Agrobiodiversity for Improving Nutrition, Health and Life Quality

Research Article

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Indigenomics Prospects of Underutilized Tropical Fruits Agrobiodiversity: A Scoping Review of Economic Botany

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Article Details:
Received: 2025-11-03
Accepted: 2025-11-27
Available online: 2025-11-30

DOI: https://doi.org/10.15414/ainhlq.2025.0029

Sustainable optimization of Underutilized Tropical Fruit Tree Species (UTFS) requires shifting focus beyond direct consumption to encompass their multi-dimensional value across ecological importance, community well-being support, cultural significance, and commercial value. Indigenomics is an integrated value system that applies indigenous economic principles to analyze the relationship between human communities and ethnobotanical resources. We conducted a systematic review, structured around the scope of the indigenomics framework to assess the research landscape of UTFS in Africa between 2014 and 2024. A total of 75 indigenous fruit species with high indigenomics potential were identified based on their multi-dimensional value across core indigenomics indicators. Tripartite analysis was performed using Ghephi 0.10 software to reveal the intricate network linking UTFS, indigenous communities, and their usage, highlighting their untapped economic opportunities. The result confirmed an indigenomics potential for the UTFS, evidenced by an average of 2.89 uses per species. Centrality metrics identified food/nutrition (66 of 75 species), medicine/health (63 species), and industrial/commercial products (42 species) as the three core indigenomics indicators of the species. Foundational species, such as *Sclerocarya birrea* (A.Rich.) Hochst., *Adansonia digitata* L., and *Vitellaria paradoxa* C.F.Gaertn.serve as critical resources linking diverse ethnic groups, particularly in high-connectivity areas of South Africa and Nigeria. However, research is geographically imbalanced, with documentation highly concentrated in South Africa (45 species) and West Africa, particularly Nigeria (23 species), leaving many other regions critically underexplored. The findings highlight the need for coordinated policies in agriculture, agrobiodiversity conservation, and commerce at local and international levels to optimize these species. The operational feasibility of Indigenomics framework requires validation through future research efforts that integrate biocultural epistemology.

Keywords: agrobiodiversity, biocultural economics, ethnobiology, indigenomics, neglected and underutilized species, sustainability

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Introduction

The African continent possesses an unparalleled wealth of agrobiodiversity, which represents a significant, yet largely untapped, resource for enhancing both ecological stability and global food security (Nkwonta et al., 2023; Nyoni et al., 2024). Agrobiodiversity, defined as the variety and variability of organisms used directly or indirectly in agricultural systems (Jones et al., 2021), has historically served as the foundation for the nutritional, medicinal, cultural, and economic well-being of indigenous populations (Nair, 2023; Bravo-Peña and Yoder, 2024). However, global climate changes, intensified by land-use shifts and urbanization, coupled with transformations in food systems, are driving the decline, region-scale loss, and potential extinction of key agrobiodiversity components (Kayode et al., 2020; Vagge and Chiaffarelli, 2023). The concurrent push for agricultural intensification, necessitated by a rising global population, has further led to a narrow commercial focus on a limited number of high-yield crops. This trend has resulted in the widespread neglect of local landraces (Jones et al., 2021), including a vast array of underutilized tropical fruit species (UTFS) (Peduruhewa et al., 2021).

Tropical fruits are often characterized by exceptional nutritional value and adaptability to low-input farming practices (Achaglinkame et al., 2019; Sileshi et al., 2023). Nevertheless, UTFS are rarely subjected to commercial cultivation and remain scarce in modern markets. Their restricted accessibility, minimal utilization, and regional specificity cause them to be frequently categorized in academic literature as "neglected" (Okigbo and Ugwu, 2021; Karanja et al., 2022; Ojuederie et al., 2024); "minor crops" (Wehner et al., 2020; Hossain et al., 2021), "lesser-known crops" (Aworh, 2015; Baiyeri and Olajide, 2022), or "orphan crops" (El Bilali et al., 2023). Consequently, the sustainable management and optimization of this latent agrobiodiversity are now critical for achieving multiple Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land) (Madsen et al., 2025).

Indigenomics offers a novel, integrated framework for analyzing the relationship between human communities and ethnobotanical resources (Hilton, 2021). It is defined as the application of indigenous socioeconomic approaches to analyze the relationships between humans and ethnobotanical resources, recognizing a species's ecological integration role, relational well-being, biocultural sovereignty, and market values. Rooted in indigenous epistemology and biocultural economic principles, this approach shifts research from potentially extractive processes toward collaborative endeavors that reinforce indigenous self-determination. Indigenous economic practices often exemplify this integrated value system. For instance, traditional Igbo entrepreneurship in Nigeria blends individual opportunity-seeking with communal reciprocity, fostering innovation while preserving cultural protocols around the cultivation and harvest of farm produce (Igwe, 2021). Similarly, Hausa agro-traders and Fulani pastoralists maintain crop and livestock diversity through practices embodying kincentric reciprocity with the land. Indigenomics, therefore, centers on leveraging indigenous economic empowerment to strengthen local value chains, foster commercialization, and improve the socio-economic conditions of the populations who traditionally utilized these resources.

Despite the intrinsic ecological suitability and economic potentials demonstrated by UTFS for centuries, comprehensive information regarding their socio-economic potential and conservation status remains fragmented. Existing research has heavily skewed toward descriptive ethnobotany (Aregay et al., 2017; Muok, 2019; Shai et al., 2020; Guzo et al., 2023; Matlala et al., 2024) and basic nutritional composition (Sibiya et al., 2020; Ampitan et al., 2022; Baiyeri and Olajide, 2022; Karanja et al., 2022; Kamanula et al., 2022a; Eswaranpillai et al., 2023; Nyoni et al., 2024). This has resulted in a significant research gap concerning the indigenous economic aspects essential for driving commercial viability and achieving sustainable development. This informational deficit limits the policy support and investment required for the widespread cultivation, domestication, and optimal utilization of these species.

Sustainable scaling and optimization of UTFS necessitate transcending direct consumption and medicinal uses to embrace their broader economic and cultural significance for indigenous communities. This systematic review, structured within the scope of indigenomics principles of community ecology and biocultural economics, assesses the research landscape of UTFS in Africa between 2014 and 2024. We aim to define the current status, research trends, and indigenomics prospects of these species, thereby providing a robust foundation for future policy and development initiatives that support the sustainable mainstreaming of Africa's vital UTFS agrobiodiversity. This approach allows for the assessment of ethnobotanical, economic, and environmental connectivity across local and regional scales.

Material and Methodology

This study employed a systematic meta-analysis of peer-reviewed literature to investigate the Indigenomics prospects and research status of UTFS in Africa over the last decade (January 2014 to May 2024).

Search Strategy and Data Collection

A comprehensive literature search was conducted across multiple scientific databases, including Scopus, Web of Science, PubMed, and Google Scholar. The search employed a combination of keywords and Boolean operators (Gionfriddo et al., 2024), utilizing terms related to the plant status = ("neglected" OR "underutilized" OR "orphan crop" OR "lesser-known crop" OR "minor crop"), AND crop type = ("fruit trees" OR "tropical fruits" OR "indigenous fruit" OR "wild edible fruit"), AND geography = ("Africa"). Thematic terms = ("agrobiodiversity" OR "ethnobotany" OR "phytochemical" OR "economic potential" OR "Indigenomics") were also used.

The search was strictly limited to articles published in the English language between 2014 and 2024. Articles were excluded if they focused primarily on major commercial fruits (such as apple, mango, orange, non-tree fruit species, and non-tropical or exotic fruit in general), did not pertain to the African continent, or lacked direct relevance to the indigenous economic themes. The initial bibliographic search yielded 947 articles, with 62 validated for inclusion in the final review. The reporting of this scoping review adhered to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Gionfriddo et al., 2024).

Assessment Criteria for Indigenomics Potential

The core criterion for assigning a high speciesIndigenomics potential was its capacity to demonstrate a foundational, multi-dimensional value holistically integrated across Indigenous socioeconomic principles. This framework assesses the species' role in ecological integration, community well-being, biocultural sovereignty, and monetary relevance, as illustrated in Figure 1. The key indicators are defined as follows:

Ecological Integration and Stewardship

Evaluates a species' ecological robustness, requiring high biodiversity (prevalence and distribution) and significant habitat interdependence (contribution to ecosystem services). This must be supported by indigenous cultivation or semi-domestication practices.

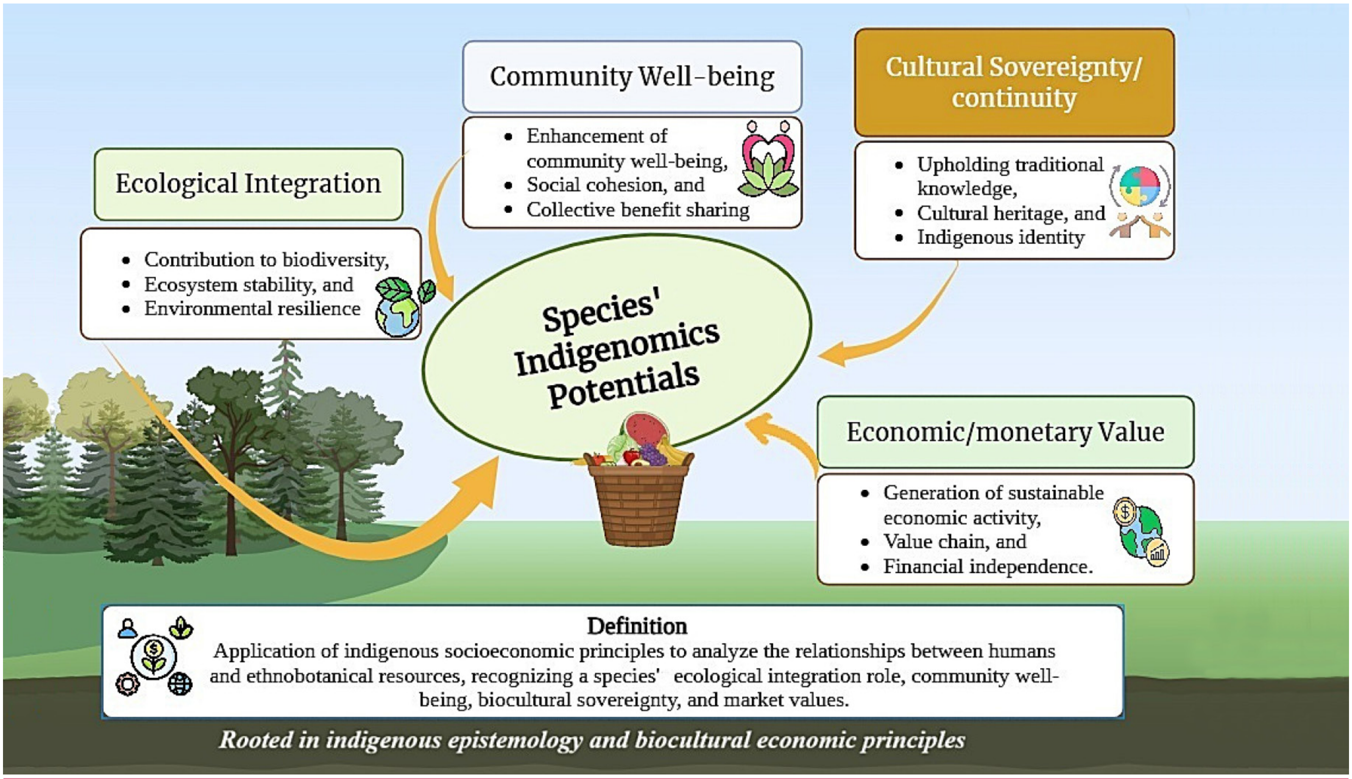


Figure 1 Indigenomics framework for species' potential

Community Well-being

Assesses the species' contribution to collective societal benefit, ensuring shared access (reciprocity), health/medicinal value, and nutrition. It must also strengthen the social fabric by promoting equity and maintaining vital traditional use practices.

Cultural Sovereignty and Continuity

Mandates cultural resilience by contributing to the inter-generational transfer of traditional knowledge. It requires a high proportion of culturally-specific uses, such as ceremonial or spiritual applications, supporting indigenous self-determination.

Market/Monetary Value

Acknowledges relevance within contemporary economic systems, requiring documented economic importance based on market commercialization and the quantity or frequency of use.

Statistical Analysis

The synthesized data was analyzed to identify research trends, geographical focus, and thematic patterns. A tripartite network analysis was conducted using Gephi 0.10 (2023) graph visualization software (Bastian et al., 2009) to map the relationships between the identified UTFS, the indigenous communities that use them, and their documented Indigenomics potential (plant uses). This visualization helped to illustrate the complex interconnections within the indigenous ecological knowledge system. We calculated the average number of functional categories (Canonical Uses) that each species is associated with across all documentation using the formula:

$$\textit{average uses per species} = \frac{\textit{total number of unique (species - uses) links}}{\textit{total number of unique species}}$$

Geographic Information System (GIS) tools were used to map the distribution of the studied UTFS across Africa, highlighting hotspots of research and areas requiring more attention. The analysis also categorized the research focus, distinguishing between studies to understand the current research landscape and identify critical gaps.

Results and Discussion

Geographical and Temporal Research Trends

The meta-analysis revealed a significant geographical bias in UTFS research across Africa in the recent decade (Figure 2). Research is highly concentrated in South Africa (54 species) and Nigeria (30 species), contrasting with Ghana (5 species) and Cameroon (1 species)

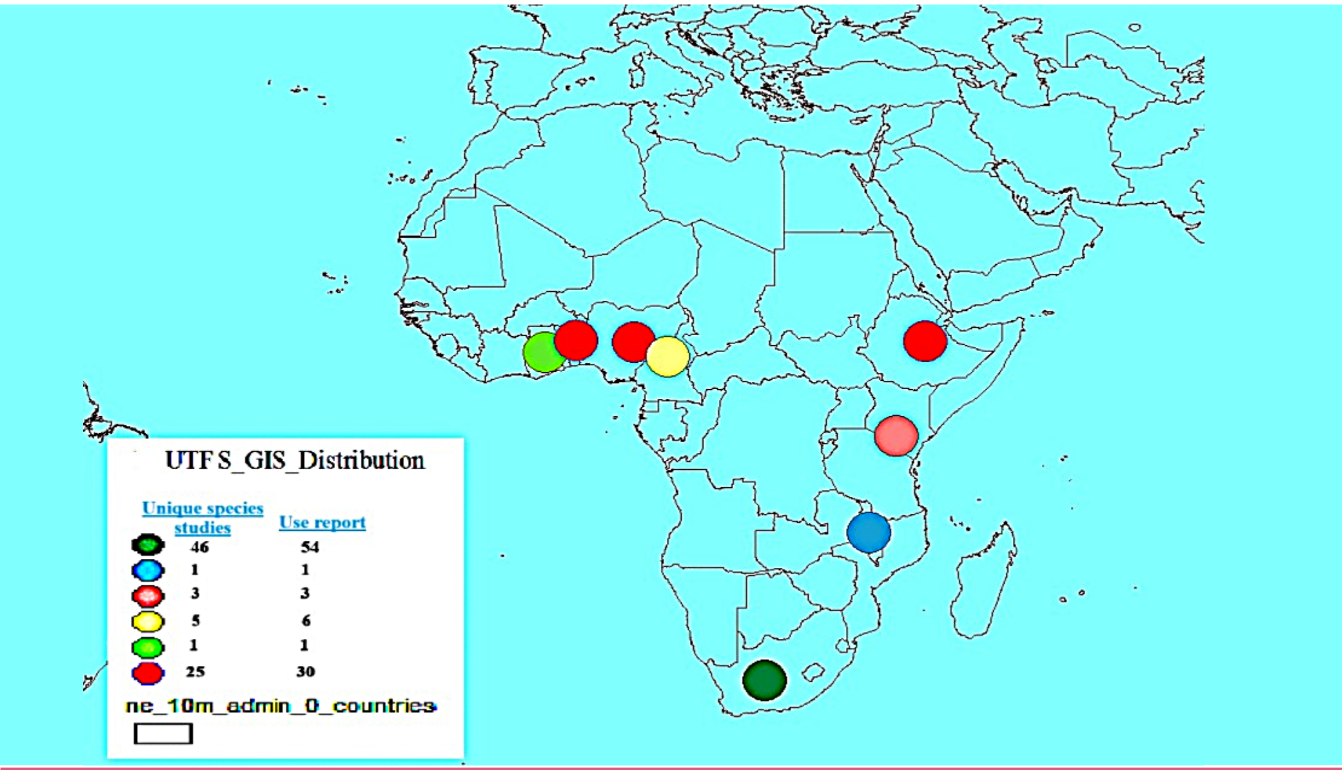


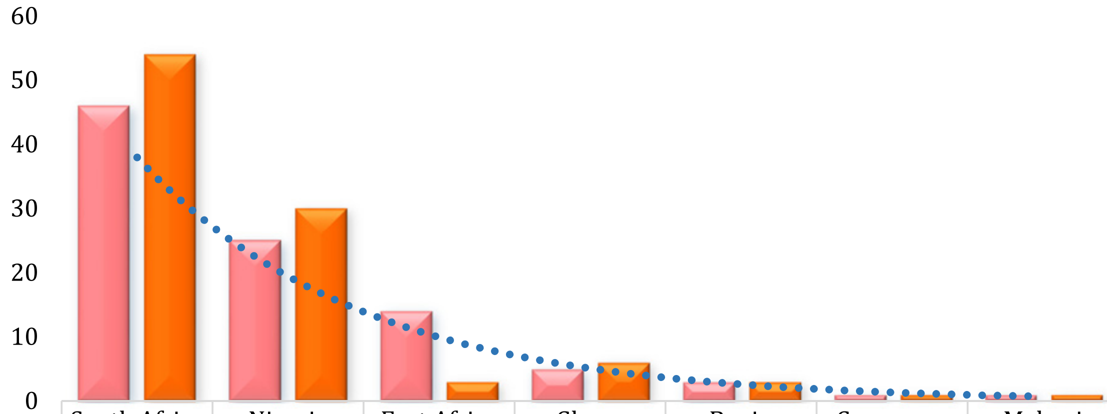
Figure 2 Underutilized Tropical Fruit Species (UTFS)_GIS_Distribution Map in Africa

in West Africa. While East Africa, represented by Ethiopia (11 species) and Kenya (3 species), showed moderate activity. Central, North, and Southeastern Africa (Malawi, 1 species) remain critically under-researched (Figure 3a). This disparity represents a substantial gap in the current understanding of the indigenomics component of UTFS agrobiodiversity across the continent.

The temporal analysis of publications shows a fluctuating but generally increasing interest in UTFS over the decade, with a noticeable peak in publications around 2020–2022 (Figure 3b), suggesting a growing recognition of their importance.

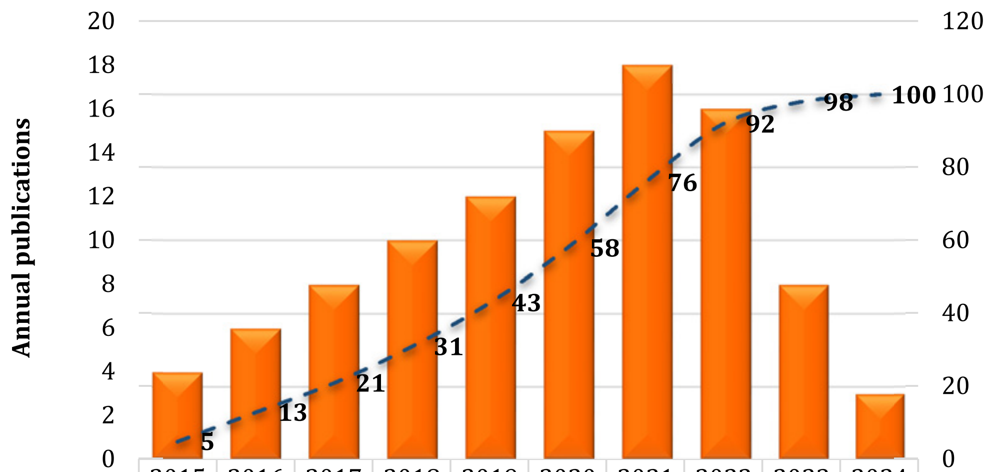
Thematic Focus of Research on UTFS

Bibliographic records indicated that existing research on UTFS in Africa over the past 10 years has primarily focused on the assessment of nutritional composition (Jacob et al., 2016; Ngemakwe et al., 2017; Achaglinkame et al., 2019; Omotayo and Aremu 2020; Sibiya et al., 2020; Ampitan et al., 2022; Baiyeri and Olajide, 2022; Karanja et al., 2022; Kamanula et al., 2022a; Eswaranpillai et al., 2023), the characterization of phytochemical and antioxidant properties (Kucich and Wicht, 2016; Sani et al., 2016; Abe-Inge et al., 2018; Kamanula et al., 2022b; Mwamatope et al., 2023), and the documentation of their ethnobotanical potentials



	South Africa	Nigeria	East Africa	Ghana	Benin	Cameroon	Malawi
unique species studied	46	25	14	5	3	1	1
use reports	54	30	3	6	3	1	1

Figure 3a Research trends of underutilized tropical fruit species (UTFS) across Africa in the last ten (10) years
* East Africa is represented as a regional grouping in the original data. Values represent the total for the last 10 years



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
annual publications	4	6	8	10	12	15	18	16	8	3
cumulative research effort	5	13	21	31	43	58	76	92	98	100

Figure 3b Research trends underutilized tropical fruit species (UTFS) across Africa in the last ten (10) years
Key highlights of the peak (2020–2022)

(Aregay et al., 2017; Muok, 2019; Shai et al., 2020; Guzo et al., 2023; Matlala et al., 2024). Advanced fields like metabolomics and chemodiversity (Nkosi et al., 2022) were also reported. Conversely, there is a clear limitation in studies addressing indigenous economic aspects (Muok, 2019), and general conservation strategies for these species (Kayode et al., 2020; Masao et al., 2023). This indicates a critical gap between understanding the biological properties of UTFS and translating that knowledge into tangible economic opportunities for local communities.

A major application area is evaluating the fruits' potential to enhance nutritional value and food security. Multiple studies in Nigeria, for example, have analyzed the nutritional composition of species like *Hyphaene thebaica* (L.) Mart. (doum palm), *Borassus aethiopum* Mart. (African fan palm), *Strychnos spinosa* Lam. (Natal orange), *Detarium microcarpum* Guill. & Perr. (sweet detar), and *Diospyros mespiliformis* (Hochst.) ex A.DC. (jackalberry) to assess their suitability for human consumption (Abubakar et al., 2017) and potential inclusion in animal feed formulation (Jacob et al., 2016). Research in Ghana identified that fruits such as *Gardenia erubescens*, *Sclerocarya birrea* (A. Rich) (Marula), *Diospyros mespiliformis*, and *Balanites aegyptiaca* are rich in essential micronutrients like Fe, Zn, vitamin A, and β-carotene, advocating for their incorporation into food nutrient databases and contemporary diets (Achaglinkame et al., 2019). Based on their high nutritional and phytochemical properties, fruits like Kei apple (*Dovyalis caffra*), *Physalis peruviana* (Cape gooseberry), and *Sclerocarya birrea* have been advocated for food product development in South Africa (Ngemakwe et al., 2017). The nutritional value of other key species like the African Baobab (*Adansonia digitata*) (Assogbadjo et al., 2021) and Monkey kola (*Cola lateritia* K. Schum) (Edoun et al., 2023) has also been thoroughly evaluated.

The biochemical evaluation of UTFS strongly supports their role as health-promoting agents. A comparative research has assessed the antioxidant properties of numerous species, including ten native South African fruits like *Syzygium cordatum* Hochst ex Sond and *Harpephyllum afrum* Bernh. ex C. Krauss, with commercial berries (Kucich and Wicht, 2016). Concurrently, studies in Nigeria have characterized the phytochemical profiles and *in vitro* antioxidant activities of species such as *Borassus aethiopum*, *Vitex doniana* (Sani et al., 2016). This chemical evidence corroborates traditional uses, with *B. aethiopum* extracts validated for managing conditions like edema and bacterial diseases (Abe-Inge et al., 2018). Furthermore, the fruit pulp extract of African Baobab was evaluated for its sub-acute toxicity (Adebisi et al., 2022) and, in a separate experiment, demonstrated a reversal of alloxan-induced diabetic alterations in rats (Adams and Eze, 2022). Advanced metabolomic and chemometric profiles of species like *Ficus capensis* (Cape fig) (Krauss), *Landolphia kirkii* T. Dyer, *Engelerophytum magalismontanum* (Transvaal milkplum or Milk plum) (Sond) Henie & J.H. Hemsl, *Parinari curatellifolia* Planch. Ex Benth (*Mobola plum*), *Sclerocarya birrea* (A. Rich) (Marula.), *Strychnos spinosa* Lam (Green monkey orange), *Strychnos madagascariensis* Poir (Black monkey orange), *Syzygium cordatum* Hochst ex Sond. var. *cordatum* (Water berry), *Ximenia caffra* var. *caffra* (Sour plum), *Vangueria infausta* Burch (Wild medlar) support their industrial application in the production of jam, fruit juices, and food flavoring extracts (Nkosi et al., 2022).

A broad ethnobotanical survey in South Africa documented the traditional uses of a wide array of fruits, including *Annona senegalensis* Pers, *Berchemia discolor* (Klotzsch), *Berchemia zeyheri* (Sond.), *Bridelia micrantha* (Hochst.), *Canthium inerme* (L.f.) Kuntze, *Carissa edulis* Vahl, *Diospyros mespiliformis* (Hochst.) ex A.DC., *Englerophytum magalismontanum* (Sond.) T.D. Penn., *Euclea divinorum* (Hiern.) *Ficus sur* (Forssk), *Ficus thonningii* (Blume) *Flueggea virosa* (Roxb. Ex Willd.) *Royle* subsp. *virosa*, *Grewia flavescens* (Juss.), *Lannea edulis* (Sond.) Engl., *Lannea schweinfurthii* (Engl.), *Lantana rugosa* (Thunb.), *Macrotyloma maranguense* (Taub.) Verdc, *Mimusops zeyheri* (Sond.), *Parinari curatellifolia* (Planch.) ex Benth., *Parinari capensis* Harv., *Sclerocarya birrea* (A.Rich.) Hochst. subsp. *caffra* (Sond.), *Searsia pendulina* (Jacq.) Moffett, *Strychnos madagascariensis* (Poir.), *Strychnos spinosa* (Lam.), *Syzygium intermedium* (Engl. & Brehmer), *Trichilia emetica* (Vahl.) subsp. *emetica*, *Vangueria infausta* (Burch.), *Ximenia americana* (Linn.), and *Ximenia caffra* (Sond.) (Shai et al., 2020). More recently, *Mimusops zeyheri* was specifically investigated for its ethnobotanical relevance in South Africa (Matlala et al., 2024). Additionally, research has addressed post-harvest challenges, such as the analysis of post-harvest treatments for the Malay apple (*Syzygium malaccense*) in Cameroon to improve its viability (Njilar et al., 2023).

Efforts to enhance the economic and ecological relevance of UTFS have been identified through studies utilizing indigenous economic concepts. This approach has helped prioritize species based on their marketing potential in regions including East Africa, Zimbabwe, and Sierra Leone (Jusu and Cuni-Snachez, 2017; Muok, 2019; Kabwe et al., 2024). Priority species include *Tamarindus indica*, *Sclerocarya birrea*, *Parinari excelsa*, *Adansonia digitata*, *Allanblackia* spp, *Vitellaria paradoxa*, *Ziphiphus mauritiana*, and *Irvingia gabonensis*.

On the conservation effort, morphological and geographic data have been established for species like *Balanites aegyptiaca* and *Beilschmiedia mannii*, which are critical for their conservation (Kayode et al., 2020; Adaja and Olajuyigbe, 2023; Hounsou-Dindin et al., 2023). Collectively, this integrated research highlights the vital role of UTFS in promoting biodiversity conservation and enhancing climate change adaptation within agroforestry systems (Omotayo and Aremu, 2020; Kayode et al., 2022; Masao et al., 2023).

Tripartite Network Analysis of UTFS, Indigenous Groups, and Uses/Applications

The tripartite network analysis reveals a complex and deeply interconnected system of knowledge and practice related to the studied UTFS. The visualization in Figure 4 shows the linkage between UTFS, Indigenous groups, and socio-economic applications. The result indicated that specific indigenous groups are custodians of knowledge for multiple UTFS, and each species often has a multitude of uses. The average number of uses per species was 2.89 (Table 1), confirming the high multi-dimensional value of UTFS. Centrality metric identified food/nutrition (connected to 66 of 75 unique species), medicine/health (63 species), and industrial/commercial products (42 species) as the three core values streamlined with indigenomics. Species including *Sclerocarya birrea* and *Diospyros mespiliformis* act as a foundational resource, linking multiple ethnic groups across varied geographic regions through shared utility. Ethnic groups in South Africa (Zulu, Xhosa, Venda) and Nigeria (Yoruba, Igbo, Hausa) demonstrated the highest connectivity to diverse uses, suggesting comprehensive utilization documentation in these regions. The network underscores that the high utilitarian value of species like *Saba senegalensis* (A.DC.) Pichon and *Sclerocarya*

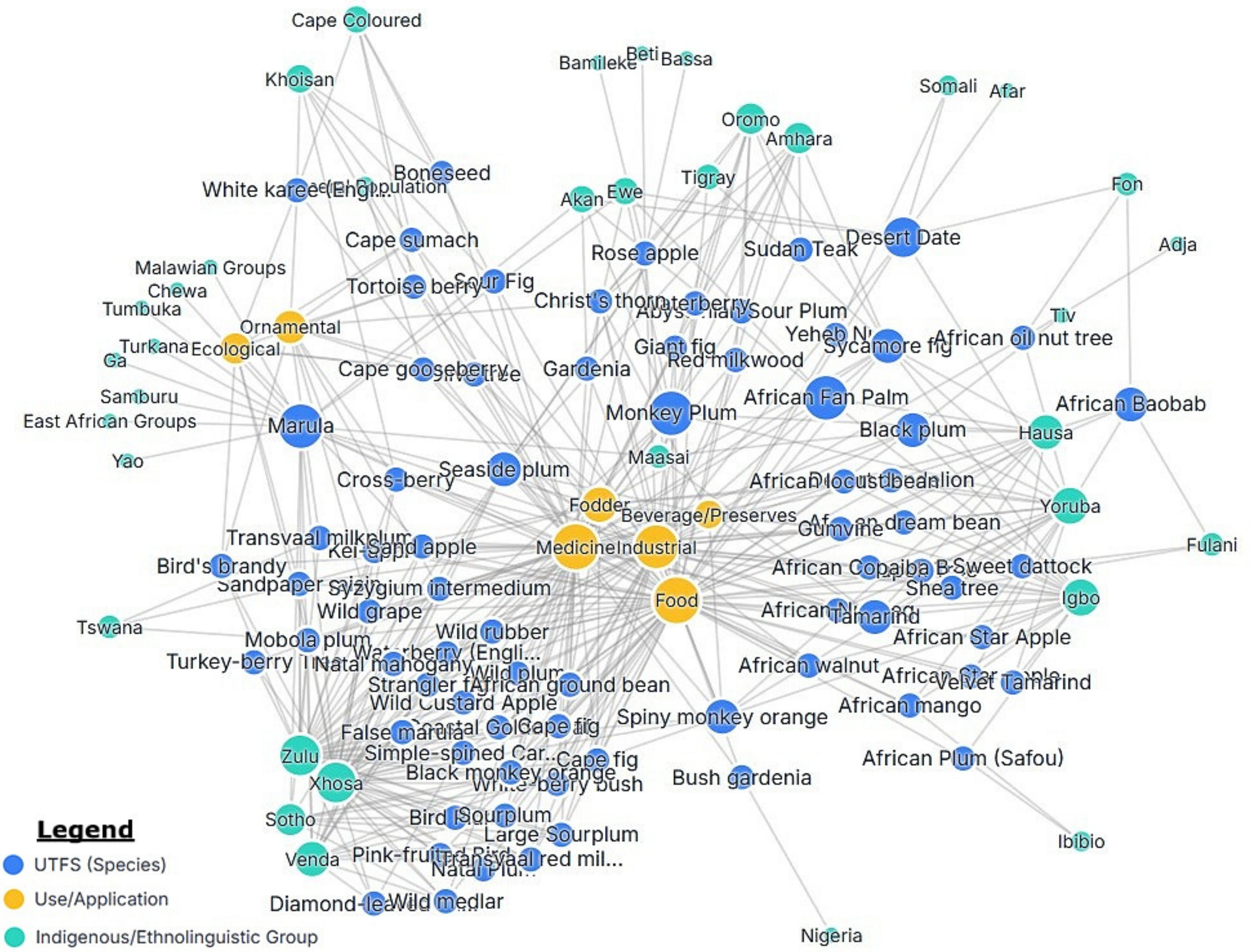


Figure 4 Tripartite network of indigenous groups and plant uses potentially linked to UTFS in Africa

Table 1 Metric value and interpretation of tripartite network analysis of uses/application of UTFS across indigenous groups in Africa

Metric category	Metric	Value	Interpretation
Node counts	unique species (a)	75	the total number of unique UTFS reviewed
	unique indigenous groups (b)	36	the diversity of ethnolinguistic groups is mentioned
	unique canonical uses (c)	13	the number of distinct functional categories (e.g., food/nutrition)
Network metrics	total tripartite edges (a-b-c)	666	the total number of documented relationships between a specific species, a group, and a use
	average uses per species	2.89	the total number of functional use categories (217) is associated with the number of unique species (75), highlighting their multipurpose nature

birrea is intrinsically linked to the rich Traditional Ecological Knowledge (TEK) held by Indigenous peoples. This structured interdependence necessitates integrated policy frameworks that simultaneously prioritize the evidence-based conservation of these essential species and the formal recognition of associated biocultural economic systems.

Overview of the Research Landscape and Indigenomics Alignment

The meta-analysis provides an insight into the current state of research concerning UTFS in Africa and critically examines their vast potential through an Indigenomics lens. The findings from the literature review and the subsequent Indigenomics potential assessment revealed a research landscape that is both promising in its validation of traditional uses and flawed by significant geographic and thematic imbalances. The high ratings demonstrated by species such as *Andansonia digitata*, *Sclerocarya birrea*, *Dacryodes edulis*, and *Vitellaria paradoxa*) (Omotayo and Aremu, 2020; Shai et al., 2020; Ampitan et al., 2022), are a direct consequence of the exceptional multifunctionality which seamlessly integrate value across the four essential Indigenomics indicators (Supplementary material).

Geographic and Thematic Disparities in UTFS Research

The geographical clustering of research is pronounced and constitutes a critical limitation to realizing Africa's full agrobiodiversity potential. West Africa, particularly Nigeria, has been a significant hub, generating valuable, in-depth knowledge on regionally important species like *Irvingia gabonensis* and *Vitellaria paradoxa* (Omonhinmin et al., 2021). Similarly, South Africa has demonstrated a high volume of ethnobotanical studies, with documentation covering a relatively large number of species (Shai et al., 2020; Nkosi et al., 2022). However, research focusing directly on the economic potential, value chain development, and market prospects (Patra et al., 2018; Nyoni et al., 2024), which is at the core of Indigenomics, was notably scarce. This concentration, while beneficial for regional development in these areas, has left vast stretches of the continent, particularly Central and North Africa, as relative *terra incognita* in UTFS research. This inequality not only limits the understanding of Africa's full spectrum of agro-biodiversity but also risks the irreversible loss of both genetic resources (Gollin, 2020) and the unique Indigenous Knowledge (IK) systems inextricably linked to the species in these under-researched regions (Skroblin et al., 2021; Masao et al., 2023).

While the extensive biochemical-centric focus is instrumental in providing scientific validation for the nutritional content, such as the zinc, iron, and vitamin A content in species from Ghana (Achaglinkame et al., 2019), and for supporting traditional medicinal uses, such as the anti-plasmodial effects of *Borassus aethiopum* (Abe-Inge et al., 2018), it often occurs in an academic vacuum. These studies, which largely focus on laboratory characterization of extracts from species like *Syzygium cordatum* and *Osyris compressa* (Kucich and Wicht, 2016), frequently operate detached from the pressing socio-economic realities of the indigenous communities that depend on these resources. This thematic imbalance is further highlighted by the scarcity of studies on crucial applied fields, including indigenous economic aspects (Muok, 2019), metabolomics and chemodiversity (Nkosi et al., 2022), value chain development (Jusu and Cuni-Snachez, 2017), and the overarching conservation of Neglected and Underutilized Species (NUS) (Ampitan et al., 2022; Masao et al., 2023).

Multifunctionality as the Nexus of Indigenomics Potential

The consistent "High" Indigenomics Potential rating across the assessed species is a powerful, empirical testament to the concept of multifunctionality (Esquivel-Marín and Alegre, 2024) inherent in traditional African resource management (see supplementary material). The data show that species are not valued for a single trait but rather for their deep, holistic integration into community well-being. The Marula tree (*Sclerocarya birrea*), for instance, provides food (fruit, nuts), industrial products (oil, timber, beverages), and traditional medicine across diverse ethnic groups, from the Zulu and Xhosa in South Africa to the Maasai in East Africa (Ngemakwe et al., 2017; Muok, 2019). This profound interconnectedness confirms the success of the overarching Indigenomics criterion.

Specific documentation illustrates the tripartite relationship between food, health, and industrial application. The analysis of wild edible fruits in Nigeria, including *Strychnos spinosa*, *Detarium microcarpum*, and *Diospyros mespiliformis*, not only evaluated their nutritional composition for human consumption but also explored their potential in animal feed formulation (Jacob et al., 2016), linking nutrition directly to livelihood and ecological stewardship. Similarly, *Ximenia americana* and *Ziziphus spina-christi* were prioritized in Ethiopia not just for palatability and medicinal use, but also based on market value and frequency of occurrence in natural habitats (Aregay et al., 2017), directly integrating the market value with ecological stewardship. These findings emphasise that the species best poised for sustainable development are those that satisfy the complementary value principle, where economic relevance does not override, but is rather an extension of their foundational ecological and biocultural utility (Cámara-Leret and Dennehy, 2019).

Recommendations and Future Research Directions

To unlock the full, equitable potential of UTFS in Africa, a radical shift in the research paradigm is required. An Indigenomics approach necessitates moving beyond mere descriptive ethnobotanical studies toward a transdisciplinary and action-oriented methodology. Future research must actively target under-researched regions, utilizing geo-referencing and community-led inventories to prevent the erosion of unique genetic and cultural assets, as advocated by Hilbert et al. (2022) and reinforced by research focusing on how neglected and underutilized plants contribute to climate change adaptation and conservation in Tanzania's semi-arid regions (Masao et al., 2023). A major bottleneck to economic realization is the scarcity of studies on value chain development, market access, and processing technologies (Patra et al., 2018). Research must prioritize applied studies on product development, such as the postharvest treatments analyzed for Malay apple (*Syzygium malaccense*) (Njilar et al., 2023) and the advocacy for food product development using species like Kei-apple (*Dovyalis caffra*) (Ngemakwe et al., 2017).

The scarcity of research on the indigenous economic potential (Muok, 2019) must be addressed through co-creation methodologies. Future projects should embrace the findings of the tripartite network analysis, which highlights the centrality of IK in the UTFS. This involves actively engaging indigenous communities in developing sustainable and equitable value chains (Donhouedé et al., 2022; Assogbadjo et al., 2023), recognizing their role as stewards of indigenous ecological knowledge (Das et al., 2022) and agrobiodiversity conservation (Kayode et al., 2020; Sileshi et al., 2023; Gauthier et al., 2025), and ensuring that commercialization respects and reinforces cultural resilience (Aregay et al., 2017; Matlala et al., 2024). The UTFS of Africa represented in this research are more than just biological resources; they are deeply woven into the social, cultural, and economic fabric of indigenous life. Embracing an Indigenomics framework is essential for policy formulation that transforms these neglected resources into powerful, locally-controlled engines for sustainable and equitable development across Africa.

Conclusions

This scoping review establishes the strategic importance of Africa's UTFS in advancing scholarly inquiry on agrobiodiversity and biocultural economies through Indigenomics framework. Prominent species such as *Tamarindus indica*, *Sclerocarya birrea*, *Parinari excelsa*, *Adansonia digitata*, *Allanblackia* spp, *Vitellaria paradoxa*, *Ziphiphus mauritiana*, and *Irvingia gabonensis* linked to multiple ethnic groups signified potential as foundational economic asset. Although tripartite analysis reveals their multidimensional value across ecological integration, nutrition, health, cultural significance, and commerce, existing research remains geographically concentrated in West Africa and thematically narrow, constraining broader application and opportunities for strengthening local economies and resilience. Indigenomics offers a transdisciplinary framework for integrating Indigenous knowledge with advanced scientific methodologies, particularly

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in agriculture, biodiversity conservation, and trade, to address these gaps. Realizing this potential requires future research that prioritizes modeling and validating the operational feasibility of Indigenomics framework, thereby generating actionable evidence-based report that will inform regional representation and sustainable development policy.

Conflicts of Interest

The authors have no competing interests to declare.

Ethical Statement

This article does not include any studies that would require an ethical statement.

Funding

Not applicable.

Acknowledgements

Not applicable.

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