frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 19 February 2025
DOI 10.3389/fsufs.2024.1508056

OPEN ACCESS

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RECEIVED 08 October 2024
ACCEPTED 20 December 2024
PUBLISHED 19 February 2025

CITATION
Munyoro JK (2025) Strengthening small-scale farmers capability to enhance local food access amid disruptions.
Front. Sustain. Food Syst. 8:1508056.
doi: 10.3389/fsufs.2024.1508056

Strengthening small-scale farmers capability to enhance local food access amid disruptions

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This research reassesses the efficacy of long-term food systems and examines the strengthening of small-scale farmers capabilities through local skills development and education programs to enhance sustainable food accessibility during disruptions. Indigenous and local knowledge provides guidance on local resource management and innovation strategies, advancing local food systems transformation and adaptive capacities. A quantitative survey was conducted, reaching 1307 small-scale farmers across 47 Kenyan counties. Chi-square tests, linear regression, and crosstabulations were applied to analyze the relationship between skills development, education levels, farming practices, supply chain disruptions, food access, and technical skills transformation. The findings show that households with higher education levels are more resilient to supply chain disruptions, facilitating improved local food and market access. These results highlight the need for policies integrating indigenous and local knowledge, education, and skills development to strengthen local food systems transformation and stability, ultimately reducing dependence on short-term humanitarian aid.

KEYWORDS

small-scale farmers, local food systems, skills development, resilience, disruption, supply chain, capability, accessibility

1 Introduction

Globally, over 5 billion people rely on food systems for survival and well-being (Schneider et al., 2023). These food systems are intricate, encompassing all activities related to producing, handling, distributing, preparing, and consuming food, alongside their resulting socio-economic and environmental impacts (Strassner and Kahl, 2020; Polman et al., 2023). Despite their complexity, current global food systems fail to ensure long-term local food accessibility (Arnalte-Mur et al., 2020). Particularly, adapting to local market dynamics is crucial for promoting long-term food access, balancing immediate efficiency with long-term adaptability and resilience (Son et al., 2024).

Given the challenges facing local food systems (LFS) and the need to strengthen small-scale farmers (SSF's) capabilities (Tura et al., 2019), this research redefines Sen's (2014) Capability Approach Theory (CAT) in the context of strengthening skills development, among small-scale farming amid LFSs disruptions. Identifying SSF's facilitates adapting to dynamic LFSs by developing local skills for food access and market accessibility and strengthening local food production. Sen (2014) emphasizes adaptive capabilities, in SSFs, for enhancing local food access amid disruptions, access to market information, and farming resources. The theory promotes long-term farming by addressing the potential impact of farming diversification, aiming for inclusive, resilient, and long-term outcomes for SSFs. Additionally, it emphasizes

equipping SSFs with competitive farming skills to reduce local disruptions (Enthoven and Broeck, 2021) and sharing timely localized farming information (Smidt and Jokonya, 2022).

For decades, international humanitarian organizations have provided food aid mainly during emergencies, often as short interventions (Rosen et al., 2013). Highlighting the need for localized strategies to strengthen resilience and reduce reliance on vulnerable global supply chains, which are highly prone to disruptions (Turetta et al., 2021). For example, the recent pandemic and conflicts, have exacerbated food systems vulnerabilities leading to increased food prices, contributing to a 20% rise in global hunger (Rosegrant et al., 2024).

Research on localized long-term farming systems among SSFs is minimal, as the global academic community often focuses on short-term solutions to food emergencies (Thrupp, 2000). Humanitarian logistics emphasizes technological use but overlooks the structural challenges and long-term effectiveness in operating urgent food delivery (Rodriguez-Espindola et al., 2020). Nevertheless, the limited technological insights for LFS are crucial for humanitarian aid practitioners and stakeholders to strengthen SSFs amid disruptions and for long-term farming systems. Current research on humanitarian operations has not yet differentiated between operational and dynamic capabilities, impacting long-term LFS (Arnalte-Mur et al., 2020).

Thus, this research applies Kenya as a case study to understand the context of the increased exposure to food system disruptions that put vulnerable households (HH) at higher risk of starvation (Stewart, 1986). According to Ong'ayo (2017), SSF's in Kenya face significant challenges in agricultural productivity and skills development, in which the farm production has declined drastically in post-independence years, dropping from 4.7% to below 2% in recent decades. The government initiatives to address these challenges through participatory extension and demand-driven training via the National Agricultural Extension Policy (NAEP) and the National Agricultural and Livestock Programme (NALEP) have failed to achieve these objectives due to low farmers' education levels affecting their understanding of information from educational materials and pamphlets, lack of comprehensive livestock support and veterinary services, unpredictable weather patterns, and low-income level among the farming communities (Ong'ayo, 2017). Similarly, Ireri et al. (2021), point out that small-scale farming in Kenya faces challenges aligned to farm input costs, and illiteracy level and emphasize the need for specialized agricultural information-sharing frameworks, suggesting localized skills development through innovative use of technology as a possible way to strengthen agricultural production, local information sharing, and increasing livelihoods.

This complexity contributes to Kenyan HH food insufficiency, highlighting the interrelationship between physical, nutritional, hygienic, and economic access to food (FAO, 2012). Therefore, addressing the meaning of effective coordination within these systems facilitates an understanding of how farming practices can manage high levels of uncertainty and enhance overall system resilience (Scholten and Schilder, 2015) and how operational capabilities can facilitate and promote local food production and distribution (Sen, 2014). Thus, addressing food systems from local perspectives, acknowledges the complexity and context-dependent nature of LFS, aiming for long-term, resilient farming production, distribution, and local food consumption (Feenstra and Campbell, 2014).

The research applies insights from Sen's (2014) Capability Approach Theory (CAT) to assess HH's well-being by emphasizing freedoms and potential over-reliance on external resources, e.g., aid. Adopting CAT's core principle of capability, besides agencies and freedom, highlights the ethical imperative for policies that foster social equity and strengthen SSFs to achieve sustainable livelihoods. The approach offers insights into LFSs by enhancing skills development to mitigate disruptions, enhancing information-sharing and fostering resilience (De et al., 2022). Skills development in post-harvest handling boosts production and storage capability while reducing waste leading to long-term food accessibility, particularly those SSF facing challenges in accessing conventional systems resulting in inadequate infrastructure (Lawal et al., 2019: Enthoven and Broeck, 2021). Stakeholder collaboration and monitoring and evaluations (M&E) initiatives strengthen SSF's capabilities (Sen, 2014) by identifying knowledge gaps, mitigating vulnerabilities, and fostering adaptive practices (Kondraganti et al., 2024; Manathunge et al., 2021). Such efforts improve market access, enhance LFS transparency and build resilience against disruptions (Bingen et al., 2003) leading to effective skills development at the nexus of collaborative needs for information-sharing, minimizing uncertainties, and boosting operational effectiveness (Scholten et al., 2014; Sen, 2014).

The research aims to understand how these skills development impacts local food and livelihoods, highlighting the need to clarify the status of local food accessibility at the local level (Argade et al., 2023). To address this challenge, the research collected baseline data using a survey to analyze social setbacks contributing to the vulnerability of SSFs and LFS, focusing on a specific research question (White, 2017). *To what extent do SSFs' skills development support their capabilities in LFSs amid supply chain disruptions, particularly in terms of accessing local food and markets?* To answer this research question, the research integrates Sen (2014) to analyze the impact of skills development based on the highest education levels attained among surveyed households and its implications for long-term local food accessibility in Kenya. Additionally, CAT emphasizes the importance of cooperation, agency, and individual empowerment to improve livelihood capabilities, ensuring resilient access to local food and markets.

Additionally, the research tests the main hypothesis *H1: The education level of SSFs significantly impacts their ability to navigate supply chain disruptions and access to local food and markets amid supply chain disruptions.* This hypothesis tests whether education and skills development are critical for SSFs to navigate complex market systems. Sen (2014) emphasizes that individual capabilities and freedom, enhanced through education and skills development, equip SSFs with knowledge and skills to manage LFS disruptions. Aligning CAT in identifying real freedoms and strengthening opportunities. According to Bassett et al. (2021), SSFs who leverage pre-existing networks and utilize technology tend to be more successful, adopt innovative practices, and maintain resilient livelihoods mitigating LFS disruptions. Making informed decisions, innovation, and using available resources effectively help to sustain livelihoods, manage disruptions, and access local food and markets (Sen, 2014).

Further, the research integrates the following four additional supporting hypotheses to strengthen the main hypothesis and clarify the significance level of how LFS affects SSF's access to local food and markets, long-term farming, and making informed decisions (Betts et al., 2021).

H2: SSF skills development in LFS have a significant impact on their access to local food and markets. Sen's (2014) CAT emphasizes

enhancing individual capability and freedom, besides achieving resources that support livelihood and well-being. Thus, skills development equips SSFs with the knowledge and competencies needed to manage complex supply chains, adapt to changes, and leverage opportunities within LFSs. This enhances SSFs' ability to make informed decisions, adapt to changes, and effectively utilize resources, expanding their real freedoms and opportunities. This hypothesis tests the effectiveness of knowledge acquisition, crucial for maximizing SSF's contribution to LFS and market access (Loring et al., 2018). It directly assesses SSFs' capability to access and utilize local markets amid disruptions, leading to improved market access, supportive policies, and enhanced LFS, ultimately providing social-economic benefits to SSFs, impacting SSFs' access to local food and markets aligning with Sen's focus on facilitating individuals achieving valuable lives through enhanced capabilities.

H3: Participation in skills development programs significantly affects SSF's ability to access farm inputs during supply chain disruptions. Sen (2014) emphasizes the importance of enhanced individual capabilities, i.e., the real opportunities available to achieve valued functions. Skills development programs strengthen SSFs' knowledge and abilities, increasing agency and empowerment. Aligning CAT's focus on strengthening real freedoms and opportunities to effectively manage disruptions and secure necessary farm inputs to sustain local food production and market access amid supply chain disruptions. Testing whether participation in skills development programs enhances competence, resilience, and ability to access farm inputs by advancing management skills, increasing market access knowledge, and fostering collective action. Based on Charatsari et al. (2020), SSF's increased competence in short-food supply chains tends to increase competency needs, suggesting that continuous skills development is crucial for maintaining and improving access to farm inputs and market opportunities during disruptions.

H4: The type of HH farming practices significantly impacts local food accessibility amid supply chain disruptions. Sen (2014) emphasizes the importance of diverse capabilities and real freedoms in achieving desired outcomes. Diversified farming practices enhance capabilities, e.g., resilience and adaptability, which are important amid disruptions. Thus, the hypothesis tests whether diverse and resilient farming practices are crucial in maintaining food access amid LFS. According to Kimani (2021), HHs that practice multiple adaptation strategies, such as crop diversification, shifting planting dates, and integrating off-farm jobs, tend to maintain farming productivity and ensure food accessibility during climate variability and disruptions.

H5: The extent of supply chain disruption in accessing local food significantly influences the transformation of HH skills. Sen (2014) emphasizes the role of external conditions in shaping individual capabilities. Amid LFS disruptions, the need for adaptive skills is paramount. CAT highlights how changing environments and challenges drive the development and transformation of skills, as households must adapt to maintain their well-being and access to livelihood. Offering insight into how the iterative process of learning from disruptions helps build resilience. Baghersad et al. (2021) state that prior experiences with supply chain disruptions and location influence the impact of disruptions severity. Consequently, farming practices experienced in handling disruptions mitigate impacts more effectively, crucial for maintaining and transforming skills during disruptions and underscoring the importance of strengthening capabilities in response to external disruptions, enhancing better adaptation and resilience.

The research integrates an online structured survey across 47 counties in Kenya, gathering responses from 1,307 HH to assess the HH's skills development, and the critical need for SSFs effectiveness in managing LFS disruptions (Ohize and Adamu, 2009). It highlights the counties' variations in SSF's resilience, emphasizing the role of education in strengthening HH's capability to manage LFS disruptions better. The research applies regression analysis and chi-square tests to address the heterogeneity of SSFs, offering robust insights into their contexts with LFS (White, 2017). Despite potential data limitations such as biases, cross-sectional constraints, and external validity concerns, the research advances humanitarian aid by enhancing SSF capabilities, addressing LFS disruptions and strengthening the importance of stakeholders' participation. Practical implications include building resilient LFS and informing policymakers to support local communities' capabilities (Sen, 2014).

2 Materials and methods

The research employed a quantitative method to study the extent to which skills development initiatives support SSF and LFS amid supply chain disruptions, particularly focusing on accessing local food and markets. The quantitative method demonstrates the effectiveness of evaluating the capability of skills development and other initiatives on SSF and LFS (Lawal et al., 2019).

2.1 Survey data

The prospective respondents were invited to participate in the survey through an online link, which directed them to a voluntary survey that took approximately 10 min to complete. The online survey was carried out using the Webropol platform, which was shared with respondents from all 47 counties in Kenya, during the period, from July to October 2023. The survey was shared randomly across prevalent social media platforms, specifically WhatsApp and Facebook. Each HH was required to answer a single online survey representing all members of the HHs (Geldsetzer, 2020). The choice of online survey sharing via social media was influenced by the wide use of internet and mobile phone services among SSF in Kenya, which significantly enhances accessing local farming systems, information sharing, market access, and distribution of local food facilitating wise decision-making (Wyche and Steinfield, 2016). Each HH answered one survey no matter the number of HHs, which was one of the guiding criteria, in the marginalized areas.

Capability Approach Theory supports the creation of social platforms and networks that connect farmers directly with consumers, thereby reducing reliance on complex and vulnerable local food systems (Sen, 2014). The online survey included 14 questions aimed at gathering insights into HH initiatives for skills development, vital for strengthening SSF's capabilities during LFS disruptions (Roseth et al., 2016). It comprised multiple choices and Likert scales, Roopa and Rani (2012) state that a well-structured questionnaire reflects the views of respondents, which range from multiple-choice to Likert scales to quantify respondents' behavior and opinions.

To answer the research question and hypotheses across household clusters, the following categorical variables were used: HH head, level of education, farming practices, access to farm inputs, disruption of local food supply chain (SC), extent of SC disruption, access to local food, access to local markets, participation in livelihood programs, and skills transformation. Additionally, the variables underscore the need for a comprehensive and contextually rich analytical framework to capture the multifaceted dynamics of the interconnection between SSF and LFS.

The sample size per county ranged from a minimum of 12 households to a maximum of 59 households. In total 1,307 households were surveyed as part of the study. Secondary data on Kenya's population, number of households, and average HH size were obtained from the Kenya National Bureau of Statistics (KNBS) report on the 2019 Kenyan Population and Housing Census (KPHC, 2019). KNBS serves as the principal agency of the Kenyan Government for collecting, analyzing, and disseminating statistical data, and the custodian of all official statistical information. Similarly, the Kenya Statistics Amendment Act (2019) outlines the KNBS as the center for planning, coordinating, and supervising official statistical programs with the National Statistical System; conducting the population and housing census every 10 years; maintaining a socio-economic database; collaborating with county governments; providing technical advice; promoting coordination among statistical stakeholders; and designing official national statistics which is released to the public domain. The primary and secondary data collected are as follows.

2.2 Characteristics of the counties surveyed

The surveyed data is as follows, including secondary data from the KPHC. Based on the KPHC (2019) database, the survey reached 3.42% of the total average households in Kenya (Table 1).

TABLE 1 Surveyed data and KPHC data for the 2019 census.

No	County	Total population (KPHC)	Total no. of HH's (KPHC)	HH's surveyed	Percentage of HH's surveyed	Average HH size (KPHC)	Percentage of average HH surveyed
1	Mombasa	1,208,333	378,422	36	0.010	3.1	0.03
2	Kwale	866,820	173,176	17	0.010	5	0.05
3	Kilifi	1,453,787	298,472	20	0.007	4.8	0.03
4	Tana River	315,943	68,242	33	0.048	4.6	0.22
5	Lamu	143,920	37,963	24	0.063	3.7	0.23
6	Taita Taveta	340,671	96,429	17	0.018	3.5	0.06
7	Garissa	841,353	141,394	33	0.023	5.9	0.14
8	Wajir	741,263	127,932	12	0.009	6.1	0.06
9	Mandera	867,457	125,763	26	0.021	6.9	0.14
10	Marsabit	459,785	77,495	32	0.041	5.8	0.24
11	Isiolo	268,002	58,072	35	0.060	4.6	0.28
12	Meru	1,545,714	426,360	37	0.009	3.6	0.03
13	Tharaka-Nithi	393,177	109,860	59	0.054	3.6	0.19
14	Embu	608,599	182,743	21	0.011	3.3	0.04
15	Kitui	1,136,187	262,942	28	0.011	4.3	0.05
16	Machakos	1,421,932	402,466	39	0.010	3.5	0.03
17	Makueni	987,653	244,669	28	0.011	4	0.05
18	Nyandarua	638,289	179,686	27	0.015	3.5	0.05
19	Nyeri	759,164	248,050	19	0.008	3	0.02
20	Kirinyaga	610,411	204,188	25	0.012	3	0.04
21	Murang'a	1,056,640	318,105	22	0.007	3.3	0.02
22	Kiambu	2,417,735	795,241	44	0.006	3	0.02
23	Turkana	926,976	164,519	18	0.011	5.6	0.06
24	West Pokot	621,241	116,182	25	0.022	5.3	0.11
25	Samburu	310,327	65,910	23	0.035	4.7	0.16
26	Trans Nzoia	990,341	223,808	22	0.010	4.4	0.04
27	Uasin Gishu	1,163,186	304,943	41	0.013	3.8	0.05

(Continued)

TABLE 1 (Continued)

No	County	Total population (KPHC)	Total no. of HH's (KPHC)	HH's surveyed	Percentage of HH's surveyed	Average HH size (KPHC)	Percentage of average HH surveyed
28	Elgeyo Marakwet	454,480	99,861	32	0.032	4.5	0.14
29	Nandi	885,711	199,426	25	0.013	4.4	0.06
30	Baringo	666,763	142,518	25	0.018	4.7	0.08
31	Laikipia	518,560	149,271	27	0.018	3.4	0.06
32	Nakuru	2,162,202	616,046	55	0.009	3.5	0.03
33	Narok	1,157,873	241,125	25	0.010	4.8	0.05
34	Kajiado	1,117,840	316,179	16	0.005	3.5	0.02
35	Kericho	901,777	206,036	40	0.019	4.4	0.09
36	Bomet	875,689	187,641	27	0.014	4.7	0.07
37	Kakamega	1,867,579	433,207	34	0.008	4.3	0.03
38	Vihiga	590,013	143,365	18	0.013	4.1	0.05
39	Bungoma	1,670,570	358,796	25	0.007	4.6	0.03
40	Busia	893,681	198,152	18	0.009	4.5	0.04
41	Siaya	993,183	250,698	16	0.006	3.9	0.02
42	Kisumu	1,155,574	300,745	38	0.013	3.8	0.05
43	Homa Bay	1,131,950	262,036	17	0.006	4.3	0.03
44	Migori	1,116,436	240,168	16	0.007	4.6	0.03
45	Kisii	1,266,860	308,054	24	0.008	4.1	0.03
46	Nyamira	605,576	150,669	14	0.009	4	0.04
47	Nairobi	4,397,073	1,506,888	52	0.003	2.9	0.01
	Total	47,524,296	12,143,913	1,307	0.781	198.9	3.42

2.3 Characteristics of the household surveyed

The gender survey question was designed to respect the cultural background of the household. Instead of asking "male" or "female," respondents were given the option to choose their HH role as listed in Table 2, even though 6% of them opted not to disclose their HH status. Thus, cultural background and socio-economic status were considered in this research (Figure 1). Moreover, HH heads led by a father were the highest, amounting to 36.5%, followed closely by households led by both parents, particularly in densely populated urban counties (Figure 2).

TABLE 2 Household heads distribution.

Household	Frequency	Percent	Cumulative frequency
Mother	256	19.6	19.6
Father	477	36.5	56.1
Both parents	424	32.4	88.5
Siblings	45	3.4	91.9
Guardian	27	2.1	94.0
Prefer not to say	78	6	100
Total	1,307	100	

2.4 Hypothesis analysis

Linear regression and chi-square statistics were used to test the study of five hypotheses. Linear regression was ideal for testing continuous data and analyzing relationships between the household variables presented in the hypotheses. In contrast, Chi-square statistics were used to analyze categorical data, testing for data independence, and goodness of fit. Both methods provided an approach for analyzing and interpreting the HH dataset.

2.4.1 Linear regression analysis

Linear regression analysis was used to analyze the significant level of the hypothesis variables. The dependent variables (access to local food and market, ability to navigate supply chain disruptions, access to farm inputs, access to local food, and technical skills transformation) and independent variables (skills development, education level, type of farming practices, and supply chain disruption) formed the basis of hypothesis in the analysis (Table 3). Linear regression is used to understand the relationship between dependent and independent variables by testing specific hypotheses to determine their significance level (Javanmard and Lee, 2017), hence identifying the critical significance of the variables at a significant level of 5, using this linear regression formula.

$Y = \beta_0 + \beta_1 X_1 + \varepsilon$, *where Y is the dependent* variable *and* X_1 *is the independent variable.*

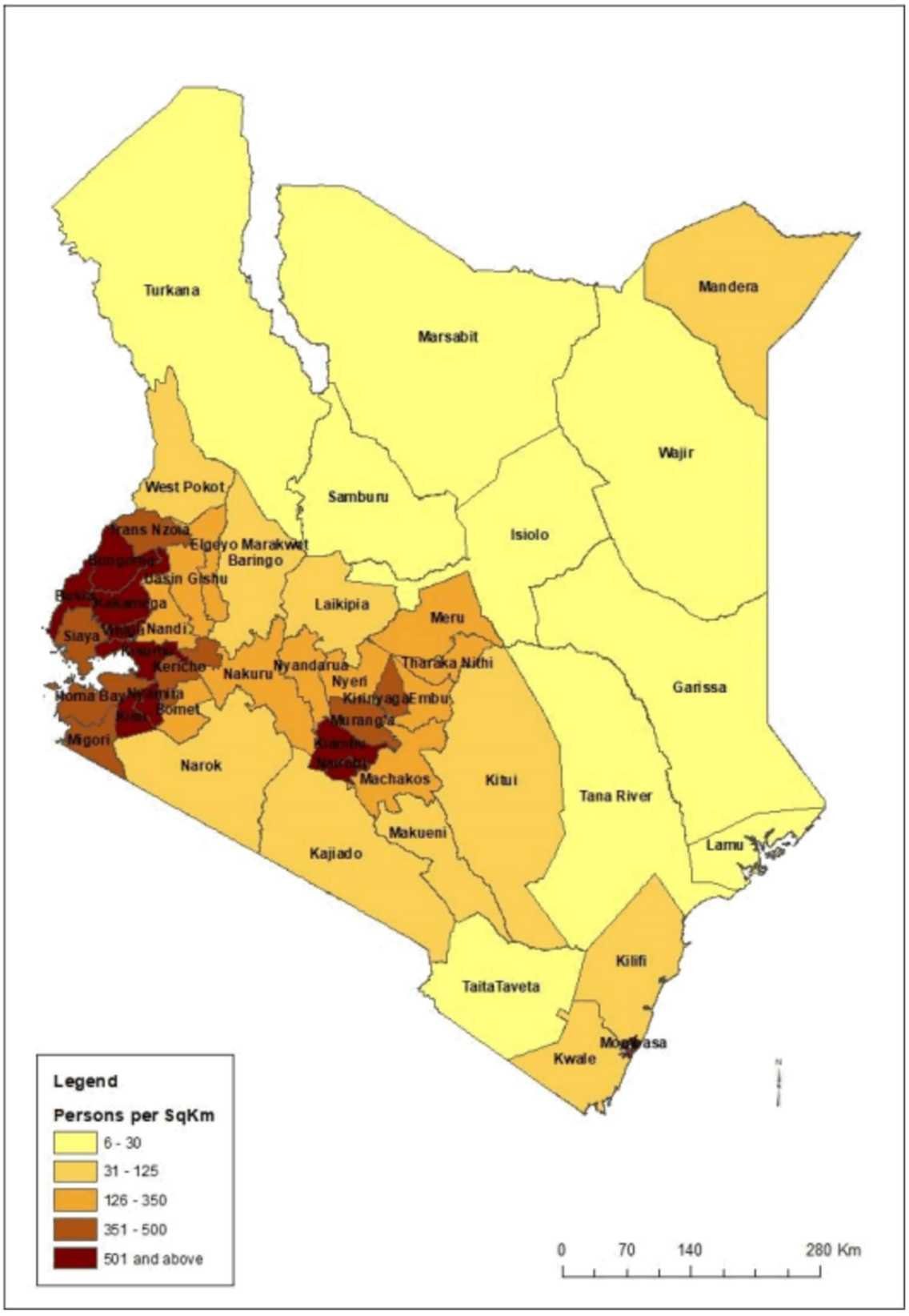

FIGURE 1
Kenyan Map displaying population distribution across the 47 Counties. Source: (KPHC, 2019).

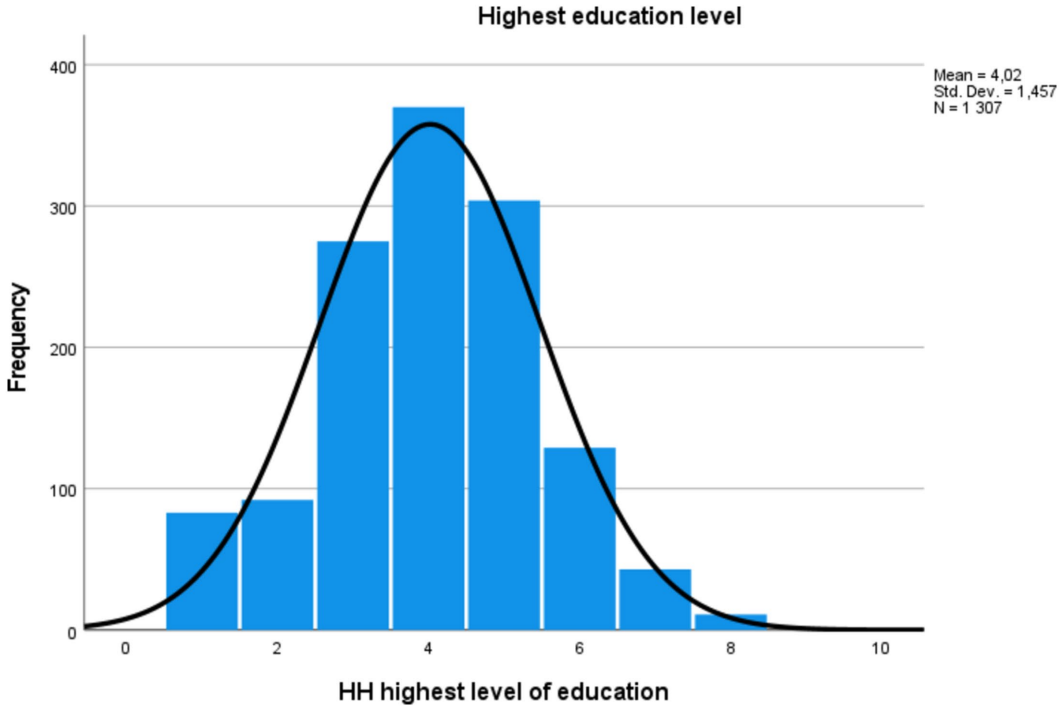

FIGURE 2
Histogram visualizing the characteristics of education level surveyed.

TABLE 3 Households variables.

H	Hypothesis	Variables	Dependent (y)	Independent (X_1)
1	Alternate Hypothesis (H1): Education level of SSFs significantly impacts their ability to navigate supply chain disruptions and access to local food and markets amid supply chain disruptions.	Educational level vs. ability to navigate supply chain disruptions	Ability to navigate supply chain disruptions	Educational level
2	Alternate Hypothesis (H1): SSF skills development in LFS have a significant impact on their access to local food and markets.	SSF skills development vs. access to local food and market.	Access to Local Food Market and markets	Skills development
3	Alternate Hypothesis (H1): Participation in skills development programs significantly affects SSF's ability to access farm inputs during supply chain disruptions.	Skills development participation vs. Access to Farm inputs.	Access farm inputs	Skills development initiatives
4	Alternate Hypothesis (H1): The HH type of farming practices significantly impacts local food accessibility during supply chain disruptions.	Type of farming practices vs. Local food accessibility	Local food accessibility	Type of farming practices
5	Alternate Hypothesis (H1): The extent of supply chain disruption significantly impacts HH technical skills transformation.	Extent of supply chain disruption (accessing local food) vs. HH technical skills transformation	Technical skills transformation.	Extent of supply chain disruption

2.4.2 Chi-square statistics

The hypotheses were further analyzed using critical values and chi-square statistics, to identify the patterns and relationships between categorical variables arranged in contingency tables (Rana and Singhal, 2015). Besides, to effectively analyze the contingency tables to determine if the observed frequencies differ significantly from the expected frequencies under the null hypothesis (Franke et al., 2012).

3 Results

The dataset was meticulously analyzed using IBM SPSS Version 28. Descriptive statistics techniques were used to examine the characteristics of the demographic dataset including HH, farm size, and highest education level. Furthermore, the analysis identified patterns related to access to farm inputs supply chain disruptions, and education level via a P–P plot to evaluate the household's participation in skills development programs. This comprehensive analysis serves as a foundation for deriving critical insights that are indispensable for informing policy decisions, implementing targeted interventions, and enhancing the effectiveness of skills development programs (Salau et al., 2014).

3.1 Demographic characteristics

The overview of the demographic dataset in all 47 Kenyan counties indicates a diverse range of counties with a moderate average and high data set variability, with a mean of 23 households per county surveyed. The farm sizes are generally small with most respondents having farms around the average of 2 acres symbolizing small-scale farming. Nevertheless, education levels are centered around a mid-level (technical college) with moderate variability, suggesting that the households are fairly educated (Table 4).

The distribution of household farm size and their respective percentage is as follows, cultural background and social status also influenced the decision to disclose farm size, whereby 12.9% of the surveyed HH preferred not to reveal this information (Table 5).

TABLE 4 Demographic dataset.

Statistics	County	HH head	Farm size	Highest level of education
No. of responses	1,307			
Mean	23.73	2.50	2.10	4.02
Std Deviation	13.286	1.246	1.109	1.457
Median	24	2.00	2.00	4.00
Mode	13	2	1	4

TABLE 5 Distribution of household farm size.

Farm size (acres)	Frequency	Percentage	Cumulative percentage
0	14	1.1	1.1
1–2	534	40.9	42
3–4	306	23.4	65.4
More than 5 acres	284	21.7	87.1
Prefer not to say	169	12.9	100
Total	1,307	100	

According to Manana (2014), small-scale farms in Kenya range from 1 to 5 acres, thus most respondents in this study are small-scale farmers. Additionally, agriculture accounts for 80% of employment in Kenya (Onyango et al., 2018). This emphasizes the significant role of small-scale farming in the Kenyan economy and access to livelihood.

3.2 Characteristics of the educational level of surveyed HHs

The descriptive statistics summary of 1,307 households surveyed indicates that most respondents have attained technical education (28.3%) or higher education (bachelor's degree at 23.3%). Reflecting a significant portion of the population has practical, technical skills that could leverage skills development initiatives and challenges. A substantial proportion of advanced education, master's degrees (9.9%), and doctoral degrees (3.3%) are potentially beneficial for leading or participating in sophisticated skills development initiatives. The highest education level attained in technical school has a mean score of 4.02 indicating that the average educational attainment falls between technical school and bachelor's degree, exhibiting a normal-like distribution with minor left skew (Figure 3).

The histogram has a slight skew to the right (positive skew), suggesting a concentration of practical and technical education is beneficial for skills development initiatives targeting hands-on, practical skills needed for SSF and LFS in navigating disruptions and accessing local food and markets. The same peak of technical education level implies that skills development initiatives can be highly effective if they are tailored to build on existing technical knowledge, such as improved farming skills, LFS, market access strategies, and leveraging current practical skills.

The presence of higher education among the surveyed respondents indicates that the potential stakeholders in LFS can lead successful skills development initiatives among the SSF and strengthen the current food systems and market access. The high prevalence level of technical and higher education suggests that skills development significantly supports the capabilities of SSFs and LFSs in managing supply chain disruptions particularly accessing local food and markets. These households with the highest education level tend to have advanced methods vital for better market access and resilience against disruptions (Table 6).

Moreover, the boxplot disparity in education levels across counties, shows that some counties have lower education levels attained while others display a wider range of education levels (Figure 4). Particularly, counties in Northern Kenya, e.g., Garissa, Mandera, Isiolo, Turkana, and Samburu, have a lower quartile level of education among the HH surveyed. Numerous factors including nomadic lifestyles and inadequate infrastructure mostly drive these disparities, many young people from pastoralist communities have limited access to education due to their geographical isolation and cultural norms.

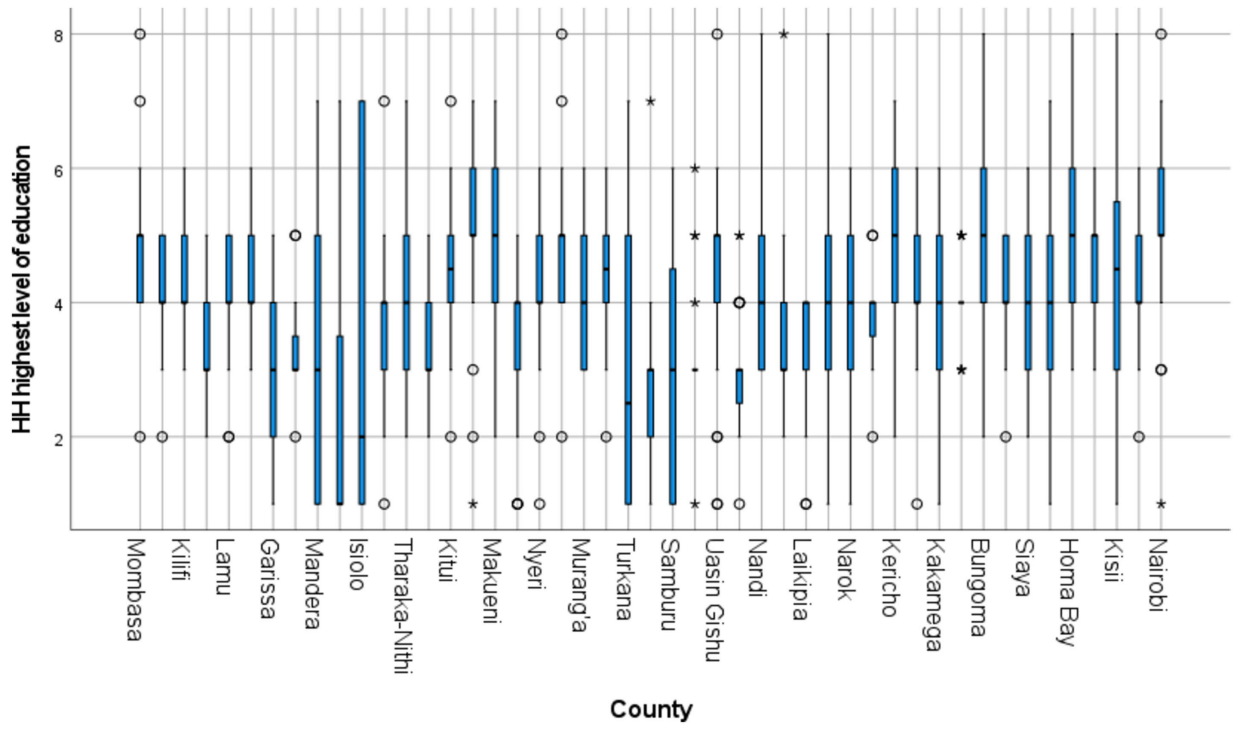

FIGURE 3
HH educational-level boxplots derived from IBM SPSS Version 28.

TABLE 6 Characteristics of education level surveyed.

No	Education level	Frequency	Percent	Cumulative percent
1	None/No formal education	83	6.4	6.4
2	Primary School	92	7	13.4
3	Secondary School	275	21	34.4
4	Technical college	370	28.3	62.7
5	Bachelor Degree	304	23.3	86
6	Master Degree	129	9.9	95.9
7	Doctoral Degree	43	3.3	99.2
8	Others	11	0.8	100
	Total	1,307	100	

3.3 Variables mean and standard deviation

Summary from the HH mean and standard deviation across the variables used in the hypothesis (Table 7).

3.4 Test results of the hypotheses

In all the five tested hypotheses, the linear regression analysis indicates that there is a significant relationship between the hypothesis's variables at the 0.05 level of significance, which is further strengthened by the chi-square test, degree of freedom, critical values, significance level at 0.05 and the coefficient of congruent, which indicates high level and strong associations between all the variables tested (Table 8).

3.4.1 Characteristics of the main hypothesis, H1, relationship between educational level and ability to navigate supply chain disruptions among the SSFs

The Chi-square value of 52,265 with 7 degrees of freedom is significantly higher than the critical value of 14,067 at the 0.05 significance level. This indicates a statistically significant relationship with p-values less than 0.001 and C of C of 0.099 demonstrating a strong association between the variables. This implies that higher education levels among the SSFs are closely associated with a better capability to navigate complex supply chain disruptions. This finding highlights the critical importance of education in enhancing the resilience of SSFs. By improving educational opportunities among the SSFs, a better understanding of managing, and mitigating the effects of supply chain disruptions is achieved, ensuring long-term, stable, and reliable access to local food and markets.

The 1.457 standard deviation of education level measures the spread out of HH education levels from the mean average of 4.02, indicating that most households surveyed have attained technical education. The standard deviation of HH's ability to navigate supply chain disruptions is low at 0.456 reflecting variations across the HHs and clustered around the mean of 1.30, thus lower ability to navigate supply chain disruptions. Education potentially strengthens SSFs' capability toward farming productivity and efficiency in accessing farming resources, improving resilience during supply chain disruptions. This shows that SSFs having moderate and higher education levels are correlated with better decision-making and problem-solving skills, enhancing their ability to adapt to changes in food accessibility during disruptions. Hence, indigenous and localized farming programs among the HH with lower education quartiles

TABLE 7 Summary from the HH mean and standard deviation across the variables used in the hypothesis.

Variables *n = 1,307*	Parameters used to measure the variables	Mean	Std. deviation
Household head *(Which individual assumes the role of the household head?)*	1. Mother 2. Father 3. Both Parents 4. Siblings 5. Guardian 6. Prefer not to say	2.50	1.246
Education level *(What is the highest level of education the HH head has completed?)*	1. None/No formal education 2. Primary School 3. Secondary School 4. Technical College 5. Bachelor's degree 6. Master's degree 7. Doctoral degree 8. Other, please specify	4.02	1.457
HH farm size *(What is the size of your household farm? Please select only one answer)*	1. 1–2 acres 2. 3–4 acres 3. More than 5 acres 4. Prefer not to say	2.10	1.109
Access to Farm inputs (*In your location, how frequently does your household access farm inputs, e.g., seeds, fertilizers, tools, etc.? Please select only one answer*)	1. Never 2. Rarely (once or twice a year) 3. Several times a year (3–10 times a year) 4. Often (more than 10 times a year) 5. Throughout the year 6. Other, Please Specify	2.59	1.040
Type of farming practices *(What is the main type of farming practices in which your household primarily engages as a means of livelihood? Please select only one answer)*	1. Subsistence farming 2. Pastoralism, nomads 3. Cash crops for sale and export 4. Co-operative farming 5. Others, please specify	1.60	0.965
Ability to navigate supply chain disruptions *(Has your household encountered any disruptions in the local food supply chain?)*	Yes No	1.30	0.456
Access to Local Food Market and markets *(Is your household able to access local food markets either to sell or buy locally produced food?)*	Yes No	1.11	0.310
Skills development participation *(Have you or a member of your household participated in any locale skills development program, specifically aimed at improving livelihood systems)*	Yes No	0.55	0.498
Extent of supply chain disruption *(To what extent, on a scale of 1–10, has the supply chain disruption impacted the capability of your household to access essential local food?)*	Rating 1 to 10	7.75	1.589
Technical skills transformation tools. *(If yes, which skills development program has your household attended within the past 3 years? Such programs are conducted by, for example; government, NGOs, church, social groups or through other stakeholders)*	1. Community engagement programs 2. Localized social media campaigns 3. Partnership with local businesses 4. Localized social events 5. Other, Please Specify	2.01	1.120

could build adaptive resilience in transforming crop production and pastoralism food systems across the country.

Thus, the education level in Kenya significantly influences the HH's capability to manage local food disruptions, primarily through the adoption of knowledge dissemination, decision-making, and adoption of innovative practices in food systems. The HH's with a higher education level possess critical skills, e.g., resource management, practices sustainable agriculture, and have access to modern farming technologies for example in Nyeri and Nakuru county, which are located in the arable lands and has improved infrastructure, besides receiving steady rainfall patterns throughout the year. While counties in the Northern Kenya, e.g., Turkana County faces greater vulnerability due to lower education levels, underdeveloped infrastructure, and located in the aid zones of Kenya.

TABLE 8 Analysis of the variable used in the five hypotheses.

H	Variables	X2 value (Chi-Square)	Degree of freedom (df)	Critical value	Significance level at $p < 0.05$	Decision at 0.05 LS	Coefficient of congruent (C of C)
1	Educational level vs. ability to navigate supply chain disruptions	52,265	7	14,067	<0.001	Accepted	0.99
2	Skills development in LFS vs. access to local food and market	27,655	1	3,841	<0.001	Accepted	0.95
3	Participation in skills development programs vs. Access to Farm Inputs	144,689	5	11,070	<0.001	Accepted	0.978
4	Type of farming practices vs. Local food accessibility	211,494	40	55,758	<0.001	Accepted	0.997
5	Extent of supply chain disruption (accessing local food) vs. HH technical skills transformation	150,089	100	124,342	<0.001	Accepted	0.996

Hence, the illiteracy level of Kenyan HH's influences their capability to access livelihood despite challenges surrounding the LFS challenges.

3.4.2 Characteristics of H2, relationship between SSF skills development and their ability to access local food and market

The statistical analysis reveals a Chi-square value of 27,655 with 1 degree of freedom, significantly exceeding the critical value of 3,841. This indicates a statistically significant relationship at the 0.05 level, with a *p*-value of less than 0.001. The C of C is at 0.95, signifying a strong association. These findings suggest SSFs' skills development is closely linked to improved access to local food and markets. Consequently, suggesting that the skills development of SSFs is significantly correlated with the ability to access food and market opportunities, underscores the importance of skill-building programs in supporting SSFs amid supply chain disruptions.

The standard deviation of SSF skills development is 0.498 indicating relatively low variability in skills level among SSFs, from the mean of 0.55. This shows that 55% of the households have attended a skills development program, in this case livelihood improvement program. Conversely, the standard deviation of the HH's ability to access local food and markets is higher at 0.310, suggesting that the SSF's ability to access local food and markets is more spread out from the 1.11 mean, suggesting that some SSFs have significant access to food and market more than others. This hypothesis shows a causal relationship between SSFs' skills development and their ability access to local food and markets, referring to the indigenous and localized training ability to scale up agricultural extension services through strengthening local food production and better market access. The geographical location of the 47 counties plays a critical role, as SSFs within major towns could have better access to skills development, food access, and markets compared to those in the marginalized areas.

The SSF's skills development have a higher potential to impact the Kenyan LFS's and access to market through specialized mechanisms, e.g., improved fishing methods among the fishing community like Kisumu County, better post-harvest handling across all counties, and strengthened market network. Specialized training in sustainable practices, financial management, and food preservation methods, enhances SSFs capability to boost their productivity, reduce local food losses, and reach profitable markets which increases food security. The counties variations in infrastructure and socio-economics status, influence the effectiveness of interventions, particularly, coastal counties like Malindi, Kilifi, and Lamu, benefits from fishing techniques along the Indian Ocean. On the other hand, Mandera, Marsabit, Garissa, and Wajir counties which are located in the remote counties, requires developed local and indigenous skills development aligned to market access and livelihood support. Despite the traditional and taboos across the country, gender sensitivity programs in the marginalized counties, especially Northern counties, could further enhance local and indigenous skills development, thus strengthening LFS, more so focusing on female headed household's role in accessing local food and market. The specialized local and indigenous skills development have a potential to strengthen SSF's resilience and enhancing local food access and promoting market participation during disruptions.

3.4.3 Characteristics of H3, relationship between HH skills development participation and their ability to access farm inputs

The Chi-square value of 144,689 with 5 degrees of freedom significantly surpasses the critical value of 11,070 at the 0.05 significance level. The *p*-value is less than 0.001 indicating a statistically significant relationship, which is supported by a C of C at 0.978 pointing to a strong association between the HH skills development participation and access to Farm Inputs. The analysis suggests that participation in skills development programs is strongly linked to improved access to farm inputs. The substantial Chi-square value and significant p-value indicate that the relationship is not due to random chance. The high C of C value further highlights the robustness of the variable's association. This implies that strengthening SSFs through skills development programs can significantly improve their capability to access essential farm inputs, thereby boosting local food production and maintaining a long-term small-scale farming practice.

The standard deviation (1.040) and mean (2.59) of HH's ability to access farm inputs has a significantly higher variability, reflecting that most SSFs accessed farm inputs either Rarely (2) or Several times a year (3). The mean indicates that 55% of the surveyed HHs participated in skills development programs, with a standard deviation of 0.498 suggesting a relatively equal distribution of participation. Hence, SSFs in Kenya face a wide range of capabilities to access farm inputs, while some SSFs have much better access than others, and their

participation in skills development as a driver toward consistent access to farm inputs is less varied. The uneven distribution of access to farm inputs is possibly due to poor infrastructure and limited access to localized farmers' training centers, particularly agricultural extension services leading to higher disparities.

This shows that the SSF's skills development capability on how to access quality farm inputs significantly impacts LFS and market access, strengthening food accessibility at the local level. Besides suggesting a mechanism for localized and indigenous farming systems, crop management, and farm input utilization which strengthen SSFs potential to increase local productivity and accessibility of quality produce. For example, according to the 2015 Farmbiz Africa report, SSFs in Trans-Nzoia county specialized training in their local languages facilitated by cooperatives organization, on how to identify and access quality maize seeds and fertilizer locally, as well as managing soil fertility has led to increased maize production across the county.

3.4.4 Characteristics of H4, the relationship between the type of SSF farming practices and their ability to access local food and markets

There is a high Chi-square value of 211,494 with 40 df, significantly higher than the critical value of 55,758 at the 0.05 significance level. The *p*-value is less than 0.001, indicating a statistically significant relationship, which is highly supported by a C of C at 0.997, suggesting an almost perfect association between the variables. This result indicates that different farming practices are strongly associated with variations in local food accessibility. The significant Chi-squares value and very high C of C emphasize the strength of this relationship, confirming that the type of farming practices significantly impacts local food access. Underscoring the need for promoting effective farming practices that strengthen access to local food and markets for SSFs, hence improving long-term local food access and households' resilience.

The 0.965 standard deviation suggests a relatively higher variability of the type of farming practiced from the mean of 1.6, thus a wide range of farming practices is carried out in Kenya, with the data points spreading out from the mean. The farming practices are as follows; subsistence farmers 64.4%, pastoralists 15.1%, cash crops for sale and export 12.2%, cooperative farming 5.1%, and 1.1% preferred not to disclose, pointing out that most of the HH surveyed are small-scale farmers. The variation could be triggered by some SSFs using advanced farming technology while the majority rely on traditional farming methods, and other SSFs are in between both methods. On the other hand, the 0.310 standard deviation suggests less variability in SSF's ability to access local food and markets, indicating that the data is clustered closer to the mean of 1.11, reflecting less desperation. This implies that most SSFs have relatively similar levels of accessing local food and markets. While SSFs differ in their respective farming practices, their access to local food and markets remains consistent. These show that internal factors (modern and traditional farming methods) and external factors particularly infrastructure, transport, and local food market regulation play a major role in strengthening SSF farming practices. Localized intervention more so farming segmentation aids in identifying patterns and clusters of farming practices carried out by different ethnic farming communities. Thus, enhancing traditional farming methods and the need for more modern farming tools and technology to strengthen market information systems and local food systems.

Besides, the type of farming practices in Kenya directly influences SSF's ability to access local food and markets, mainly through mechanisms such as productivity, sustainability, and market readiness. The agroforestry county of Nyeri, has diverse farming systems enhancing soil fertility and providing multiple income streams, ranging from dairy farming to floriculture, in which the SSFs are able to access both local food and market opportunities. Meanwhile, the drought-resistant Makueni county produces sorghum and millet which leverages climate-smart practices ensuring a consistent food supply and market access despite arid conditions. The adoption of value-added farm products, e.g., yoghurt production by SSF especially in Kiambu county and sun-drying fruits in Machakos, Kitui, and Taita Taveta counties, increases market access and reduces perishability of local products. On the other hand, monoculture and traditional farming methods across the Northern Kenyan counties limit resilience and market access of locally produced food, due to lower productivity and unfavorable agro-climatic shocks.

3.4.5 Characteristics of H5, the relationship between the extent of supply chain disruption and the transformation of household's technical skills vital in accessing local food

The Chi-square tests yielded a value of 150,089 with 100 df which is significantly higher than the critical value of 124,342 at the 0.05 significance level. The *p*-value is less than 0.001, indicating a statistically significant relationship supported by the C of C at 0.996, denoting a strong relationship between the variables. This suggests that the extent of supply chain disruption at the local level is closely linked to the transformation of a household's technical skills. The significant Chi-square value and the nearly perfect C of C emphasize the robustness of this relationship, confirming that the greater disruptions are associated with more significant transformations in technical skills. This implies that strengthening HH technical skills is crucial for coping with and navigating the impacts of supply chain disruptions. Thus, strengthening the HH's technical skills improves resilience and promotes access to local food amid disruptions.

Additionally, the current extent of the supply chain disruption among SSFs was assessed based on a rating of 1 to 10. Most ratings clustered closely around the mean of 7.75 with a standard deviation of 1.589, thus most ratings fall between 6.16 and 9.34. Meaning that most households by the time of collecting these data were facing high levels of supply chain disruption while accessing local food and markets. However, their use of technical transformation tools had a mean of 2.01, that is most HH preferred option two, i.e., localized social media, particularly radio to pass information for strengthening their farming skills and accessing livelihood. The standard deviation of 1.120 shows that most responses are between 0.89 and 3.13, that is option one or three (Community engagement programs and Partnerships with local businesses), indicating less variability between the lower and higher mean. Thus, sharing technical information through localized social media platforms, e.g., radio, tv, WhatsApp groups, Facebook, and posters has a higher influence on supply chain disruptions and resilience.

The extent of supply chain disruption across Kenya significantly influences the transformation of HH technical skills, as a key

determinant of accessing local food. When supply chains are disrupted due to, for example, agro-shocks and infrastructure challenges, HHs are often exposed to alternative, adaptive and resilient farming practices to maintain their livelihood. For instance, in arable lands like Meru County, disruptions in farm inputs lead SSFs to adopt organic farming methods, developing their skills on how composite manure and natural pests' control can maintain local food production. While in the arid lands like Turkana County, SSFs occasionally faces disruptions in accessing local food, alternatively they tend to cultivate drought-resistant crops like sorghum while intercropping it with cowpeas as an early maturing and drought-resistant crop (Imana and Zenda, 2023), beside diversifying herd composition to overcome drought and diseases (Opiyo et al., 2015).

3.5 HH's education-level probability testing result

To strengthen the main hypothesis *(H1),* a P–P plot was used to compare the distribution of household education levels to a normal distribution curve, with points closely following the diagonal line indicating that the *H1* data does not deviate significantly from a normal distribution curve. After transforming the data with logarithms and differences, the plot shows that the household education levels approximately follow a normal distribution (Figure 4).

The scatter plot possesses a positive trend between education level and supply chain disruptions, reflecting an additional relation with the SSF's potential to navigate disrupted LFS. With the increase in education, households can identify core capabilities and develop more understanding of complex supply chains, while potentially offering greater returns and increased exposure to disruptions. The adaptability to disruptions plays a major role amid disruptions of supply chain systems and dynamic LFS. Accessing local food and markets, households who are better educated possess a significant role in strengthening LFS, though they also encounter greater challenges in disrupted supply chains. Their education level leads to a broader well-being measure and knowledge beyond farming income dependency, enhancing a meaningful life quality.

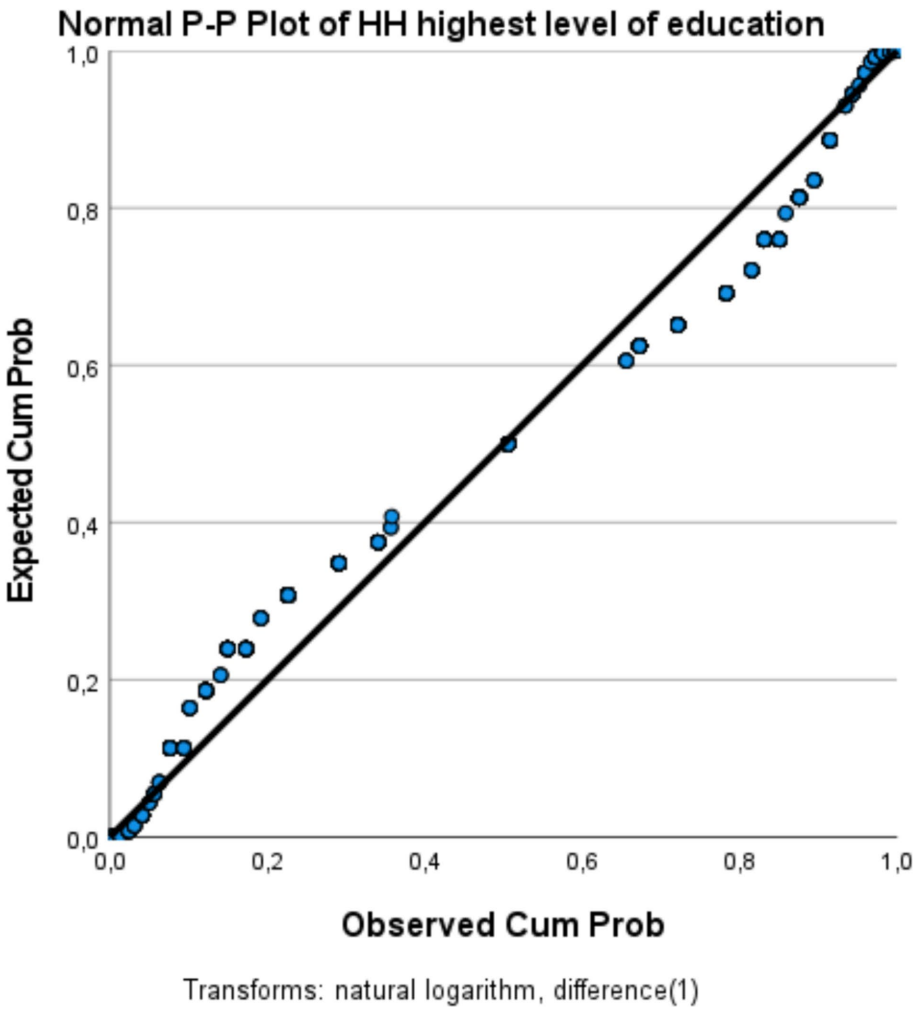

FIGURE 4
Probability to probability (P–P) test of household's education level.

4 Discussion

Sen (2014) highlights the significance of enhancing SSFs capabilities and freedoms to strengthen access to LFS during disruptions. Shifting the focus from resource accessibility to individual capability, the study validates H1, that education through skills development is crucial for SSF's to manage supply chain disruptions. Specialized skills development fosters knowledge transformations and making better decisions to adapt to local challenges. The Kenya government through the county government and stakeholders have the potential to adopt strategies like financial literacy programs for improving resource management, localized training in sustainable farming systems, and digital literacy initiatives to leverage mobile platforms access and real-time information, particularly during LFS disruptions.

Strengthening skills development (H2 and H3) is paramount for navigating supply chain disruptions and enhancing market access. This aligns with the CAT's emphasis on empowering individuals to achieve valued livelihood, through the integration of modern farming technologies, indigenous and localized skills development, and improved infrastructure particularly roads, storage facilities, and post-harvest loss reduction, this possesses high chances of promoting equitable and sustainable food systems, especially in the marginalized regions like Northern Kenya. Sen (2014) states that, up-to-date knowledge on productivity and adaptation to market demands ensures resilience and inclusive LFS during challenging times.

Adaptability and resilience are highlighted by diversified farming practices, adaptive information-sharing, and effective resource management (H4 and H5). Thus, individual development of SSF's capabilities facilitates long-term food sustainability, impacts indigenous food production methods, and ensure long-term sustainable livelihoods at the local level. The CAT framework underscores the importance of SSF's skills in accessing local markets and sustaining community well-being, highlighting that resilience against LFS disruptions requires tailored support for marginalized communities and ethnic minorities (Enthoven and Broeck, 2021).

Education emerges as a pivotal factor in strengthening SSF'S capabilities to manage LFS disruptions, thus offering SSF's specific skills to diversify crop production and rotation and advancing use of technology for information sharing tend to improve local food accessibility enhancing local supply chain resilience. Adding value to local produce through localized storage and preservation to extend local food cycle, strengthening the local economy, long-term food sustainability, and timely food accessibility (Enthoven and Broeck, 2021). On the other hand, disparities in education access and socio-economic status per county and ethnic minorities calls for interventions to ensure equitable development across all the 47 Kenyan counties.

The study advocates for resilient policies to strengthen SSF's resilience through targeted programs, particularly indigenous education focused on farming diversification, sustainable practices, and market access, which are grounded by subsidies for SSF's participating in the specialized training programs. This approach calls for stakeholders' collaboration who include local government, local communities, community organizations, non-profit organizations, and farmer-to-farmer networks, thus fostering long-term, equitable fairness, and sustainable LFS to advance indigenous farming systems. Besides, aligning with these diversified United Nations Sustainable Development Goals (SDGs); zero hunger, poverty eradication, good health and well-being, quality education, decent work and economic growth, reduced inequalities, sustainable economic growth, responsible consumption and production, climate action and partnership for achieving goals.

Future research could explore on county socio-economic variations, especially aligned to gender as each indigenous farming community is different from others, in addition further research could look at the entrepreneurial opportunities for SSFs' at the nexus of food system disruptions and resilience, leveraging indigenous and local knowledge (ILK) for sustainable and long-term local food production. The ILK possesses critical insights entailing sustainable resource management necessary in strengthening SSF's adaptive capacity in response to hunger, disruptions, crises, and socio-economic hardships. Besides, providing guidance on local resource management and innovation strategies for advancing local food systems transformation, promoting adaptive capacities, and transforming LFS. Thus, a robust M&E framework aligned with national strategic goals would support supply chain resilience through stakeholders' collaboration and information sharing, ensuring equitable input distribution, and provision of agricultural extension services, particularly in the marginalized areas of Northern Kenya.

Last but not least, society challenges tend to impact cross-cultural skills development and stakeholders' engagement. Although this study focuses on Kenyan SSFs, this focus could limit the generalizability of the findings to other countries, necessitating a broader research perspective. By aligning skills development through stakeholder engagements and accessing local market, SSFs can achieve long-term resilience, sustainable transformation, and local food accessibility during supply chain disruptions.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval for this research was obtained from the Kenya National Commission for Science, Technology and Innovation (NACOSTI), License No: NACOSTI/P/23/28830. Written informed consent from the participants was also obtained in accordance with the national legislation and institutional requirements.

Author contributions

JM: Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work was supported by the Paulo foundation grant number 16-10776-18 and Marcus Wallenburg Foundations grant number 18-5877-33.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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