinary practices have also shown its veterinary uses, as some local communities use the leaves and stems to control ticks in livestock [31]. Finally, *Tylosema fassoglense* has nectariferous properties, pointing to its possible role for ecosystem functioning [32].

However, this emerging literature is highly fragmented and lacks a comprehensive systematization of the characteristics, properties, and benefits of the species. Furthermore, the apparent lack of domestication and awareness of its value has hampered the production, commercialization, and utilization of the species [33]. Arguably, this low utilization of *Tylosema fassoglense* can be partly attributed to the major knowledge gaps that are partly due to this fragmented knowledge.

It is in this context of knowledge fragmentation that the present study aims to systematize the current knowledge about *Tylosema fassoglense*. We conducted a systematic literature review focusing on the agroecology and distribution of the species, as well as its nutritional and medicinal properties. Through this systematic review, our objective is to explain the possible significance of this plant from diverse agro-ecological, social, economic, nutritional, and health perspectives. This can help identify the potential of the species and the main knowledge gaps to inform future research regarding its production, commercialization, and utilization. Collectively, this information can help to support protection of the species, while also increasing its exploitation and value, as a means of promoting sustainable development in the communities where it is encountered.

2. Materials and Methods

2.1. Data Collection and Analysis

For the transparent and complete implementation and reporting of the systematic review, we adopt the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach [34]. The PRISMA approach has mostly been applied in the health sciences [35], but has been gaining popularity in other research fields, including agriculture and food systems [36–38]. The approach entails the very clear documentation of literature identification, screening, eligibility, and inclusion in diagrams [34]. (See Supplementary Materials).

We performed a comprehensive search of the academic literature using the keywords "*Tylosema fassoglense*" OR *Tylosema*.

We searched for relevant academic literature in two major academic databases, namely Web of Science (WoS) and Scopus. The second keyword "*Tylosema*" was used as it is common for the evidence on *Tylosema fassoglense* to be included in studies focusing on other species within the *Tylosema* genus [27,28,32]. This literature search was undertaken in December 2023. Beyond the studies identified through Scopus and WoS, we also included relevant literature from other sources such as the reference lists of reviewed papers. The retrieved items included peer-reviewed journal articles, as well as book chapters and conference proceedings in English. The eligibility criteria for this systematic review were as follows:

- Evidence only on *Tylosema fassoglense*, not on other species of the genus *Tylosema* (e.g., *Tylosema esculentum*) or other NUS;
- Empirical studies, not reviews or conceptual pieces;
- Geographical focus on Sub-Saharan Africa, not on other parts of the world;
- Thematic focus on the agroecology/distribution, nutritional properties, and medicinal properties of *Tylosema fassoglense*.

The first two authors independently screened the articles to determine their suitability based on the inclusion/exclusion criteria outlined above. This includes both the articles identified in Scopus/WoS, as well as those retrieved from further manual searches and citation screening. After reading the titles and abstracts of all identified items, 37 manuscripts matched the inclusion criteria above and were all selected for further in-depth reviewing. Figure 2 outlines the documents identified, screened, and included in the different stages of the systematic review. These manuscripts were fully reviewed by the first author to both assess the final suitability for the systematic review and to extract the relevant data using an abductive approach [39] (see next paragraph). This was then checked and validated by the second and third authors to avoid any discrepancies. All authors approved the final selection.

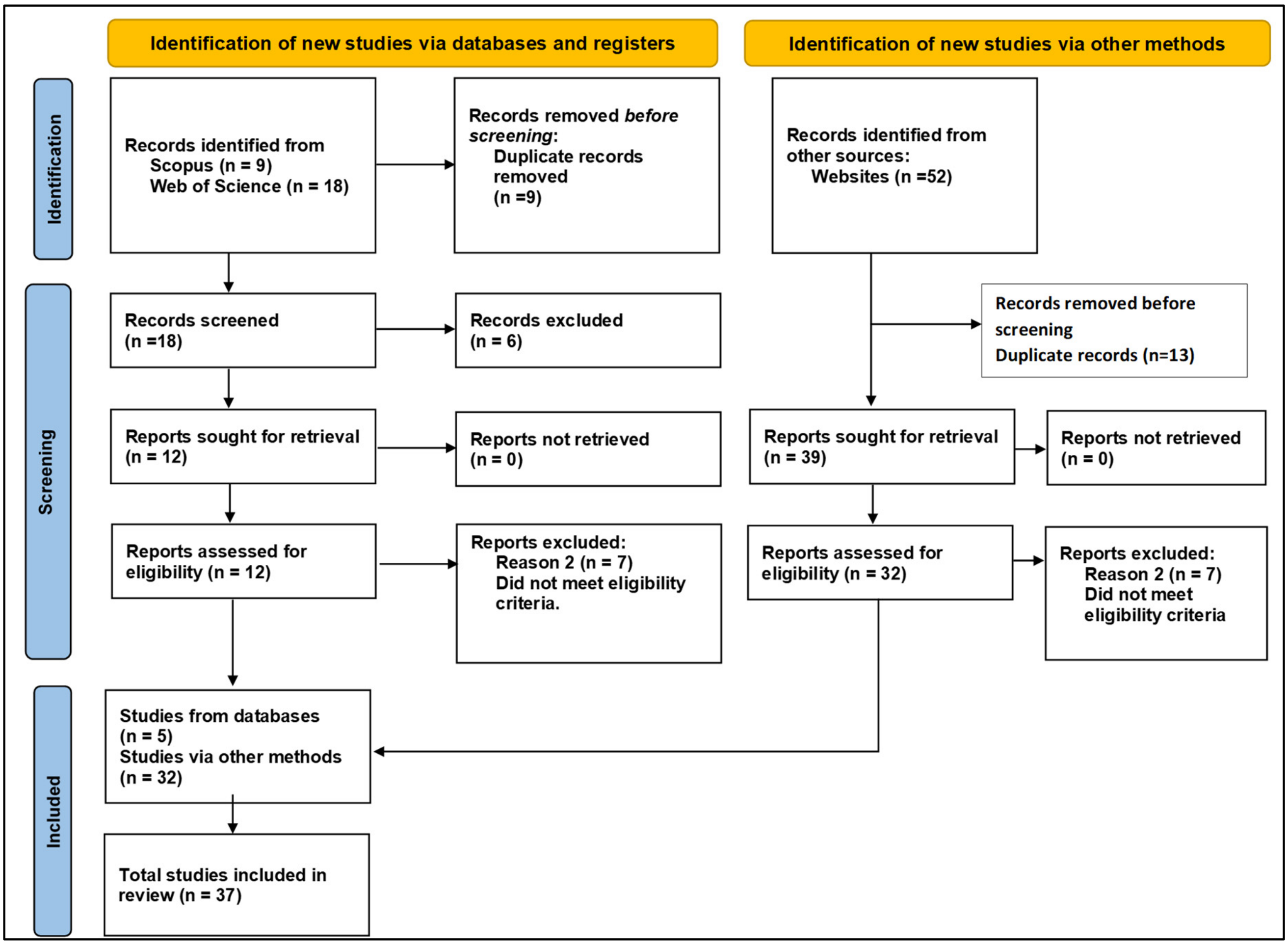

Figure 2. PRISMA diagram outlining the identification, screening, eligibility, and inclusion of the reviewed items.

Depending on the specific focus of each reviewed study (e.g., agroecology/distribution, nutritional properties, medicinal properties), relevant information was elicited and synthesized. This information is seen in Table 1. We did not use any specific method to prepare the data for the synthesis (e.g., data conversion, data imputation). Furthermore, due to the inability to elicit consistent information from the reviewed studies due to their very different thematic focus and utilized methods, it was not possible to conduct a statistical synthesis or meta-analysis (see section on "Limitations"). For the synthesis of the elicited information, we use narratives and tabulations of the information outlined in Table 1. See sections on "Literature Patterns", "Agro-Ecology and Distribution", "Nutritional Properties", and "Medicinal Properties".

Table 1. Type of information extracted from the reviewed items.

Information	Nature of Information Extracted
Region of study	- Region: Southern Africa, Western Africa, Eastern Africa, Entire Sub-Saharan Africa, and Other - Country: South Africa, Angola, Namibia, Kenya, Uganda, Tanzania, Burundi, Ethiopia, and Other.
Item type	- Peer-reviewed article - Book chapter - Conference proceeding
Year of study	- No limitation. Considered items that were published between 1960–2023
Thematic focus of the article	- Agro-ecology/distribution - Nutritional properties - Medicinal properties
Specific focus for medicinal properties	- Antipyretic - Antiplasmodial - Antioxidant - Anti-inflammatory - Treatment of infertility - Management of respiratory diseases - Other
Specific focus for agroecology/distribution	- Geographic areas/ranges - Taxonomic description - Morphological characteristics - Genetic diversity and improvement - Diseases management - Other
Specific focus for nutritional properties	- Phyto-chemical compounds (e.g., glycosides, tannins, saponins, anthraquinones, steroids, alkaloids, and terpenoids) - Macro- and micro-nutrient content (e.g., Calcium, Potassium, Iron, Phosphorus, Zinc, crude protein, carbohydrate, fat, amino acid, ash, dry matter) - Other
Studied part of the plant	- Whole plant - Roots, seeds - Stem - Barks - Leaves - Tuber - Other
Element on local knowledge	- Yes - No
Integration of local and scientific knowledge	- Yes - No - NA

Finally, the review is not registered in any relevant register, while there is no formal review protocol prepared beyond the information provided in the materials and methods of this manuscript.

2.2. Limitations

Despite the strengths of the systematic review approach adopted in this study in terms of literature selection reliability and study reproducibility, we need to point out some of its limitations. The main limitations include (a) the omission of grey literature and indigenous/experiential knowledge, (b) the reliance on research documents written in English, (c) keyword limitations, and (d) the inability to conduct a meta-analysis.

First, as outlined in the section on "Data Collection and Analysis", our systematic review relied on critical reading and information elicitation from the academic literature, such as peer-reviewed articles, book chapters, and conference proceeding. It is likely that some of the relevant information about the agroecology/distribution and the medicinal and nutritional properties of *Tylosema fassoglense* can be found in non-academic reports and through indigenous/experiential knowledge holders. Such knowledge, although very important in the context of agroecosystem management and NUS [40], cannot be extracted reliably and assessed systematically. We reflect on this topic in more detail in the Discussion section (Leveraging Local Knowledge).

Secondly, the reviewed documents were published in the English language, as are the overwhelming majority of documents included in Scopus and WoS. However, when seeing the distribution range of *Tylosema fassoglense* (Section on "Agro-Ecology and Distribution"), it is likely that relevant studies could have been written in other languages such as French, Portuguese or Swahili, among others. Although, documents in the English language have also been the basis of other systematic reviews in the field of agro-diversity [41], they may introduce certain biases, which the reader should be aware when generalizing the findings of this systematic review. In any case, the number of identified and reviewed items is in close range to other systematic reviews in the context of NUS and/or food systems in Sub-Saharan Africa contexts [42–44].

Third, systematic reviews are very sensitive to keyword selection. To ensure the widest possible capture of relevant literature, we used two keywords (name of species and genus, see section on "Data Collection and Analysis"), avoiding synonyms for agroecological, nutritional, and medicinal characteristics. In particular, we included the keyword "*Tylosema*", as we noticed that some publications contained information about *Tylossema fassoglanse* alongside other species of the genus. However, we do acknowledge the possibility that some broad studies and databases that contain information about multiple other NUS (even outside the *Tylossema* genus), might also include information for *Tylossema fassoglanse* (especially for nutrient composition). To account for this possibility, we scanned the reference lists of the reviewed papers to identify such broad studies and databases, but we believe that this is not particularly common as we did not find many such studies and databases. However, although low, we cannot discount the possibility that our systematic review failed to capture relevant information from other broad studies and databases not covered in the reviewed papers.

Fourth, due to the small amount of available literature, the fragmented scope (including in terms of assessed nutrients and phytochemicals), and the different variables used, it was not possible to conduct a statistical synthesis of the findings or a meta-analysis, to better understand the effect ranges for the nutritional and medicinal properties of *Tylosema fassoglense*. Thus, it was not possible to establish proper confidence intervals for the nutritional/medicinal properties or factors affecting heterogeneity, nor to conduct formal sensitivity analysis and bias analysis to respectively assess the robustness of effects and identify possible publication biases [45]. This prevents, to a large extent, the ability of this study to assess in robust quantitative terms the benefits of *Tylosema fassoglense*, which should be considered when generalizing the findings of this study (see more reflections in "Discussion" section). In this respect, our study should be seen as a first attempt to systematically synthesize the knowledge about the agronomy/distribution and medicinal/nutritional properties of *Tylosema fassoglense*, reflect on its potential to contribute to human wellbeing and environmental sustainability, and identify the main knowledge gaps in relation to these aspects.

3. Results

3.1. Main Literature Patterns

Of the 79 identified manuscripts, a total of 37 items met the inclusion criteria and were reviewed in depth (see Appendix A for all reviewed items). The 42 items were excluded because they were either duplicates or out of the scope based on inclusion criteria (see section on "Data Collection and Analysis"). The main geographic coverage was eastern and southern Africa, with a few studies from central Africa (Table 2). There were no research items from western Africa. Most of the reviewed items (46%) focused on the species' medicinal properties, with comparatively fewer on its nutritional properties (22%) and agro-ecological characteristics (32%).

Table 2. Main literature patterns.

		Fraction of Studies (%)	Number of Studies
Geographic focus	Eastern Africa	68	25
	Southern Africa	27	10
	Outside Africa	5	2
Local knowledge	Yes	41	15
	No	59	22
Scientific knowledge	Yes	41	15
	No	59	22
Integration of local and scientific knowledge	Yes	16	6
	No	16	6
	NA	68	25
Thematic focus	Medicinal properties	46	12
	Agroecology/distribution	32	17
	Nutritional properties	22	8
Studied plant part	Root	32	12
	Seed	19	7
	Beans	14	5
	Leaves	14	5
	Whole plant	11	4
	Tubers	8	3
	Flowers	3	1
Source of the plant	Wild	40	15
	Cultivated	3	1
	N/A	57	21

Most articles studied the root, followed by the seeds, beans, and leaves (Table 2). Only a few articles focused on the whole plant, tubers, and flowers. The seeds and sometimes the whole plant, leaves, and roots were studied in articles that focused on agroecological characteristics (Table 3). Roots were mostly studied in articles that focused on medicinal properties. The beans and seeds were the plant parts mostly studied in articles that focused on nutritional properties. Only a few articles (42%) contained information from local knowledge, and only a few of these integrated it with scientific knowledge. Finally, in most of the studies it was not indicated whether the plant (or its specific parts) was collected from the wild or was cultivated. However, 41% of the studies, mostly from the eastern part of Africa, reported that the plant was collected from the wild, while only 3% indicated that the plant was cultivated.

Table 3. Studied plant part by thematic focus.

Article Focus	Beans	Leaves	Roots	Seeds	Tubers	Whole Plant	Flower	Total
Agroecology/distribution	0	2	1	4	0	4	1	12
Medicinal properties	0	3	11	0	3	0	0	17
Nutritional properties	5	0	0	3	0	0	0	8
Total	5	5	12	7	3	4	1	37

3.2. Agro-Ecology and Distribution

The agro-ecological aspects that were covered included taxonomy (57%), seed germination (29%), and crop improvement (14%) (Table 4). Studies on taxonomy tended to study the entire plant. Conversely, roots, seeds, and leaves were used in studies focusing on crop improvement, seed germination, and genetic diversity. Agro-ecological aspects varied from one region to another. Also, a few studies on taxonomy and crop improvement had been carried out in the southern Africa, particularly in Namibia and Angola [15,46]. Studies on seed germination were found in eastern Africa (Kenya and Ethiopia) [47,48], including some outside Africa, nevertheless using plant samples from Africa [49,50]. Abiotic conditions influencing seed germination were mostly studied and included light requirements for breaking dormancy, temperature, and water, as well as the effects of heat on germination. The study on crop improvement considered the morphological characteristics of the species in nutrient acquisition (nitrogen fixation).

Table 4. Agro-ecological aspects studied in relation to parts of the plant.

Agro Ecological Aspect	Part of Plant Studied	Sources
Taxonomy	Leaves	[15]
Crop improvement	Roots	[46]
Seed germination	Seeds	[33,47,48]
Taxonomy	Whole plant	[49,50]

Although DNA structure was beyond the scope of this systematic review, some studies (3 out of 37) utilized DNA sequencing technics to study taxonomy. Two of the studies had been conducted in China (using plant samples from Africa) and one in Africa (Namibia). These included the following: (a) a study that indicated high gene amplification for *Tylosema esculuntum* when *Tylosema fassoglense* DNA was introduced, as an indication of phylogenetic similarity [51]; (b) a parsimony study that suggested a close relationship between *Tylosema fassoglense* and *Bauhinia subgenus Phanera* in the evolutionary cycle [50]; (c) a study that reconstructed the phylogenetic relationships among Cercidoideae and legumes (including *Tylosema fassoglense*) that revealed a closer resemblance in plastomes structure, as an indication of similarities in evolutionary process [49].

In terms of distribution, according to the reviewed studies, *Tylosema fassoglense* is mainly distributed in eastern and southern regions across Sub-Saharan Africa, as shown in Table 5. It is found in the tropical and arid regions of eastern Africa, with a wide distribution in Ethiopia, Kenya, Uganda, Tanzania, South Sudan, and Burundi (Table 5, Figure 3). In the southern part of Africa, the plant is found in poor semi-arid soil regions across Angola, Namibia, Zimbabwe, South Africa, Zambia, Eswatini, Malawi, and Mozambique. The plant is also distributed across DRC Congo. However, within these specific countries, studies have focused only on a few regions, which makes the knowledge of the distribution range of the species rather incomplete (Figure 3).

Table 5. Distribution of *Tylosema fassoglense* in Sub-Saharan Africa.

Country	Region	Temperature (°C)	Rainfall (mm)	Source
Ethiopia	Abdurafi	N/A	N/A	[30]
	Gambela	N/A	N/A	
	Tepi	N/A	N/A	
	Arba Minch	N/A	N/A	
South Sudan	Juba	N/A	N/A	[15]
Uganda	Arua	N/A	N/A	[15]
	Mbale	N/A	N/A	[15]
	Buyende	18–26	35–150	[52]
Kenya	Mombasa	N/A	N/A	[30,53]
	Taita Taveta	N/A	N/A	
	Homa Bay	15–35	N/A	[54]
	Lake Victoria Basin	16–28	106–124	[48]
	Kisumu	20–35	1200–1300	[55]
	Mt Elgon	24.4	920–1650	[25]
	Kitale			
	Nandi	15–26	1200–2000	[56]
	Mau Forest	N/A	N/A	
Burundi	Rumonge Ruzizi	N/A	N/A	[53]
Tanzania	Moyowosi	N/A	N/A	[30,57]
	Katubuka	N/A	N/A	
	Morogogo	N/A	N/A	
	Lindi	N/A	N/A	
DRC	Likasi	N/A	N/A	[15]
	Kilwa	N/A	N/A	
Angola	Malanje	N/A	N/A	[58]
	Waku Kungo	N/A	N/A	
	Lubango	N/A	N/A	
	Dongo	N/A	N/A	
Namibia	Opuwo	N/A	N/A	[58]
	Tsumeb	N/A	N/A	
Zambia	Zambezi	N/A	N/A	[15]
	Lusaka	N/A	N/A	
	Choma	N/A	N/A	
	Katima-Mulilo	N/A	N/A	
Zimbabwe	Harare	N/A	N/A	[15]
	Bulawoyo	N/A	N/A	
	Mutare	N/A	N/A	
Mozambique	Maputo	N/A	N/A	[53]
	Nampula	N/A	N/A	
	Montepuez	N/A	N/A	
Malawi	Kusungu	N/A	N/A	[15]
South Africa	Limpopo	30–39	450–800	[58]
	Mpumalanga	N/A	N/A	
Eswatini	Mbabane	N/A	N/A	[15]

N/A shows that there was no data for temperature or rainfall.

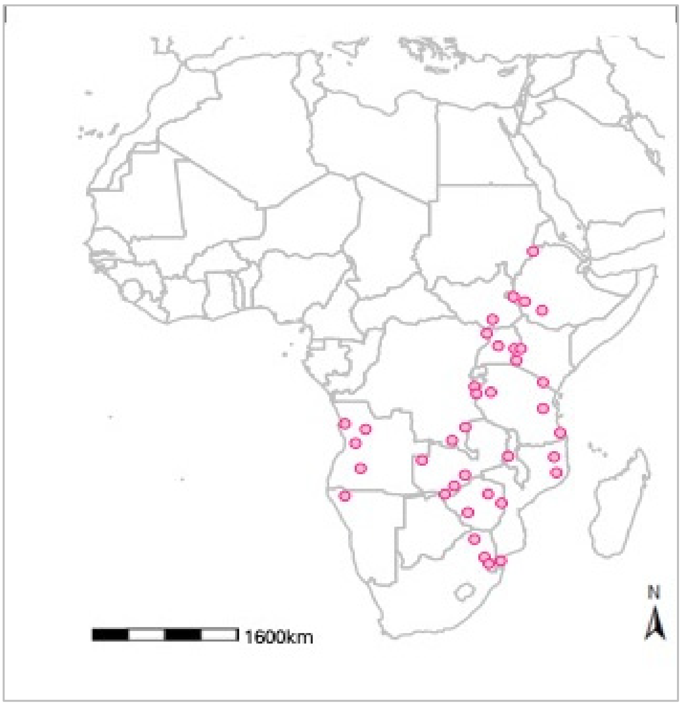

Figure 3. Geographical distribution of *Tylosema fassoglense* in Sub-Saharan Africa. The red circles on the map indicates the specific area *T. fassoglense* was found, as tabulated in Table 1. Image generated using the ggmap-ggplot2 package on RStudio (v4.2.2).

The minimum, maximum, and average value for temperature and rainfall from the study sites of *Tylosema fassoglense* from the articles is shown in Table 5. Only a few articles had reported climatic conditions for the sites. These studies were mostly from Kenya and Uganda in eastern Africa and a few from South Africa in the southern part of Africa. Overall, the minimum, maximum, and average temperature ranged from 12 to 30, 16 to 39, and 14 to 34.4 °C. The values varied between eastern and western regions of Africa. The southern part of Africa had the highest production temperature compared to the eastern part, as shown in Table 5. The rainfall amount ranged from 35 mm to 1200 mm for the minimum values, 120 mm to 2000 mm for maximum, and 75 mm to 1600 mm for average values. The rainfall amounts in eastern and southern Africa also varied, as shown in Table 5.

3.3. Nutritional Properties

The nutritional properties of *Tylosema fassoglense* are shown in Table 6. Most of the studies (63%) on nutrition were from the southern part of Africa (South Africa, Namibia, Angola, Botswana), while 37% were from the eastern part (Kenya, Burundi, Tanzania). The most favorable physical and physicochemical properties were contained in the bean and seeds of the plant. This led to the bean being used for human consumption [16,24,58]. There were more studies that had carried out analysis on the protein, fat, and fiber content (n = 5) compared to carbohydrate and micro-nutrient content (n = 2), fatty acid content (n = 1), and amino-acid composition (n = 1) (Table 6). The contents for the different properties are also shown in Table 6. Besides chemical analysis, there was a study that focused on the microstructure of protein bodies and organelles to support characterization and utilization of the proteins [24].

The contents for the different properties are also shown in Table 6. Only 88% (7 out of 8) of the studies on nutrition had carried out nutritional and phyto-chemical analysis. There were only a few studies (2 out of the 37) which had conducted inhibitory studies, mostly from the eastern side of Africa [53,59]. The studies showed that *Tylosema fassoglense* contains trypsin inhibitor 295 TUI mg^{-1} and phytates 35 $kg/^{-1}$ [53], nitric oxide synthase, and guanylyl cyclase inhibitor [59]. There were also a few studies to indicate the presence of toxic substances such as cyanogenic glycoside in *Tylosema fassoglense* [53,60].

Table 6. Physical and physico-chemical properties and micro- and macro-nutrient content in parts of *Tylosema fassoglense*.

Category	Variable	Plant Part	Content	Unit	Source
General properties	Dry matter	Seeds	2.5–76.4	g/100 g	[60]
	Ash	Seeds	2.5–4.7	g/100 g	[24,58,60]
	Fiber	Seeds	5.2–27	g/100 g	[24,58,60]
Nutrients	Protein	Seeds	24–40.5	g/100 g	[16,24,53,58,60]
		Pods	6.4	g/100 g	
	Carbohydrate	Seeds	14.9–20.5	g/100 g	[24,60]
	Energy	Pods	446	kJ/100 g	[61]
	Vitamin C	Seed	0.0035	g/100 g	[60]
		Pods	0.039	g/100 g	[59]
	Moisture	Pods	72.5	%	[60]
	Sugar	Seeds	0.0233	%	[60]
	Calcium	Seeds	0.0937–0.156	g/100 g	[24,58]
	Phosphorus	Seeds	0.4050–1.123	g/100 g	[24,58]
	Magnesium	Seeds	0.3580–0.402	g/100 g	[24,58]
	Iron	Seeds	0.0012–0.0014	g/100 g	[24,58]
		Pods	0.0005	g/100 g	[24,58,61]
	Potassium	Seeds	0.9423–1.123	g/100 g	[24,58]
	Sodium	Seeds	0.0029–0.0069	g/100 g	[24,58]
	Zinc	Seeds	0.0031–0.0041	g/100 g	[24,58]
		Pods	0.0022	g/100 g	[53,58,60]
	Copper	Seeds	0.0006–0.0009	g/100 g	[24,58]
	Manganese	Seeds	0.0013–0.0029	g/100 g	[24,58]
Fatty acids	Palmitic	Seeds	2.8–15.7	g/100 g	[53]
	Linoleic	Seeds	36–42	g/100 g	[53]
	Oleic	Seeds	32–35	g/100 g	[53]
Amino acids	Lysine	Seeds	5.5	g/100 g	[16]
	Methionine	Seeds	0.3	g/100 g	[16]
	Phenylalanine	Seeds	4.2	g/100 g	[16]
	Threonine	Seeds	3.3	g/100 g	[16]
	Tyrosine	Seeds	11.9	g/100 g	[16]
	Valine	Seeds	3.9	g/100 g	[16]
	Arginine	Seeds	7.8	g/100 g	[16]
	Cysteine	Seeds	1	g/100 g	[16]
	Histidine	Seeds	2.8	g/100 g	[16]
	Isoleucine	Seeds	3.3	g/100 g	[16]
	Leucine	Seeds	5.8	g/100 g	[16]
Physicochemical properties	Acid value	Seeds	0.249	g KOH/100 g	[30]
	Iodine value	Seeds	94.06	g I/100 g	[30]
	Peroxide value	Seeds	0.000634	geq/100 g	[30]
	Refractive index	Seeds	1.47	At 40 °C	[30]
	Saponification value	Seeds	4.593	g KOH/100 g)	[30]
	Unsaponifiable matter	Seeds	0.587	g/100 g	[30]

3.4. Medicinal Properties

A large percentage (88%) of studies on medicinal properties were from the eastern part of Africa (Kenya, Uganda, Tanzania), while a few (12%) were from the southern part (South Africa). The medicinal content from different parts of the plants are shown in Table 7. *Tylosema fassoglense* contains different phytochemicals with possibly valuable medicinal properties [59]. This includes phenolics, alkaloids, flavonoid, terpenoids, and tannins, which have been mainly identified in roots [24,51]. A few studies (2 out of the 37) from eastern Africa [50,60] identified that *Tylosema fassoglense* contains trypsin inhibitor (295 TUI mg^{-1}) and phytates (35 kg^{-1}) [53], nitric oxide synthase, and guanylyl cyclase inhibitor [59].

Table 7. Phytochemical properties in parts of *Tylosema fassoglense*.

Variable	Plant Part Studied	Content	Unit	Source
Polyphenols	Roots	1729	mg/100 mL	[25]
Flavonoid	Roots	600	mg/100 mL	[24]
Tannins	Roots	1114	mg/100 mL	[24]
Alkaloids	Roots	8060	mg/100 mL	[24]
Phenols	Roots	6796	mg/100 mL	[24]

Different parts of *Tylosema fassoglense*, especially the roots, have been known to be used by local communities to treat diverse ailments (Table 8), such as abdominal pain, renal disorders, arthritis, epilepsy, sexually-transmitted diseases, pneumonia, jaundice, hypertension, and cancer, among others [24,32,53,55,57,61]. Less prevalent has been the use of leaves that have been associated with anti-oxidant activities and for the treatment of acne and wounds [52]. Most of this information comes from ethnobotanical studies that captured local knowledge, and only in a very few cases was this knowledge integrated with scientific findings. For example, ethnobotanical knowledge collected from Luo communities in Kenya on the use of the plant to treat malaria was screened in vitro, verifying the likely substantial antiplasmodial properties of the plant [54]. Similarly, the knowledge of local communities in the Mt Elgon area of western Kenya about the possible anti-cancer properties of the plant helped to identify the high flavonoid, tannin, phenol, and terpenoid content (among others) of the species, which have been associated with anti-cancer effects [25].

Table 8. Plant parts used for the treatment of diverse ailments.

Medicinal Focus	Part of Plant	Local Knowledge	Scientific Knowledge	Source
Abdominal pains and stomach problems	Roots	Yes	No	[62]
Antiplasmodial activity (malaria treatment)	Tubers	Yes	Yes	[54]
Antioxidant activity	Leaves, Seeds, barks	Yes	No	[57]
Renal disorders, arthritis, epilepsy, cancer	Roots	Yes	No	[56]
Infertility in men and women	Tubers	Yes	No	[56]
Acne, wounds and sexually-transmitted diseases (syphilis)	Root and Leaves	Yes	No	[52]
Asthma and pneumonia	Roots	Yes	No	[55]
Gastrointestinal and urinary problem, anemia, fever, and pneumonia, and to heal the uterus after childbirth, venereal diseases, jaundice, and hypertension	Roots	Yes	No	[55,63]
Cancer	Roots	Yes	Yes	[25]

Table 8. *Cont.*

Medicinal Focus	Part of Plant	Local Knowledge	Scientific Knowledge	Source
Antidiarrheal activity	Tubers	No	Yes	[59]
Antimicrobial activity	Roots	No	Yes	[28]
Complementary use with anti-retroviral therapy	Leaves	Yes	Yes	[64]
Medicinal	Roots	Yes	Yes	[29]
Anemia	Roots	Yes	No	[26]
Antenatal use	Roots	Yes	Yes	[65]
Treatment of malaria, fever and Gastro-intestinal	Roots	No	Yes	[66]
Control of ticks in livestock	Leaves	Yes	No	[31]

4. Discussion

Under-utilized and neglected (NUS) species can contribute to transforming agricultural production systems to deliver food security and nutrition, health benefits, and better livelihoods. However, systematized studies that can inform research and development initiatives to promote NUS are largely missing. In this study, consideration was given to the NUS *Tylosema fassoglense*, which constitutes an important biodiversity in many communities within Africa yet remains under-utilized. The findings showed that the species has agro-ecological, nutritional, and medicinal potential that can be tapped to support human wellbeing.

4.1. Potential Agro-Ecological and Climatic Advantages

The reviewed studies suggest that the distribution and occurrence of *Tylosema fassoglense* is mainly in eastern and the southern Africa. A few studies have also identified the species in other parts of Sub-Saharan Africa (e.g., central Africa) (Figure 2). In most of the reviewed studies, the *Tylosema fassoglense* plants (or its specific parts) were collected from the wild rather than controlled cultivated conditions on farms (Table 2). Some of these localities are characterized by high temperatures and low rainfall (Table 5), and marginal soils (mostly sandy) [30]. Such conditions are somewhat comparable to the climatic and soil characteristics associated with *Tylosema esculuntum* [67], which is an indication of biogeographical similarities between the species.

The ability of *Tylosema fassoglense* to grow in such marginal conditions is likely due to morphological characteristics such as long tuberous roots and large vegetative systems [14]. For example, its large vegetative system, when decomposed, can release various nutrients to the soil, improving soil fertility [61], while the condensed canopy can act as a natural shade, lowering soil temperature and reducing water loss through evaporation. Growing in such marginal soils and water-scarce environments can present certain advantages over other plant species in terms of adaptation to climate change, especially in arid and semi-arid areas [68]. In fact, several studies have highlighted that many NUS can be promising climate-smart options for local food systems in Sub-Saharan Africa given their generally good ability to adapt to challenging local environments [69,70].

Beyond its hardy nature and climate change adaptation potential, the plant might also offer certain ecological functions. For example, its attractive yellow flowers and nectar and the shade from its canopy can provide food and a natural habitat to pollinators such as bees and other insects [71]. In addition, its large tubers that store water and its deep root may provide food and shelter for soil-dwelling organisms within deeper layers in the soil, such as earthworms, fungi, bacteria, and other microorganisms [72]. These organisms are critical for the decomposition of organic matter, nutrient cycling, and overall soil health [73], possibly playing critical roles in the indigenous ecosystems within the range of *Tylosema fassoglense*.

Considering the above, it is possible that *Tylosema fassoglense* has some potential in supporting sustainable agricultural systems, which is, nevertheless, yet unrealized. Arguably, this unrealized potential is partly due to the fragmented knowledge base, as only a few of the reviewed studies have focused on agro-ecological aspects such as seed germination and crop improvement [44,49]. The generally low prevalence of the species in cultivated systems in our reviewed studies is possibly an indication of low domestication, but at the same time when considered alongside the species' extensive distribution might offer opportunities to identify wild populations with superior traits for the cross-breeding and development of superior strains [74,75]. Therefore, further research is urgently needed to establish the agro-ecological characteristics and potential of the plant. This can include, among other things, a fine resolution mapping of its distribution (and the factors affecting it), as well as an understanding of its yield potential in different systems, its climate change adaptation potential, and its general role within its agro-ecosystem. This type of information needs to be compared with other species in the genus (especially *Tylosema esculuntum*), other NUS, and eventually other established crops. Such knowledge will form an important evidence base to guide crop improvement, production, and ultimate conservation efforts [76].

4.2. Nutrition and Food Security

According to Table 6, *Tylosema fassoglense* contains various micro- and macro-nutrients, as well as favorable physical and physico-chemical properties, which suggest that the species can be a promising option for food and nutrition [15,24,52]. Most nutrition studies on *Tylosema fassoglense* have focused on the seeds and beans of the plant, which generally have the highest nutrient content and the more favorable phytochemical and physical properties (Table 6). This reflects other studies that have also indicated the high nutritional value of seeds in other NUS species [77,78].

Studies show that the plant contains diverse micro-nutrients (e.g., potassium, calcium, magnesium, sodium, zinc, sodium, iron, molybdenum) and amino acids, which can make it a valuable source of such nutrients [24,58]. These nutrients are essential in the normal growth, development, and functioning of the human body. For example, zinc, potassium, calcium, and magnesium play vital roles in insulin production and regulation, and their adequate intake can prevent the occurrence of type 2 diabetes [79]. Zinc regulates human metabolism and prevents osteoporosis/deterioration of bones, reduces inflammation and occurrence of cardiovascular diseases, especially among the elderly [80]. Calcium plays a central role in bone formation and also has anti-cancer properties [80]. Phosphorus is an important bone health and cell membrane [80]. Iron is important for hemoglobin formation [81], as has been overemphasized in the literature over time.

However, the diets of local communities in many parts of Africa are often scarce in such nutrients, and this has resulted in high micro-nutrient deficiency rates in many parts of the World [82]. Arguably, the integration of *Tylosema fassoglense* in local diets, especially in the arid and semi-arid areas of southern and eastern Africa where the species is found, could help tackle micro-nutrient deficiencies. Several studies have outlined the potential of NUS to improve micro-nutrient intake, both in Africa [10,13,81] and other parts of the world [83].

Although the current evidence base about the nutritional value of *Tylosema fassoglense* is promising, it is much less mature than the other major species of the *Tylosema* genus, the *Tylosema esculentum* (commonly known as marama bean). Studies have shown that marama beans have very valuable nutritional properties as they are rich in minerals such as calcium, magnesium, phosphorus, and zinc [84]. Marama beans also have some potential as a prebiotic due to it high soluble solids content [85]. Studies have shown that marama beans have very valuable nutritional properties as they are rich in minerals such as calcium, magnesium, phosphorus, and zinc [84]. Marama beans have also some potential as a prebiotic due to it high soluble solids content [85].

However, there are a few comparative studies showing similar content for some micro- and macro-nutrients between the two species. For example, the ash and carbohydrate content of *Tylosema fassoglense* (Table 6) is comparable to *Tylosema esculuntum* (3.29 g/100 g and 14.07 g/100 g, respectively) [86]. Similarly, both species have similar content for some minerals (Ca, Mg, P, and Zn) [84] and seem to be characterized by low protein, fiber, and energy content (34.71 g/100 g, 3.94 g/100 g, and 2.28 MJ/100 g, respectively, for *Tylosema esculuntum*) (see Table 6 for values for *Tylosema fassoglense*). However, the microstructure of *Tylosema fassoglense* is higher compared to *Tylosema esculentum* [24]. It is important to note that a proper comparison (especially with established crops such as soybeans), is not possible at this stage because of the limited data to conduct meta-analysis for the reasons explained in the section on "Limitations" (i.e., few observations, different variable, and tests). Such comprehensive comparisons are a major gap in the literature, hence the need for more comprehensive and coherent studies that show the nutritional content of *Tylosema fassoglense.*

Overall, despite its nutritional content and the ability to grow in marginal areas that are vulnerable to climate change (Table 5), *Tylosema fassoglense* remain underutilized for food and nutrition compared to *Tylosema esculuntum*, which has traditionally been an important food species for some local communities in parts of Southern Africa (e.g., South Africa, Namibia) [87]. This suggest the need for much deeper research to understand the nutritional characteristics of the species, along with how it can be integrated in local diets. For example, beyond laboratory studies about the nutritional characteristics of the plant, studies should explore in which form and during which times of the year the species would be an acceptable source of nutrition for local communities, as well as its acceptability from consumers in other areas. This can provide more information of whether the species has potential as a seasonal food supplement, a diet diversification strategy similar to other NUS [88,89] (especially during periods that other food sources are scarce), or can become a core element of the regional diets.

4.3. Medicinal Uses

As shown in this study, different parts of *Tylosema fassoglense*, including its roots, leaves, seeds, and tubers, contain various bioactive and phytochemical compounds that have medicinal value (Table 6). Such phytochemicals include phenols, flavonoids, terpeneids, tannins, saponins, and glycosides. These compounds play a key role in human health as they inhibit enzymes associated with the development of human diseases. Some of the compounds identified in different parts of the plant have been associated with antiplasmodial, anti-cancer, and anti-oxidant properties, as well as benefits for gastro-intestinal, respiratory, cardiovascular, reproductive, sexually-transmitted, and renal health issues (Table 8).

Of the different plant parts, the roots have possibly the highest medicinal potential due to the presence of many compounds associated with antioxidative, hypoglycemic, hypocholesterolemic, antimicrobial, and immunomodulatory activity [90,91]. For example, alkaloids, flavonoids, tannins, phenols, terpenoids, phlobatannins, and anthraquinones were identified in the roots of the plant from samples collected from the Mt Elgon region of Kenya [25]. Furthermore, phenolics were identified in roots, barks, and seeds from samples of the species obtained from the Rorya area in Tanzania [57].

The presence of such phytochemical and medicinal properties has also been shown in some species within the genus and among other NUS found across Sub-Saharan Africa. For instance, extracts from the tuber and bean of *Tylosema esculentum* within the same genus have been shown to have strong antiviral properties against rotavirus infection [89], and high content of phenolic acids, flavonoids, and proanthocyanidins associated with substantial antioxidant properties [70,92]. Similarly, among many other NUS [13], studies have identified multiple phytochemicals with possible pharmacological properties in pearl millet [69], various legumes (Adzuki beans, Africa yam beans, Jack beans, Lima beans, Bambara groundnuts, and Kidney beans) [13,93], and in moringa [70].

Parts of the *Tylosema fassoglense* plant also contain inhibitory enzymes associated with medicinal properties, such as trypsin inhibitors phytates, nitric oxide synthase, and guanylyl cyclase inhibitor [50,60]. In particular, phytates inhibit calcium salt crystallization to reduce vascular calcifications and soft tissue calcifications [94]. Nitric oxide synthase and guanylyl cyclase inhibitor combined have a physiological function in vascular toning, cell adhesion, neurotransmission, inhibition of platelet aggregation, and regulation of the immune systems [95]. For example, some of these proteins have anti-inflammatory, anti-tumor, and anti-viral properties and help treat several diseases, such as pancreatitis, hypertension, diabetes, and thrombosis [96]. They can provide an important entry point in developing drugs for cardiovascular diseases, cancer, and wound healing [97], and prevent the emergence of neurodegenerative diseases such as Alzheimer's and Parkinson's diseases [98]. However, only two out of 37 reviewed studies assessed inhibitory enzymes. This represents another major research gap in the species that should be investigated before ascertaining the full medicinal benefits of the species.

Regarding the actual medicinal uses, in contrast to many other NUS (including *Tylosema esculentum*), *Tylosema fassoglense* is rather understudied. Only a few studies have used ethnobotanical information to explore the actual medicinal uses of the species by local communities in the region [24,51,53,55,57]. Interestingly, there seems to be regional variation in this reviewed literature regarding which part of the plant and how and for which ailment it is utilized. For example, in parts of Kenya, the tubers are boiled and used to treat malaria and infertility in women, while the roots are used to treat renal disorders, arthritis, epilepsy, and infertility in women [32,53], as well as pneumonia/asthma [55] and cancer [25]. In parts of Kenya, the leaves are concomitantly used with antiretroviral therapy to manage the side effects of antiviral medicine to people living with HIV [64]. In parts of Tanzania, the leaves are used to make herbal tea with anti-oxidant properties, which when consumed can protect the human body against ailments such as bacterial and fungal infections [57]. In parts of Uganda, the roots and leaves are used to treat acne, wounds, and sexually-transmitted diseases such as syphilis [57]. In parts of Zimbabwe, the roots are used to treat abdominal problems [62]. These findings demonstrate the large variation in the medicinal uses of *Tylosema fassoglense*, which can inform context-specific research and development initiatives. However, the underlying mechanisms and actual effectiveness/contribution in treating such ailments is not clear. This is a major knowledge gap at the moment that would require extensive research to identify the full medicinal potential of the species.

It is also worth noting that there is a large diversity of medicinal uses and targeted ailments for the same species among other NUS found in Sub-Saharan Africa [13]. For example, honey bush has been used to treat diverse health conditions such as digestive problems, arthritis, diabetes, stress, colic, hypertension. and chest ailments by local communities in parts of South Africa [99]. Additionally, tigernut is used to treat colon cancer, heat stress, and gastro-intestinal and aphrodisiac ailments by local communities in Benin [100]. Sword bean is used by local communities to treat abdominal dropsy and kidney-related Lumbago [101]. Such studies have also pointed to substantial regional variations in medicinal uses for the same NUS, which usually reflects the local knowledge of local communities [102,103].

4.4. Economic Potential

The promising medicinal and nutritional properties outlined above also imply the possible economic potential of the plant for the development of food and medicinal products. Theoretically, parts of the plant can be used as raw materials for the development of nutraceutical and cosmetic and pharmaceutical products. Beyond its medicinal and nutritional properties, the oil extracted from the seeds [30] has similar physico-chemical properties comparable to oils used in the food and cosmetic/detergent industry [104–107]. This can be attained through value addition and agro-processing, which will ultimately enhance rural livelihoods. This potential is yet to be utilized as studies about the economic value of *Tylosema fassoglense* are largely missing. The only reviewed study about the economic value of the plant is related to its role in ceramic pot-making in the Luo community in Kenya [105]. This is in contrast to other NUS in the same genus, such as *Tylosema esculuntum*, where studies have explored its economic potential. For example, studies have explored the engineering properties of *Tylosema esculuntum* that are relevant for processing and value addition [19] and the storage conditions that reduce oxidative stress and enhance its shelf life [106]. Research on the economic utilization of the species, and how it can be translated to improved rural livelihoods, is scarce. Research is needed to identify the most promising economic uses and possible markets and value chain configurations before investing in initiatives seeking to increase the production and commercialization of the species.

4.5. Leveraging Local Knowledge

Local knowledge is grounded in strong experiential knowledge and cultural practices that sometimes span many generations and are specific to certain localities. Many scholars have highlighted that such knowledge can be particularly valuable in preserving biodiversity, as well as in enhancing food security and food systems sustainability [79,83]. Scholars have also pointed to the need to integrate such knowledge in policy and practice [108]. Arguably, considering the major knowledge gaps for *Tylosema fassoglense* outlined in the previous sections, it would be critical to leverage local knowledge and integrate it with modern scientific knowledge to improve the understanding, management, conservation, and utilization of this understudied NUS.

Interestingly, most of the reviewed studies documenting local knowledge were ethnobotanical studies that focused on the medicinal uses of the plant. Surprisingly, none of the reviewed studies had documented local knowledge about the nutritional, agro-ecological, and economic potential and uses of *Tylosema fassoglense*. Furthermore, only a few studies integrated local and scientific knowledge in understanding the properties of the species. A few studies had used local ethnobotanical knowledge (plants parts, e.g., roots, leaves, and seeds, and which ailment they treated) to aid laboratory analysis for active ingredients. Examples included studies that (a) linked traditional uses among the Luo and Kuria ethnic groups in Kenya with antiplasmodial activity, and (b) traditional use of tubers as antidiarrheal, with high phyto-chemical content (e.g., phenolic, alkaloids, flavonoids) [59]. It is evident that studies integrating local and scientific knowledge are largely missing, especially for agro-ecological characteristics and nutritional uses. This is another major knowledge gap that should be targeted through coordinated research efforts. For instance, local knowledge could be collected through ethnomedicinal and ethnopharmacologal studies [83], which could help identify, as a first step, which plant parts are used, for which purpose, and at what doses and frequencies. This can point to the possible presence of bioactive compounds, which through further laboratory screening could confirm the actual medicinal properties, especially in terms of active ingredients and required doses.

In terms of nutritional properties, local knowledge can be mobilized to identify which parts of the plant are consumed, at which times of the year, why they are preferred, how they are prepared and consumed, and what nutritional needs they meet. This can provide extremely valuable information about the different factors affecting decisions to harvest the species and inform subsequent scientific research that explores how to integrate the species better to local diets, and whether it has potential in becoming a more significant component for regional diets.

In terms of agroecological characteristics and distribution, local knowledge can be mobilized to identify harvesting areas of the species and the traits preferred by the communities (e.g., larger size of edible components, ability to grow in marginal conditions). This knowledge can help improve our knowledge about the geographic distribution of the species and create finer resolution distribution maps to enhance genetic conservation. More importantly, this knowledge can help identify populations with useful traits that can be selected for cross-breeding to develop improved strains of the species through further scientific research.

5. Conclusions

In this paper, we conducted a systematic review of the current literature about the distribution, agroecological characteristics, and the nutritional and medicinal properties of *Tylosema Fassoglense*. *Tylosema Fassoglense* is a rather promising, but understudied, NUS encountered mostly in eastern and southern Africa. By reviewing 37 studies in depth, we identified that the species has some agro-ecological advantages because, due to its physiology, it can grow in arid and semi-arid conditions. Furthermore, it has nutritional, medicinal, and economic potential, given the presence of various micro/macro-nutrients and phytochemicals in its different parts. However, the available literature is both scarce and fragmented. This results in a rather inadequate evidence base to leverage the possible benefits of the species and upscale production, commercialization, and utilization efforts.

Overall, the species remains rather under-exploited, and is yet to receive substantial research and development interest. Future research studies should aim at adopting a system approach that critically explores the challenges and solutions (from production to utilization), to identify the full potential and scope of scaling up efforts and integration in agricultural policies. This would require extensive research on multiple fronts. Based on the findings of this systematic review, we identify four priority research areas.

First, robust and replicable laboratory studies should comprehensively assess the nutrient and phytochemical content of the species, as well as compare it with other species in the *Tylosema* genus (particularly *Tylosema esculuntum*), other similar NUS, and conventional crops. Second, there should be studies that integrate ethnobotanical knowledge with robust pharmacological evidence to unravel whether and how the species can treat diverse ailments across different geographical contexts. Third, socioeconomic studies (both on the producers' and consumers' side) should identify the most promising economic uses and possible markets and value chain configurations for the species. Fourth, research studies should provide a much more comprehensive understanding of the favorable traits of the species and how they can be improved through selective cross-breeding and the development of improved strains. Research across all these four priority areas will arguably benefit from the stronger integration of local knowledge and scientific methods.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16146046/s1.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Articles on *Tylosema fassoglense* That Were Included in the Study

Authors	Title	Year	Journal	Vol	Issue
Shopo, Bridgett; Mapaya, Ruvimbo J.; Maroyi, Alfred [62]	Ethnobotanical study of medicinal plants traditionally used in Gokwe South District, Zimbabwe	2022	South African Journal of Botany	149	
Kudamba, Ali; Lubowa, Muhammad; Kafeero, Hussein M; Okurut, Shaban A; Nsubuga, Hakim; Abiti, Twaha; Walusansa, Abdul; Kayendeke, Joweria; Nanyingi, Hasifah; Mubajje, Muhamad S; [25]	Phytochemical Profiles of Albizia coriaria, Azadirachta indica, and *Tylosema fassoglensis* used in the Management of Cancers in Elgon Sub-Region	2022	Fortune Journal of Health Sciences	5	3
Victor, Otieno, Elena, Castillo-Lorenzo, Felister, Nzuve, John, Kimenju, William, Omondi, TizianaUlian [33]	Dormancy and Light Requirement for Germination of Sprawling Bauhinia (*Tylosemafassoglense*) Seeds	2022	Journal of Botany Research	5	1
Jane Namukobe, Anthony Lutaaya, Savina Asiimwe and Robert Byamukama [52]	An ethnobotanical study of medicinal plants used in the management of dermatological disorders in Buyende and Kayunga Districts, Uganda	2021	European Journal of Medicinal Plants	32	2
Mapesa W.A.; Waweru M.P.; Bukachi F.; Wafula K.D. [59]	Aqueous Tuber Extracts of *Tylosema fassoglense* (Kotschy ex Schweinf.) Torre and Hillc. (Fabaceae). Possess Significant In-Vivo Antidiarrheal Activity and Ex-Vivo Spasmolytic Effect Possibly Mediated by Modulation of Nitrous Oxide System, Voltage-Gated Calcium Channels, and Muscarinic Receptors	2021	Frontiers in Pharmacology	12	March
Meshack O. Onyambu, Gladys N. Mokua, Geoffrey M. Maroko, AugustusO. Nyakundi [64]	Use of Complementary and Alternative Medicine Interventions in the Management of HIV/AIDS in Kisii County, Kenya: A Qualitative Study of Traditional Healers	2021	Asian Journal of Traditional, Complementary and Alternative Medicines	4	January
Otieno, V.; Ulian, T.; Nzuve, F.; Kimenju, J. [48]	Germination response to temperature and water potential for Sprawling bauhinia (*Tylosema fassoglense*), a potential crop for Kenya	2020	South African Journal of Botany	132	
Mailu, James Kiamba; Nguta, Joseph Mwanzia; Mbaria, James Mucunu; Okumu, Mitchel Otieno; [55]	Medicinal plants used in managing diseases of the respiratory system among the Luo community: an appraisal of Kisumu East Sub-County, Kenya	2020	Chinese Medicine	15	95

Authors	**Title**	**Year**	**Journal**	**Vol**	**Issue**
Onyango, Philip, Nyunja, Regina, Opande, George, Fedha Sikolia, Stephen [32]	Inventory, reward value and diversity of Apis mellifera nectariferous and polleniferous forage in eastern Mau forest, Kenya	2019	International Journal of Scientific Research Publications	9	2
Ochanga, Okumu; Kilonzo, Mhuji [57]	Antioxidant properties of aqueous and ethyl acetate extracts of some plants used as herbal tea in Tanzania	2018	Oxidants and Antioxidants in Medical Science	7	1
Wang, Yin-Huan; Wicke, Susann; Wang, Hong; Jin, Jian-Jun; Chen, Si-Yun; Zhang, Shu-Dong; Li, De-Zhu; Yi, Ting-Shuang; [49]	Plastid genome evolution in the early-diverging legume subfamily Cercidoideae (Fabaceae)	2018	Frontiers in Plant Science	9	132
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Kigen, Gabriel; Maritim, Alice; Some, Fatuma; Kibosia, John; Rono, Hillary; Chepkwony, Simon; Kipkore, Wilson; Wanjoh, Bernard; [56]	Ethnopharmacological survey of the medicinal plants used in Tindiret, Nandi County, Kenya	2016	African Journal of Traditional, Complementary and Alternative Medicines	13	3
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Owuor, B. O.; Ochanda, J. O.; Kokwaro, J. O.; Cheruiyot, A. C.; Yeda, R. A.; Okudo, C. A.; Akala, H. M. [54]	In vitro antiplasmodial activity of selected Luo and Kuria medicinal plants	2012	Journal of Ethnopharmacology	144	3
Takundwa, M; Chimwamurombe, PM; Kunert, K; Cullis, CA; [51]	Developing DNA barcoding (matK) primers for marama bean (*Tylosema esculentum* (Burchell) Schreiber)	2012	African Journal of Biotechnology	11	97
Adongo, John Onyango, Omolo, Josiah O, Njue, Alice WMatofari, Joseph W [28]	Antimicrobial activity of the root extracts of *Tylosema fassoglensis* Schweinf. Torre & Hillc (Caesalpiniaceae)	2012	Science Journal of Microbiology	2012	209
J. M. Ochora 1, J. M. Onguso2 and J. I. Kany [110]	On the Agroforestry System and in Situ Conservation of Medicinal Plant Germplasm in Trans-Nzoia District, Kenya	2012	Conference proceeding		June
N4ED [61]	Potentially Important Food Plants of Ethiopia	2012	Report		
Amonsou, Eric; Taylor, John; Minnaar, Amanda [24]	Microstructure of protein bodies in marama bean species	2011	LWT—Food Science and Technology	44	1
Van Wyk, B. -E. [111]	The potential of South African plants in the development of new food and beverage products	2011	South African Journal of Botany	77	4
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Holse, Mette; Husted, Søren; Hansen, Åse [58]	Chemical composition of marama bean (*Tylosema esculentum*)—A wild African bean with unexploited potential	2010	Journal of Food Composition and Analysis	23	6
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Amonsou, Eric Oscar [112]	Characterisation of Marama Bean Protein	2010	LWT-Food Science and Technology	44	1

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Castro S., Silveira P., Coutinho A.P., Figueiredo E. [15]	Systematic studies in *Tylosema* (Leguminosae)	2005	Botanical Journal of the Linnean Society	147	1
Hao, Gang; Zhang, Dian-Xiang; Zhang, Ming-Yong; Guo, Li-Xiu; Li, Shi-Jin; [50]	Phylogenetics of Bauhinia subgenus Phanera (Leguminosae: Caesalpinioideae) based on ITS sequences of nuclear ribosomal DNA	2003	Botanical Bulletin of Academia Sinica	44	3
Tabuti, J R S, Lye, K A, Dhillion, S S [65]	Traditional herbal drugs of Bulamogi, Uganda: plants, use and administration	2003	Journal of Ethnopharmacology	88	2003
Gashaw, Menassie; Michelsen, Anders; [47]	Influence of heat shock on seed germination of plants from regularly burnt savanna woodlands and grasslands in Ethiopia	2002	Plant ecology	159	2002
Dakora F.D., Lawlor D.W., Sibuga K.P. [46]	Assessment of symbiotic nitrogen nutrition in marama bean (*Tylosema esculentum* L.), a tuber-producing underutilized African grain legume	1999	Symbiosis	27	03-Apr
Dubois, Michel; Lognay, Georges; Baudart, Evelyne; Marlier, Michel; Severin, Michel; Dardenne, Gaston; Malaisse, François; [53]	Chemical characterisation of *Tylosema fassoglensis* (Kotschy) Torre & Hillc oilseed	1995	Journal of the Science of Food and Agriculture	67	2
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