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Potentiality of Neglected and Underutilized Species (NUS) as a future resilient food: A systematic review

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ABSTRACT

Food security is still a significant challenge in developing and emerging countries, and sustainable foods are currently in demand. Considering the significance of future smart and sustainable foods, neglected and underutilized species are the best choice for a rapid global population, particularly in developing and poor countries. Considering the urgency of food security and value addition to the Sustainable Development Goal of Zero Hunger, the systematic review aims to give an overview of the potentialities of neglected and underutilized species following a PRISMA framework. The articles were collected from Scopus, PubMed, Web of Science, and google scholar databases. For the collection of published articles, the keywords "Neglected species," " Underutilized species," "Neglected and Underutilized plants," "SDG and Underutilized plants," and "NUS and Food security" were entered. 134 articles were selected that were published from 2000 to 2022 following the PRISMA method. The species diversity and their respective geographical location were shortlisted, revealing that most of the articles were published between 2019 and 2022, indicating the increased demand for the potentialities of NUS. The shortlisted articles were approved for systematic review in the context of nutrition and safe food security, medicinal value and safe food accessibility, sustainable production and resilience, small-scale producers' income generation, and genetic diversity maintenance. The aspects have unveiled that NUS is a valuable asset in achieving the target of zero hunger. The species diversity revealed that most documented NUS are studied or researched from Asia's developing and poor countries, followed by Africa. NUS are exposed to hindrances as they are poorly highlighted in the mainstream ground of Sustainable Development Goals. Hence, key strategies must be undertaken to develop their utilization and integration into current agricultural practice. Thus, NUS can widen the prospect of becoming a future resilient food.

1. Introduction

The diversity of plants has kept the food chain intact by maintaining biodiversity, recycling nutrients, and giving earthly organisms the essentials they need to survive. Whether directly or indirectly, plant species are the primary source of food security, subsistence, improved livelihoods, and economic growth for people worldwide. Thus, plant species start the process of ensuring global food security. Although the sustainable use of common species is the goal of food security, the situation is somewhat problematic. Only a small portion of plant species are used extensively as food on a worldwide scale, whereas the majority of all species are yet unknown, uncared for, and underutilized. These species include small-scale, indigenous, orphan, and wild edible species. Out of 30,000 plant species, an estimated 7000 are edible and primarily used for human food security [1]. Over the decades, the number has seen significant changes as modern breeding program contributed to widespread high yielding varieties and cultivars development [2]. According to the recent database, 27,000 plant species are referenced as edible to fulfill the target of feeding people with enriched diets [3]. People are suffering from malnutrition. Protein-energy malnutrition, vitamin A deficiency, and iron deficiency are the most common worldwide, with estimates of 500, 200, and 1600 million people, respectively, out of a total population of 70,000 million [4]. Poor life cycles, insufficient supply, undiscovered nutritional values, lack of recognition, and

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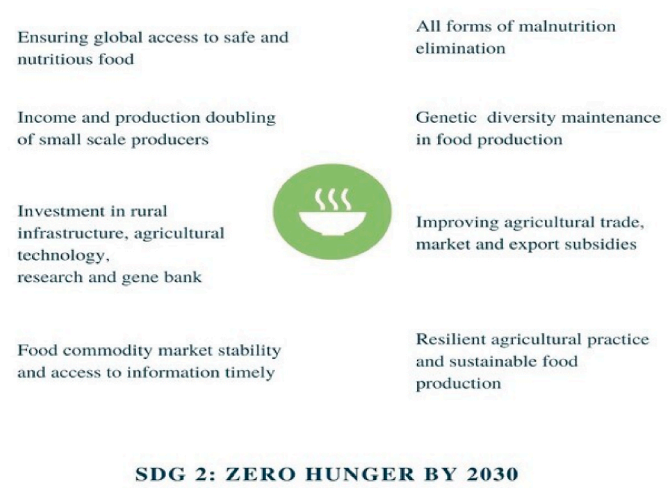

Fig. 1. Targets of sustainable development goal of zero hunger.

consumers' lack of awareness are the leading causes of their carelessness. Most species are viewed as famine food, which raises concerns about reputational insecurity. Due to the severe gene pool extinction brought on by agricultural modernity, most species are on the edge of extinction and therefore considered neglected. Since most species are still unknown despite being able to provide secure sustenance, maintaining genetic variety has proven challenging. Among the 90% undiscovered plant species, 77% of plant species are at the risk of extinction, and the severity is extreme for Africa continent where the extinction could be 45% by 2085, and 97% would observe reduced number of plant species diversity [5].

Meanwhile, the FAO research states that approximately 8.9% of the world's population experiences hunger, with 10 million people experiencing it annually and 60 million in five years [6]. Due to fast population expansion, natural deterioration, and urbanization, developing countries struggle to secure food security. Food crises occurred in 1972-73 and 2007–08, when worldwide rice scarcity caused malnutrition, starvation, and agricultural failure [7]. Since that critical juncture, global access to safe and secure food has been a requirement. The NUS's integration into current agricultural output needs examination in response to vulnerable circumstances such as starvation and food crises. The NUS comprise fruit bearing plants, timber plants, medicinal, ornamental, cereal, forage plants, and thereby contribute to human societies and ecosystem. The cost effectiveness is driven by the cultivation of NUS due to low demand of input, and resilient agriculture practices [8]. Even if most small-scale producers struggle with poor output and income, these economically significant species can be utilized to benefit underprivileged farmers or producers. There are 17 sustainable development projects that need to be completed by 2030, with the second aim being the globe having "zero hunger," and the major challenge still being food security [9].

Fig. 1 shows the main SDG 2 targets of "Zero Hunger" which strives to promote human nutrition, ensure food security, and end hunger. Effective use of neglected nutrient-dense species, domesticated, wild, regional, semi-domesticated, traditional, and niche, could remedy the problems [10]. Therefore, identifying prospective natural resources that could include plant resources has become vital. The NUS are recognized as promising solution to address nutrition and hunger problem in the climate change scenario [11]. Such NU plant resources have a variety of uses, including those for food, fuel, medicine, energy, and economic gain. As a result, eliminating hunger or starvation can help to accomplish sustainable development goals. The low-input, largely marginal-land-use plants that are underutilized and ignored have great nutritional and therapeutic values. Because of this, it is accessible to all types of people. These characteristics support maintaining good health. Considering how many minerals, vitamins, and carotenoids neglected and underused species (NUS) consume, their contribution to improving the micronutrient content of the human diet could be significant. The best alternate strategy is to choose NUS to reduce hunger for people experiencing poverty in developing countries when major crops fail to generate a large amount of production, thereby causing economic gains by storing carbon and producing valuable timber. Because of their positive environmental effects, underutilized species need consideration in biodiversity conservation efforts.

The spread of NUS has been observed worldwide. However, the truth is that underutilized species are not adequately recognized outside of a specific geographic region. Regarding the Sustainable Development Goal of Zero Hunger, the nutritional and medicinal aspects, economic value, sustainability, and genetic diversity were rarely discussed in existing literature, and their potential contributions were only briefly touched upon. Most research focuses on unique understudied and overlooked species in a specific geographic area. All known neglected and underutilized species were systematically reviewed to determine their potential benefits to food security, the eradication of malnutrition, sustainable production, small-scale producers' income creation, and the preservation of genetic variety. The analysis additionally screened all documented NUS from published research studies according to the pertinent geographic component. The goal of the paper was to describe the obstacles to using NUS. Finally, the suggested techniques' structural analysis was carried out using available research. These recommendations' implications might offer a valuable angle for eradicating world hunger that can ensure global food security. Therefore, in this study, it is hypothesized that NUS has a wide spectrum of potentiality to address the SDG target of "Zero Hunger", and can be proved as a future resilient food in the face of food security issues. This study has focused on addressing NUS and their potentiality regarding food security from all geographic continents. It also reflects the recommended strategy to enhance the potentiality of NUS for food security in response to the potential constraints. The widespread genetic diversity of NUS has been listed, which would facilitate further research scope regarding sustainable approaches to conservation, and enhanced production to address food security challenges.

2. Methodology

The PRISMA framework was used for the systematic review and related analysis from peer-reviewed journal papers on underutilized and neglected plant species [12].

2.1. Search strategy

The PRISMA framework served as the foundation for starting the systematic review. The first step was to conduct keyword searches on publications in Scopus (Science Direct, Taylor and Francis, Wiley, Springer Nature, etc.), PubMed, Web of Science (Clarivate), and Google Scholar databases. Keywords "Neglected species," " Underutilized species," "neglected and underutilized plants," "SDG and Underutilized plants," and "NUS and food security" were used for article retrieval. The database was interrogated for scientific articles about underappreciated and neglected plant species published between 2000 and 2022. The identification was achieved using English as the basis.

2.2. Quality assessment and article screening

The 737 records from the detected data were imported into Zotero software (version 6.0.9). The duplicate or repeated records (286) were eliminated in the following stage. A total of 451 records were examined. The titles and abstracts of 338 pertinent articles were reviewed to determine their eligibility. The title and abstract were considered irrelevant since they departed from the research topic, which was 113 in number.

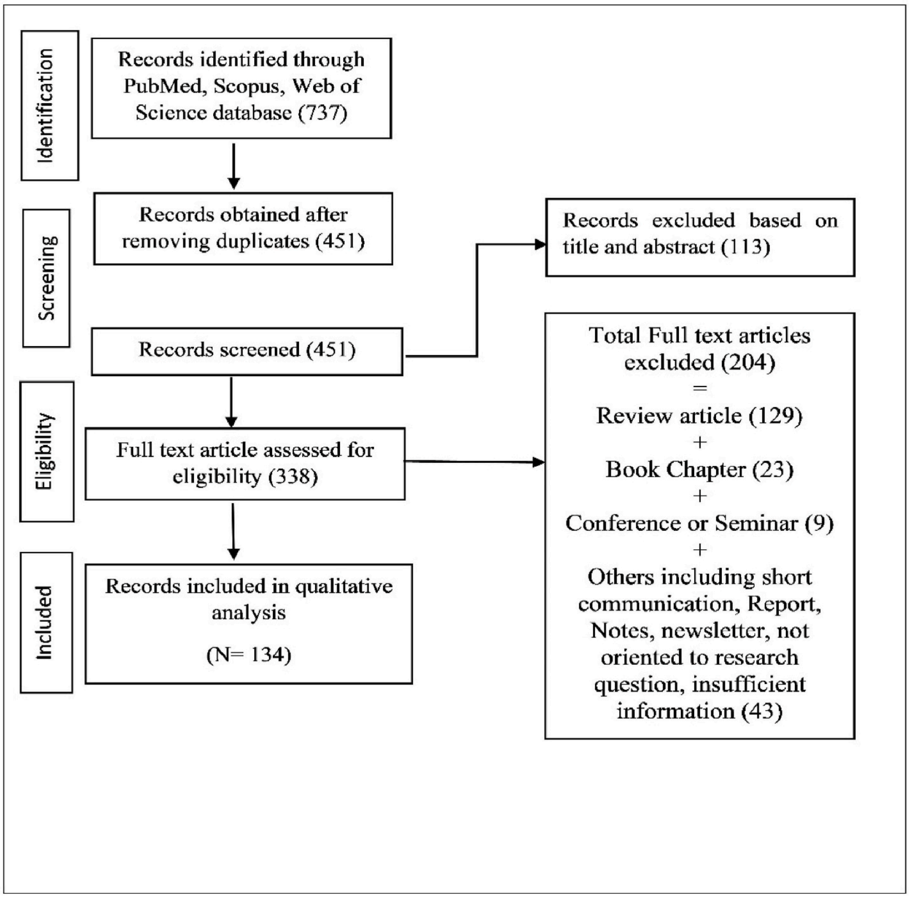

Fig. 2. Methodology of article inclusion following PRISMA framework (preferred reporting items for systemic reviews and meta-analysis).

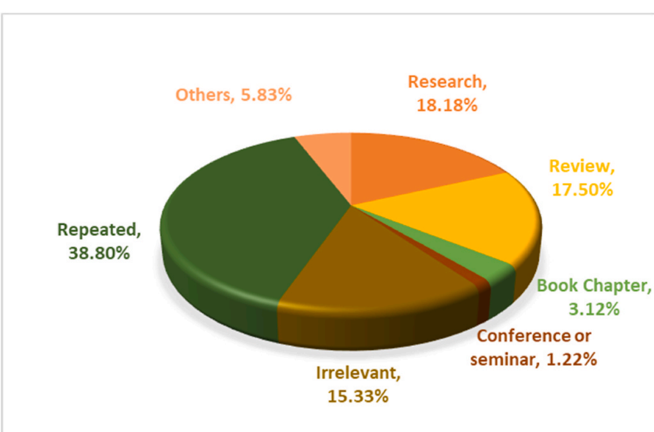

Fig. 3. Number of different types of articles in the context of neglected and underutilized species.

2.3. Exclusion criteria

In the eligibility part, particular articles were discarded based on criteria. The studies of review articles, book chapters, conference or seminar papers, short communication, reports, notes, and newsletters not oriented to the research question and contained insufficient information were excluded. Such articles were of a total of 204 in number.

2.4. Inclusion criteria

The published research (134) that focused on highlighting underutilized and neglected plant species and emphasizing their potential prospects served as the inclusion criteria for the publications (Fig. 2).

2.5. Articles analysis

The study objectives for reviewing the chosen papers included the studies' publication year, study site, and relevant neglected and underutilized species. SPSS 26 and MS Excel were utilized for the

Table 1
Respective Publishing Years of Research with Frequencies and Per cents.

Research Article Publication Year	Frequencies	Percent
2000	1	0.75
2004	1	0.75
2008	3	2.24
2010	3	2.24
2011	2	1.49
2012	9	6.72
2013	7	5.22
2014	6	4.48
2015	6	4.48
2016	5	3.73
2017	6	4.48
2018	12	8.96
2019	16	11.94
2020	19	14.18
2021	22	16.42
2022	16	11.94
Total	134	100

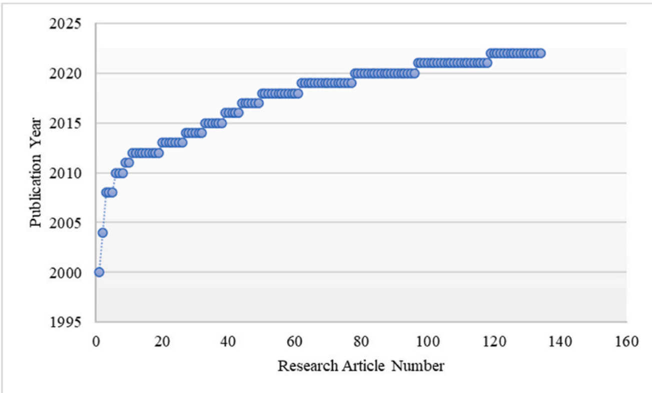

Fig. 4. Distribution of research articles over two decades.

descriptive analysis and graphical representation. The outcome of published articles was expressed using frequencies and percentages. In contrast, pie charts and plots provided visual representations of the distribution of the eligible research articles from 2000 to 2022 and published articles. Fig. 2 depicts the overall procedure.

2.6. Article types and publishing years

Fig. 3 represents the article's type with frequencies and percentages collected from Scopus and Web of Science databases. Among 737 articles, 38.8 percent were repeated, followed by 18.2 percent were research articles (Fig. 3). The proportion of reviews, irrelevant book chapters, and conferences or seminars was 17.5 percent, 15.3 percent, 3.1 percent, and 1.2 percent, respectively. The irrelevant articles mostly contained inconsistent abstracts and titles, insufficient information, and did not address research objectives. The others comprised short notes, short communication, encyclopedias, supplement articles, etc., 5.8 percent of the collected studies.

Table 1 represents the publication of research articles on NUS. Among 134 research articles, the publications of neglected and underutilized species were steady from 2000 (0.75%) to 2011 (1.49%). The research number was not satisfactory till 2017 (4.48%).

A gradual increase in research articles was observed from 2018 (8.96%) to 2021 (16.42%) (Fig. 4). The highest number of research articles in the context of NUS was published in 2021, which indicates the necessity and urgency of NUS for combating food and nutritional security under the consequences of climate change. There is a growing interest growing interest on the research for NUS and their potentiality to address food security issues in response to climate vulnerability [2,13], and climate resistance and richness of nutrition including minerals, vitamins and bioactive compounds [14].

3. Potentialities determination

3.1. Species richness of neglected and underutilized plant species

Species that are neglected and underutilized can contribute to the Sustainable Development Goal of "Zero Hunger" in a positive way. Utilizing NUS can nourish human health due to the known species diversification, which is important for commercial and therapeutic purposes. Even though practically every continent has access to NUS, these underappreciated species are barely counted and recognized based on nutritional security. By supplying protein in a more accessible form, underutilized species can help with the current food and socioeconomic concerns [15]. Despite their antioxidant, medicinal, and nutritional benefits, gooseberry and cornelian cherries are underutilized wild edibles in Herzegovina and Bosnia [16]. Ricebean (*Vigna umbellata*), gradually recognized as an underutilized crop with the nutrition value and food security capability in India and Nepal, was exposed to declined production due to disruption in global and local value chains and technological disruption disadvantages and genetic factors [17]. Marama bean, or *Tylosema esculentum*, is a plant native to Southern Africa that is still untapped for its protein, lipids, dietary fiber, ash, vitamin E, minerals (Fe, Zn), and lignans content (secoisolariciresinol, pinoresinol, and lariciresinol) [18].

Concerning the nutritional value of underutilized species, Bolivia and Peru's mashua, arracacha, and yacon was found to contain minerals, lipids, fibers, starch, fructooligosaccharides, or functional components like antioxidants and glucosinolates, sugars, organic acids, anthocyanins, phenols, glucosinolates and carotenoids, protein, amino acids, etc. [19]. *Aegle marmelos* L. (Bael) is an underutilized species in Srilanka prevalent with organoleptic properties; the most preferred high-yielding fruit species were Polonnaruwa-Supun and Rambukkana [20]. Despite having highly developed organoleptic qualities, the perennially underused fruit species known as the cherimoya (Annona cherimola Mill.), native to Ecuador, Bolivia, and Peru, has a lower economic usage [21]. The historical importance of African leafy vegetables in food security made them highly preferred and demanded in rural households [22]. Hydrothermal processing of *Boerhaavia diffusa* and Portulaca oleracea, two leafy vegetables, revealed that they substantially contained phenolics and antioxidant properties [23]. It indicates that natural weeds and indigenous vegetables derive from the cropland ecosystem are a potential source of the human diet and animal feed with cost-effectiveness. In Brazil, urban gardens were occupied by underutilized species and seeds, leaves, and fruits of *Coleus amboinicus Lour.*, *Eryngium foetidum* L., *Talinum fruticosum (L.) Juss.* and *Pereskia aculeata Mill*, discovered to be primarily consumed, thereby indicating the ability of NUS to support food preservation, cultivation and effecient suppliment food to local people [24]. Large-scale production facilities of Chaya (*Cnidoscolus aconitifolius*) can contribute to food security as it has nutritional properties, easier cultivation, and desired traits [25]. Besides the healthier diet diversification, sorghum could break colonial stereotypes of aspirational foods that could be integrated into the food system as a significant cultural and alternative staple food in South Africa.

Syzygium guineense, Rubus apetalus, Solanum nigrum, Portulaca oleracea, and Amaranthus graecizans may be sources of protein, minerals (Fe, Zn, and Ca), vitamin A, and C, and lower levels of anti-nutrients [26]. These might help Ethiopians improve their diets and fill in food shortage gaps. *O. macrocentra Engelm., O. engelmannii Salm-Dyck ex Engelmann., and O. phaeacantha Engelm.*, three wild, neglected opuntia species from Mexico, were enhanced with nourishing and antioxidant qualities, protein, functional components, and nutraceuticals with biological benefits [27]. *Luffa acutangular and L. aegyptiaca,* are underused vegetable crops in Sri Lanka with unique morphological and sensory characteristics [28]. The Winged bean (*Psophocarpus tetragonolobus (L.) DC.*) is a less well-known nutritious legume with high levels of protein and minerals, and its principal characteristic is its ability to withstand stress [29]. Leucine, phenyl-alanine, lysine, and antioxidants are abundant in Ethiopian Chaya (*Cnidoscolus chayamansa*), which is underutilized yet contains significant amounts of amino acids and antioxidants in both its leaves and stem [30]. The presence of amino acids and phenolic acid indicates that this can provide health benefits to rural people in developing countries. The underutilized whole or dehulled Bambara groundnut (*Vigna subterranea*) seeds contained phenolic acids, flavonoids, lignins, and mono-terpenoids (iridoids), phytochemicals that give evidence of beneficial properties of such species in food and industrial application [31]. The underutilized crop Zombi pea (*Vigna vexillata (L.) A. Rich*) is available as a form of tuber and seed in Asia and Africa, respectively [32], and they are an edible food source. *Artocarpus altilis, Carpolobia lutea, Chrysopyllum albidum, Anthonotha macrophylla, Vitalleria paradoxa, Tetracarpidum conophorum, Piper guinensis and Tetrapleura tetraptera* fruit species identified in Nigeria contained adequate body functioning food nutrients, and antinutrients were below lethal dose [15]. The evidence supports that NUS species prevailing from all regions can provide nutritional properties.

Lasia spinosa (L.) is a neglected indigenous vegetable in Sri Lanka comprising nutritional properties where rhizome contains significant ascorbic acid content [33]. Meanwhile, the African Yam Bean (AYB), Sphenostylis *stenocarpa*, is the understudied leguminous legume prevalent in the African region to which tuber and seeds help in people's diet and nutrition security [34]. In the African areas where people are fighting hunger, NUS is the saviour of the local people. Another study carried out in Ghana found that the Yam Bean (Pachyrhizus erosus), a neglected legume, has chemical and functional properties. The flour made from this legume has a significant amount of moisture, crude fat, crude fiber, carbohydrate, low fat, and energy content, indicating that it could be a useful substitute for other flours [35]. The underappreciated African yam bean (*Sphenostylis stenocarpa*), which is grown widely in Nigeria, has excellent nutritional content (protein, amino acids, minerals, etc.) [36]. The native, unappreciated Jicama or yam bean (*P. erosus*) of Central America and Mexico has edible tuberous roots, seeds, and bean flour [37]. Yam species (*Dioscorea* spp.*)* from Benin of, Africa, is well appreciated nutritious food [38]. Oca, Mashua, Olluco, Arracacha, Ajipa, Yacon, Achira, Maca, and Mauka are underutilized Andean root and tuber crops with the potential to generate money for local farmers and provide nutritional advantages and food security [39]. Therefore, tuber crops can be a potential NUS in the global context.

Because of their nutritional content, the underutilized species of legumes, gourds, and oil seeds are also potential energy sources. The underutilized legume from India, *Cassia hirsuta* L., has mineral content like potassium and magnesium, suggesting these legumes offer an alternative to human nutrition. It also had crude protein, fat, fiber, ash, and carbs [40]. It implies that these wild species have antioxidants and nutritional qualities comparable to those of cultivated species, which has implications for the food security of the local population. *Cucumis* L. species used to produce numerous foods, including fruits, vegetables, and pickles, are [41]. The fruit known as the cherimoya (*Annona cherimola Mill.*) did not receive official recognition in Latin American developing nations such as Peru, Bolivia, and Ecuador [42]. Fonio (*Digitaria exilis*), taro (root and tuber), oil seed, and pulse Bambara groundnut (*Vigna subterranea* L.*Verdc.*) species revealed neglected and underutilized, recognized as minor with local importance are highly nutritious [43]. Similarly, *Carapa procera*, *Pentadesma butyracea,* and *Lophira lanceolata* are underutilized oil seed species in west Africa [44]. The untapped potential of stinging nettle (*Urtica simensis Hochst. ex. A. Rich.*) from Ethiopia expressed that this species regarded as famine and poor man food capable of supplying nutrition and securing food requirements [45]. Minor species from Bangladesh, such as the River ebony (*Diospyros peregrina*), Monkey Jack (*Artocarpus lakoocha*), Red Pear (*Protium serratum*), Cowa (*Garcinia cowa*), and Flacourtia (*Flacourtia jangomas*) were effective in total soluble solids, vitamins, and minerals [46]. Their commercial cultivation can alleviate the need for nutrition by preventing diseases caused by nutritional deficiency. African vegetable species *Cucurbita* sp. represent an enriched micronutrient source, response to hidden hunger through nutrition and food security, though leafy vegetables undergo post-harvest loss and turn to waste [47]. *S. occidentalis and T. occidentals* from Nigeria investigated enriched with protein content, moisture, energy calorie, carbohydrate, and low fat; thereby can help in achieving Millennium Development Goal (MDGs) by alleviating malnutrition and hunger [48]. The Argentinean plant "red chilto" (*Solanum betaceum Cav*) was investigated to have hypo-glycemic, antioxidant, and hypolipemic effects where the powder contained vitamin C, anthocyanins, phenolic acids (rosmarinic and caffeoylquinic acid), carotenoids, condensed tannins, fibre, and potassium [49].

Significant amounts of nutrients, including vitamins A, B, and C, minerals (Ca, Zn, Fe, Mg), moisture content, phytates, and oxalates were present in The Tanzanian underutilized species of Bitter Lettuce (*Launea cornuta*), Wild Cowpea (*Vigna vexillata*), Bitter Cucumber (*Momordica foetida*), and Malabar Spinach (*Basella alba*) [50]. These support the contribution towards mitigating hidden hunger and ensuring Sustainable Development Goals. Culinary banana (*Musa* sp.) is the least expensive vegetable source in the diet of local Indian people [51]; due to its diversification, its chemical composition can play in food security and induce high-valued flour. Consequently, the NUS could manifest as famine foods, and people from every corner suffering from hunger can lead a better life by using neglected species.

3.2. Helath promoting profile of NUS and contribution to safe food accessibility

NUS received approval for access to safe food due to its therapeutic qualities. *Chukrasia tabularis A.Juss.* is a canopy tree with underutilized residuals (leaves) that may contain phenolic and bioactive components that help treat metabolic problems [52]. Ethiopia is home to the underutilized species *Maerua subcordata (Gilg) DeWolf* (Capparidaceae), characterized as being effective enough as a food source, famine food (tuber), and other ethnomedicinal qualities [53]. wild yams (*Dioscorea* spp.) from India contained phenol (2.19–9.62 mg/g dry weight), *D. pentaphylla, D. pubera, and D. bulbifera* contained normal amounts of flavonoid (0.62–0.85 mg/g dry weight), antioxidant capacity (1.63–5.59 percent), and scavenging activity [54]. *Abelmoschus ficulneus* had significant antioxidant ferric reducing (FRAP) activity and radical scavenging activity (10.65 $\pm$ 0.06 percent), while wild *Abelmoschus* had high levels of protein, fat, carbohydrate, fiber, and energy, indicating that this wild taxon is advantageous for human health and commercial cultivation [55]. Incorporating K, Fe, and Zn into underutilized plants from the Solanaceae family, such *Solanum aethiopicum*, *S. macrocarpon*, and *S. torvum*, which are popular in Ghana, can be an effective method for combating non-communicable diseases and hidden hunger [56]. Quelite species *Cnidoscolus aconitifolius* (Chaya), *Anoda cristata* (Alache), *Crotalaria pumila* (Chepil) found to have the anti-helicobacter pylori potential and associated diseases that can add value in maintaining good health in Mexico [57]. *Anchomanes difformis* from Nigeria had polyphenolic and flavonoid content and antioxidant and radical scavenging activity [58]. *Parkia roxburghii* from India, a poorly recognized leguminous tree, was found to have antioxidant potential and free radical scavenging activity that hinted a powerful urge to maintain genetic diversity important in disease prevention [59]. Utilizing the full potential of underused species requires research into domestication, ecotype selection, the creation of beneficial agricultural practises, breeding, and the manufacture of medicinal plants, whereas bioactive capacity and high productivity are essential to understand as anti-inflammatory activities, medicinal properties, catechins, productivity, and favorable environment contained within *E. crassifolium* (Hairy Stork's-Bill) in Southeast Mediterranean [60]. In Africa, sweet-sour fruits *Vangueria madagascariensis* (VM) were investigated to contain biomedicinal and antioxidant properties, which actively manage bacterial infections and diabetes [61]. Orientin, quercetin, luteolin, chloro-genic acid, and rutin were found to be functional biochemical properties of *Oxalis cordata* and *Xylopia aromatica*, two underutilized species from Brazil, along with inhibitory activity on pancreatic lipase (*C. cordata*) and against di-peptidyl-peptidase IV (*X. aromatica*) [62]. The nutritional, medicinal, and antioxidant properties of *C. grandis*, *D. mespiliformis*, *C. rotundifolius*, *E. foeminea*, and *G. villosa* in southwest Saudi Arabia examined to have vitamins, minerals, antioxidants, and phenolic compounds at varying ranges, with C. grandis having both DPPH-scavenging and antioxodant properties [63]. Allium genus *plants A. ampeloprasum* and *A. porrum* are untapped vegetables containing pharmacologically active substances, such as anti-candida chemicals, that reflect its emphasis on drug discovery [64]. The Peruvian Sacha Inchi (*Plukenetia volubilis* L.), a neglected species, showed promise for nutrition and health advantages in terms of cholesterol control, general health improvement, traditional medicine, and nutritional value, among other things [65]. Two unnoticed species from India, *M. bracteata* and *M. imbricata* contained phytopharmaceuticals and neutraceuticals values of antioxidant, anti-inflammatory properties, and M. bracteate was effective against Parkinson's disease [66]. Underutilized seeds of Avocado (*Persea americana* Miller) had high radical scavenging, antimicrobial and larvicidal activity against *Candida albicans* and *Aedes aegypti*, respectively, indicating its potential to synthesize drug molecules and Silver nanoparticles (Ag NPs) [67]. Unsaturated fatty acids, terpene alcohol, non-polar chemicals, and antifungal and antibacterial activity in *Camellia sinensis* flowers suggest that these neglected flowers may have benefits for the cosmetic, nutraceutical, and pharmaceutical industries [68]. It indicates that NUS can contribute to industrial development besides its access to safe food. There are also some promising species. Such as *Urtica dioica* L. (stinging nettle) from Italy was observed as promising species in the herbalist and medicinal sector as it provided satisfactory bioactive compounds and yield [69]. Italian medlar (*Mespilus germanica* L.) actively included mono-terpenes (γ -terpinene), organic acids (malic and citric acid), as well as a variety of poly-phenolic compounds with varying antioxidant and anti-inflammatory properties [70]. *P. bipinnatifidus* and *P. pseudoginseng* from India contain antioxidant potential against a few free radicals with an enormous value of chlorogenic acid, gallic acid, vanillic acid, glutamic acid, arginine and poly-unsaturates, minerals, trace elements, tuber contained an adequate amount of dietary fiber, protein, and carbohydrates [71]. The prominent presence of Dactylorhin and o-coumaric in Indian underutilized medicinal species *Dactylorhiza hatagirea* (Salep) revealed that these species have value in the formulation of phytomedicines and foodstuffs, and its antioxidant properties contribute to reducing oxidative stress and glycemic activity [72]. The evidences revealed that NUS are capable of ensuring safe food access which can accomplish the goal of food security. The health-promoting profile of NUS has the potential to improve dietary diversity while fighting malnutrition and hunger. In the aspect of nutrient-dense profile, NUS has made significant remarks in providing macronutrients of carbohydrates, fats, and proteins, and micronutrients of vitamins, minerals, and bioactive compounds. NUS contributed to food production diversification by adding diversified species to human diets that empower supplements of nutrients such as proteins, fiber, and amino acids. According to research, Ghanaian turkey berries have medicinal and nutritional benefits and can cure anemia [73]. Oil extraction of *Persea schiedeana Nees* present in Mexico was studied to have significant antioxidant and fatty acid contents [74]. Red chile is a top dietary supplement source with phytochemical quality, according to the elements present. Vitamin C requirements can be fulfilled by 400 g and 200g of *S. biafrae* or *C. volubile* per day, where Ca contents were higher in *S. biafrae* [75]. Mexico's underutilized *Amaranthus hybridus*, comprises phytochemicals and minerals, such as vitamin C, flavonoids, phenolics, antioxidants, and other bioactive components [76]. *Viburnum Mullaha's* nutritional value and biochemical analysis found that it is abundant with carbohydrates, protein, and fat and that 100g of Indian cranberry fruit berries could offer 284.4 kcal [77]. Brazil's underappreciated Camu-Camu (*Myrciaria dubia*) fruit gained notoriety for having incredible vitamin C content, with 300 mg of ascorbic acid per 100 g EP [78]. Famine food, such as monkey orange (Strychnos spp.) found in Zimbabwe, Southern Africa, has the ability to improve nutrition security, health benefits, disease resistance, and provide an alternative to the monotonous staple food of the rural people, women, and children [79]. The chemometric analysis revealed that genotypes of winged bean (*Psophocarpus tetragonolobus (L) DC*) contained phenol, flavonoid, antioxidant properties, and other secondary metabolites [80]. Traditional green leafy vegetables that aren't grown have underappreciated sources of minerals, vitamin C, and carotenoids (β–carotene, lutein) [81].

3.3. Contribution of NUS to sustainable production and resilient agricultural practices

In accomplishing sustainable production, NUS comprises significant features such as climatic resilience, utilization of limited resources appropriately, and conservation of natural resources. In terms of climatic resilience, a semi-arid environment could be in favor by utilizing underutilized drought-tolerant leguminous species, namely Bambara groundnut (*Vigna subterranea* L. *Verdc*.) [82]. An analysis of the Bambara groundnut (*Vigna subterranea* L. *Verdc*) revealed their contribution to China's agriculture due to their high yield, modest price, and widespread cultivation, decreasing vegetable protein importation and contributing to food security, nitrogen fixation, land rehabilitation [83]. Bambara groundnut (*Vigna subterranea (L.) Verdc*.), an underutilized species from South Africa, holds the potential survival ability in marginal conditions, semi-arid and arid conditions, and contribute to food and nutritional security [84]. Underutilized legumes hyacinth bean (*Lablab purpureus (L.) Sweet*), winged bean (*Psophocarpus tetragonolobus* L.), grass pea *(Lathyrus sativus* L.), and Bambara groundnut (*Vigna subterranea (L.) Verdc*.). are enormous protein source and adapted to the stressed condition [85]. Another study revealed that the international demand and nutritional demand led Quinoa (*Chenopodium quinoa* Willd.) in Peru to become a superfood from little-known plants [86]. Meanwhile, *V. radiata, V. unguiculata, V. vexillata* (tuber cowpea) belong to the underutilized genus Vigna where nitrogen fixation and carbon-nitrogen ratio are associated [87]. In Spain, the two neglected leguminous species known as grass pea and chickling pea have a reputation for being able to withstand the country's most extreme weather conditions (drought, bad soil) and its usance as both human and animal food [88]. The abaca-based agroecosystem facilitated more or less cation exchange capacity values in the Philippines [89]. Unused fruit peel leftovers such as mono-terpene hydrocarbons and oxygenated mono-terpenes, both essential oils, have been investigated for their potential to function as benign phytotoxins and bio-herbicides [90]. The co-pyrolysis of underused biomass, such as Sago waste and Napier grass with rice husk, is an efficient method for creating valuable chemicals and biofuels using high-graded bio-oils [91]. Field cress (*Lepidium campestre* L.) is a sustainable oilseed plant that is underutilized that possesses characteristics of reducing below-ground environmental pollution and decreasing fertilizer dependency, thereby maintaining soil quality and response to climate change [92]. Some chayote [*Sechium edule (Jacq.) Swartz*.] landraces of India are adapted to harsh environmental conditions, thereby utilizing marginal land area [93]. *Solanum aethiopicum Shum*, a leafy vegetable, substantially contains the feature of drought resistance [94]. The *Indigofera glandulosa Wendl.* (Barbada) species is widely cultivated in India due to its versatility in low-input agriculture and high medicinal and nutritional value in terms of carbohydrates, proteins, vitamins, vital amino acids, and nitrogen fixation [95]. Indian or Malabar spinach (*Basella alba and Basella rubra*) possess growing features in deteriorated soil conditions and suitability to warmer climates by actively delivering nutrients (Ca, Fe, Mg, P, K, Zn, Cu, Mn, Na, Se), flavones, and amino acids [96]. Despite having unexpected characteristics of high neurotoxin -diamino propionic acid, -N-Oxalyl-L-, grass pea (*Lathyrus sativus* L.), an important agronomic and forage crop is resistant to abiotic stresses like flood, drought, and salinity in semi-arid areas of China, Asia, Europe, and Africa, is a neglected species [97]. Moth bean (*V. aconitifolia*) and Bambara groundnut (*V. subterranea*) are underused species from Africa and Asia that are major Vigna taxa that can withstand salinization [98]. The underutilized Mexican Creole wheat landraces kept contributing to the development of climate-resilient and high-yielding varieties of wheat [99]. In Zimbabwe, respondents reported that underutilized weed species provided multiple benefits, including food and nutrition security and economic benefits [100]. In the formulation of new food products for food industries, underutilized Acacia seed species of Australia can be utilized, such as *Acacia cowleana* and *Acacia coriacea* (comprising flavonoids, phenolics, anti-nutrients)*, A. victoriae* (fiber and enormous starch content, radical scavenging activity) with high solubility and water absorption index (A. *coriacea* and *A. victoriae*) and high oil absorption index (*A. cowleana)* [101]. Presence of all these content hints that underutilized seeds are fruitful for their nutrition, physiochemical, antinutritional, and functional properties and in the preparation of fiber

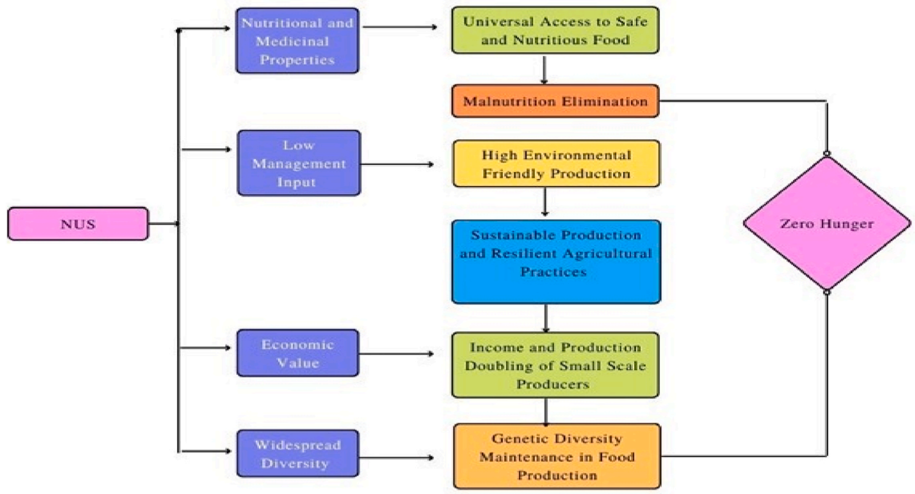

Fig. 5. Contribution of NUS to sustainable development goal of zero hunger target.

products, meat extenders, bakery products, etc. The underutilized *Manglietia glauca, Durio zibethinus*, *Parkia speciosa*, and *Sandoricum koetjape*, *Gmelina arborea* found in West Java are promising exotic and indigenous tree species that support smallholders' livelihood by supplying fruit, timber, spice in low management situation [102]. On the ground of medicine, environment, food, nutrition, and ecology, the spectrum of underutilized fruit species *C. decidua* is mass as it can tolerate saline conditions and its suitability for arid or extreme temperatures [103]. Bottle gourd [*Lagenaria siceraria (Molina) Standly*], underutilized species from Africa found to have satisfactory assimilation in response to water stress which indicates that such landrace could be utilized as alternative food securing crop for rural livelihood as they showed similar performance to hybrids [104]. A study in Sri Lanka revealed that urban consumers were attracted significantly by underutilized crops, and to address income security and food security, these species hold a solid position to be capitalized [105]. In eastern Africa, a study on a nutritious crop, Hook or oyster nut (*Telfairia pedatastudy*) expressed that this oilseed species is efficiently grown in a local agroecosystem where no additional management is required and broaden the pathway of livelihood improvement of smallholders [106]. Therefore, the objectives of sustainable production could be fulfilled by NUS thorugh its greater contribution to climatic resilience.

3.4. Income and production enhancement of small-scale producers

In some localities, small-scale producers are associated with the production of NUS through which functional benefits are obtained comprising service functions where the economic aspect is significant. The production of underutilized species of Pumpkin (*Cucurbita moschata Duchesne*) in Benin, Africa, substantially found to be used for various purposes such as consumption, therapeutic, commercial, and occult purposes [107], which can contribute to industrial development. The revelation of antioxidant activity and polyphenol content of Chinese quince (*Pseudocydonia sinensis schneid.*) originated in Slovakia and Ukraine unveiled that this fruit species is a valuable source of bioactive compounds that is valuable to the food and agriculture industries [108]. Medicinal, feed, fence, and coagulant uses for the neglected West African agroforestry species, *Moringa oleifera Lam.* could increase producers' livelihoods [109]. Henna (*Lawsonia inermis*), coriander (*Coriandrum sativum*), nigella (*Nigella sativa*), and cumin (*Cuminum cyminum*) neglected species in Yemen used extensively in food flavoring and medical treatments and have the potential to diversify sources of income and enable sustainable production [110]. As a result of the exploitation of NU species, the growth of processing industries occurs. In Morocco, the neglected chestnut tree (*C. sativa*) provides subsistence and additional money by selling to the local market [111]. Copoazu (*Theobroma grandiflorum*), Amazon grape (*Pourouma cecropiifolia Mart.*), Manaca (*Euterpe precatoria Mart.*), Seje (*Jessenia bataua Mart.*), Peach tomato (*Solanum sessiliflorum Dunal.*), Peach palm (*Bactris gasipaes Kunth*), Guama (*Inga edulis Mart.*) and Temare (*Pouteria caimito Radlk.*) from Venezuela, supply agroforestry food products including fruit, forage, timber, fuel, etc. which have substantial commercial value [112]. In the Philippines, yam (Lab-o") remained an economically important food and medicine source of food among indigenous and tribal [113]. Therefore, NUS's commercial values and beneficial outcomes contribute to generating income. The juice yield, architecture, morphology, nutrition, and cosmetic and therapeutic benefits of seabuckthorn (*Hippophae salicifolia*), a potentially underutilized species of India, gave economic gain in addition to ecological advantages [114]. In Congo (DRC), several neglected and underutilized species were identified among rural households, which are a significant source of food and income [115]. The selection of complementary and genetically unique breeding lines, such as underutilized cowpea species, can develop high-yielding cultivars that can help commercial and small-scale farmers to greater adoption directed towards nutrition and food security [116]. The income generation opportunity can help change the fate of vulnerable people through livelihood improvement.

3.5. Genetic diversity

NUS comprises a wide spectrum of genetic resources that can help conserve the biodiversity of extinct species. *Artocarpus nangkadak, Syzygium samarangense, Salacca sumatrana, Lansium domesticum, Flacourtia inermis, Pometia pinnata* are Indonesian fruit species with enormous genetic resources [117]. The center of genetic diversity of the Winged bean [*Psophocarpus tetragonolobus (L.) DC.*] in Thailand indicates its local importance throughout Asia and Africa [118]. The underutilized crops and associated cropping systems are significant components of agricultural biodiversity [119]. The wild relatives of cultivated crops are primarily underutilized and possess the features of vast genetic resources, high production, and abiotic stress tolerance [120]. *Citrullus lanatus* from southern Africa is portrayed as a rich source of watermelon diversity and provide water and food for wildlife and human, where the germplasm of such species is mostly abiotic stress tolerant such as drought and diseases [121]. The underutilized genetic resource of Piper botanicals, namely *Piper guineense, Pipta africanum* (rootbark, leaf), *Aristolochia repens* found active against *Callosobruchus maculatus*, a pest of grain legumes, besides their contribution to food

Table 2
Documented NU Species and their Diversity in Asian Geographical Location.

NUS species	Local/English name	Country	References
Vigna umbellata	Ricebean	India and Nepal	[17]
Aegle marmelos L.	Bael	Sri Lanka	[20]
L. Aegyptiaca	Sponge gourd	Sri Lanka	[28]
Luffa acutangular	Ridged gourd	Sri Lanka	[28]
Lasia spinosa (L.)	Unicorn plant	Sri Lanka	[33]
Cassia hirsuta L.	Wooly cassia	India	[40]
Viburnum mullaha	Starry Viburnum	India	[77]
Artocarpus lakoocha	Monkey jack	Bangladesh	[46]
Diospyros discolor	Velvet apple	Bangladesh	[46]
Diospyros peregrina	River ebony	Bangladesh	[46]
Garcinia cowa	Cowa	Bangladesh	[46]
Flacourtia indica	Governor's plum	Bangladesh	[46]
Flacourtia jangomas	Flacourtia	Bangladesh	[46]
Protium serratum	Red pear	Bangladesh	[46]
Acerola (Malpighia glabra L.*)*	Wild crape myrtle	Bangladesh	[78]
Myrciaria dubia	Camu-camu	Bangladesh	[78]
Portulaca oleracea L.	Beldroega	Bangladesh	[78]
Pereskia aculeata	Ora-pro-nobis	Bangladesh	[78]
Xanthosoma taioba	Taioba	Bangladesh	[78]
Hibiscus sabdariffa L.	Vinagreira	Bangladesh	[78]
Astrocaryum aculeatum	Tucuma	Bangladesh	[78]
(Butia eriospatha)	Butia	Bangladesh	[78]
Musa spp.	Culinary banana	India	[51]
Dioscorea spp	Yam	India	[54]
D. Pentaphylla	Yam	India	[54]
D. Pubera	Yam	India	[54]
D. Bulbifera	Yam	India	[54]
Parkia roxburghii	Tree bean	India	[59]
C. Grandis	Ivy Gourd	Saudi Arabia	[63]
D. Mespiliformis	Jackalberry	Saudi Arabia	[63]
C. Rotundifolius	Madagascar potato	Saudi Arabia	[63]
E. Foeminea	Ephedra	Saudi Arabia	[63]
G. Villosa	hairy star of Bethlehem	Saudi Arabia	[63]
M. Imbricata	Not mentioned	India	[66]
M. Bracteata	Not mentioned	India	[66]
P. Pseudoginseng	Himalayan ginseng	India	[71]
P. Bipinnatifidus	Lacy Tree Philodendron	India	[71]
Vigna subterranea L. *Verdc*	Bambara groundnut	China	[83]
Musa texlilis Nee	Abaca	Philippines	[89]
Sechium edule (Jacq.) Swartz.	Chayote	India	[93]
Indigofera glandulosa Wendl.	Barbada	India	[95]
Basella alba	Malabar spinach	India	[96]
Basella rubra	Malabar spinach	India	[96]
Artocarpus altilis (Parkinson) Fosber	Sukun or Bread fruit	Indonesia	[102]
Swietenia macrophylla King	Mahogany	Indonesia	[102]
Euphoria longana (Lour.) Steud	Lengkeng or Longan	Indonesia	[102]
Citrus microcarpa Linn.	Jeruk or Citrus	Indonesia	[102]
Coffea robusta Lindl, ex De Willd	Kopi or Coffee	Indonesia	[102]
Pangium edule Reinw	Kluwak or Football fruit	Indonesia	[102]
Dryobalanops aromatica Gearth	Camphoor	Indonesia	[102]
Hevea brasiliensis Muell. Arg.	Karet or rubber	Indonesia	[102]
Litsea noronhae Blume	Ki Huru or Litsea	Indonesia	[102]
Leucaena leucocephala (Lam.) De Wi	Lamtoro or Leucaena	Indonesia	[102]
Citrus aurantifolia (Christm.) Swingle	Lime	Indonesia	[102]
Anthocephalus cadamba (Roxb.) Miq.	Jabon	Indonesia	[102]
Paraserienthes falcataria (L.) Nielsen	Peacock	Indonesia	[102]
Psidium guajava Linn.	Jambu Batu	Indonesia	[102]
Mangifera kemanga Blume	Kemang or Kemang	Indonesia	[102]
Peronema canescens Jack	Sungkai or False elder	Indonesia	[102]
Maesopsis eminii Engl.	Umbrella tree	Indonesia	[102]
Toona sureni (Bl.) Merr	Australian red ceda	Indonesia	[102]
Pinus merkusii Jungh	Pine or Pinus	Indonesia	[102]
Manilkara zapota (L.) Van Royen	Naseberry	Indonesia	[102]
Tectona grandis Linn. F.	Ati or Teak	Indonesia	[102]
Syzygium aqueum (Burm.f.) Alston	Watery rose apple	Indonesia	[102]
Melia azedarach L	Chinaberry	Indonesia	[102]
Arenga pinnata (Wurmb.) Merr	Aren or Sugar palm	Indonesia	[102]
Persea americana Mill Fruit	Alpukat or Avocado	Indonesia	[102]
Altingia excelsa Noronha	Rasamala	Indonesia	[102]
Alstonia scholaris (L.) R.Br	Pulai or Dita bark	Indonesia	[102]
Gnetum gnemon Linn.	Melinjo	Indonesia	[102]
Lawsonia inermis	Henna	Yemen	[110]
Coriandrum sativum	Coriander	Yemen	[110]
Nigella sativa	Nigella	Yemen	[110]
Cuminum cyminum	Cumin	Yemen	[110]
Dioscorea villosa	Lab-o	Philippines	[113]
Hippophae salicifolia	Seabuckthorn	India	[114]
Psophocarpus tetragonolobus (L.) DC.	Winged bean	Thailand	[118]
Artocarpus nangkadak	Jackfruit	Indonesia	[117]
Syzygium samarangense	Java apple	Indonesia	[117]
Salacca sumatrana	Snake fruit	Indonesia	[117]
Lansium domesticum	Langsat	Indonesia	[117]
Flacourtia inermis	Lobi-lobi	Indonesia	[117]
Pometia pinnata	Fijian longan	Indonesia	[117]
Dioscorea pentaphylla L.	Yam	Philippines	[123]
C. Evansii,	Kumpat	Philippines	[123]
H. Lophophora	Not mentioned	Philippines	[123]
S. Calyptrate	Not mentioned	Philippines	[123]
D. Hispida	Not mentioned	Philippines	[123]
Hornstedtia conoidea	Not mentioned	Philippines	[123]
P. Edule	Not mentioned	Philippines	[123]
Calamus sp.,	Not mentioned	Philippines	[123]
Kaempferia. Angustifolia	Not mentioned	India	[124]
Kaempferia. Elegans	Silver spot	India	[124]
Kaempferia galanga	Aromatic ginger	India	[124]
Kaempferia rotunda	Peacock ginger	India	[124]
Malpighia glabra L	West Indian cherry	India	[125]
Mangifera andamanica L.	Wild mango	India	[125]
Morinda citrifolia L.	Noni	India	[125]
Syzygium aqueum (Burm.f) Alst.	Water Rose Apple	India	[125]
Annona squamosa L.	Custard Apple	India	[125]
Averrhoa carambola L.	Carambola	India	[125]
Averrhoa bilimbi L.	Bilimbi	India	[125]
Dillenia indica L.	Chalta	India	[125]
Annona muricata L.	Sour sop	India	[125]
Ficus racemosa L.	Fig	India	[125]
Fagopyrum esculentum Moench	Phapar	Nepal	[126]
Eleusine coracana (L.) Gaertn.	Kodo	Nepal	[126]
Panicum miliaceum L.	Cino	Nepal	[126]
Setaria italica (L.) Beauvois	Kaguno	Nepal	[126]
Perilla frutescens (L.) Britton	Silam	Nepal	[126]
Amaranthus viridis L.	Latte dana	Nepal	[126]
Chenopodium album (L.)	Bethe	Nepal	[126]
Ipomoea batatas (L.) La	Sakhara khand	Nepal	[126]
Sesamum orientale L.	Til	Nepal	[126]
Vigna umbellata (Thunb.)Ohwi & Ohashi	Masyan	Nepal	[126]
Dioscorea alata L.	Ghar tarul	Nepal	[126]
Dioscorea bulbifera L.	Ban tarul	Nepal	[126]
Colocasia esculenta (L.) Schott	Gaba	Nepal	[126]
Macrotyloma uniflorum (Lam.) Verdc	Gahat	Nepal	[126]
Benincasa hispida (Thunb.) Cogn	Kubindo	Nepal	[126]
Phaseolus vulgaris L	Asare simi	Nepal	[126]
Lathyrus sativus L.	Khesari	Nepal	[126]
Brassica nigra (L.) Koch	Rayo	Nepal	[126]
Sechium edule (Jacq.) Sw.	Skush	Nepal	[126]

(continued on next page)

Table 2 (*continued*)

NUS species	Local/English name	Country	References
Myrica esculenta buchham.ex D. Don	Kaphal	Nepal	[126]
Aegle marmelos (L.) Correa	Bel	Nepal	[126]
Aesandra butyraceae (Roxb.) Baehni	Chyuri	Nepal	[126]
Phyllanthus emblica L.	Aamala	Nepal	[126]
Citrus maxima (Burm. Ex Rumph.) Merr	Bhogate	Nepal	[126]
Syzygium cumini (L.) Skeels	Jamun	Nepal	[126]
Dryopteris cocheleata (D. Don) C. Chr.	Niuro	Nepal	[126]
Curcuma angustifolia Roxb.	Besar	Nepal	[126]
Vigna mungo (L.) Hepper	Mas	Nepal	[126]
Cucurbita pepo L.	Pharsi	Nepal	[126]
Asparagus racemosus Willd	Kurilo	Nepal	[126]
Spinacia oleracea L.	Palungo	Nepal	[126]
Citrus aurantifolia (Christ.) Swingle	Kagati	Nepal	[126]
Citrus limon (L.) Burn f.	Nibuva	Nepal	[126]
Cuminum cyminum L.	Jira	Nepal	[126]
Citrus junos Tanka	Kali jyamir	Nepal	[126]
Raphanus sativus L.	Mula	Nepal	[126]
Vicia faba L.	Bakula	Nepal	[126]
Glycine max (L.) Merr.	Bhatmas	Nepal	[126]
Psidium guajava L.	Amba	Nepal	[126]
Coriandrum sativum L.	Dhaniya	Nepal	[126]
Capsicum annuum L.	Khursani	Nepal	[126]
Juglans regia L	Okhar	Nepal	[126]
Hordeum vulgare L	Jau	Nepal	[126]
Luffa cylindrica (L.) Roem	Ghiu toria	Nepal	[126]
Sorghum vulgare Pers	Junelo	Nepal	[126]
Urtica dioca L.	Sisnu	Nepal	[126]
Cannabis sativa L.	Bhang	Nepal	[126]
Melastoma melabathricum L.	Angheri	Nepal	[126]
Zanthoxylum armatum DC.	Ankhe timur	Nepal	[126]
Rubus ellipticus Sm.	Ausali	Nepal	[126]
Mentha spicata L.	Padina	Nepal	[126]
Allium wallichii Kunth	Ban lasun	Nepal	[126]
Dendrocalamus hamiltonii Nees & Am.	Tama	Nepal	[126]
Dioscorea deltoidei Wall.ex Griseb.	Vyakur	Nepal	[126]
Polygonum molle D. Don	Thotne	Nepal	[126]
Cyanthea spinulosa Wall. Ex Hook.	Chhatre	Nepal	[126]
Oreocnide frutescence (Thunb.) Miq.	Chiple	Nepal	[126]
Berberis asiatica Roxb. Rx DC	Chutro	Nepal	[126]
Cinnamomum verum J.Presel	Dalchini	Nepal	[126]
Centella asiatica (L.) Urb	Ghodtapre	Nepal	[126]
Coccinia grandis (L.) Voigt	Golkakro	Nepal	[126]
Rumex nepalensis Spreng.	Halhale	Nepal	[126]
Mahonia nepalensis DC.	Jamune mandro	Nepal	[126]
Agaricus campestris L.	Chatre Chyau	Nepal	[126]
Amanita muscaria	Rate Chyau	Nepal	[126]
Ficus sarmentosa Buch ‑ Ham. Ex. Sm.	Berulo	Nepal	[126]
Castanopsis indica (Roxb. Ex Lindl.)	Katus	Nepal	[126]
Persea odoratissima (Nees) Kosterm.	Kaulo	Nepal	[126]
Ficus lacor Buch-Ham	Kavro	Nepal	[126]
Nasturtium officinale R.Br.	Khole sag	Nepal	[126]
Asparagus racemosus Willd.	Kurilo	Nepal	[126]
Rhododendron arboretum Smith	Laligurans	Nepal	[126]
Choerospondias axillaris (Roxb.) B.L. Brutt & A.W. Hill	Lapsi	Nepal	[126]
Not mentioned	Hunkholo	Nepal	[126]
Arundinaria falcata	Nigalo	Nepal	[126]
Not mentioned	Gophla	Nepal	[126]
Not mentioned	Ghangur	Nepal	[126]
Ophioglossum vulgatum L.	Jibre Saag	Nepal	[126]
Not mentioned	Seuda Saag	Nepal	[126]

Table 2 (*continued*)

NUS species	Local/English name	Country	References
Not mentioned	Khauda Saag	Nepal	[126]
Not mentioned	Nausitha Saag	Nepal	[126]
Not mentioned	Naigya	Nepal	[126]
Not mentioned	Guyeli	Nepal	[126]
Not mentioned	Kairo	Nepal	[126]
Not mentioned	Nauri	Nepal	[126]
Not mentioned	Kabu Saag	Nepal	[126]
Not mentioned	Aalmale Saag	Nepal	[126]
Not mentioned	Badmale Saag	Nepal	[126]
Dryopteris sp.	Bhadaure niuro	Nepal	[126]
Dryopteris sp.	Ekle nuiro	Nepal	[126]
Dryopteris sp.	Tangalide nuiro	Nepal	[126]
		Nepal	
Dryopteris sp.	Mnolide nuiro		[126]
Alocasia alba Schott	Kiriala	Sri Lanka	[127]
Musa paradisiaca L.	Alu kesel	Sri Lanka	[127]
Persea americana Mill.	Alligator Pera	Sri Lanka	[127]
Momordica charantia L.*var. Charantia C.B. Clarke*	Batu karavila	Sri Lanka	[127]
Vigna radiata (L.) R. Wilczek	Udu	Sri Lanka	[127]
Anacardium occidentale L.	Gaskaju	Sri Lanka	[127]
Manihot esculenta Cratz	Mayyokka	Sri Lanka	[127]
Capsicum annuum L.	Henmiris	Sri Lanka	[127]
Annona reticulata A.K.A.	Weli Anoda	Sri Lanka	[127]
Datura stramonium L.	Danthuraala	Sri Lanka	[127]
Solanum macrocarpon L.	Wambotu	Sri Lanka	[127]
Amorphophallus campanulatus (Roxb.) BL. Exdence	Rajala/Kidaran	Sri Lanka	[127]
Eleusine coracana (L.) Gaertn.	Kurakkan	Sri Lanka	[127]
Setaria italica (L.) P. Beauvois	Thanahal	Sri Lanka	[127]
Sesamum indicum L.	Thala	Sri Lanka	[127]
Arachis hypogaea L.	Ratakaju	Sri Lanka	[127]
Psidium guajava L.	Pera	Sri Lanka	[127]
Macrotyloma uniflorum (Lam.) Verdc.	Kollu	Sri Lanka	[127]
Artocarpus heterophyllus Lam.	Kos	Sri Lanka	[127]
Vigna unguiculata L. Walp.	Cowpea	Sri Lanka	[127]
Dioscorea esculenta (Lour.) Burkill	Kukulala	Sri Lanka	[127]
Zea mays L.	Badairingu (Local)	Sri Lanka	[127]
Moringa oleifera Lam.	Murunga	Sri Lanka	[127]
Vigna radiata (L.) R.Wilczek	Mungeta	Sri Lanka	[127]
Cucumis melo L.	Kekiri/Gon kekiri	Sri Lanka	[127]
Abelmoschus esculentus (L.) Moench	Bandakka	Sri Lanka	[127]
Punica granatum L.	Delum	Sri Lanka	[127]
Panicum miliaceum L.	Meneri	Sri Lanka	[127]
Cucurbita maxima L.	Henwattakka	Sri Lanka	[127]
Luffa acutangula L. *Roxb.*	Henwatakolu	Sri Lanka	[127]
Momordica dioica Roxb. Ex Willd.	Thumba Karavila	Sri Lanka	[127]
Aegle marmelos (L.) Correa	Beli	Sri Lanka	[127]
Citrullus lanatus (Thunb.) Matsum. & Nakai	Panikomadu (Pathtakka)	Sri Lanka	[127]
Ipomoea batatas (L.) Lam.	Batala	Sri Lanka	[127]
Lycopersicon esculentum Mill.	Takkali	Sri Lanka	[127]
Psophocarpus tetragonolobus (L.) DC.	Dambala	Sri Lanka	[127]
Feronia limonia (L.) Swingle	Divul	Sri Lanka	[127]
Ficus semicordata Buch.-Ham. Ex D.Don,	Khinyau	West Nepal	[128]
Hydrocotyle nepalensis Hook.,	Khochad	West Nepal	[128]
Debregesia longifolia (Burm.f.) Wedd.,	Tashiari	West Nepal	[128]
Girardinia diversifolia (Link) Friis	Chalne sisnu	West Nepal	[128]
Garuga pinnata Roxb.	Ramsin	West Nepal	[128]
Bauhinia purpurea	Taki	West Nepal	[128]
Ficus hispida	Khasreti	West Nepal	[128]
Aloe vera	Hattibar	West Nepal	[128]
Pyrus pashia Buch.-Ham. Ex D. Don	Mael	West Nepal	[128]

(*continued on next page*)

Table 2 (*continued*)

NUS species	Local/English name	Country	References
Terminalia bellerica (Gaertn.) Roxb	Barro	West Nepal	[128]
Ocimum gratissimum Linn., Large basil	Babari	West Nepal	[128]
Ficus benghalensis	Bar	West Nepal	[128]
Amaranthus viridis	Range sag	West Nepal	[128]
Erythrina arborescens Roxb.,	Aejingo	West Nepal	[128]
Morus serrata Roxb.,	Kimbu	West Nepal	[128]
Choerospondias axillaris (Roxb.)	Lapsi	West Nepal	[128]
Saccharun spontaneum	Kans	West Nepal	[128]
Phoenix sylvestris Roxb.,	Khajur	West Nepal	[128]
Rhus javanica	Bhakildo	West Nepal	[128]
Swertia angustifolia Buch.-Ham. Ex D.Don,	Chirayito	West Nepal	[128]
Polygonatum cirrhifolium (Wall.) Royle,	Khiraula	West Nepal	[128]
Fimbristylis dichotoma (L.) Vahl, Mat	Jire jhar	West Nepal	[128]
Indigofera atropurpurea Rottl. Ex DC.	Sakhino	West Nepal	[128]
Abrus precatorius	Ratigedi	West Nepal	[128]
Elephantopus scaber	Gomukhi	West Nepal	[128]
Impatiens balsamina	Patpate	West Nepal	[128]
Vetiveria zizanoides	Kush	West Nepal	[128]
Cassia fistula	Amaltas	West Nepal	[128]
Cucumis sativa	Airelu	West Nepal	[128]
Lyonia ovalifolia (Wall.) Drude	Aayanr	West Nepal	[128]
Maesa chisia Buch.-Ham. Ex D. Don	Belaune	West Nepal	[128]
Sarcococca coriacea (Hook.) Sweet,	Telparo	West Nepal	[128]
Rosa sericea Lindl	Jangali gulaf	West Nepal	[128]
Litsea monopetala (Roxb.) Pers.	Kutmiro	West Nepal	[128]
Fagopyrum esculentum Moench.	Phapar	West Nepal	[128]
Jasminum humile	Jai	West Nepal	[128]
Rapidophora glauca (Wall.) Schott	Haddijor	West Nepal	[128]
Tricosanthes tricuspidata Lour.	Indreni	West Nepal	[128]
Coccinia grandis (Linn.) Voigt	Matkakadi	West Nepal	[128]
Pleione humulis (Sm.) D.Don	Manidana	West Nepal	[128]
Acmella calva (DC.) Jansen	Marethi	West Nepal	[128]
Setaria italica (Linn.) Beauvois	Kagno	West Nepal	[128]
Smilax ovalifolia Roxb. Ex D. Don	Kukurdaina	West Nepal	[128]
Cynoglossum zeylanicum Thunb. Ex. Lehm.	Musekudo	West Nepal	[128]
Delphinium brunonianum Royle,	Maure	West Nepal	[128]
Piptanthus nepalensis (Hook) D.Don	Solsaino	West Nepal	[128]
Butea monosperma (Lam.) Kuntze	Dhak	West Nepal	[128]
Ipomoea carnea Jacq.	Behay	West Nepal	[128]
Solanum nigrum Linn., Black	Bihi	West Nepal	[128]
Rubus biflorus	Two flower raspberries	India	[129]
R. Ellipticus	Golden Himalayan raspberry	India	[129]
R. Fasciculatus	Not mentioned	India	[129]
R. Foliolosus	Not mentioned	India	[129]
R. Macilentus	Not mentioned	India	[129]
R. Nepalensis	Not mentioned	India	[129]
R. Niveus	Mysore raspberry	India	[129]
R. Paniculatus	Calopsis	India	[129]
R. Pentagonus	Not mentioned	India	[129]
R. Ellipticus	Himalayan raspberry	India	[129]

Table 3
Documented NU Species and their Diversity in African Geographical Location.

NUS species	Local/English name	Country	References
Artocarpus altilis	Breadfruit	Nigeria	[15]
Carpolobia lutea	Not mentioned	Nigeria	[15]
Chrysopyllum albidum	Star apple	Nigeria	[15]
Anthonotha macrophylla	Not mentioned	Nigeria	[15]
Vitalleria paradoxa	Shea tree	Nigeria	[15]
Tetracarpidium conophorum	English walnut	Nigeria	[15]
Piper guineense	Edo pepper	Nigeria	[15]
Tetrapleura tetraptera	Perkese	Nigeria	[15]
Tylosema esculentum	Marama bean	South Africa	[18]
Abelmoscus esculentua	Okra	Nigeria	[81]
Adansonia digitata	Baobab tree	Nigeria	[81]
Amaranthus dubius	Red spinach	Nigeria	[81]
Amaranthus viridis	Green amaranth	Nigeria	[81]
Basella alba	Malabar spinach	Nigeria	[81]
Basella rubra	Malabar spinach	Nigeria	[81]
Crassocephalum crepidioides	Redflower ragleaf	Nigeria	[81]
Launaea taraxacifolia	Wild lettuce	Nigeria	[81]
Senecio biafrae	Not mentioned	Nigeria	[81]
Solanum americanum	American black nightshade	Nigeria	[81]
Solanum macrocarpon	African eggplant	Nigeria	[81]
Talinum triangulare	Ceylon spinach	Nigeria	[81]
Vernonia amygdalina	Bitter leaf	Nigeria	[81]
Strychnos spp.	Monkey orange	Zimbabwe, Southern Africa	[79]
Sorghum bicolor	Great millet	South Africa	[130]
Amaranthus graecizans L.	Liima	Ethiopia	[26]
Solanum nigrum L.	Obxi	Ethiopia	[26]
Hypolepis sparsisora (Schrad.) Kuhn.	Giixo	Ethiopia	[26]
Portulaca oleracea L.	Meteri	Ethiopia	[26]
Dioscorea alata L.	Boyna	Ethiopia	[26]
Dioscorea cayenensis Lam. (yellow)	Buri	Ethiopia	[26]
Dioscorea prehensilis Benth. (white)	Buri	Ethiopia	[26]
Ficus sycomorus L	Harbo	Ethiopia	[26]
Rubus apetalus Poir.	Gora	Ethiopia	[26]
Syzygium guineense Wall.	Bedesa	Ethiopia	[26]
Tristemma mauritianum J F Gmel.	Bedesa	Ethiopia	[26]
Carissa spinarum L.	Agamsa,	Ethiopia	[26]
Cnidoscolus chayamansa	Chaya	Ethiopia	[30]
Vigna vexillata (L.) A. Rich	Zombi pea	Africa	[32]
Pachyrhizus erosus	Yam Bean	Ghana	[35]
Sphenostylis stenocarpa	African Yam Bean	Africa	[34]
Sphenostylis stenocarpa	African yam bean	Nigeria	[36]
Dioscorea spp.	Yam	Benin	[38]
Urtica simensis Hochst. Ex. A. Rich	Stinging nettle	Ethiopia	[45]
Cucurbita sp.	Not mentioned	Africa	[47]
Solanum torvum	Turkey berry	Ghana	[73]
Senna occidentalis Linn	Oshigbuomma	Nigeria	[48]
Newbualdia leavis Seemann Bureau	Omirima	Nigeria	[48]
Solanum nigrum Linn	Ewa	Nigeria	[48]
Ficus capensis Thunb.	Ekwuakpuru	Nigeria	[48]
Ipomoea aquatica Forsk.	Ekwu nwuda	Nigeria	[48]
Synedrella nodiflora Gaertner.	Ekwu ewu	Nigeria	[48]
Vernonia cinerea (L.) Less.	Orubu egu	Nigeria	[48]
Ageratum conyzoides L.	Ekwu eyu	Nigeria	[48]
Acanthus montanus (Nees) T. Anders.	Ezi Agu	Nigeria	[48]
Mucuna flagellipes Hook. F.	Egbara	Nigeria	[48]
Zanthoxylum zanthoxyloids Lam	Nkaa	Nigeria	[48]
Amaranthus spinosus L.	Enene ogwu	Nigeria	[48]
Lactuca sativa var. *Longifolia* L.	Lettuce	Nigeria	[48]
Telfairia. Occidentalis Hook	Ugu	Nigeria	[48]

(continued on next page)

Table 3 (*continued*)

NUS species	Local/English name	Country	References
A. Cepa L.	Alibasa	Nigeria	[48]
Launea cornuta	Bitter Lettuce	Tanzania	[50]
Vigna vexillata	Wild Cowpea	Tanzania	[50]
Momordica foetida	Bitter Cucumber	Tanzania	[50]
Basella alba	Malabar Spinach	Tanzania	[50]
Maerua subcordata (Gilg) dewolf	Not mentioned	Ethiopia	[53]
Solanum aethiopicum	Ethiopian eggplant	Ghana	[56]
S. Macrocarpon	African eggplant	Ghana	[56]
S. Torvum	Beduru	Ghana	[56]
Cyphostemma adenocaule	Swahili	Nigeria	[58]
Anchomanes difformis	Olikhoror	Nigeria	[58]
Ampelocissus Africana	Grape	Nigeria	[58]
Vangueria madagascariensis	Sweet Sour	Africa	[61]
Vigna subterranea (L.) Verdc.	Bambara groundnut	South Africa	[84]
Lagenaria siceraria (Molina) Standly	Bottle gourd	Africa	[104]
Telfairia pedatastudy	Hook or oyster nut	Eastern Africa	[106]
Cucurbita moschata Duchesne	Pumpkin	Benin, Africa	[107]
Moringa oleifera Lam.	Not mentioned	West Africa	[109]
C. Sativa	Chestnut tree	Morocco	[111]
Allium sativum	Tungulusumu	D.R. Congo	[115]
Amaranthus spp.	Lengalenga	D.R. Congo	[115]
Anona muricata	Mustafere	D.R. Congo	[115]
Colocasia esculenta	Bifunu	D.R. Congo	[115]
Canarium album	Muzeituni	D.R. Congo	[115]
Carica papaya	Papayi	D.R. Congo	[115]
Cucurbita pepo	Mabogi	D.R. Congo	[115]
Dioscorea spp.	Maliga	D.R. Congo	[115]
Mucuna pruriens	Mukuna	D.R. Congo	[115]
Vigna unguiculata	Kunde	D.R. Congo	[115]
Persea americana	Voka	D.R. Congo	[115]
Hibiscus sabdariffa	Ngaingai	D.R. Congo	[115]
Moringa oleifera	Moringa	D.R. Congo	[115]
Psidium guajava	Pera	D.R. Congo	[115]
Passiflora edulis	Marakuja	D.R. Congo	[115]
Duchesmnea indica	Mafrenze	D.R. Congo	[115]
Citrus reticulata	Mandarina	D.R. Congo	[115]
Solanum macrocarpon	Nyanya	D.R. Congo	[115]
Solanum indicum	Kashongo	D.R. Congo	[115]
Physalis peruviana	Mbuma	D.R. Congo	[115]
Solanum nigrum	Mbogabuchungu	D.R. Congo	[115]
Zingiber officinale	Tangawizi	D.R. Congo	[115]
Salanum aethiopicum	Ntolya	D.R. Congo	[115]
Vigna unguiculata L. *Walp*	Cowpea	South Africa	[116]
Citrullus lanatus	Watermelon	South Africa	[121]
Piper guineense	Benin pepper	Nigeria	[122]
P. africanum	African greenheart	Nigeria	[122]
Aristolochia repens	Birthwort	Nigeria	[122]
Dioscorea spp.	Yam	DR Congo	[131]
Gynandra L	Not mentioned	Benin, West Africa	[132]
Balanites aegyptiaca (L.) Delile	Not mentioned	Benin, West Africa	[132]
Lophira lanceolata Tiegh. Ex Keay	Not mentioned	Benin, West Africa	[132]
Sesamum indicum L.	Not mentioned	Benin, West Africa	[132]
Ricinodendron heudelotii (Bail.) Pierre.	Not mentioned	Benin, West Africa	[132]
Eleusine coracana L.	Finger millet	Kenya	[133]
Macrotyloma geocarpum	Kersting's groundnut or Doyi	Benin, Africa	[134]
Carapa procera	Not mentioned	West Africa	[135]
Pentadesma butyracea	Not mentioned	West Africa	[135]
Lophira lanceolata	Not mentioned	West Africa	[135]
Amaranthus cruentus L.	Red amaranth	Ghana	[136]
Amaranthus hybridus L.	Green amaranth	Ghana	[136]
Basella alba L.	Malabar spinach	Ghana	[136]
Celosia argentea L.	plumed cockscomb	Ghana	[136]
Corchorus olitorius L.	Tossa jute	Ghana	[136]
Cleome gynandra L.	African cabbage	Ghana	[136]
Cucumeropsis edulis Hook. F.	White seed melon	Ghana	[136]
Curcurbita maxima Duchesne	Pumpkin	Ghana	[136]
Justicia tenella (Nees) T. Ander.	Not mentioned	Ghana	[136]
Langenaria siceraria (Mol.) St.	Bottle gourd	Ghana	[136]
Sechium edule (Jac.) Sw.	Chayote	Ghana	[136]
Sesamum radiatum Schum. Et Thonn.	Benniseed	Ghana	[136]
Solanum aethiopicum L.	Bitter tomato	Ghana	[136]
Solanum macrocarpon L.	African eggplant	Ghana	[136]
Solanum nigrum L.	European black nightshade	Ghana	[136]
Solanum torvum Swartz	Devil's fig	Ghana	[136]
Talinum triangulare (Jacq.) Willd.	Ceylon spinach	Ghana	[136]
Telfaria occidentalis Hook. F.	Fluted pumpkin	Ghana	[136]
Trichosanthes cucumerina L.	Snake gourd	Ghana	[136]
Vernonia amygdalina Delile	Bitter leaf	Ghana	[136]
Vitex doniana L.	Black plum	Ghana	[136]
Colocasia esculenta (L.) Schott	Taro	Ghana	[136]
Dioscorea bulbifera L.	Air yam	Ghana	[136]
Dioscorea cayenensis Lam.	Yellow yam	Ghana	[136]
Dioscorea dumetorum L.	Cluster yam	Ghana	[136]
Dioscorea praehensilis L.	Bush yam	Ghana	[136]
Ipomea batatas (L.) Lam.	Sweet potato	Ghana	[136]
Solenostemon rotundifolius (Poir.) J.K. Morton	Country potato	Ghana	[136]
Xanthosoma sagittifolium (L.) Schott.	Arrowleaf elephant ear	Ghana	[136]
Digitaria exilis (Kippist) Stapf	White fonio	Ghana	[136]
Eleusine coracana Gaertn.	Finger millet	Ghana	[136]
Eragrotis tef (Zucc.) Trotter	Teff	Ghana	[136]
Oryza glaberrima Steud.	African rice	Ghana	[136]
Pennisetum glaucum (L.) R. Br.	Pearl millet	Ghana	[136]
Setaria italica (L.) P. Beauvois	Foxtail millet	Ghana	[136]
Sorghum bicolor (L.) Moench	Great millet	Ghana	[136]
Cajanus cajan (L.) Millsp.	Pigeon pea	Ghana	[136]
Canavalia ensiformis (L.) DC.	Jack bean	Ghana	[136]
Canavalia gladiate (Jacq.) DC.	Sword jack bean	Ghana	[136]
Cassia occidentalis L.	Coffee senna	Ghana	[136]
Centrocema pubescens Benth.	Butterfly pea	Ghana	[136]
Crotalaria L. *Spp.*	Rattlepods	Ghana	[136]
Macrotyloma geocarpum (Harms) Mare'ch. Et Baud.	Ground bean	Ghana	[136]
Mucuna pruriens (L.) DC.	Monkey tamarind	Ghana	[136]
Phaseolus lunatus L.	Lima beans	Ghana	[136]
Pueraria phaseloides (Roxb.) Benth.	Tropical kudzu	Ghana	[136]
Vigna subterranean (L.) Verdc.	Bambara nut	Ghana	[136]
Adansonia digitata L.	baobab tree	Ghana	[136]
Artocarpus altilis (Parkinson) Fosberg	Breadfruit	Ghana	[136]
Borassus aethiopicum Mart.	African fan palm	Ghana	[136]
Chrysophyllym albidum G. Don	White star apple	Ghana	[136]
Cola millenii Schott et Endl.	Kola nut	Ghana	[136]
Dacryodes klaineana Vahl	African cherry fruit	Ghana	[136]
Dialium guineense Willd.	Velvet tamarind	Ghana	[136]
Diospyros vignei F. White	Ebony trees	Ghana	[136]
Diospyros soubreana F. White	Ebony trees	Ghana	[136]

(*continued on next page*)

Table 3 (*continued*)

NUS species	Local/English name	Country	References
Drypetes chevalieri Vahl	Not mentioned	Ghana	[136]
Irvingea gabonensis (Aubry-Lecomte ex O'Rorke) Baill.	Bush mango	Ghana	[136]
Heisteria parvifolia Sm.	Not mentioned	Ghana	[136]
Morinda morindiode L.	Not mentioned	Ghana	[136]
Parkia biglobosa (Jacq.) R. B. ex G. Don f.	African locus bean	Ghana	[136]
Salacia cornifolia Hook. F.	Not mentioned	Ghana	[136]
Sclerocarya birrea (A. Rich.) Hochst.	Marula	Ghana	[136]
Synsepalum dulcificum (Schumacher et Thonn.) Daniell.	Miracle berry	Ghana	[136]
Uvaria chamae P. Beauv.	Bush banana	Ghana	[136]
Ximenia americana L.	Hog plum	Ghana	[136]

security, nutrition security and income generation in Nigeria [122]. From the above literature review, it is evident that NUS adds value to the Sustainable Development Goal of Zero Hunger following the comprehensive pathway (Fig. 5). The widespread diversity of NUS is tabulated in Tables 2–7.

3.6. NUS distribution worldwide

The distribution of NUS is widespread worldwide, including in developing and poor countries. Fig. 6 represents the distribution of documented species in respective continents.

Most of the documentation of NUS is prevalent in the Asia continent (49.84 percent), followed by Africa (30.88 percent) and South America (15.36 percent). The lowest documented species found in Australia (0.49 percent), followed by Europe (1.14 percent) and North America (2.29 percent), indicated its need to document the neglected and underutilized species.

4. Constraints of NUS richness

There are some limiting factors that constraint the widespread richness advancement of NUS. Among the major constraints lack of consciousness regarding the potentialities of NUS, and lack of research oriented program are major concern. These factor primarility limit consumers acceptance of the species. For instance**,** Yam (*Dioscorea* spp.) production is restricted due to a lack of enthusiasm among farmers due to production loss in DR Congo [131]. NUS effectively aids in the adaptability to climatic change, but there is still a need for sustainable conservation and exploitation [13]. In Uganda, 20% of the recognized species regularly consume wild food plants, while the other 80% are regarded as being neglected [140]. The complexities in identifying wild edible species and traditional knowledge decline are the reason for the underutilization of respective species [140]. Despite having the potential to enhance human health, livelihood, and food security, the regional competitiveness of underused seed species of *L. javanica*, *L. multiflora*, and *L. graveolens* has not been achieved in conventional agriculture [141]. Grain legume Kersting's groundnut (*Macrotyloma geocarpum*), locally known as Doyi is profoundly distributed in Benin with high economic and nutritional value but neglected due to development and scientific research programs, high production cost, backdated cultural practices, and abiotic factors [134]. Taro's widely distributed marginalized crop (*Colocasia esculenta (L.) Schott*) has significance as a vegetable and food crop which is on the verge of disregard because of urgent research needs from development organizations like academia and agriculture [142]. *Physalis angulata* is less exploited in Brazil as the cultivation technique is still backdated and unestablished [143]. The lack of research driven intitives restict the innovation of potential way to utilize the plant species comprising toxicity and wilderness and make

Table 4
Documented NU Species and their Diversity in South American Geographical Location.

NUS species	Local/English name	Country	References
(T. Tuberosum)	Mashua	Peru and Bolivia	[19]
(A. Xanthorrhiza)	Arracacha	Peru and Bolivia	[19]
(S. Sonchifolius)	Yacon	Peru and Bolivia	[19]
Annona cherimola Mill.	Cherimoya	Ecuador, Bolivia and Peru	[21]
Talinum fruticosum (L.) Juss.	Cariru	Brazil	[24]
Amaranthus deflexus L.	Bredo	Brazil	[24]
Coleus amboinicus Lour.	Hortela-grosso	Brazil	[24]
Momordica charantia L.	Goya	Brazil	[24]
Dysphania ambrosioides (L.) Mosyakin & Clemants	Lombrigueira	Brazil	[24]
Portulaca oleracea L.	Beldroega	Brazil	[24]
Eryngium foetidum L.	Coentro-bravo	Brazil	[24]
Schinus terebinthifolia Raddi	Aroeira	Brazil	[24]
Xanthosoma taioba E. G. Gonç.	Taioba	Brazil	[24]
Tripogandra diuretica (Mart.) Handlos	Trapoeraba	Brazil	[24]
Pereskia aculeata Mill.	Carne-de-pobre	Brazil	[24]
Turnera subulata Sm.	Chanana	Brazil	[24]
Cymbopogon citratus (DC.) Stapf	Capim-santo	Brazil	[24]
Cajanus cajan (L.) Huth	Andu	Brazil	[24]
Peperomia pellucida (L.) Kunth	Alfavaca-de-cobra	Brazil	[24]
Ocimum campechianum Mill.	Alfavaquinha	Brazil	[24]
Cucumis anguria L.	Maxixe	Brazil	[24]
Moringa oleifera Lam.	Moringa	Brazil	[24]
Solanum stramoniifolium Jacq.	Jurubeba	Brazil	[24]
Sonchus oleraceus L.	Serralha	Brazil	[24]
Basella alba L.	Bertalha	Brazil	[24]
Plantago major L.	Tansagem	Brazil	[24]
Trichosanthes cucumerina L.	Quiabo-de-metro	Brazil	[24]
Curcuma longa L.	Cúrcuma	Brazil	[24]
Solanum americanum Mill.	Maria-pretinha	Brazil	[24]
Ocimum gratissimum L.	Alfavaca-cravo	Brazil	[24]
Mentha pulegium L.	Poejo	Brazil	[24]
Hibiscus rosa-sinensis L.	Hibisco	Brazil	[24]
Cnidoscolus aconitifolius (Mill.) I. M. Johnst.	Chaya	Brazil	[24]
Piper umbellatum L.	Capeba	Brazil	[24]
Boerhavia diffusa L.	Pega-pinto	Brazil	[24]
Oxalis barrelieri L.	Azedinha	Brazil	[24]
Boehmeria caudata Sw.	Urtiga-mansa	Brazil	[24]
Averrhoa bilimbi L.	Biri-biri	Brazil	[24]
Costus amazonicus (Loes.) J. F. Macbr.	Cana-de-macaco	Brazil	[24]
Bidens pilosa L.	Pico-pico	Brazil	[24]
Brassica juncea (L.) Czern.	Mostarda	Brazil	[24]
Solanum betaceum Cav.	Tamarilho;	Brazil	[24]
Spondias purpurea L.	Seriguela	Brazil	[24]
Genipa americana L.	Jenipapo	Brazil	[24]
Canavalia ensiformis (L.) DC.	Feijão-de-porco	Brazil	[24]
Galinsoga parviflora Cav.	Fazendeiro	Brazil	[24]
Fridericia chica (Bonpl.) L. G. Lohmann	Crajiru	Brazil	[24]
Echinodorus macrophyllus (Kunth) Micheli	Chapéu-de-couro	Brazil	[24]
Piper peltatum L.	Santa-maria	Brazil	[24]
Physalis pubescens L.	Fisalis	Brazil	[24]
Kalanchoe pinnata (Lam.) Pers.	Corama	Brazil	[24]
Conyza bonariensis (L.) Cronquist	Buva	Brazil	[24]
Terminalia catappa L.	Castanhola	Brazil	[24]
Pteridium aquilinum (L.) Kuhn	Samambaia	Brazil	[24]
Artocarpus altilis (Parkinson) Fosberg	Fruta-pao	Brazil	[24]
Pouteria caimito (Ruiz & Pav.) Radlk.	Abiu	Brazil	[24]

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Table 4 (*continued*)

NUS species	Local/English name	Country	References
Celosia argentea L.	Celosia	Brazil	[24]
Maranta arundinacea L.	Araruta	Brazil	[24]
Vigna unguiculata (L.) Walp.	Feijao-de-corda	Brazil	[24]
Sicana odorifera (Vell.) Naudin	Maracujina	Brazil	[24]
Asystasia gangetica (L.) T. Anderson	Coromandel	Brazil	[24]
Hylocereus undatus (Haw.) Britton & Rose	Pitaia	Brazil	[24]
Syzygium malaccense (L.) Merr. & L.M. Perry	Jambo	Brazil	[24]
Annona cherimola Mill.	Cherimoya	Peru, Bolivia, and Ecuador	[42]
Oxalis tuberosa Molina	Oca	South America	[39]
Ullucus tuberosus Caldas	Ulluco	South America	[39]
Tropaeolum tuberosum Ruíz & Pav	Mashua	South America	[39]
Pachyrhizus ahipa (Wedd.) Parodi	Ajipa	South America	[39]
Smallanthus sonchifolius	Yacon	South America	[39]
Arracacia xanthorrhiza Bancr.	Arracacha	South America	[39]
Mirabilis expansa (Ruíz & Pav.) Standl.	Mauka	South America	[39]
Lepidium meyenii Walp.	Maca	South America	[39]
Canna edulis Ker Gawl.	Achira	South America	[39]
Pitanga	Brazilian Cherry	Brazil	[78]
Solanum betaceum Cav	Red chilto	Argentina	[49]
Oxalis cordata	Not mentioned	Brazil	[62]
Xylopia aromatica	Not mentioned	Brazil	[62]
Plukenetia volubilis L.	Sacha Inchi	Peru	[65]
Chenopodium quinoa Willd.	Quinoa	Peru	[86]
Theobroma grandiflorum (Willd. Ex Spreng.	Copoazu	Venezuela	[112]
Pourouma cecropiifolia Mart.	Amazon grape	Venezuela	[112]
Euterpe precatoria Mart.	Manaca	Venezuela	[112]
Solanum sessiliflorum Dunal.	Peach tomato	Venezuela	[112]
Bactris gasipaes Kunth	Peach palm	Venezuela	[112]
Inga edulis Mart.	Guama	Venezuela	[112]
Pouteria caimito Radlk.	Temare	Venezuela	[112]
Triticum sp.	Creole wheat	Mexico	[99]

Table 5
Documented NU Species and their Diversity in north American Geographical Location.

NUS species	Local/English name	Country	References
O. Macrocentra Engelm	Purple prickly-pear	Mexico	[27]
O. Phaeacantha Engelm	Tulip prickly pear	Mexico	[27]
O. Engelmannii Salm-Dyck ex Engelmann.	Cactus apple	Mexico	[27]
P. Erosus	Jicama	Central America and Mexico	[37]
Amaranthus hybridus	Quintonil	Mexico	[76]
Persea schiedeana Nees	Not mentioned	Mexico	[74]
Cnidoscolus aconitifolius	Chaya	Mexico	[57]
Anoda cristata	Alache	Mexico	[57]
Crotalaria pumila	Chepil	Mexico	[57]
V. Radiata	Tuber Cowpea	USA	[87]
V. Unguiculata	Tuber Cowpea	USA	[87]
V. Vexillata	Tuber Cowpea	USA	[87]
Triticum sp.	Creole wheats	Mexico	[99]
Brassica oleracea L. *Var. Viridis*	Collard	America	[137]

them valuable for other purposes. For example, despite having significant protein and oil content, winged bean (*Psophocarpus tetragonolobus (L.) DC.*) undergoes the phases of overlook because of its anti-nutritional qualities [139]. In Benin of West Africa, the top prioritized species recorded *Cleome gynandra* L., *Balanites aegyptiaca (L.) Delile, Lophira lanceolata Tiegh. ex Keay, Sesamum indicum* L., *Ricinodendron heudelotii (Bail.) Pierre*. were wild oil plants found to give food, fuel, medicine, and cosmetics services despite their negligence due to wildness and toxicity [132]. The organoleptic assessment showed a lower preference for *L. aegyptiaca* species [28]. Home gardeners and commercial farmers have adopted commercial hybrids, which led to genetic erosion of Collard (*Brassica oleracea* L. *var. viridis*), thereby has been a neglected landrace in the USA [137].

Table 6
Documented NU Species and their Diversity in European Geographical Location.

NUS species	Local/English name	Country	References
Ribes uva-crispa L.	Gooseberry	Herzegovina and Bosnia	[16]
Cornus mas L.	Cornelian cherry	Herzegovina and Bosnia	[16]
Urtica dioica L.	Stinging nettle	Italy	[69]
Mespilus germanica L.	Medlar	Italy	[70]
Lathyrus sativus L.	Grass pea	Spain	[88]
Lathyrus cicera L.	Chickling pea	Spain	[88]
Foeniculum vulgare Mill.	Fennel	Spain	[138]
Chondrilla juncea L.	Skeleton weed	Spain	[138]
Cichorium intybus L.	Chicory	Spain	[138]
Scolymus hispanicus L	Golden thistle	Spain	[138]
Silybum marianum (L.) Gaertn.	Milk thistle	Spain	[138]
Taraxacum obovatum (Willd.) DC.	Dandelion	Spain	[138]
Humulus lupulus L.	Hop	Spain	[138]
Silene vulgaris (Moench.) Garcke	Bladder campion	Spain	[138]
Beta maritima L.	Sea beet	Spain	[138]
Bryonia dioica Jacq.	Red bryony	Spain	[138]
Tamus communis L.	Black bryony	Spain	[138]
Allium ampeloprasum L.	Wild leek	Spain	[138]
Papaver rhoeas L.	Poppy	Spain	[138]
Rumex papillaris Boiss. Et Reut.	Sorrel	Spain	[138]
Rumex pulcher L	Fiddle Dock	Spain	[138]

Table 7
Documented NU Species and their Diversity in Oceania Geographical Location.

NUS species	Local/English name	Country	References
Acacia cowleana	Acacia	Australia	[101]
Acacia coriacea	Acacia	Australia	[101]
A. Victoriae	Acacia	Australia	[101]

5. Recommendation for effective utilization of NUS

5.1. Conservation strategy

Fig. 7 illustrates the suggested primary strategies for NUS integration. NUS needs conservation strategies such as genetic resource conservation, gene pool utilization, and intensive research on breeding programs should undertake**.** Commercial cultivation and therapeutical importance conservation require appropriate conservation strategies [71]. Genetic heritage conservation and maintenance should be explored [111]. Complementation of firm and ex-situ conservation is necessary [21]. Conservation of genetic resources, livelihood improvement projects, and knowledge transfer tailoring should be encouraged [110]. To secure nutrition and food requirements, the genetic resources of NUS contain potentialities where their conservation needs to be executed by breeding programs and eliminating causes of gene erosion [144]. Regarding both in-situ and ex-situ conservation, the score for underutilized species was deemed the lowest globally [144]. Again, the utilization and exploration of species for animal and human food are

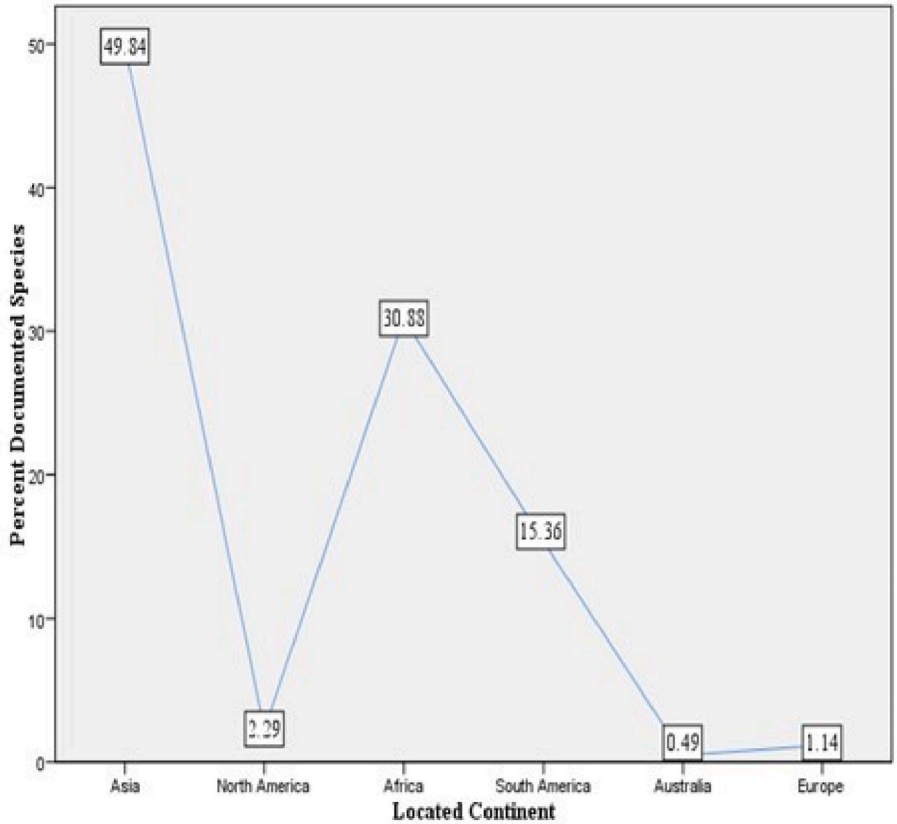

Fig. 6. Distribution of documented NUS in different continents.

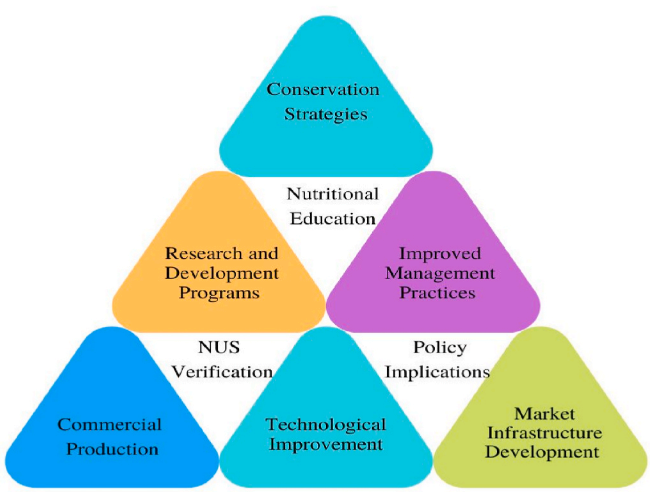

Fig. 7. Recommended strategies for NUS integration.

intensively suggested [95]. Ex situ collection and species conservation should be encouraged [121]. The constraints in production and marketing induced the erosion of genetic resources, so it is crucial to adopt conservation practices [107]. Using gene pools such as *Leymus racemosus* can facilitate more improved cultivars (wheat) that are environmentally stress-resistant [145]. Acknowledging cultural aspects, the place of origin, and the innovation of underutilized species is necessary [130]. The physiological response of landraces to various stress conditions should be investigated [84]. Molecular identification and wild toxic species identification should be explored [113]. The management of genetic resources is essential for breeding programs in the future [118]. The utilization of underutilized genetic diversity in gene pools such as wheat by effective technology and breeding tools can develop species that are environmentally friendly, resistant to biotic stress, and contain yield-enhanced alleles [146].

5.2. Commercial production

Commercial production of NUS benefit the local communitites in aspects of nutritional diversity, economic opportunity, environmental sustainability, and biodiversity enrichment. The nutritional diversity can be optimized by introducing diverse diets at a large scale. It is quite evident that the plants having enriched bioactive compounds and micronutrients have high market value. Dehydroascorbic and ascorbic acid are present in underutilized wild vegetables, indicating the need to incorporate them into the diet and as functional food additives [138]. Another study revealed that Rubus spp. in India contains a substantial antioxidant potential, phenol, anthocyanin, and ascorbic acid, indicating its requirement for commercial production, genetic diversity collection, and conservation [129]. Because, the large scale production can empower farmers economically, particularly the marginalized and rural farmers can be benefitted. The farmemrs require low input in the maintenance and production of NUS at the field level compared to other conventional crops. The biodiversity is preserved by the acceleration of NUS production that ensures maintenance of ecosystem balance, genetic diversity, high adaptability, and uplifting habitat provision. While, being the climate resilient species, the lack of effective agricultural practices limits the large-scale production of NUS [129]. Hence, commercialization of NUS with effective agricultural adaptation strategies help small holders to produce economically viable products. Thus, the market potential of such viable plants can be increased, and farmers can diversify their source of income rather than depending on major single crop. Therefore, to respond to the food crisis, large-scale production, and further investigation are required for commercialization of

NUS [32].

5.3. Research and development programs

Research and development initiatives with the help of manufacturers, business owners, researchers, and the government could aid in the promotion of NUS [126]. There are requirements for intensive research and investment in underutilized crops for transforming agriculture in developing Asian countries [83]. There are dearth of evidence highlighting the issue of research initiatives, and investment related initiatives. There should be a sustainable connection between socio-economic and environmental demands [86]. Research and development projects and post-harvest processing development should be launched to encourage waste reduction and sustainable use [26]. Consequently, research and development programs can help expand NUS's widespread expansion.

5.4. Improved management practice and market infrastructure development

Improved management and infrastructure can widen the scope of effective utilization of NUS, income generation opportunities, and food security opportunities. Improved marketing, packaging, and NUS promotion could increase local communities' resilience and economy [13]. For example, incorporating underutilized wild foods *Dioscorea pentaphylla* L., *C. evansii*, *H. lophophora*, *S. calyptrate*, *D. hispida*, *Hornstedtia conoidea*, *P. edule*, and *Calamus* sp. into the Philippines' food system can help value chains and rural community development [123]. Concern should be given to improved agronomic methods and quantifying water use [104]. Finger millet, an underutilized cereal crop, enabled higher yields for small farms in Kenya, where technical efficiency was improved by conservation tillage and better diversity, indicating expanded household nutrition and revenue production prospects for the marginalized area [133].

5.5. Technological improvement

There is an urgent need to explore resource-based multipurpose food and plant species opportunities and technological transfer [114]. Quality seed supply, training for farmers, technological advancement, development of market opportunities, and research policy should be promoted [115]. Initiatives must be taken for further genotypic improvement [80]. Propagation is necessary for promoting nutritional ingredients [70]. Natural and anthropogenic factors have made species extinct; in this case, mass propagation can save the species from being lost [103]. Effective utilization of propagating materials for genetic resource conservation, heterosis exploitation, and off-season production should be implemented [93]. Understanding the genetic diversity for breeding programs and conservation is recommended [34]. High-quality tree species adoption, improved marketing practices, available and high-quality germplasm dissemination, management practice, and propagation should be undertaken [102]. Developing new cultivars is possible by breeding underutilized fruit species [117]. Molecular characterization, rare cultivar conservation, improved cultivar introduction, and biochemical analysis should be induced [134]. Programs on crop improvement adoption of appropriate agricultural practices for improving nutritional quality and adaptability should be undertaken [96]. Technological advancement is a prerequisite to elevating shelf life [79]. The screening treatments on draught screening and phenotyping in germplasm should be guided [94]. Optimization of processing methods should be encouraged for micronutrient evaluation [81]. Breeding initiatives could increase the consumption of underused legumes [139]. Evaluating different methods for constructing core germplasm collection can be practical [42]. The functionality of bioactive compounds and antioxidant activity could be increased by various processing methods to increase the effectiveness of underused vegetables [23]. Meanwhile, fermentation improved the nutritious value and leaf preservation of leafy crops, specifically *Cucurbita* sp. [47]. *Parkia roxburghii G. Don (yongchak)* seeds were processed using various ways namely ash, sodium bicarbonate, sugar and water, dry heating, and fermentation, which significantly reduced the anti-nutritional contents (tannins, saponins, phytate, trypsin inhibitors, lectins, chymotrypsin inhibitors), and consequently significantly increased protein, starch digestibility, minerals, protein, amino acids [147]. Domestication of species, namely Field cress (*Lepidium campestre* L.), can improve the foundational features [92]. It is vital to investigate species concerning environmental conditions [106]. Hence, technological advancement is an effective approach.

5.6. NUS verification

Verification needs execution to determine NUS preference. There are significant toxicity lies with NUS in aspects of natural toxins, allergenicity, anti-nutritional factors, heavy metals, and chemicals. It is quite evident that natural toxins underlie in plant species which could be harmful at certain levels of consumption such as beans containing lectins can affect health if not consumed without being cooked properly. While allergic reactions can impact certain individuals causing symptoms like rash and itching are common symptoms, and antinutritional factors within NUS interfere with nutrient absorption in the human body. The locality where NUS are grown in contaminated soil with heavy metals and pesticide residues can be contaminated with cadmium, mercury, and lead that potentially lead to harmful effects on the human body. In vitro analysis should be done to validate the effects of antioxidant compounds and biological functions [54]. The untouched parameters of the underutilized species should be explored [30]. Antioxidant potential fruit species should be evaluated [16]. Evaluation of wild germplasm with field species based on which best variety should be registered [74]. Antinutrient detection and consumption promotion of underutilized vegetables should be implemented [50]. Verifying the importance of species, medicinal and agricultural features, possible hazards, and health and nutritional characteristics are advised [53]. Further research on pathogenicity should be implemented [36].

5.7. Policy implications

Considering the overall recommended strategies, the policy implication is a must. Policy programs extension for nutritional benefits enlightenment [48] and clinical trials should be conducted [49]. It is vital to encourage the growth of the value chain and cultural aspects [38], which can broaden the range of local farmers' products. Some wild edible plants have the underutilized potential to contribute to women's diets significantly; therefore, it is a prerequisite to investigate those species' nutritional composition and dietary potential, market value, and integration into the existing farming system [148]. Policy on establishing the species development program and improving the seed delivery system for better conservation of germplasm [131]. Adoption of agricultural innovation for conservation practices, policy implications, and promotion of improved seed varieties should be considered [133].

5.8. Nutrition education

Public consciousness, government support, and a strong market structure are essential [22] for sustainable production, conservation, improving livelihood, and food security and nutrition education should be implemented [73]. Informing people of the nutritional values of root and tuber crops, product transformation, farmers' training, and permanent market establishment for neglected species could be initiated [39]. The documentation of nutritional properties is essential for the efficient conservation and management of dependent habitats and natural resources [77]. Exploration and collecting knowledge on nutritionally balanced neglected legumes can enhance nutrition and food

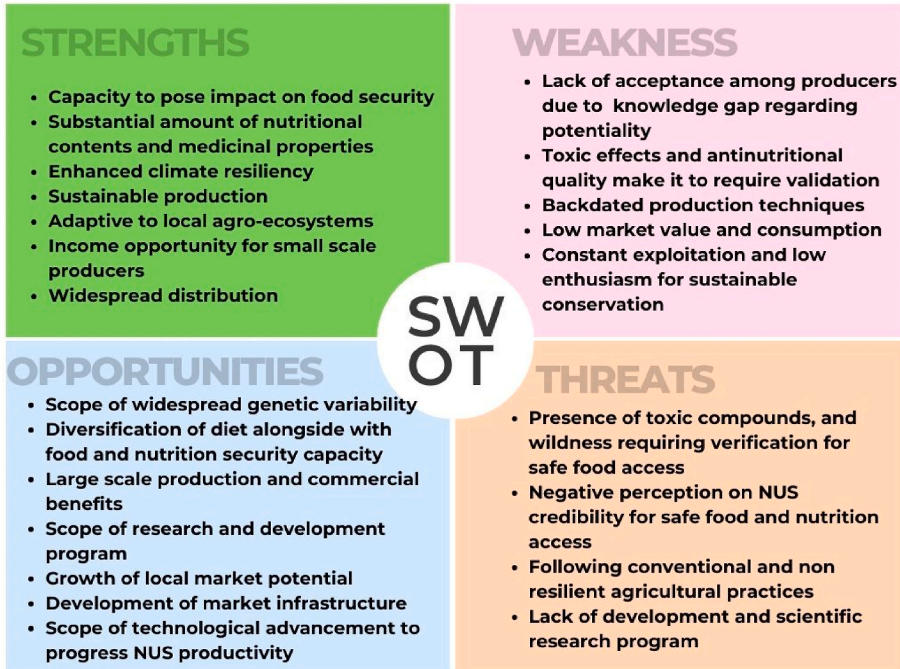

Fig. 8. SWOT Analysis on NUS for achieving SDG of "Zero Hunger".

security [147]. Existing knowledge improvement, intensive production, and promotion of diversified uses should be initiated [109]. Antioxidants, carbohydrates, phytochemicals, polyphenols, anthocyanin, carotenoids, tannin, and ascorbic acid were discovered in underutilized Indian fruits [125], indicating the further exploration of antioxidant mechanisms should be undertaken. Implementing more research, strategic policies, domestication, and raising local and public awareness need emphasis [45] to strengthen the food-securing capacity of respective underutilized and neglected species. Underutilized species and their intricately interconnected habitats should be the subject of a thorough inquiry [119]. Based on overall analysis Fig. 8, summarizes the overall SWOT analysis for NUS.

6. Conclusion

Neglected and underutilized species comprise significant portions of dietary nutrition in food-deficit countries with low income, including proteins, minerals, vitamins, medicinal qualities, etc. In areas where food availability is still limited, NUS can boost local diets and lessen the monotonous reliance on agricultural items. NUS can serve as the main source of nutrient-dense food frequently missing from essential staple crops. They contribute greatly to revenue creation, traditional and cultural heritage, and sustainable production because they need fewer inputs and managerial care. The extensive use of NUS attests to its greater genetic resources and potential to continue preserving genetic variety. Despite the wide-ranging possibilities, NUS is only little considered, and they are given the least attention. Adopting conservation policies, research and development initiatives, better management techniques, commercial production, technology advancements, and market infrastructure development are so necessary. Once NUS has been validated, it can be included in standard farming practices. Nutrition education should be required, and policy reforms should be enacted to advance NUS's investigation.

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The manuscript is not under consideration for publication elsewhere. The publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or any other language, including electronically without the written consent of the copyright holder.

CRediT authorship contribution statement

Mohammad Samiul Ahsan Talucder: Writing – review & editing, Validation, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization. **Umama Begum Ruba:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Md. Abu Sayed Robi:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis.

Declaration of competing interest

Authors declare no conflict of interest

Data availability

No data was used for the research described in the article.

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