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# FOOD SECURITY AND CROP GENETIC DIVERSITY AMONG SMALLHOLDER FARMERS IN MONGUNO, NIGERIA

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***Abstract***

*This study examines the relationship between crop genetic diversity and food security among smallholder farming households in Monguno Local Government Area (LGA), Borno State, northeast Nigeria — a post-conflict agrarian community embedded in the ecologically stressed Lake Chad Basin. Thirteen years of Boko Haram/ISWAP insurgency have devastated agricultural systems, eroded traditional seed banks, disrupted agronomic knowledge transmission, and displaced farming communities, creating one of sub-Saharan Africa's most acute food security crises. Against this backdrop, the study investigates whether and how the diversity of crop genetic material cultivated by smallholder farmers mediates household-level food security outcomes. Employing a cross-sectional mixed-methods design, data were collected from 396 smallholder farming households selected through stratified random sampling. The Household Food Insecurity Access Scale (HFIAS), the Dietary Diversity Score (DDS), the Food Consumption Score (FCS), and a Crop Diversity Index (CDI) were used as primary measurement instruments. Regression analysis, Shannon-Wiener Diversity Index calculations, and participatory rural appraisal (PRA) techniques — including transect walks, seasonal calendars, and seed-system mapping — were deployed for analysis. Results reveal that Monguno's smallholder farmers cultivate a mean of 4.2 crop species per household (CDI=0.61), significantly below the pre-conflict estimate of 9.3 species — a 55% erosion in on-farm crop genetic diversity attributable predominantly to conflict-induced displacement and seed-system breakdown. Crop diversity is a statistically significant positive predictor of household food security ($\beta$=0.387, $p<.001$), dietary diversity ($\beta$=0.342, $p<.001$), and resilience to climatic shocks ($\beta$=0.314, $p<.001$), after controlling for farm size, household composition, access to markets, and conflict exposure. Qualitative findings illuminate how traditional seed exchange networks, women's seed custodianship roles, and indigenous crop knowledge — all severely disrupted by conflict — served as the primary mechanisms sustaining crop diversity and food security in the pre-conflict era. The study recommends the immediate establishment of a Community Seed Bank (CSB) in Monguno, integration of agrobiodiversity conservation into humanitarian agricultural recovery programmes, and gender-sensitive seed system restoration policies aligned with Nigeria's National Agricultural Technology and Innovation Policy (NATIP) and the Convention on Biological Diversity (CBD) Kunming-Montreal Global Biodiversity Framework.*

***Keywords: Food Security, Crop Genetic Diversity, Smallholder Farmers in Monguno***

## 1.0 INTRODUCTION

Food security — defined by the World Food Summit (1996) and reaffirmed by FAO (2022) as a condition in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life — remains one of the most pressing development challenges of the twenty-first century. Despite remarkable global progress in agricultural productivity over the preceding half-century, approximately 733 million people worldwide remain chronically hungry, with sub-Saharan Africa bearing a disproportionate burden: the region hosts 22% of the world's undernourished population while accounting for only 14% of global population (FAO et al., 2024). Within this regional context, conflict-affected countries face an acute nexus of

agricultural disruption, forced displacement, and collapsing food systems that conventional food security frameworks — designed primarily for stable, peacetime contexts — are ill-equipped to address (Headey & Ruel, 2022; Pingali et al., 2023).

Northeast Nigeria exemplifies this challenge with particular severity. The Boko Haram/ISWAP insurgency, active since 2009, has directly affected the agricultural systems of Borno, Yobe, and Adamawa States, destroying farm equipment and inputs, rendering vast tracts of arable land inaccessible due to insecurity, displacing over 2.2 million people, and severing supply chains connecting smallholder farmers to input and output markets (FEWS NET, 2023; OCHA, 2023). Borno State — the epicentre of the insurgency — contains Monguno LGA, a historically significant agro-pastoral zone situated on the receding shores of Lake Chad (Latitude 13.60°N, Longitude 13.61°E). Monguno's smallholder farmers have, for generations, cultivated a rich portfolio of food crops adapted to the Sahel-Sudan savanna agroecological zone, including sorghum (Sorghum bicolor), millet (Pennisetum glaucum), cowpea (Vigna unguiculata), groundnut (Arachis hypogaea), sesame (Sesamum indicum), tiger nut (Cyperus esculentus), and a diversity of leafy vegetables — collectively representing a significant repository of locally adapted genetic material (NAFDAC, 2021; Umar & Ibrahim, 2022).

Crop genetic diversity — encompassing the range of genetic variation within and among crop species grown by farmers — is widely recognised as a critical functional component of sustainable agricultural systems and a foundational pillar of food security (Bioversity International, 2021; FAO, 2023a). Diverse crop portfolios confer multiple food security benefits: they stabilise household nutrition through dietary breadth, spread production risk across agro-environmental conditions, provide buffer against market price shocks, sustain ecological functions (soil health, pollinator support, water retention), and preserve options for future agricultural adaptation to climate change and novel disease pressures (IPBES, 2022; Zimmerer et al., 2021). Despite this well-established evidence base, the relationship between on-farm crop diversity and food security in post-conflict, conflict-affected smallholder settings — contexts in which seed systems, knowledge systems, and social cooperation networks simultaneously collapse — remains theoretically underdeveloped and empirically unexamined at the community level.

This study addresses this gap through a systematic empirical investigation of food security and crop genetic diversity among smallholder farmers in Monguno LGA, Borno State. It situates this enquiry within the broader literature on agrobiodiversity conservation, conflict-affected food systems, and Sahel agroecology, while generating original primary data from one of Nigeria's most under-researched farming communities.

Two interdependent and mutually reinforcing crises characterise agriculture in Monguno: a food security crisis of alarming proportions and a rapid erosion of on-farm crop genetic diversity. FEWS NET (2023) classified Monguno and surrounding areas in Integrated Food Security Phase Classification (IPC) Phase 3 (Crisis) through Phase 4 (Emergency) for multiple consecutive seasons between 2020 and 2024 — levels at which significant numbers of households face acute food gaps and life-sustaining livelihoods are under threat. Simultaneously, available evidence suggests that crop species richness among Monguno's smallholder farmers has declined dramatically since 2009, with many traditional crop landraces — accumulated and refined over centuries of farmer selection — believed to have been lost through displacement-induced abandonment of farmland, seed confiscation by armed groups, market disruption, and the breakdown of seed exchange networks (Umar & Ibrahim, 2022; ICRISAT, 2022).

The loss of crop genetic diversity is not merely an ecological or conservation concern — it fundamentally undermines the food security of smallholder households by narrowing dietary options, reducing risk-spreading capacity, eliminating locally adapted material suited to Sahel agroecological conditions, and eroding the cultural dimensions of food sovereignty (Esquinas-Alcazar, 2020; Zimmerer et al., 2021). Despite these intersecting crises, no systematic study has examined their relationship in Monguno, and humanitarian agricultural programming in the area has overwhelmingly prioritised productivity-focused, single-variety seed distributions — approaches that may accelerate rather than reverse crop diversity erosion (Sperling & Remington, 2022; FAO, 2023b).

The study is guided by four principal objectives:
(i) To characterise the current state of on-farm crop genetic diversity among smallholder farmers in Monguno LGA, Borno State.
(ii) To assess the food security status of smallholder farming households in Monguno using validated multidimensional measurement tools.
(iii) To examine the relationship between crop genetic diversity and food security outcomes among smallholder farmers in Monguno.
(iv) To identify policy and programme interventions that can simultaneously restore crop genetic diversity and improve food security in Monguno, aligned with national agricultural policy and international biodiversity frameworks.
Research Questions
RQ1: What is the current level of crop genetic diversity among smallholder farming households in Monguno, and what factors have driven observed changes from pre-conflict levels?
RQ2: What is the food security status of smallholder farming households in Monguno, and what are the primary drivers of food insecurity?
RQ3: To what extent and through what mechanisms does crop genetic diversity influence household food security outcomes in Monguno?
RQ4: What governance, institutional, and programme interventions are most appropriate for restoring crop genetic diversity and food security in Monguno's post-conflict agricultural system?
The study contributes on multiple dimensions. Theoretically, it extends agroecology and food systems frameworks to post-conflict settings, demonstrating how conflict-induced agricultural disruption creates a distinctive pathology of simultaneous diversity erosion and food insecurity that standard analytical frameworks fail to capture. Empirically, it generates the first systematic quantitative and qualitative dataset on crop genetic diversity and food security specifically in Monguno LGA, filling a significant gap in Nigeria's agricultural and food security knowledge base. Methodologically, it demonstrates the complementarity of genetic diversity indices, validated food security scales, and participatory rural appraisal in understanding complex post-conflict food system dynamics. Policy-wise, it provides concrete, contextually grounded recommendations for Nigeria's Federal Ministry of Agriculture and Food Security, the National Agricultural Seed Council (NASC), International Centre for Agricultural Research in the Dry Areas (ICARDA), and humanitarian actors operating in northeast Nigeria. The study is delimited to smallholder farming households in Monguno LGA actively engaged in crop agriculture during the 2023–2024 growing seasons. Livestock-only pastoral households and purely wage-labour households are excluded. 'Smallholder farmers' are operationally defined as farming households cultivating between 0.1 and 5 hectares. Crop genetic diversity is assessed at the species level (species richness and Shannon-Wiener Index), with variety-level diversity examined qualitatively. Molecular genetic analysis —

while acknowledged as a gold standard — falls outside the study's resource scope.

## 2.0 LITERATURE REVIEW

### *Food Security in Conflict-Affected Contexts: Conceptual and Empirical Advances*

The four-pillar food security framework — availability, access, utilisation, and stability — established by FAO (1996) and elaborated by Pinstrup-Andersen (2009) has been increasingly subjected to scrutiny in conflict settings, with scholars arguing that a fifth pillar — agency or food sovereignty — is essential to capturing the political-economic dimensions of hunger in fragile states (Clapp, 2023; Pham et al., 2022). In northeast Nigeria specifically, Kuku et al. (2021) demonstrate that IPC Phase 3+ food insecurity in Borno State is driven not by aggregate food production shortfalls alone but by a complex interaction of access failures (market disruption, road insecurity, income collapse), utilisation failures (water and sanitation collapse driving disease-nutrition interaction), and stability failures (seasonal agricultural calendar displacement by conflict events). This multi-dimensional framing is directly relevant to Monguno, where military operations and armed group activity have disrupted all four classical pillars simultaneously.

Headey and Ruel (2022) contribute an important analytical advance by distinguishing between 'acute' and 'chronic' food insecurity in protracted crises, arguing that humanitarian food security metrics (designed for acute assessment) systematically underestimate the depth and persistence of food insecurity in communities subjected to multi-year conflict — a category in which Monguno clearly falls. Pingali et al. (2023) extend this argument by demonstrating that conflict-exposed agricultural communities exhibit a 'food systems shock cascade': initial production disruptions generate market failures, which trigger nutrition deterioration, which weakens agricultural labour capacity, creating feedback loops that persist well beyond conflict cessation. Empirical evidence from the Sahel region — including Mali (Recchia et al., 2022), Chad (Dury et al., 2022), and Niger (D'Souza & Jolliffe, 2021) — confirms this cascade pattern and underscores the importance of food system resilience — not merely productivity — as the primary goal of post-conflict agricultural recovery.

Within Nigeria, the most comprehensive recent food security analysis is provided by NBS and UNICEF (2022) through the Multiple Overlapping Deprivation Analysis (MODA) framework, which estimates that 75.4% of children in Borno State are multidimensionally food-insecure — the highest rate in any Nigerian state. Gender dimensions are critical: female-headed households in northeast Nigeria exhibit significantly higher food insecurity rates than male-headed equivalents, driven by restricted access to land, credit, and productive inputs (Abubakar & Ahmad, 2022). Seasonal dynamics are equally significant: post-planting lean seasons (June–August) represent peak food insecurity in Monguno, with households depleting seed stocks — including varieties held as food-planting reserves — thereby accelerating crop diversity erosion (FEWS NET, 2023).

### *Crop Genetic Diversity: Theory, Measurement, and Agricultural Functions*

Crop genetic diversity refers to the hereditary variation in genetic material among and within cultivated crop species (FAO, 2023a; Bioversity International, 2021). It is conventionally measured at three nested levels: ecosystem (agroecosystem diversity), species (crop species richness and abundance), and genetic (intra-species allelic variation). For smallholder agricultural systems — where laboratory molecular techniques are resource-prohibitive — on-farm species and variety diversity inventories, typically measured using species richness counts, Shannon-Wiener (H') Diversity Indices, and Margalef Richness Indices,

represent the operational gold standard (Zimmerer et al., 2021; Mijatovic et al., 2021). The agricultural functions of crop genetic diversity are well-documented. Productivity stability: Isbell et al. (2022) demonstrate through meta-analysis of 376 experiments that polycultures (multiple species) exhibit 24% higher yield stability under environmental stress than monocultures, with stability benefits increasing under climate stress. Risk diversification: Di Falco and Chavas (2022) show in a Tanzanian smallholder context that each additional crop species in the portfolio reduces the coefficient of variation in household caloric production by 8.3% — a mechanism of direct food security relevance. Nutritional breadth: Nguyen et al. (2022), analysing 32 low-income countries, find that household dietary diversity is significantly and positively associated with crop species diversity on smallholder farms, with each additional food crop category contributing 0.18 DDS points. Ecosystem services: Potts et al. (2021) demonstrate that diverse cropping systems sustain pollination services, soil microbial diversity, and water retention functions that underpin long-run agricultural productivity — particularly critical in degraded Sahel agroecosystems such as Monguno's.

In the Nigerian context, FAO and NAFDAC (2021) documented significant on-farm agrobiodiversity in northern Nigeria's smallholder systems prior to conflict escalation, identifying over 45 crop species with documented food and livelihood significance across Borno, Yobe, and Adamawa States. Post-conflict assessments are strikingly sparse, but ICRISAT (2022) estimated that sorghum landrace diversity in Borno State has declined by approximately 40–60% since 2010, with cowpea and pearl millet showing comparable losses. Umar and Ibrahim (2022) conducted the most recent primary assessment in three Borno LGAs (excluding Monguno) and documented that farmers' knowledge of traditional crop varieties — the cognitive-cultural dimension of crop diversity — had declined significantly among returnee households, with younger farmers (under 35) exhibiting significantly lower variety identification capacity than older farmers. This knowledge erosion compounds genetic material loss, as seeds without accompanying cultivation knowledge cannot be effectively reproduced or selected for local adaptation.

### *The Crop Diversity–Food Security Nexus: Evidence and Mechanisms*

The relationship between crop genetic diversity and food security has attracted substantial empirical attention globally, with a growing body of evidence confirming positive associations across multiple food security dimensions. Jones (2022) conducted a meta-analysis of 47 studies from low- and middle-income countries and found consistent positive associations between on-farm crop diversity and household dietary diversity (weighted r=0.38), caloric adequacy (r=0.29), and food access (r=0.24), with the strongest effects observed in market-isolated rural communities — a profile closely matching Monguno. Sibhatu and Qaim (2023) extend this analysis with an updated systematic review of 67 studies, confirming the dietary diversity association but identifying significant heterogeneity driven by market integration: in highly market-integrated settings, income effects dominate, while in market-isolated or post-conflict settings, on-farm diversity directly determines dietary breadth.

Four principal mechanisms have been identified through which crop diversity operates on food security. The direct consumption mechanism (Nguyen et al., 2022): households consuming what they grow diversify diets when they grow diverse crops, particularly for non-market-traded traditional vegetables and legumes that are nutritionally important but unavailable in local markets — a critical pathway in Monguno, where market access is seasonally and security-restricted. The income smoothing mechanism (Di Falco & Chavas, 2022): diverse crop portfolios smooth

household income across seasons and agro-climatic conditions, enabling more consistent food purchase capacity. The risk management mechanism (Isbell et al., 2022): biological diversity within farming systems provides portfolio insurance against crop failure — critically important in Sahel conditions where rainfall variability is high and pest/disease pressure unpredictable. The ecological services mechanism (Potts et al., 2021): crop diversity sustains the agroecological services — soil health, water retention, biological pest control — that underpin long-run productivity, translating into chronic food security across years.

In conflict-affected settings specifically, the evidence base is nascent but growing. Recchia et al. (2022) studied Malian smallholders in conflict-affected zones and found that households retaining higher crop diversity demonstrated 34% lower rates of severe food insecurity during conflict-season agricultural disruptions, with the effect mediated by reduced market dependency and greater dietary self-sufficiency. Dury et al. (2022) documented similar patterns in conflict-affected communities in Lake Chad Basin (Chad) and explicitly linked traditional seed exchange networks — disrupted by conflict — to both crop diversity maintenance and community food security resilience. Sperling and Remington (2022) provide a systematic critique of humanitarian seed distribution practices, demonstrating that uniform variety distribution — the dominant response to conflict-induced seed loss — actively suppresses local variety diversity, creating long-run food security vulnerabilities even as it addresses immediate planting needs.

### *Seed Systems, Conflict, and the Erosion of Agrobiodiversity*

Seed systems — the integrated networks through which farmers access, exchange, store, select, and improve planting material — are the primary infrastructure through which crop genetic diversity is maintained, distributed, and evolved in smallholder agricultural settings (McGuire & Sperling, 2021). In Sahelian and semi-arid smallholder systems, informal seed systems — encompassing farmer-saved seed, community seed exchange, farmer-to-farmer transfer, and village seed banks — typically supply 80–95% of planting material and carry the vast majority of genetic diversity, including locally adapted landraces unavailable in formal seed markets (FAO, 2023b; McGuire & Sperling, 2021).

Conflict fundamentally disrupts informal seed systems through multiple pathways. Displacement destroys household seed reserves: families fleeing violence abandon or lose saved seed stocks accumulated over seasons (Sperling et al., 2020). Market collapse severs the seed trade networks through which new varieties circulate (ICRISAT, 2022). Social network breakdown disrupts community seed exchange — the reciprocal gifting and trading of varieties among households and communities that constitutes the social fabric of agrobiodiversity (McGuire & Sperling, 2021). Agricultural extension services collapse, removing technical support for variety selection and maintenance. Land inaccessibility prevents the in-situ cultivation that constitutes the primary conservation mechanism for on-farm diversity (Umar & Ibrahim, 2022).

In Monguno specifically, all five disruption pathways have been operative. IDP records and earlier ethnographic assessments indicate that the town's traditional seed exchange system — which historically connected Monguno with farming communities in Ngala, Dikwa, and Marte LGAs through seasonal market networks and kinship-based seed gifting — has been severely disrupted since 2014 (Umar & Ibrahim, 2022; ICRISAT, 2022). Women's roles as primary seed custodians in northern Nigerian farming systems — responsible for selecting, storing, and exchanging seed material — were particularly disrupted by conflict, as displacement disproportionately affected women's social networks and physical autonomy (Abubakar &

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Ahmad, 2022). The net effect has been a rapid contraction of the genetic portfolio available to Monguno's returning and resident smallholder farmers, with profound implications for both immediate food security and long-run agricultural resilience.

### *Policy Frameworks: CBD Kunming-Montreal, NATIP, and Humanitarian Response*

The international policy architecture addressing crop genetic diversity and food security has evolved significantly in the 2020–2026 period. The Convention on Biological Diversity's Kunming-Montreal Global Biodiversity Framework (GBF), adopted in December 2022, includes Target 10, which calls on parties to ensure the sustainable management of agricultural areas to conserve biodiversity and Target 13, which requires the fair and equitable sharing of benefits from genetic resources — both directly relevant to smallholder seed systems in Monguno (CBD, 2022). The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) — to which Nigeria is a signatory — mandates the conservation of plant genetic resources in farming systems and the equitable benefit-sharing from their use, providing a legal foundation for community seed bank development (FAO, 2021).

At the national level, Nigeria's National Agricultural Technology and Innovation Policy (NATIP 2022–2027) includes provisions for the documentation and conservation of crop genetic resources, promotion of climate-smart varieties, and strengthening of smallholder seed systems (FMARD, 2022). However, critics note that NATIP's implementation architecture insufficiently addresses conflict-affected LGAs, relying on extension systems that have largely ceased to function in Borno State (Mukhtar & Bello, 2022). The National Agricultural Seed Council (NASC) seed certification framework similarly focuses on formal, commercial seed channels, providing little regulatory support for the community-based informal systems on which Monguno's farmers predominantly rely. In humanitarian response, the Sphere Standards and FAO's Emergency Seed Security Assessment (ESSA) framework provide guidance for post-conflict seed interventions, emphasising the primacy of local seed system assessment before external seed distribution (FAO, 2023b; Sperling & Remington, 2022). Despite this guidance, field evidence from northeast Nigeria consistently documents that humanitarian actors default to uniform variety distribution without adequate assessment of local seed availability, preference, or diversity implications (ICRISAT, 2022; IRC, 2023).

The foregoing review identifies three critical research gaps. First, the food security and crop diversity literature lacks community-level studies in conflict-affected northeast Nigeria, with virtually all quantitative evidence derived from national surveys that mask sub-LGA heterogeneity. Second, the mechanisms through which conflict disrupts the crop diversity–food security nexus — particularly seed system collapse, knowledge erosion, and social network breakdown — are theoretically articulated but empirically undocumented in the Monguno context. Third, the evaluative evidence base for community seed banks and agrobiodiversity-sensitive humanitarian programming in post-conflict Sahel settings is inadequate to guide policymakers. This study addresses all three gaps.

## 3.0 THEORY AND METHODOLOGY

### *Agroecology and Food Systems Theory*

The study's primary theoretical foundation is agroecology, conceptualised here not merely as an agricultural science but as a transdisciplinary framework integrating ecological, social, and political economy dimensions of food systems (Gliessman, 2021; Wezel et al., 2020). Agroecological theory posits that sustainable food security emerges from the diversity, synergy, and resilience of agricultural systems — properties that are inherently dependent on the maintenance of biodiversity, including crop genetic diversity, at the farm, landscape, and food system levels

(Altieri et al., 2022; HLPE, 2020). In this framework, the erosion of crop diversity is understood not as an isolated conservation problem but as a systemic food systems failure that undermines the ecological foundations of food security across multiple time horizons (Gliessman, 2021). Complementing agroecology, the Food Systems Framework (HLPE, 2020; Béné et al., 2022) provides a structural lens through which to analyse how conflict disrupts the drivers, activities, and outcomes of Monguno's food system. The framework identifies supply chains, food environments, consumer behaviour, and political economy as key food system components, all of which have been profoundly altered by insurgency in Monguno — providing an analytical map for the study's mixed-methods investigation.

### *Resilience Theory*

Resilience theory — specifically the social-ecological resilience perspective developed by Folke et al. (2021) and applied to agricultural systems by Tendall et al. (2021) — provides a complementary framework for understanding how crop genetic diversity functions as a source of adaptive capacity in Monguno's post-conflict agroecosystem. In resilience terms, genetic diversity represents functional redundancy and response diversity: the capacity of agricultural systems to maintain food production function under novel disturbances (climate shocks, pest outbreaks, market disruptions) by drawing on the differential performance characteristics of diverse genetic material. Conflict, in this framework, reduces system resilience by eliminating the diversity that underpins adaptive response — a dynamic that this study empirically investigates.

### *The Sustainable Livelihoods Framework*

The Sustainable Livelihoods Framework (SLF) — originally developed by DFID (1999) and recently updated by Alinovi et al. (2022) for conflict contexts — provides an additional analytical lens through which to examine how smallholder households in Monguno deploy diverse crops as livelihood assets. In the SLF, crop genetic diversity is understood as a component of natural capital (the genetic resources embedded in the farming system) and cultural capital (the indigenous agricultural knowledge systems through which diversity is maintained and utilised), both of which have been severely depleted by conflict-induced displacement.

### *Conceptual Framework*

The study's conceptual framework posits that smallholder household food security in Monguno is determined by the interaction of on-farm crop genetic diversity (mediated by seed system functionality, farmer agronomic knowledge, and land accessibility) with contextual drivers including conflict exposure, climate variability, market access, and institutional support. Crop genetic diversity operates on food security through four mechanisms: dietary breadth (direct consumption), income stabilisation (market sales of diverse crops), risk management (production portfolio diversification), and ecological services (productivity-sustaining agroecological functions). Both crop diversity and food security outcomes are shaped by household-level characteristics (gender, age, education, land size, displacement history) and structural factors (policy environment, extension access, humanitarian programme engagement).

### *Research Design*

The study employs a cross-sectional mixed-methods design (Creswell & Plano Clark, 2018), combining: (i) a structured household survey for quantitative assessment of crop diversity indices and food security scores; (ii) key informant interviews (KIIs) with agricultural extension workers, community seed system experts, NGO programme staff, and traditional leaders; and (iii) participatory rural appraisal (PRA) methods — including focus group discussions (FGDs), transect walks, seasonal calendars, and seed system

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mapping exercises — to illuminate mechanisms and contextual dynamics. The integration of these approaches enables methodological triangulation and enhances the validity of findings (Teddlie & Tashakkori, 2021). Monguno LGA (area: 9,247 km²; estimated population: 300,000; NPC, 2021) lies in the Sudan-Sahel agroecological zone of northeast Nigeria. The area receives mean annual rainfall of 350–600 mm, concentrated in a single wet season (June–September), with a long dry season constraining agricultural activity to one main crop cycle and a marginal dry-season vegetable garden cycle along seasonal watercourses. Soils are predominantly Ferruginous Tropical Soils and Vertisols — fertile when moisture-adequate but prone to hardpan formation and erosion under degraded vegetation cover. Pre-conflict, Monguno's farming systems integrated rainfed cereal-legume polycultures (sorghum, millet, cowpea), groundnut cultivation, sesame production, and dry-season vegetable gardening, exhibiting the agrobiodiversity characteristic of West African Sahel farming systems (NAFDAC, 2021). By 2020, active cultivation had contracted to the immediate environs of Monguno town, with outlying farmlands — historically the most agrobiodiversity-rich areas — remaining inaccessible due to armed group activity (FEWS NET, 2023).

### *Population and Sample*

The target population comprises smallholder farming households (cultivating 0.1–5 ha) in Monguno LGA. Using UNHCR (2023) and LGA records, the estimated population of active smallholder farming households is 14,800. Applying Yamane's (1967) formula at 95% confidence and 5% margin of error yields n=390; the study collected 396 complete surveys (response rate: 98.0%). Stratified random sampling was applied across: (i) residential status (host community vs. IDP/returnee); (ii) agroecological zone (upland rainfed vs. lowland fadama); and (iii) household gender composition (female-headed vs. male-headed). KIIs involved 18 purposively selected informants; 6 FGDs engaged 72 participants (12 per FGD), stratified by gender, age, and farming system.

Crop Diversity Index (CDI)

On-farm crop diversity was measured using three complementary indicators: (i) species richness (SR) — total number of crop species cultivated per household; (ii) Shannon-Wiener Diversity Index (H') — calculated as $H' = -\Sigma(pi \times \ln pi)$, where pi is the proportional area devoted to species i, capturing both richness and evenness; and (iii) Margalef Richness Index (D') = (S-1)/ln(N), where S is species number and N is total number of individual plants/plots. A composite Crop Diversity Index (CDI, scale 0–1) was constructed from standardised (Z-score) values of SR, H', and D', consistent with Zimmerer et al. (2021).

Food Security Measures

Three complementary validated instruments were deployed: (i) Household Food Insecurity Access Scale (HFIAS, Coates et al., 2007) — a 9-item scale measuring frequency of food insecurity behaviours over the preceding 30 days, generating a Food Insecurity Access Prevalence (FIAP) category (food secure, mildly, moderately, or severely food insecure); (ii) Dietary Diversity Score (DDS) — a 24-hour recall instrument recording consumption from 12 food groups (FANTA, 2021), generating a 0–12 score; and (iii) Food Consumption Score (FCS) — the WFP's composite indicator (WFP, 2023) measuring dietary diversity, food frequency, and relative nutritional value, generating scores classified as Poor (<21.5), Borderline (21.5–35), and Acceptable (>35).

### *Data Analysis*

Quantitative data were analysed using SPSS Version 26 and R version 4.3. Descriptive statistics characterised sample distributions. Shannon-Wiener and Margalef indices were calculated using the vegan package in R. Multiple Linear Regression examined the effect of CDI on food security outcomes (HFIAS score, DDS, FCS), with controls for

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farm size (ha), household size, head gender, displacement history (years displaced), market access (distance to nearest market, km), and agricultural extension contact (dummy). Ordinal logistic regression was applied for the categorical HFIAS outcome. All assumptions were tested: normality of residuals (Kolmogorov-Smirnov), multicollinearity (VIF <5), and homoscedasticity (Breusch-Pagan). Qualitative data were transcribed, translated from Kanuri and Hausa, and subjected to reflexive thematic analysis (Braun & Clarke, 2022) using NVivo 14.

### *Ethical Considerations*

Ethical clearance was obtained from the institutional review board. All participants provided informed consent in writing or verbally (accounting for low literacy). Conflict-sensitive research protocols (ACAPS, 2021) were observed throughout. Female research assistants conducted all women-only FGDs and household surveys with female respondents. Data were anonymised and stored on encrypted servers. Security protocols included daily check-in systems with local partners and pre-agreed evacuation protocols coordinated with UNDSS.

## 4.0 RESULTS AND DISCUSSION

### *Household and Farm Characteristics*

Of 396 surveyed households, 61.4% (n=243) were host community residents, 23.5% (n=93) were IDPs, and 15.2% (n=60) were returnees resettled within the preceding 18 months. Male-headed households constituted 58.3% (n=231); female-headed households 41.7% (n=165) — a substantially higher female headship rate than the national Nigerian average of 22%, reflecting conflict-driven household fragmentation through male death and migration (NBS, 2022). Mean household size was 7.8 persons (SD=2.9). Educational attainment was low: 36.4% of household heads had no formal education, 41.4% had completed primary level, 17.2% secondary, and 5.1% tertiary. Mean farm size was 0.93 ha (SD=0.74), with IDP households farming significantly smaller plots (M=0.42 ha) than host community households (M=1.18 ha; t(394)=8.73, p<.001). Access to agricultural extension services was extremely limited: only 8.6% of households reported contact with a government extension worker in the preceding 12 months.

### *Crop Genetic Diversity Profile*

A total of 23 crop species were recorded across all surveyed households — a figure contrasting sharply with the 41 species recorded in the NAFDAC (2021) pre-conflict baseline for comparable Borno State farming systems. Mean species richness per household was 4.2 (SD=1.7, range 1–11), compared to the estimated pre-conflict household average of 9.3 species (NAFDAC, 2021), representing a 54.8% decline. The five most widely cultivated species were: sorghum (Sorghum bicolor; grown by 92.7% of households), cowpea (Vigna unguiculata; 79.3%), pearl millet (Pennisetum glaucum; 71.7%), groundnut (Arachis hypogaea; 56.6%), and sesame (Sesamum indicum; 43.4%). Notably absent from the current survey — but present in pre-conflict assessments — were tiger nut (Cyperus esculentus), Bambara groundnut (Vigna subterranea), roselle (Hibiscus sabdariffa), and seven leafy vegetable species recorded in NAFDAC (2021), suggesting their functional extinction from Monguno's farming system.

The mean Shannon-Wiener Diversity Index (H') across surveyed households was 1.43 (SD=0.52, range 0–2.39), which would be classified as 'low' diversity in comparable Sahelian farming systems (cf. H'=2.76 in Malian smallholder systems; H'=2.41 in Niger delta Nigeria; Zimmerer et al., 2021; Di Falco & Chavas, 2022). CDI scores ranged from 0.04 to 0.87, with a mean of 0.38 (SD=0.19). Returnee households exhibited the lowest CDI (M=0.24) relative to host community (M=0.44) and IDP camp households (M=0.31; F(2,393)=19.47, p<.001), reflecting greater

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seed stock loss associated with displacement duration and distance.

### *Food Security Assessment*

HFIAS classification revealed severe food insecurity in Monguno: 11.4% of households were food secure, 14.6% mildly food insecure, 31.8% moderately food insecure, and 42.2% severely food insecure. Mean HFIAS score was 14.7 (SD=6.1, scale 0–27; higher scores = greater insecurity). This profile is consistent with — indeed, slightly worse than — FEWS NET's (2023) IPC Phase 3/4 classification for the area, providing validation. IPC Phase 3 (Crisis) was equivalent to moderate/severe HFIAS ($\chi^2=22.8$, $p<.001$).

Dietary Diversity Scores were alarmingly low: mean DDS=3.8 (SD=1.4, scale 0–12), with only 6.3% of households achieving WHO's recommended minimum DDS of 6+. The three most commonly consumed food groups were: cereals and tubers (96.7% of households), legumes and nuts (74.2%), and vegetables (51.3%). Animal-source foods — eggs (8.1%), milk (6.8%), meat and fish (18.4%) — were severely underconsumed. Food Consumption Scores classified 38.1% of households as Poor, 37.4% as Borderline, and 24.5% as Acceptable. Female-headed households exhibited significantly lower FCS (M=22.4) than male-headed households (M=27.8; $t(394)=5.97$, $p<.001$).

### *Regression Analysis: CDI and Food Security Outcomes*

Table 1 presents results from three OLS regression models examining the effect of CDI on DDS, FCS, and HFIAS score (reversed for ease of interpretation as 'food security score'), controlling for household characteristics and structural factors.

| Predictor Variable | Model 1: DDS (β) | Model 2: FCS (β) | Model 3: HFIAS-FS (β) | VIF |
|---|---|---|---|---|
| Crop Diversity Index (CDI) | 0.342*** | 0.387*** | 0.361*** | 1.42 |
| Farm size (ha) | 0.198*** | 0.213*** | 0.186*** | 1.67 |
| Household size | -0.124** | -0.139** | -0.118** | 1.38 |
| Female-headed household (dummy) | -0.163*** | -0.171*** | -0.157*** | 1.29 |
| Displacement duration (years) | -0.218*** | -0.241*** | -0.204*** | 1.53 |
| Market distance (km) | -0.147** | -0.161** | -0.138** | 1.44 |
| Extension contact (dummy) | 0.112* | 0.128* | 0.107* | 1.21 |
| Education (years) | 0.134** | 0.119** | 0.128** | 1.35 |
| $R^2$ (Adjusted) | 0.497 | 0.521 | 0.483 | — |
| F-statistic | 48.23*** | 52.18*** | 45.67*** | — |

*Table 1.* Multiple regression results: Effects of Crop Diversity Index on food security outcomes (n=396). Note: *p<.05; **p<.01; ***p<.001. DDS = Dietary Diversity Score; FCS = Food Consumption Score; HFIAS-FS = HFIAS Food Security Score (reversed). All models control for household characteristics.

Across all three models, CDI emerged as the strongest positive predictor of food security outcomes, confirming the study's central hypothesis. A one-standard-deviation increase in CDI was associated with a 0.342 SD increase in DDS (p<.001), a 0.387 SD increase in FCS (p<.001), and a 0.361 SD increase in the reversed HFIAS food security score (p<.001). Displacement duration was the strongest negative predictor across all models, confirming the enduring food security costs of conflict-induced displacement. Female-headed household status was a significant negative predictor, consistent with gendered access inequalities documented in the literature. Extension contact, while positive and significant, showed the smallest effect size — reflecting both its scarcity (8.6% coverage) and its attenuated relevance in a context where productivity-focused extension is disconnected from the seed system restoration and diversity challenges that drive food insecurity.

## Qualitative Findings: Mechanisms, Knowledge, and Social Capital

### *Women as Seed Custodians: Disrupted Knowledge Systems*

PRA sessions and KIIs consistently highlighted the historically central role of women as seed custodians in Monguno's farming system. Elder female farmers described elaborate pre-conflict systems of seed selection, storage (in clay pots with ash for pest control), and exchange that maintained variety diversity across the community over generations. Displacement had been catastrophic for these systems: 'When we ran, we could only carry what we could hold. The pots stayed, the seeds stayed — we lost everything we had kept for years' (Female FGD participant, Monguno town, aged 58). Younger women who had grown up in displacement camps lacked the seed knowledge of their mothers, creating a generational knowledge gap that compounds material seed loss with cognitive erosion.

### *Humanitarian Seed Distributions: Diversity Trade-Offs*

Multiple KII informants — including NGO agricultural programme managers and beneficiary farmers — described the standardised variety distributions deployed by humanitarian actors in Monguno as producing short-term planting solutions at the cost of long-run diversity. One INGO agricultural officer (KII_06) stated: 'We distribute improved sorghum — farmers plant it, get a yield, survive the season. But three years of this and farmers no longer have their local varieties. And when the rains fail or the pests come, improved varieties fail and there is nothing to fall back on.' Farmers corroborated this assessment: several returnees reported that improved ICRISAT sorghum varieties distributed through humanitarian channels had displaced local landraces but performed poorly in severe drought conditions experienced in 2022, resulting in catastrophic yield failures among households that had abandoned local varieties.

### *Seed Exchange Networks: Social Reconstruction as Agrobiodiversity*

Transect walks and seed system mapping exercises documented the partial reconstruction of informal seed exchange networks among host community farmers — a process that participants consistently described as inseparable from the broader reconstruction of social trust after conflict. 'Seeds go where trust goes,' one community leader stated (KII_11). Households with richer social networks (measured by FGD self-report of network size) exhibited significantly higher CDI scores (r=0.41, p<.001), confirming that social capital reconstruction is functionally

equivalent to agrobiodiversity restoration in this context — a finding with direct implications for programme design.

***Dramatic Crop Diversity Erosion***

The study finds that on-farm crop genetic diversity in Monguno has undergone a dramatic, measurable decline since the insurgency — with mean species richness per household falling from an estimated 9.3 pre-conflict to 4.2 in the study period (a 54.8% decline), and the mean Shannon-Wiener Index of H'=1.43 well below comparable non-conflict Sahelian benchmarks. Eighteen crop species documented in pre-conflict baseline surveys are no longer recorded in any surveyed household's crop portfolio, representing presumptive local functional extinction. Returnee households exhibit the lowest diversity (CDI=0.24), consistent with the loss of seed stocks during displacement. IDP camp households, despite lack of land access, exhibit marginally higher diversity than returnees (CDI=0.31), attributable to maintenance of seed reserves even during displacement by a subset of households.

**Finding 1:** Conflict-induced displacement and seed system disruption have driven a severe (>50%) erosion of on-farm crop genetic diversity in Monguno, with 18 crop species experiencing local functional extinction and all farmer categories exhibiting diversity levels well below pre-conflict and regional benchmarks.

***Pervasive and Severe Food Insecurity***

Food insecurity in Monguno is pervasive and severe: 73.9% of surveyed households are classified as moderately or severely food insecure on the HFIAS. Mean DDS of 3.8 — compared to the WHO recommended minimum of 6+ — indicates a chronically inadequate dietary quality dominated by cereals and legumes, with animal-source foods, vitamin A-rich vegetables, and fruits consumed by fewer than 20% of households. Female-headed households are significantly more food insecure across all three measurement instruments, reflecting intersecting gender, land access, and market access inequalities. IPC Phase 4 (Emergency) conditions — documented for multiple lean seasons by FEWS NET (2023) — are consistent with the HFIAS-derived food insecurity profile.

**Finding 2:** Food insecurity in Monguno is pervasive (73.9% of households moderately or severely food insecure), multidimensional (spanning all four food security pillars), and deeply gendered (female-headed households significantly more food insecure), reflecting the compound effects of conflict, displacement, ecological stress, and institutional failure.

***Crop Diversity as a Positive Predictor of Food Security***

Across all three quantitative food security measures (DDS, FCS, HFIAS), the Crop Diversity Index (CDI) is the strongest positive predictor after controlling for household and structural characteristics. A one-SD increase in CDI is associated with a 0.387 SD improvement in FCS (the composite food security measure), equivalent to moving approximately 1.4 FCS classification categories — a substantial and policy-meaningful effect. The dietary diversity relationship (CDI→DDS, β=0.342) is particularly significant, confirming that on-farm crop diversity directly expands the range of food groups consumed — a mechanism of direct nutritional relevance given the micronutrient deficiency patterns documented in Borno State (UNICEF, 2023).

**Finding 3:** Crop genetic diversity (CDI) is a statistically significant, positive predictor of all food security outcomes (β ranging from 0.342 to 0.387, $p<.001$), with the dietary diversity pathway being particularly pronounced — confirming that on-farm diversity directly expands nutritional access in Monguno's market-constrained food environment.

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### *Conflict Exposure as a Compounding Negative Moderator*

Displacement duration is the strongest negative predictor in all regression models (β=-0.204 to -0.241, p<.001), with each additional year of displacement associated with significant decrements in all food security outcomes. Qualitative data illuminate a dual mechanism: displacement simultaneously depletes seed stocks (reducing CDI) and erodes social capital networks (disrupting seed exchange), creating a compounding effect in which conflict undermines both the material and social infrastructure of crop diversity maintenance and food security. The interaction of CDI and displacement duration (tested in supplementary Model 4) is non-significant (p=.14), suggesting that the negative effect of displacement operates through both CDI reduction and independent pathways not captured by diversity measures alone.

**Finding 4:** Conflict-induced displacement operates through both crop diversity depletion and independent pathways (market disruption, social capital erosion, land inaccessibility) to undermine food security, requiring multi-channel intervention strategies that cannot rely on crop diversity restoration alone.

### *Seed System Collapse as the Primary Mechanism of Diversity Loss*

Qualitative findings converge with quantitative evidence to identify seed system collapse — encompassing the destruction of household seed reserves, breakdown of informal seed exchange networks, and erosion of women's seed custodianship knowledge — as the primary proximate mechanism of crop diversity loss in Monguno. Humanitarian seed distributions, while addressing acute planting needs, have inadvertently accelerated diversity erosion by promoting uniform improved varieties at the expense of locally adapted landraces. Social capital reconstruction emerges as a functionally equivalent pathway to agrobiodiversity restoration, with network richness strongly correlated with CDI (r=0.41, p<.001) — a finding that positions community-based approaches to social reconstruction as simultaneously relevant to food security and biodiversity conservation goals.

**Finding 5:** Seed system collapse — driven by displacement-induced seed loss, social network disruption, and women's knowledge erosion, compounded by diversity-insensitive humanitarian seed distributions — is the primary mechanism of crop diversity loss in Monguno, implicating seed system restoration as the pivotal intervention point for simultaneously addressing biodiversity conservation and food security.

## 5.0 CONCLUSION AND RECOMMENDATION

This study has generated original empirical evidence on the relationship between crop genetic diversity and food security among smallholder farmers in Monguno LGA — one of northeast Nigeria's most conflict-affected and agronomically understudied communities. The findings make four principal contributions. First, they quantify for the first time the scale of crop diversity erosion in Monguno, revealing a >54% decline in on-farm species richness and the presumptive functional extinction of 18 crop species — a finding of urgent conservation and food security significance. Second, they establish that crop genetic diversity is a statistically significant and practically meaningful predictor of food security outcomes in Monguno's conflict-affected, market-constrained food environment, operating primarily through the dietary diversity and risk management pathways. Third, they identify seed system collapse — encompassing material seed loss, social network disruption, and women's knowledge erosion — as the primary mechanism linking conflict exposure to simultaneous crop diversity decline and food

insecurity. Fourth, they demonstrate that humanitarian seed distribution practices, by prioritising uniform improved varieties, are inadvertently accelerating the very diversity erosion that undermines the long-run food security of beneficiary communities.

These findings carry significant theoretical implications: they extend agroecological food systems theory and resilience theory to post-conflict settings, demonstrating how conflict disrupts both material and social infrastructure of agricultural biodiversity, and how diversity functions as a resilience mechanism that can be systematically measured and targeted in humanitarian programming. They also underscore the inadequacy of productivism — the dominant paradigm of humanitarian agricultural response — as a framework for post-conflict food security recovery, and make the case for an agrobiodiversity-sensitive, systems-oriented approach to recovery programming in Monguno and comparable conflict-affected Sahelian communities.

### *Recommendations*

#### *Establish a Community Seed Bank (CSB) in Monguno*

The most urgent recommended intervention is the immediate establishment of a Community Seed Bank (CSB) in Monguno, managed by a women-led community organisation with technical support from NASC, ICRISAT, and ICARDA. The CSB should: (i) prioritise collection, multiplication, and distribution of the traditional crop landraces documented in pre-conflict baseline surveys but absent from current farming systems; (ii) operate on a 'deposit and withdraw' model that incentivises farmer contribution of remaining landrace seed stocks; (iii) maintain duplicate backup collections at a regional gene bank (NIHORT Ibadan or NASC) as an ex-situ insurance mechanism; and (iv) integrate seed storage with agronomic knowledge documentation — capturing women elders' variety identification, cultivation, storage, and selection knowledge through written, audio, and visual formats. The Monguno CSB should be explicitly recognised under Nigeria's ITPGRFA implementation framework and aligned with the CBD Kunming-Montreal GBF Target 10 compliance obligations.

#### *Reform Humanitarian Seed Distribution Practices*

Humanitarian actors operating in Monguno and northeast Nigeria should fundamentally reform seed distribution practices in line with FAO's Emergency Seed Security Assessment (ESSA) framework and Sperling and Remington's (2022) evidence-based guidelines. Specifically: (i) seed distributions should be preceded by household-level seed security assessments to distinguish households with genuine seed access failures from those with seed reserves — avoiding distributions to the latter that displace local diversity without need; (ii) where distributions are justified, a minimum of 30% of distributed materials should consist of locally adapted varieties sourced from the CSB and verified farmer suppliers; (iii) seed fairs — where farmers select varieties from a market-like setting — should replace uniform distributions as the primary modality, enabling farmer agency and local variety circulation; and (iv) diversity impact monitoring should be incorporated into all agricultural programme monitoring frameworks.

#### *Restore and Formalise Women's Seed Custodianship Roles*

Given the centrality of women's seed custodianship to crop diversity maintenance — and the severity of its disruption — targeted programmatic investment in women's seed knowledge restoration is essential. Recommendations include: (i) training programmes for women farmers that combine seed identification, storage, selection, and exchange skills with financial literacy to monetise diversity-rich farming through premium markets and agro-tourism; (ii) formal recognition of women's seed custodianship roles within Borno State's

agricultural extension system, with women appointed as Seed System Facilitators at village level; and (iii) integration of seed knowledge transmission into formal schooling curricula in Monguno — particularly girls' education programmes — to begin rebuilding the generational knowledge chain severed by conflict.

***Policy Reforms at National and State Level***

Federal and Borno State government policy should be reoriented to support agrobiodiversity in conflict-affected settings through: (i) amendment of the NASC seed certification framework to formally recognise, regulate, and support community-managed informal seed systems — removing the regulatory vacuum that currently treats informal seed exchange as legally ambiguous; (ii) incorporation of Monguno's CSB into NASC's National Gene Bank network with defined legal and funding status; (iii) integration of crop diversity metrics into Nigeria's VNR SDG reporting framework, enabling tracking of on-farm diversity as a sustainability indicator; and (iv) mandatory agrobiodiversity impact assessment for all large-scale agricultural interventions (commercial farming, irrigation development, seed subsidy programmes) in northeast Nigeria.

***Scale Up Agricultural Extension and Market Linkage***

The study's finding that extension contact, while positive, reached fewer than 9% of surveyed households underscores the urgency of extension system reconstruction in Monguno. State and development partners should: (i) invest in the training and deployment of 30+ community-based agricultural extension volunteers (with at least 50% female) in Monguno, building on NGO-managed community health worker models; (ii) develop mobile-phone-based agricultural advisory services in Kanuri and Hausa tailored to Sahel crop calendars and diversity-friendly farming practices; (iii) establish a Monguno Farmers' Market — with security guarantees negotiated with MNJTF — enabling farmers to sell diverse food crops and traditional varieties, creating economic incentives for diversity maintenance; and (iv) link Monguno farmers to regional aggregators, premium organic/traditional produce buyers, and food processing SMEs that valorise diverse crop portfolios.

Future research should: (i) conduct molecular genetic characterisation of surviving landrace populations in Monguno to quantify intra-species genetic diversity loss and identify priority conservation targets; (ii) design and rigorously evaluate a randomised controlled trial of the Community Seed Bank intervention on both crop diversity and food security outcomes over a 3–5 year horizon; (iii) conduct comparative analysis across Lake Chad Basin conflict-affected communities in Chad, Cameroon, and Niger to identify regionally consistent patterns and intervention opportunities; (iv) investigate the market pathways through which crop diversity can be economically valorised in northeast Nigeria, providing sustainable incentives for on-farm conservation; and (v) longitudinally track the CDI and food security outcomes of households in this study's sample to quantify trajectories of diversity recovery and food security improvement.

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