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Research Article

POTENTIAL FUTURE SMART FOOD PLANT SPECIES NEGLECTED AND UNDERUTILIZED AT ZAKIGANJ OF SYLHET DISTRICT BANGLADESH

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Abstract

Neglected and underutilized plant species (NUPS), often referred to as future smart foods, hold immense potential for enhancing food security, nutritional diversity, and climate resilience in marginal environments. This study investigated the diversity, cultivation status, and adoption constraints of NUPS in homestead agroforestry systems at Zakiganj Upazila of Sylhet District in Bangladesh a subtropical, flood-prone region characterized by high rainfall (2,540–3,810 mm annually) and acidic soils. Using a survey-based design, data were collected through face-to-face interviews with 120 randomly selected respondents across nine unions from January to June 2025 at Zakiganj Upazila. Though the NUPS are in the verse of extinction, results revealed that still 58.3% of households cultivating them primarily due to their climate tolerance (31.7%), low input requirements (28.3%), and local availability (25.0%). Key information sources of neighbors (29.2%) and extension workers (25.0%) showed major constraints comprised of lack of knowledge (38.3%), limited seed availability (25.0%), and perceived low yields (21.7%). Only 45.8% of respondents had received relevant training. Biodiversity analysis of the seven dominant NUPS (betel nut, mulberry, bonkochu, toikor, lukluki, shaplagota, and jaralebu) showed exceptionally high diversity, with a Shannon-Weaver Index (H′) of 1.9360 (near maximum 1.9459), evenness of 0.9949, and Simpson's Index of Diversity (1–D) of 0.8544, indicating balanced species distribution. These findings highlighted the critical and important role of traditional homegardens in conserving resilient, nutrient-dense NUPS amid a lot of climate stresses. Improving knowledge gaps, seed systems, and extension services are essential to mainstream these orphan crops, which in turn, will support dietary diversification, hidden hunger mitigation, and sustainable agriculture in the vulnerable regions of Bangladesh.

Introduction

Neglected and underutilized plant species (NUPS), also termed orphan crops or Future Smart Foods, comprise of diverse wild, semi-domesticated, and under little attention of research domain exhibiting exceptional climate resilience, nutrient density, and adaptability to marginal environments, positioning them as vital resources for enhancing food security, dietary diversity, and sustainable agriculture amid escalating climatic pressures (Li and Siddique, 2018; Borelli et al., 2020). Global agri-food systems depend predominantly on three staples like rice, wheat, and maize which are collectively supplying over 50% of human caloric intake, fostering vulnerability to stresses, agro-biodiversity loss, and dietary monotony linked to micronutrient deficiencies (Khoury et al., 2014; Talucder et al., 2024). Zakiganj Upazila of Sylhet district of Bangladesh, a subtropical flood-prone region with high rainfall (2,500–4,000 mm annually),

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acidic soils and having of a number of NUPS such as taro (*Colocasia esculenta*), water spinach (*Ipomoea aquatica*), and millets integrate well into homestead agroforestry, requiring minimal inputs and tolerating abiotic stresses (Mabhaudhi et al., 2019; Padulosi et al., 2013). NUPS surpass major staples in nutritional profiles, delivering elevated micronutrients (iron, zinc, calcium), dietary fiber, proteins, and bioactive compounds that mitigate hidden hunger and non-communicable diseases. Finger millet (*Eleusine coracana*), for instance, contains up to 364 mg calcium per 100 g—approximately three times that of milk along with antioxidants and resistant starch beneficial for glycemic control and bone health (Kumar et al., 2016; Puranik et al., 2021). Many NUPS also possess ethno-medicinal properties, amaranth (*Amaranthus* spp.) exhibits anti-inflammatory and antioxidant effects, indigenous legumes like cowpea provide hepato-protective compounds, and species such as moringa and Bambara groundnut offer antimicrobial, antidiabetic, and antihypertensive bioactives, supporting traditional therapies while addressing oxidative stress and chronic conditions prevalent in resource-limited settings (Mudau et al., 2022; Hunter et al., 2019). Despite these attributes, barriers like limited research, policy neglect, seed access constraints, and eroding traditional knowledge often custodian by women impede mainstreaming (Tadele, 2019; Chivenge et al., 2015). Thus, research in genomic advancements of NUPS and FAO's Future Smart Food Initiative which prioritize nutrient-dense, resilient and attaining SDG 2 (Zero Hunger) through diversified systems are needed proper attention for future food demand fulfillment (Chiurugwi et al., 2019; Li and Siddique, 2020). This piece of research work tries to focus on these objectives.

Materials and methods:

Study Area

The study was conducted at Zakiganj Upazila of Sylhet District, Bangladesh, a region well known for its rich homestead agroforestry systems and high plant biodiversity. Zakiganj belongs to one of the 30 agro-ecological zones of Bangladesh and represents a prominent area for traditional homegarden agroforestry practices, making it suitable for exploring Neglected and Underutilized Plant Species (NUPS) as future smart foods. Geographically, the upazila is located between 24°51′–25°00′ N latitude and 92°13′–92°30′ E longitude. It is bordered by Kanaighat Upazila and Meghalaya State of India to the North, Assam State of India to the South and East, and Beanibazar Upazila to the West. Administratively, Zakiganj comprises of nine union parishads: Barahal, Barathakuri, Birorsri, Kajalshar, Khaskanakpur, Kolachora, Manikpur, Sultanpur, and Zakiganj (Alam et al., 2014). A location map of the study area is shown in Fig. 1.

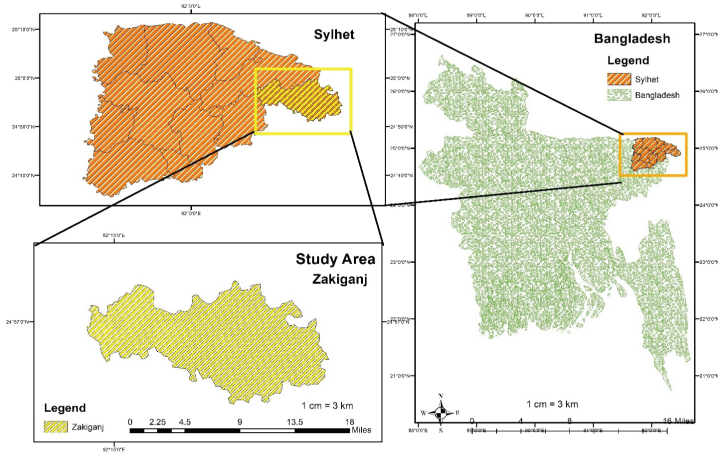

Figure 1. Study area map.

Physiography and Climate

Physiographically, Zakiganj falls under the Northern and Eastern Hill unit and the High Hill or Mountain Ranges sub-unit of Bangladesh. The landscape is dominated by hogback ridges with steep western scarps, cliffs, and occasional waterfalls. The area experiences a tropical monsoon climate with mean annual rainfall ranging from approximately 2,540 mm to 3,810 mm. Three distinct seasons prevail: a cool and dry season (November–March), a hot pre-monsoon season (April–May), and a warm, humid monsoon season (June–October). The soils are mainly dystric cambisols, characterized by yellowish-brown to reddish-brown loams and strongly acidic conditions, which favor the growth of several NUPS adapted to marginal environments (Haque et al., 2025).

Research Design and Sampling Procedure

A survey-based research design was adopted, as most rural households do not maintain formal records of farming activities. The study followed systematic steps including selection of the study area, identification of relevant variables, sampling of respondents, construction of survey instruments (questionnaire), data collection, processing, and analysis. Simple random sampling was used to select respondents. A total of 120 respondents were selected from the nine unions of Zakiganj Upazila. From each union, average 13 respondents were randomly chosen to ensure representative coverage of homestead agroforestry practitioners.

Survey Instrument and Data Collection

A semi-structured questionnaire containing both open- and closed-ended questions was developed in line with the study objectives. The questionnaire was pre-tested and revised based on feedback from the research supervisor to ensure clarity, logical sequencing, and relevance. Data were collected through face-to-face interviews conducted in Bengali to minimize response errors. Interviews were carried out at respondents' homes or fields during their leisure time. Data collection took place from January to June 2025, and each completed questionnaire was carefully checked for consistency and completeness.

Variables of the Study

The number of Neglected and Underutilized Plant Species (NUPS) present in homestead agroforestry systems was considered the dependent variable. Selected socio-economic characteristics were treated as independent variables.

Measurement of Dependent Variable

NUPS distribution was assessed by directly counting the number of NUPS species present in homestead agroforestry systems through field observation and respondent consultation. Species availability, abundance, and distribution patterns were documented during repeated field visits.

Data Processing and Statistical Analysis

Collected data were coded, tabulated, and analyzed in accordance with the study objectives. Descriptive statistics such as frequency, percentage, mean, standard deviation, and ranking were used to summarize respondent characteristics and NUPS status. Pearson's Product Moment Correlation Coefficient (r) was employed to examine relationships between independent variables and NUPS distribution using MS Excel and SPSS software.

Biodiversity Indices

Plant species diversity was quantified using the Shannon–Weaver Diversity Index (H′) and Simpson's Diversity Index. The Shannon–Weaver Index was calculated based on species relative abundance to assess overall diversity. Simpson's Index was used to measure species dominance and concentration, where higher values indicate greater diversity (Simpson, 1949).

Results

Agricultural Practices and Main Crops

Farmers at Zakiganj Upazila practiced a diversified cropping system, with vegetables emerging as the most frequently cultivated crop (26.7%), followed by rice (23.3%), jute (20.8%), tea (16.7%), and maize (12.5%) (Table1). This pattern reflects a combination of staple food production, cash crop cultivation, and market-oriented vegetable farming.

Table 1. Main crops grown by respondents in Zakiganj Upazila (n=120)

Crop	Frequency	Percentage (%)
Vegetables	32	26.7
Rice	28	23.3
Jute	25	20.8
Tea	20	16.7
Maize	15	12.5

Adoption and Cultivation Status of Neglected and Underutilized Plant Species (NUPS)

The study findings present a comprehensive overview of the cultivation, drivers, constraints, and perceptions surrounding Neglected and Underutilized Plant Species (NUPS). As indicated in Table 2, a majority of respondents (58.3%) were engaged in NUPS cultivation. Their primary motivations, also detailed in Table 2, were the species' climate tolerance (31.7%), low input requirements (28.3%), and easy availability (25.0%), underscoring their value as pragmatic adaptations to challenging agricultural environments. Information regarding these crops was primarily obtained through informal and formal local networks, with neighbors (29.2%) and extension workers (25.0%) being the key sources, as shown in Table 2. However, significant adoption barriers were prevalent. Table 2 identifies a critical "lack of knowledge" as the foremost constraint (38.3%), compounded by limited seed availability (25.0%) and a perception of low yield (21.7%). This knowledge gap is further reflected in the support and training landscape. While NGOs (37.5%) and government agencies (29.2%) were the main sources of support (Table 2), a substantial 33.3% of farmers received no assistance. Correspondingly, Table 2 reveals that only 45.8% of respondents had received NUPS-related training, leaving a majority without formal guidance. Interestingly, farmers' perceptions of NUPS climate resilience, presented in Table 2, were varied but cautious, with the largest group (37.5%) perceiving only "moderate" resilience, followed by "low" (33.3%) and "high" (29.2%) resilience.

Table 2. Farmers' Practices, Constraints, Support, and Climate Resilience Perception of NUPS in Zakiganj, Sylhet (n=120)

Farmers' Perception NUPS	Frequency	Percentage
Cultivation status of NUPS among respondents		
Yes	70	58.3
No	50	41.7
Reasons for cultivating NUPS		
Climate tolerant	38	31.7
Low input requirements	34	28.3
Easily available	30	25.0
Nutritious	18	15.0
Sources of information on NUPS		
Neighbors	35	29.2
Extension workers	30	25.0
Mass media (TV/Radio)	25	20.8
NGOs	20	20.0
Major constraints to NUPS adoption		
Lack of knowledge	46	38.3
Limited seed availability	30	25.0
Low yield perception	26	21.7
Poor market access	18	15.0
Sources of support for NUPS cultivation		
NGOs	45	37.5
Government	35	29.2
Receipt of NUPS-related training		
Yes	55	45.8
No	65	54.2
Farmers' perception of NUPS climate resilience		
Moderate	45	37.5
Low	40	33.3
High	35	29.2

NUPS Cultivation Status

The study documented a diverse range of 16 neglected and underutilized plant species (NUPS) being cultivated in Zakiganj, Sylhet, with varying degrees of prevalence (Table 3). Betel nut (*Areca catechu*) emerged as the most commonly cultivated NUPS, with 8.3% (n=10 each) of respondents reporting its cultivation, likely due to its cultural significance and economic value in the region. Other notable species included Toikor (*Garcinia pedunculata*) and Huilka (*Phlogacanthus thyrsiflorus*), each representing 6.7% (n=8 each) of responses, followed by Mulberry (Morus spp.) and Shim/Uri (*Lablab purpureus*) at 5.8% (n=7 each). Several species – including Paloisak (Basella alba), Linseed (*Linum usitatissimum*), Bilatidhonia (*Eryngium foetidum*), Lukluki (*Leea macrophylla*), Bonkochu (*Piper chaba*), Jara lebu (*Citrus assamensis*), Shapla gota (*Nymphaea nouchali*), Kechor (*Artocarpus lacucha*), Watermelon (*Citrullus lanatus*), Mon (*Clerodendrum viscosum*), and Defol showed moderate cultivation (4.2–5.0%, n=5–6 each). The findings highlight that while betel nut dominates as the most prevalent NUPS, the community maintains considerable agro-biodiversity by cultivating multiple underutilized species, each likely serving distinct nutritional, medicinal, or economic purposes.

Table 3. Presence of NUPS at Zakiganj

Species	Frequency	Percentage
Lukluki	5	4.2
Mulberry	5	4.2
Bonkochu	6	4.7
Jara lebu	5	4.2
Toikor	6	5.0
Shapla gota	5	4.2
Betle nut	10	8.7
Watermelon	5	4.2
Linseed	6	5.0
Bilatidhonia	6	5.0
Mon	5	4.2
Shim/uri	7	5.8
Defol	5	4.2
Total	**120**	**100.0**

Species Diversity Indices

Based on the analysis of the seven most abundant NUPS (total observations=78), the diversity was found to be remarkably high. The calculated value of Shannon-Weaver Index (H') was found 1.9360 (Table 4) which was very close to the theoretical maximum (H'max=1.9459) for seven species. This near-maximum value, coupled with a species evenness (E) of 0.9949 (Table 10), indicates an extremely balanced and equitable distribution of observations among the dominant species. The individual contributions to the total H' value, detailed in Table 10, show that Betel Nut (frequency=14) made the largest contribution (0.3082), followed closely by Mulberry and Bonkochu (0.2879 each), with the remaining species Toikor, Lukluki, Shapla gota, and Jara lebumaking progressively smaller but still substantial contributions.

Table 4. Shannon-Weaver diversity indices for dominant NUPS

Species	Frequency	Proportion (p_i)	p_i × ln(p_i)	Contribution to H'
Betel Nut	14	0.1795	-0.3082	0.3082
Mulberry	12	0.1538	-0.2879	0.2879
Bonkochu	12	0.1538	-0.2879	0.2879
Toikor	11	0.1410	-0.2762	0.2762
Lukluki	10	0.1282	-0.2633	0.2633
Shapla gota	10	0.1282	-0.2633	0.2633
Jara lebu	9	0.1154	-0.2492	0.2492
Total	78	1.0000		1.9360
Shannon-Weaver Index (H')	1.9360			
Species richness (S)	7			
Maximum diversity (H'max)	1.9459			
Evenness (E)	0.9949			

Simpson's diversity indices for dominant NUPS

This analysis further confirms the high diversity within the dominant NUPS. As shown in Table 5, Simpson's Index (D) is 0.1456, with the complementary Simpson's Index of Diversity (1-D) being 0.8544. This high value for 1-D indicates a very low probability (approximately 14.56%) that two randomly selected observations are of the same species, reinforcing the finding of high species diversity. The near-perfect evenness value of 0.9968 aligns with the Shannon-Weaver results, demonstrating an extremely uniform distribution of individuals across the seven species. Mulberry contributes the most to the Simpson's Index value (0.0322), consistent with its highest frequency, yet this contribution remains small relative to the total, reflecting the balanced community structure. Together with the previous Shannon-Weaver analysis, these indices provide robust evidence that the cultivated NUPS are characterized both by high species richness and exceptional equitability.

Table 5. Simpson's diversity indices for dominant NUPS

Species	Frequency	Proportion (p_i)	p_i^2	Contribution to D
Mulberry	14	0.1795	0.0322	0.0322
Betel nut	12	0.1538	0.0237	0.0237
Bonkochu	12	0.1538	0.0237	0.0237
Toikor	11	0.1410	0.0199	0.0199
Lukluki	10	0.1282	0.0164	0.0164
Shapla gota	10	0.1282	0.0164	0.0164
Jara lebu	9	0.1154	0.0133	0.0133
Total	78	1.0000		0.1456
Simpson's Index (D)	0.1456			
Simpson's Index of Diversity (1–D)	0.8544			
Species richness (S)	7			
Evenness (E_D)	0.9968			

Discussion

The findings of neglected and underutilized plant species (NUPS) in Zakiganj Upazila reveal a robust integration of homestead agroforestry systems, where 58.3% of respondents are actively cultivating them primarily for their climate tolerance (31.7%) and low input requirements (28.3%). These align with global recognition of NUPS as future smart foods resilient to abiotic stresses in marginal environments like the flood-prone, acidic soils of Sylhet (Mabhaudhi et al., 2019; Padulosi et al., 2013). The remarkably high Shannon-Weaver Diversity Index ($H' = 1.9360$, near to the maximum 1.9459 for seven species) and evenness ($E = 0.9949$), along with Simpson's Index of Diversity ($1–D = 0.8544$), indicated exceptional equitability among dominant species such as betel nut (*Areca catechu*), mulberry (*Morus spp.*), bonkochu (*Piper chaba*, likely a wild taro variant), toikor (*Garcinia pedunculata*), lukluki (*Leea macrophylla*), shaplagota (*Nymphaea* spp. seeds), and jaralebu (*Citrus medica*). These locally adapted taxa, often semi-domesticated or wild-harvested in Bangladeshi homesteads, exemplify underutilized resources with superior nutritional rich profile in micronutrients, fiber, and bio-actives compared to staple monocultures (Li and Siddique, 2020; Borelli et al., 2020). However, adoption barriers including lack of knowledge (38.3%), seed scarcity (25.0%), and limited training (only 45.8% received guidance) are the major limitations and widespread constraints which are eroding traditional knowledge and limiting mainstreaming (Tadele, 2019; Alam, 2023; Ruba & Talucder, 2023). Farmers' cautious perception of moderate-to-low climate resilience (70.8%) underscores the

need for targeted extension, despite inherent adaptations. Promoting these NUPS through policy support, seed systems, and value-chain development could enhance dietary diversity, mitigate hidden hunger, and booster agro-biodiversity in vulnerable subtropical regions, directly contributing to SDG 2 (Zero Hunger) and sustainable agriculture amid climate change (Ali and Bhattacharjee, 2023; Hossain et al., 2021). Thus, the findings indicate future research prioritization in genomic characterization and participatory breeding to elevate these orphan crops from local homesteads to resilient food systems.

Conclusion

The study areas of Zakiganj Upazila, Sylhet District, Bangladesh, demonstrates that neglected and underutilized plant species (NUPS) are truly integrated with homestead agroforestry systems, with over half of the respondents (58.3%) actively cultivating them due to their climate resilience, low input needs, and local availability. The exceptionally high species diversity (Shannon-Weaver Index H′ = 1.9360; Simpson's 1–D = 0.8544) and equitable distribution among dominant taxa such as betel nut, mulberry, bonkochu, toikor, lukluki, shaplagota, and jaralebu highlight the rich agrobiodiversity conserved in traditional home gardens of this area. Despite these strengths, significant constraints including lack of knowledge, limited seed access, inadequate training, and cautious perceptions of resilience hinder wider adoption and mainstreaming. These findings underscore the potential of NUPS as future smart foods for enhancing nutritional security, dietary diversity, and climate-adapted agriculture in flood-prone subtropical regions of Bangladesh. It could be said that targeted interventions to overcome knowledge and seed system gaps can elevate these orphan crops from marginal status to key components of sustainable food systems, contributing directly to SDG 2 (Zero Hunger) and climate resilience. The findings of this research focus for future studies on comprehensive nutritional profiling and ethno botanical documentation of the identified dominant NUPS to quantify their micronutrient and bioactive content. Participatory varietal selection and on-farm trials could improve yield and market acceptability. Genomic characterization and breeding programs tailored to local acidic, flood-prone soils would enhance resilience and productivity. Additionally, research on value-chain development, gender integration of knowledge transmission, and policy frameworks for seed systems and extension services are essential to facilitate scaling and mainstreaming of these climate-smart, nutrient-dense species across similar agro-ecological zones in Bangladesh and beyond.

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