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## COVID-19 Impact on Household Water-Energy-Food Accessibility Concerning Achieving the Sustainable Development Goals in Cities and Societies of Northern Nigeria

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# COVID-19 Impact on Household Water-Energy-Food Accessibility Concerning Achieving the Sustainable Development Goals in Cities and Societies of Northern Nigeria

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## Abstract

The recent COVID-19 pandemic has considerably impacted negatively on many aspects of human life such as access to basic necessities including water, energy and food. This article aims to investigate the impact of the COVID-19 lockdown on the water, energy and food accessibility in Katsina state, Nigeria. The survey involved the administration of a questionnaire to a total of 900 households out of which 66.7% representing 600 urban households and 33.3% are linked to 300 households of the rural sampled households. The null hypothesis ( $H_0$ ) was that there was no significant influence of the COVID-19 pandemic on the water, energy and food security concerning households. A paired  $t$ -test analysed the statistical mean of the water-energy-food accessibility under two scenarios (i.e. pre-COVID-19 and post-COVID-19 lockdown). The investigation found that the lockdown measures introduced to control the spread of COVID-19 had a significant influence on the accessibility of water, energy and food. Results revealed that admission to safely managed water provisions dropped from 30.0 to 24.6% across the scenarios. The electricity index access has also reduced from 1.9 to 1.5. Additionally, households that experience severe food insecurity have significantly increased from 4.9 to 38.6% during the pre- and post-COVID-19 lockdown, respectively. Concerning the investigated households for both the urban and rural strata, the investigation highlights the need for policy intervention to ensure that vulnerable households are not disproportionately affected during crises such as a pandemic. The findings will be useful to policymaking and will advance awareness towards achieving the sustainable development goals (SDG).

**Keywords** COVID-19 pandemic · Electricity index · Lockdown · Resilient society · Resource accessibility · Water, energy and food nexus

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Extended author information available on the last page of the article

## Introduction

Water, energy and food are interconnected resources that are crucial for the well-being and livelihoods of humans supported by the sustainable development goals (SDG) (Biggs et al., 2015). However, Nigeria faces significant challenges in managing the water, energy and food nexus because of rapid population growth. As the population grows, the water demand for food production and preparation is enhancing, but access to clean and reliable water sources, particularly in rural regions, is a major concern (Sani & Scholz, 2021). The overexploitation of groundwater and contamination issues exacerbates water scarcity problems. Energy is also vital for agriculture, but Nigeria's energy sector suffers from infrastructure deficiencies and corruption, resulting in frequent power outages and unreliable energy access. Additionally, food security is a critical challenge in Nigeria, with millions facing food insecurity due to poverty, natural disasters and conflicts (Sani & Scholz, 2021). The nation heavily relies on food imports, particularly for staples like rice, which strains foreign exchange reserves. Therefore, increasing domestic food production is crucial for improving food security in Nigeria (Mmahi & James, 2023).

The 2015 Sustainable Development Agenda, established by the United Nations, aims to address social, economic and environmental challenges and move towards sustainable development (UNDP, 2015; Meramveliotakis & Manioudis, 2024). It consists of 17 goals and 169 targets. Water, energy and food resources play a crucial part in meeting these goals and are interconnected, known as the “nexus” (Stephan et al., 2018). Specifically, SDG 2 focuses on no hunger, SDG 6 concentrates on safe water and sanitation and SDG 7 emphasises inexpensive and clean energy. The importance of these resources and their interdependence has been highlighted throughout the global COVID-19 crisis. This pandemic has had a direct influence on the progress towards these SDG (Geng et al., 2022). The access to safe water and proper sanitation is essential in preventing the spread of viruses, as regular handwashing is a vital preventive measure. However, in areas with water scarcity or contamination, people may struggle to follow basic hygiene practices, making them more susceptible to the virus (Shiretha et al., 2022). Additionally, the pandemic has increased the demand for energy due to the implementation of stay-at-home policies. This has particularly affected heating, cooking and air conditioning needs. In some cases, energy shortages have even impacted on food availability and preferences, as well as the household water supply (Sani & Scholz, 2021). Overall, the COVID-19 crisis posed significant challenges to the achievement of the SDG concerning water, energy and food. The pandemic has underscored the crucial role of clean water, sanitation and energy access in ensuring public health and well-being. Addressing these challenges while promoting sustainable development (Manioudis & Meramveliotakis, 2022) has become even more critical in the face of the ongoing global crisis.

The COVID-19 pandemic was an international health emergency, which caused widespread infections and deaths. It also had negative effects on socio-economic developments, leading to a crisis around the world. Subsequently to the COVID-19 occurrence, the Nigerian government declared a 3-week national lockdown to avert the increase of the virus spread on 30 March 2020. The

lockdown was extended further until 2 June 2020 (covering a period of 3 months). Some actions were instigated by the federal and state authorities: travel restrictions, which caused disruptions such as limited movement of goods and services. Travel restrictions by closing transport systems severely disrupted resource supply chains including water, energy and food supplies. In addition, limiting mass crowding had significantly impacted on the resource accessibility due to local market closures preventing the trade of food and energy locally. Thus, the pandemic caused economic decline and pushed many households into poverty, causing an increase in hunger among the population (WHO, 2022). Water, energy and food resource management faces challenges such as limited accessibility, increasing demand and risks from the international market. Considering an anticipated global population of about 9 billion by 2050, food and energy production are expected to increase by 70% and 50%, respectively, while water demand will increase by 55%. Half of the global population is predicted to experience water stress by 2050 (UNDP, 2015). Limited access to land and water will lead to trade-offs and competition between food and energy production. These challenges have been exacerbated by the pandemic, with directly impacts on both water and food contamination, and indirectly effects unemployment, social unrest and disruptions in supply chains. Low- and middle-income states are particularly susceptible to these impacts (Diffenbaugh et al., 2020).

Studies highlighted the vulnerabilities and gaps in the existing systems and proposed strategies for enhancing resilience and sustainability in the face of similar future crises (Cheshmehzangi, 2020; Deaton & Deaton, 2020). The pandemic served as a wake-up call for the importance of integrated approaches to address the interdependencies between the water, energy and food segments. The research findings emphasised the need for cross-sectoral collaboration and coordinated policies to ensure a more secure and resilient future (Durodola et al., 2020), although several studies (Table 1) were reviewed that explored, assessed and analysed the impact of the deadly disease on either a single or two elements of the water, energy and food nexus components and by extension to the SDG in the local context. The pandemic threatened human well-being and the SDG, negatively affecting water, energy and food accessibility. This study compares pre- and post-lockdown accessibility in Katsina state, evaluating its impact on sustainability and the SDG.

The COVID-19 pandemic was unique. In just a few months, it has spread from China to every continent, transmitting the virus to millions of people and killing hundreds of thousands of them. As of April 2023, COVID-19 has killed nearly 7 million people. On 18 November 2022, the overall deaths due to COVID-19 in Africa and Nigeria reached 257,984 and 3155, respectively (WHO, 2022). Recently, on the 15th summit of the International Health Regulations (IHR) Emergency Committee concerning the coronavirus 2019 disease (COVID-19) held on 4 May 2023, the Director General of the World Health Organisation (WHO) declares “with great hope” an end to COVID-19 as a public health emergency, but stressed that this statement did not mean the deadly disease is not anymore a global threat. Nevertheless, even if the disease has ended, humanity will continue to suffer from the effects it leaves behind for decades to come.

**Table 1** Summary of literature review concerning the COVID-19 pandemic

Literature	Objective	Outcomes	Limitation
Ostadtaghizadeh et al. (2022)	To explore the importance of water on health followed by the effect of the pandemic on water and sanitation services To explain the Sustainable Development Goal (SDG) 6 in relation to the pandemic	Lessons learned from the water challenge and the pandemic	Although the pandemic affected the water sector, its impacts are still being investigated. This is due to limited data and monitoring measures tracking the water quality in flowing watercourses during lockdowns and restrictions in movement
Gbedemah et al. (2022)	To examine water access and its associated challenges as well as the different strategies utilised by households to deal with challenges in the Yilo Krobo Municipality (Ghana) during the start of the pandemic	About 69% of households had pipe-borne water access during the pandemic compared to 8% who uses unhygienic water supply sources. Most households (55%) depended on pipe-borne water outlets located outside homes. Key access challenges during the pandemic were the high cost of water (41%) despite that water supply was free at the beginning of the pandemic	The paper does not evaluate the impact of strategies on the development of the pandemic
Abu-Bakar et al. (2021)	To quantify the influence of the lockdown on aggregate water demand	Findings show groups with low and high demand of water indicating a significant difference in the pattern of water use during the lockdown due to the pandemic	The investigation was conducted exclusively among the urban household neglecting their rural counterparts
Sherpa et al. (2022)	To analyse the impact of the pandemic on access to inexpensive and environmentally friendly energy	The study encompasses the significance of SDG7 (affordable and clean energy) before and during the pandemic concerning the energy sector. Moreover, the study assesses the sustainability of energy provision and its challenges during the pandemic	The study lacks a comparative assessment before and after the pandemic concerning its effects on resource accessibility

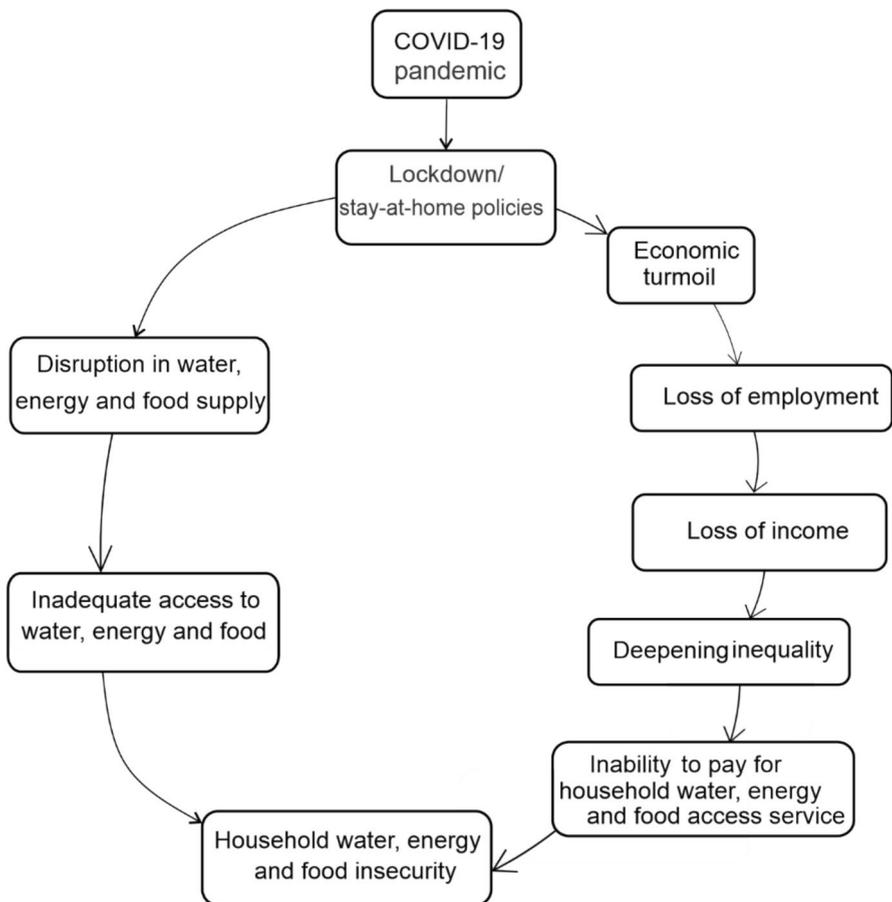
**Table 1** (continued)

Literature	Objective	Outcomes	Limitation
Krarti and Aldubyan (2021)	To systematically analyse strict stay-at-home orders and lockdowns To assess impacts on the electricity demand for the residential sector	The analysis indicates that the overall electricity demand reduced due to the lockdown. However, the demand associated with commercial buildings linked to manufacturing and the housing sector has increased by 30% during the entire lockdown of 2020. The elevation is because of higher occupancy rates during the day leading to increased heating, air conditioning, light and other overall appliance usages	The analysis was conducted on electricity use while other energy sources were neglected
Cheshmehzangi (2020)	To access household cooking energy sources across 3 scenarios (before the pandemic, during the COVID-19 outbreak and lockdown as well as post-lockdown) in China	The article highlights temporary impacts on the household energy use and long-term ones on the transportation sector	The study was conducted at the beginning of the pandemic and, therefore, it did not capture secondary influences on the access to resources
Ghanbari et al. (2022)	To assess the impact of the pandemic on both food security and diversity concerning households in rural areas	Results revealed that socio-economic and demographic attributes of household heads were significantly linked with food security and dietary diversity throughout the pandemic	The assessment was made throughout the quarantine. It follows that sampling was a challenge
Galanakis (2020)	To explore the food systems during the pandemic	The study assessed the global food security problematic during lockdown and stressed the importance of a sustainable food chain avoiding future food and health challenges	Food accessibility, which is a cardinal pillar of food security, has not been addressed

**Table 1** (continued)

Literature	Objective	Outcomes	Limitation
Shupler et al. (2021)	To investigate the drivers of urban food and energy insecurity due to the pandemic in a large informal settlement	The findings revealed complex associations between household demographics, finances, diet and cooking patterns. There is an opportunity for adopting a food-energy nexus approach to address several SDG including no hunger and safe energy access	The observations might not be representative for other regions due to different lockdown procedures impacting on the trade of food and fuel

The pandemic has led to a significant increase in unemployment and poverty in many countries including Nigeria (Li et al., 2023). The lockdown measures implemented to reduce the virus spread have led to a reduction in household resources including water, energy and food. The lockdown has led to increased need for water, energy and food because of hygiene concerns, stay-at-home policies and panic buying. This has resulted in a reduction in household water supply, energy supply chain disruptions and food provision. The lockdown has also negatively impacted on access to water services, sustainable household energy provisions and food markets (Fig. 1). The contagion has underlined the value of a resilient and sustainable water, energy and food nexus, which is vulnerable to disruptions and requires coordinated efforts to ensure sustained admission to these essential resources (Stephan et al., 2018). The pandemic has highlighted the necessity for coordinated action to warrant continuous access to these resources, as the demand for them has already



**Fig. 1** Impact of the coronavirus disease 2019 (COVID-19) on the water, energy and food security on household level

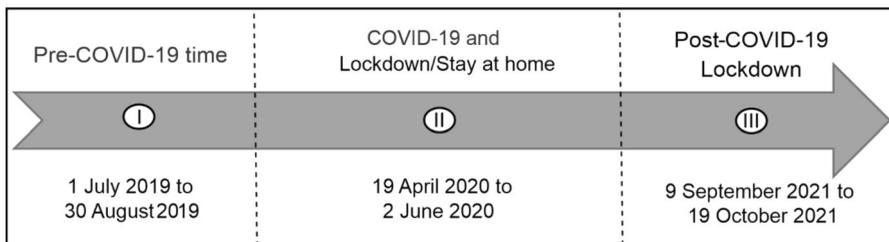
exceeded available provisions in sub-Saharan Africa due to fragile social and economic systems.

## Methodologies and Materials

### Survey Data

The primary methodology of data gathering was employed in this investigation, which was conducted through administration of questionnaires in Katsina state. The questionnaire is shown in ESM 1. An organised questionnaire was constructed for the survey and used to collect general household information. The information included data on household water, energy and food accessibility. All questionnaires were developed in English, translated into the local language Hausa (Chadic language belonging to the Afroasiatic language family) and back-translated to English to check for translation errors. The questionnaire survey was conducted face-to-face by 16 assistants in the field. All investigators spoke local languages and were familiar with their sampling community. Moreover, they received training in questionnaire handling. The interviews themselves were also conducted in local languages. The design of questionnaires was according to common standards. Interview sections covered household statistics, family compositions and socio-economic characteristics (Angelsen et al., 2011). Moreover, the questionnaire was designed in an innovative way based on the integrated nexus approach perspective where all the three elements of the nexus are incorporated rather than a single constituent. It also involved urban and rural characteristics, in relation to the various water, energy and food source ease of access within the surveyed sessions.

Two different data collection sessions were conducted for the study. During the first session, data were collected in 2019 (before the pandemic and corresponding lockdown periods) where 1785 family units were surveyed. This sampling size was seen as sufficiently large to allow for a robust statistical analysis (see the “Statistical Analysis” section). The first session started in early July 2019 and ended in late August 2019, covering a period of 2 months, as illustrated in Fig. 2. Prior to the pandemic, the first session of the study was designed to assess the resource accessibility and track progress towards achieving the ambitious SDG. The lockdown, which is a non-pharmaceutical intervention to reduce the virus spread, was implemented across



**Fig. 2** Three phases of the timeline and the survey (coronavirus disease 2019, COVID-19)

many infected regions including the sampled communities in Katsina state. Thus, this stratification was in line with several investigations (Diftenbaugh et al., 2020) that indicated disruptions in various resource supplies including water, energy and food as a result of the lockdown measures. Furthermore, other studies (Durodola et al., 2020; Geng et al., 2022) revealed the drawback impacts of the pandemic and its associated policies on the ambitious SDG. Thus, the second session of the survey was designed to compare the outcome of the first survey with the second one to judge the impact of the deadly disease on resource accessibility and tracking progress towards realising the SDG in Katsina state.

The survey exercise was repeated in September and October 2021. To ensure that the sample was fully representative in the study area, a stratified arbitrary sampling method was used across the two regional strata (rural and urban) in the region based on Katsina State Urban and Regional Planning Board parameters (KTURPB, 2018). Accordingly, six communities were carefully selected to be the study sampling communities. This inbuilt redundancy allowed for a solid data set for subsequent analysis. The number of households surveyed reflected the total number of houses that were involved in the two different surveys. Exactly 900 questionnaires were distributed to the households, out of which 600 (66.7%) and 300 (33.3%) were served to urban and rural areas of Katsina state, respectively (Table 2). The variation of sample size was due to practical and logistical reasons during the second survey that was impacted by governmental restrictions. The spatial location of the sampled communities is shown in Fig. 3.

## Outcome Variables

The essential variable outputs for the study were availability to diverse water sources, cooking energy sources and groceries supplies across the two scenarios (i.e. pre- and post-COVID-19 lockdown). Thus, each household in the sampling communities was examined concerning accessibility to a variety of water and cooking energy sources, and accessibility to food (frequencies of food purchase pattern). The Joint Monitoring Programme classification of improved and unimproved water sources was employed for categorisation (UNICEF & WHO, 2020). In addition, to find out the water service access availability, water quality experiments were accomplished applying the standard

**Table 2** Questionnaire distribution across the sampling communities of the study area

Stratum	Sampling community	Number of questionnaires administered
Urban	Katsina	200
	Dutsinma	200
	Funtua	200
Rural	Dan-Yashe	100
	Kai-kai	100
	Kuringafa	100
Total		900

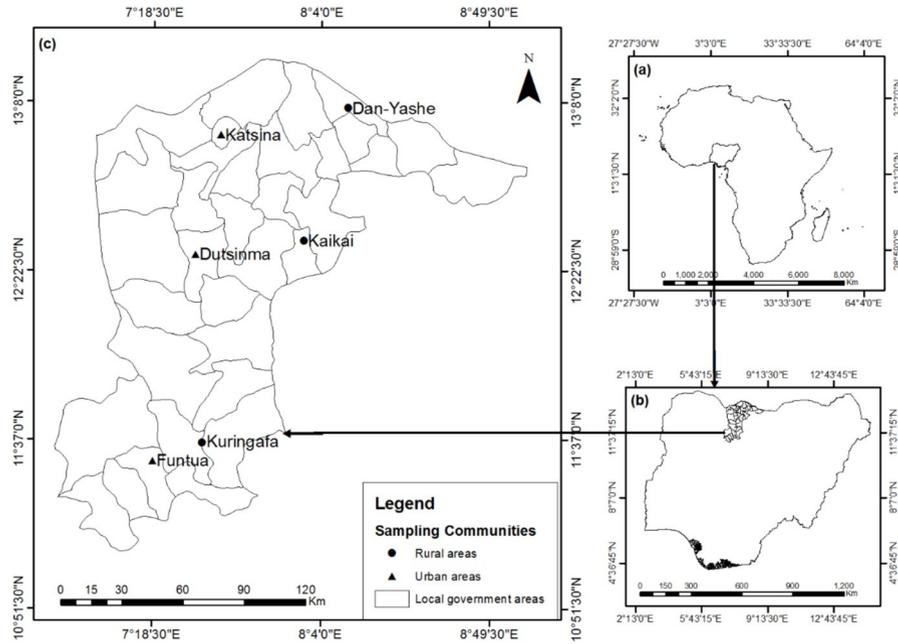


Fig. 3 (a) Africa, (b) Nigeria; and (c) the representative Katsina state case study

Joint Monitoring Programme portable equipment for *Escherichia coli* (UNICEF & WHO, 2020). Water quality testing was conducted in about 20% of the surveyed family units and was linked to the availability to different water sources. The assessment was undertaken together with the Water Laboratory of the Department of Geography belonging to Umaru Musa Yaradua University, Katsina, Nigeria. Moreover, accessibility to various energy sources was classified into clean (non-solid) and unclean (solid) energy sources adopting WHO classification (WHO, 2006). Additionally, a multi-tier frame was implemented to quantify the fraction of the households’ electricity availability index using Eq. (1).

$$\text{Index} = (P_T \times T) \tag{1}$$

where  $P_T$  signifies the fraction of families at tier  $T$  with a tier number {0, 1, 2, 3, 4 and 5}.

Household food accessibility was analysed based on a method published by Frongillo et al. (2003). To further investigate the household’s water, energy and food safety, a response linked to their ability to pay for water, energy and food accessibility services was further explored. Table 3 shows the security ladder for water, energy and food in advancement from bottom to top concerning security.

**Table 3** Household water, energy and food classification with respect to how secure access may be

Access category	Security class	Variables
Water source access (UNICEF & WHO, 2020)	Secured sources	Rainwater, protected spring, protected dug well, borehole or tube well, public tap or standpipe, piped water to yard and piped water into dwelling
	Unsecured sources	Surface water, tanker truck, cart with tank or drum (water vending), unprotected dug well and unprotected spring
Energy source access (WHO, 2006)	Clean (non-solid) sources	Electricity, natural gas, liquefied petroleum gas, ethanol and methanol, and kerosene
	Unclean (solid) sources	Dung, agricultural residue, fuelwood, charcoal and coal
Households' food flow (purchase patterns)	Food security	Less-repeated purchase and large-quantity purchase
	Food insecurity	High-repeated purchase and small-quantity purchase

## Statistical Analysis

Study characteristics such as accessibility to different improved and unimproved water sources, clean and unclean energy sources as well as food access and consumption frequencies were calculated and presented in percentages. The paired *t*-test was used to determine whether there is a difference between the water, energy and food accessibility regarding the two scenarios of pre- and post-COVID-19 lockdown for the same investigated households across the scenarios. Furthermore, to explore the associations of the households' ability to pay for water, energy and food access services before and after the COVID-19 lockdown, a Pearson product moment correlation (PPMC) analysis was applied. The analysis considered 95% confidence limits and  $\alpha=0.05$ . Data input and statistical analyses were undertaken applying the International Business Machines Corporation (IBM) Statistical Package for the Social Sciences (SPSS) Statistics 24 package.

## Results and Discussion

### Socio-economic Attributes of the Family Units' Heads

The family units' heads were represented by older married males with a rather low education and wealth profile. Table 4 indicates that most of the respondents were above 40 years old, but only 8% were found to be above 60 years. Most of the participants were male (81%). The residual 19% were female. In the traditional Hausa society, it would have been inappropriate to ask for non-binary respondents. It follows that the purely estimated hidden error associated with this simplification might be up to 0.5%. Across the surveyed households, the study revealed that 73% of household heads were married, while 12% and 7% of them were divorcees and widows, respectively. Furthermore, 40% of the respondents did not have a formal education. Only 7% of the respondents were found to be postgraduates. The graduate respondents comprised 14%, while 16% passed primary school, 12% passed secondary school and 12% obtained a higher secondary level degree, i.e. either an ordinary national diploma or a national certificate of education.

Furthermore, Table 4 reveals that the high-income earning household heads across the sampled communities that earned above N180,000 (\$500) were about 6%. In comparison, 13% of the households' heads earned less than N18,000 (\$50) per month. Moreover, the investigation indicated that the bulk (63%) of the households tend to have a large number of family member (above five members) across the surveyed households. This implies a high demand for the use of water, energy and food.

The study also revealed that 28.3% and 42.6% of the surveyed family units survived below the international poverty line during the pre- and post-COVID-19 lockdown, respectively. It further revealed that 22.9% and 43.4% of the participants survived below the national poverty line during the pre- and post-COVID-19 lockdown in this order. Previous studies (Janssens et al., 2021; Josephson et al., 2021) have shown serious impacts of the pandemic on low-income earners. Thus, this suggests

**Table 4** Socio-economic attributes of the households across the sampled communities

Variable	Item	<i>n</i>	%
Gender	Male	729	81
	Female	171	19
	Total	900	100
Marital status	Married	657	73
	Divorcee	108	12
	Widow	63	7
	Total	900	100
Educational status	No education	360	40
	Primary school	144	16
	Secondary school	108	12
	Ordinary national diploma/national certificate of education	99	11
	University degree	126	14
	Advanced university degree	63	7
	Total	900	100
Average monthly income	< N18,000 (\$50)	117	13
	N18,000–36,000 (\$50–100)	153	17
	N36,001–72,000 (> \$100–200)	171	19
	N72,001–144,000 (> \$200–300)	135	15
	N144,001–180,000 (> 400–500)	270	30
	Above 180,000 (> \$500)	54	6
	Total	900	100
Age (year)	20–25	99	11
	26–30	117	13
	31–35	99	11
	36–40	135	15
	41–45	162	18
	45–50	81	9
	51–55	36	4
	56–60	99	11
	> 60	72	8
	Total	900	100
Household size (person)	1–2	27	3
	3–4	63	7
	5–6	243	27
	7–9	270	30
	≥ 10	297	33
	Total	900	100

that poor households are more likely to experience inaccessibility to safe and adequate water, clean cooking fuels and high frequency of food flows during emergency situations like the COVID-19 pandemic.

The “Socio-economic Attributes of the Family Units’ Heads” section indicates the importance of re-evaluating resource systems by undertaking security reviews particularly in consultation with representative family unit’s heads from poor families in the countryside. The SDG in relation to the water, energy and food nexus can only be successfully implemented on household level due to engagement with community leaders representing households.

### Household’s Water Accessibility Across the Settings

The household’s accessibility to adequate water supplies deteriorated during the pandemic. Table 3 highlights the access levels of various supplies of household water across the two scenarios of pre- and post-COVID-19 lockdowns in the surveyed urban and rural households. Water access involves various types of improved and unimproved sources. The study also revealed the high proportion of ease-of-use to different improved household water supply sources during the pre-COVID-19 lockdown. On the other hand, the accessibility level to the improved water sources dropped significantly during the post-COVID-19 lockdown.

Access to improved household water supply sources is fundamental and varied between urban and rural locations. Table 5 indicates different types of family unit water sources concerning pre-COVID and post-COVID scenarios in the corresponding urban and rural villages. Findings indicate a range of water sources for domestic use in this investigation. The paired *t*-test for access to different family unit water sources concerning the two different situations within the urban and rural examined households highlighted a significant ( $p < 0.005$ ) deviation among the urban and rural residents.

**Table 5** Accessibility to various household water sources across the coronavirus disease 2019 (COVID-19) scenarios concerning urban and rural strata

Water source	Pre-COVID-19				Post-COVID-19 lockdown			
	Urban		Rural		Urban		Rural	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Water piped into dwelling	7	1.2	0	0	2	0.3	0	0
Water piped to yard	18	3	0	0	5	0.8	0	0
Private borehole	267	44.5	0	0	185	30.8	0	0
Public borehole	72	12	19	6.3	107	17.8	36	12
Protected dug well	12	2	29	9.7	27	4.5	14	4.7
Unprotected dug well	17	2.8	99	33	19	3.2	97	32.3
Water vendor	207	34.5	81	27	242	40.4	94	31.3
Surface water	0	0	39	13	0	0	39	13
Tanker truck	0	0	33	11	13	2.2	20	6.7
Total	600	100	300	100	600	100	300	100

*n*, sample number

The study revealed that water vendors were found across the two scenarios (pre- and post-COVID-19 lockdown) in the corresponding urban and rural divisions. In urban section, the general use of privately owned boreholes observed a rising trend across the two settings, whereas the consumption intensity of water vendor uses as a source of family water supply varied. There was a drastic reduction of urban household-owned private boreholes from 44.5% during the pre-COVID-19 situation to 30.8% after the pandemic lockdown. Access to piped water into dwellings and pipe water to the yards had the lowest respective proportions (1.2% and 3.0%) and were only found during the pre-COVID-19 scenario in the urban strata.

In rural communities, Table 5 further illustrates higher proportions of accessibility to various unimproved water sources among various households across the two scenarios. Unprotected dug wells (33.0% and 32.3%), water vendors (27.0% and 31.3%) and tanker trucks (11.0% and 6.7%) were accessed as sources of household water supply for the pre- and post-COVID-19 lockdown, respectively. Moreover, public boreholes (6.3% and 12.0%) and protected dug wells (9.7% and 4.7%) as sources of improved water were recorded for the pre- and post-COVID-19 lockdown in this order.

Additionally, findings revealed that there was a lack of access to pipe water into dwellings, pipe water to yards and privately own boreholes, which form the high level of improvement of household water supply in the rural stratum. Conversely, surface water, which forms the lowest level of unimprovement of the water supply, was recorded at 13% for both situations in the rural stratum.

The study further investigated the family unit's capability to pay for water access benefits. It was found that only 58% of the surveyed households are paying for the water access while the remaining 42% access water from various sources without any payment. The findings revealed that 72% of the households that paid for water access services were always able to pay for the service before the COVID-19 lockdown. The proportion of ability to pay for the household water access services reduced considerably to 39% after the COVID-19 pandemic.

Furthermore, a paired *t*-test showed that there were no significant differences in access to various water sources between the two scenarios of pre- and post-COVID-19 lockdown in Katsina state. Although the paired *t*-test results indicated no significant difference in water accessibility between the two scenarios, the study further investigated the family's power to pay for food access benefits. The PPMC was used to verify the strength and direction of the households' ability to pay for the water access services concerning the pre- and post-COVID-19 lockdown scenarios. The data analysis signified a weak association ( $r=0.49$ ). Nevertheless, the *p*-value was below 0.05, which indicates the significance of the association.

The results revealed that there was a severe negative effect of COVID-19 on the accessibility of water. This finding coincided with several studies that also exposed a profound influence of COVID-19 on related water accessibility aspects. For example Ogunbode et al. (2021) assessed the pandemic and the associated restrictions on passage of the participants to look for household water. Various strategies were implemented to safeguard household water accessibility, which involved night fetching, rotation, purchase and surface sources among others.

The study further indicated that an overwhelming majority of the investigated households powerfully approved that the COVID-19 pandemic had severe effects on household water supply and exposed them to adversity indicated by searching for water whereas trying to circumvent physical contact with other humans. Stoler et al. (2021) reported that most investigated households experienced various forms of water insecurity due to COVID-19 control measures including inadequate water for handwashing, bathing and other hygiene-related activities.

Water is the most essential element of the nexus. Therefore, the need for all-time safe access to clean water across all urban and rural community locations to address a key SDG has been highlighted in the “Household’s Water Accessibility Across the Settings” section. The local government must provide sustainable access to improved water resources at a neighbourhood scale particularly in rural communities.

### Accessibility to Household Cooking Energy Sources Throughout the Scenarios

The accessibility to cooking energy sources changed between both scenarios leading to a deterioration of sustainable sources. Table 6 indicates the accessibility levels of various sources of family cooking energy across the two scenarios of pre- and post-COVID-19 lockdown in both the urban and rural sampled family units. The investigation reveals an elevated proportion of accessibility to various clean (non-solid) sources of cooking energy supply during pre-COVID-19 lockdown in the urban stratum. The overall use of non-solid cooking energy sources witnessed a downward trend. Table 4 reveals that 67.2% of the cooking gas during pre-COVID-19 period reduced to 22.8% throughout the post-COVID-19 lockdown scenario. The findings highlight a similar trend for electricity: 0.8% was recorded during the pre-COVID-19 and only 0.2% after the COVID-19 lockdown. An accessibility level of 0.3% concerning kerosene was only recorded during the pre-COVID-19 study. Moreover, access to fuelwood witnessed an upward trend as a source of household

**Table 6** Accessibility to various cooking energy sources across the coronavirus disease 2019 (COVID-19) scenarios in the urban and rural strata

Energy source	Pre-COVID-19				Post-COVID-19 lockdown			
	Urban		Rural		Urban		Rural	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>N</i>	%
Electricity	5	0.8	0	0.0	1	0.2	0	0.0
Cooking gas	403	67.2	0	0.0	137	22.8	0	0.0
Kerosene	2	0.3	0	0.0	0	0.0	0	0.0
Charcoal	21	3.5	5	1.7	165	27.5	0	0.0
Sawdust	0	0.0	0	0.0	29	4.8	3	1.0
Fuelwood	169	28.2	258	86.0	268	44.7	261	87.0
Agricultural residue	0	0.0	37	12.3	0	100.0	36	12.0
Total	600	100.0	300	100.0	600	100.0	300	100.0

*n*, sample number

cooking fuel from the pre- to the post-COVID-19 situation across the strata. There was a drastic increase of urban accessibility to fuelwood: 22.8% for the pre- and 44.7% for the post-COVID-19 scenarios. On the other hand, agricultural residue (post-harvest waste) was only found across the two scenarios in the rural stratum.

The accessibility level to the solid (unclean) energy sources raised significantly during post-COVID-19 lockdown. Concerning the pre-pandemic situation, a high proportion (45%) of accessibility to cooking gas (liquefied petroleum gas) classified as a clean cooking energy source was noted. In addition, 0.6% and 0.2% of electricity and kerosene use, respectively, were recorded.

Table 6 also indicates the accessibility level to various sources of clean (non-solid) and unclean (solid) cooking energy during the post-COVID-19 lockdown throughout the urban and rural strata. Unlike all through the pre-pandemic lockdown, the accessibility to various non-solid cooking fuel sources diminished in the metropolitan areas. The research showed that the accessibility to liquefied petroleum gas (cooking gas) dropped from 67.2 to 22.8% after the lockdown. Consequently, there was an increased accessibility to charcoal and fuelwood as cooking energy sources. The study witnessed dramatic increases in accessibility to charcoal: 3.5% for the pre-COVID-19 lockdown and 27.5% after the lockdown. A similar trend was also recorded for fuelwood access: 28.2% before the COVID-19 lockdown and 47% thereafter. The findings discovered that during the post-COVID-19 lockdown, there was an energy switch to sawdust (4.8%), which was not identified during the pre-lockdown scenario. No significant change was found for accessibility to agricultural residue across the scenarios. The paired *t*-test analyses for household's cooking energy accessibility revealed that there were significant differences in the energy accessibility across the scenarios ( $p < 0.001$ ). In the rural stratum, Table 6 further indicates that during the pre-COVID-19 lockdown, the accessibility to charcoal diminished from 1.7 to 0.0%.

The study further investigated the household ability to pay for cooking energy access services. The findings revealed that 81% of the households that pay water access services were always able to pay for the service before the COVID-19 lockdown. This figure drastically reduced to 42% after the COVID-19 pandemic. The PPMC was used to uncover the strength and direction of association households' ability to pay for the energy access service scenarios pre- and post-COVID-19 lockdown. There was a weak association ( $r = 0.47$ ), but the *p*-value was below 0.05, which implies significance of this association.

The research highlighted a great proportion of accessibility to different clean energy sources for cooking during the pre-COVID-19 time. The findings corresponded well with some other studies (Cuerdo-Vilches et al., 2021; Shupler et al., 2021; Soava et al., 2021) that stress the negative impact of the pandemic on household energy accessibility and consumption. The pandemic lockdown has resulted in food and energy insecurity in households, with many switching from clean energy sources to polluting fuels. A study has shown that restricted households in Madrid have exhibited patterns of energy consumption, leading to vulnerability and energy poverty (Cuerdo-Vilches et al., 2021). In Romania, the economic turmoil has negatively impacted on electricity consumption and household economic prosperity, with

many unable to take action against increased energy consumption and prices (Soava et al., 2021).

Similar to the “Household’s Water Accessibility Across the Settings” section concerning water access, there is also a need for secure access across all communities to energy as outlined in the “Accessibility to Household Cooking Energy Sources Throughout the Scenarios” section. The local government must provide sustainable access to energy resources at least for cooking purposes at a neighbourhood scale to support the corresponding SDG.

### Household’s Food Purchase Frequencies and Ability to Pay for Food Items

Households shopping patterns changed during the pandemic. Table 7 indicates various food purchase frequencies for different family units across six populations. A significant variety of family food purchases monthly, weekly and everyday patterns were found across the two scenarios pre- and post-COVID-19 lockdown. Some households predominantly produced their own food.

The frequency of food purchases across the investigated households revealed how often a household buys food items, which varies depending on factors such as households’ income and access to food markets. Understanding the frequency of food access (purchase) can provide insights into household food consumption patterns to identify potential challenges or opportunities for improving food security. The study indicated the high proportions of monthly and weekly bulk food purchase arrangements throughout the pre-COVID-19 lockdown. The highest proportion (62%) of households purchased food items monthly. Almost 18% of the households purchased their various food items weekly, while the lowest proportion (5%) of food purchase pattern during the pre-COVID-19 lockdown scenario was daily. In addition, 16% of the surveyed households accessed their food through self-production via farming.

Table 7 further reveals the food purchase patterns during the post-COVID-19 lockdown. Monthly food purchase and production of own food considerably reduced. The study shows that monthly food purchases dropped from 61 to 15%.

**Table 7** Household food accessibility across the coronavirus disease 2019 (COVID-19) scenarios for urban and rural strata

Frequency of food purchase pattern	Pre-COVID-19				Post-COVID-19 lockdown			
	Municipal		Countryside		Municipal		Countryside	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Monthly	519	86.5	39	13.0	127	21.2	9	3.0
Weekly	36	6.0	122	40.7	237	39.5	137	45.6
Daily	26	4.3	18	6.0	225	37.5	123	41.0
Produced own food	19	3.2	121	40.3	11	1.8	31	10.4
Total	600	100.0	300	100.0	600	100.0	300	100.0

*n*, sample number

Consequently, there was an increase in the weekly and daily patterns of purchase: 42% and 39%, respectively.

Furthermore, a paired *t*-test exposed that there were no significant differences in access to various water sources between the two scenarios of pre- and post-COVID-19 lockdown periods in Katsina state. Although the paired *t*-test result indicated no significant difference in water accessibility between the two scenarios, the study further investigated the family's capacity to pay for food access benefits. The outcomes uncovered that 80% of the families were always able to pay for the food purchases before the COVID-19 lockdown. The proportion of ability to pay for the household food purchases reduced considerably to 30% after the COVID-19 lockdown. The PPMC was used to verify the strength and direction of relationship regarding the households' ability to pay for the energy access service scenarios pre- and post-COVID-19 lockdown. Pearson's *r* signified a weak association ( $r=0.321$ ). Nonetheless, the *p*-value was below 0.05 demonstrating a significant measure of this association.

The pandemic's effects on food security in different areas have been documented in earlier research. There has been a notable decline in purchasing power and an increase in food prices in Iran according to Rad et al. (2021). There was a wide range of food insecurity among Indonesian households, with low-income households being more susceptible (Syafiq et al., 2022). About 93% of low-income family units in Bangladesh reported having food insecurity of one kind or another, underscoring the need for more investigations into the pandemic's effects on food security (Kazi et al., 2022). Moreover, in their analysis of the effects of the pandemic on family unit food insecurity and hardship in Ghana, Bukari et al. (2022) drew attention to the high rates of poverty, which may impede the availability of resources.

Table 8 comparatively assesses various levels of progress towards achieving relevant SDG indicators across the two scenarios. The assessment is directly related to SDG 1, 2, 3, 6 and 7. The corresponding relevant indicators are 1.1.1, 1.2.1, 1.4.1, 2.1.2, 3.9.1, 3.9.2, 6.1.1, 7.1.1 and 7.1.2.

Moreover, Table 8 illustrates the comparative representation of the SDG indicators across the scenarios. Relevant to SDG 1.1.1, which indicates the share of population beneath the international poverty line, findings show that during the pre-COVID-19 lockdown, 28% of the surveyed households survived below the 2020 international poverty line during the investigation. This number increased to 43% living below the 2022 international poverty limit after the lockdown. The study further revealed that relevant to SDG 1.2.1, which indicates inhabitants living beneath the national poverty threshold, 23% of investigated households were below the nationwide poverty line during the pre-COVID-19 lockdown. This number has risen to 43% after the lockdown. Additionally, related to the SDG 2 on no hunger (especially related to indicator 2.1.2), the findings revealed that during the pre-COVID-19 lockdown scenario, 18% of the investigated families purchased food on a weekly (moderate sustenance insecurity) basis. While during the post-19 lockdown, this figure increased to 42%. In relation to SDG 1.4.1, which indicates a percentage of population living in families with access to rudimentary services, the study also illustrated that 30% of the inspected homes had access to carefully managed drinking water services during the pre-COVID-19 lockdown. This proportion was reduced to

**Table 8** Progress towards addressing the sustainable development goals (SDG) applying appropriate indicators across the coronavirus disease 2019 (COVID-19) scenarios in Katsina state

SDG	SDG indicator	Indicator's description	Context within the scenarios	
			Pre-pandemic lockdown	Post-pandemic lockdown
SDG 1: no more poverty	1.1.1	Percentage of population below the international poverty threshold, sex, age, employment status and geographical region (urban/rural)	At least 28.3% of the surveyed households lived below the 2020 international poverty threshold (\$1.90/person/day) at the time of the survey. Exact data for respondents' wages were not obtainable, as data on salary were as data on earnings were gathered as an ordinal variable	At least 42.6% of respondents lived below the 2022 international poverty threshold (\$2.15/person/day) at the time of the survey. Precise data for respondents' wages were not obtainable, as data on salary were collected as an ordinal variable
	1.2.1	Population living below the national poverty threshold	22.9% of respondents lived below the national poverty threshold of N137,430 (\$381/person/year). The ratio of people living below the poverty limit could be marginally higher, considering that precise figures for respondents' incomes were not available as data on pay were collected as an ordinal variable	43.4% of participants lived below the national poverty line. The proportion of people existing below the poverty line could be slightly higher, contemplating that detailed figures for respondents' wages were not accessible as data on income were assembled as an ordinal variable
	1.4.1	Proportion of population living in households with access to basic services	30.0% of the investigated households had access to safely managed drinking water services 53.3% of the sampled households had access to either safely managed or basic sanitation facilities 45.5% of the sampled households accessed clean fuels	24.6% of the investigated households had access to safely managed drinking water services 53.3% of the sampled households had access to either safely managed or basic sanitation facilities 15.3% of the sampled households accessed clean fuels

Table 8 (continued)

SDG	SDG indicator	Indicator's description	Context within the scenarios	
			Pre-pandemic lockdown	Post-pandemic lockdown
SDG 2: zero hunger	2.1.2	Prevalence of moderate or severe food insecurity in a population based on the Food Insecurity Experience Scale	18% and 4.9% of the investigated households bought food stuff on a weekly (moderate food insecurity) and daily (critical food uncertainty) basis, correspondingly	42% and 38.6% of the investigated households bought food stuff on a weekly (moderate food insecurity) and daily (severe food uncertainty) basis, respectively
SDG 3: health and well-being	3.9.1	Mortality attributed household and ambient air pollution	54.5% of the investigated households were using various solid fuels sources (fuel wood, charcoal and agricultural residue/post-harvest waste) for cooking	84.7% of the investigated households were using various solid cooking fuels (fuel wood, saw dust, charcoal, agricultural residue and dung)
	3.9.2	Mortality attributed to unsafe water, sanitation and lack of hygiene	Results indicated that 52.9% of the investigated households have access to numerous sources of rather dirty water	Results indicated that 58.2% of the investigated households have access to many unimproved water sources
SDG 6: clean water and sanitation	6.1.1	Rate of population utilising safely managed drinking water services	30.0% of the investigated households had access to safely managed potable water supplies	24.6% of the participating households had access to well-managed drinking water services

**Table 8** (continued)

SDG	SDG indicator	Indicator's description	Context within the scenarios	
			Pre-pandemic lockdown	Post-pandemic lockdown
SDG 7: affordable and clean energy	7.1.1	Proportion of population with access to electricity	Although 87.3% of the investigated family units were tied to the general electricity grid, due to the nature of unreliable and weak electricity provision, the access to electricity index using multi-tier framework was 1.9	63.9% of the investigated participants were linked to the general electricity grid. Due to the nature of variable and unsustainable electricity supply, the access to electricity index using multi-tier framework was only 1.5
	7.1.2	Proportion of population with primary reliance on clean fuels and technology	45.5% of the investigated households were using non-solid fuel (electricity, kerosene and cooking gas) with various respective improved cooking stoves (electric cooking stove, cooking gas stove and kerosene stove). In contrast, 55.5% of the households relied on a variety of unclean solid fuel supplies, which include fuel wood, charcoal and agricultural post-harvest waste for cooking	15.3% of households accessed clean fuel (non-solid fuel sources that comprise electricity, cooking gas and kerosene) in contrary to 84.7% of households relying on a range of unclean fuel (solid fuel sources, which included fuel wood, saw dust, charcoal and agricultural post-harvest waste for food preparation

25% after the lockdown. Additionally, during the pre-pandemic scenario, the overall access index to household electricity was low (1.9) and dropped even further (1.5) after the COVID-19 lockdown, implying that households were inhibited in getting reliable and effective energy services for lighting and other utilisations.

Relevant to SDG 3.9.1, which indicates household mortality attributed to ambient air pollution, the research discovered that throughout the pre-COVID-19 lockdown scenario, 55% of the households investigated were using numerous solid fuel types such as fuel wood, charcoal and agricultural residue (e.g. post-harvest waste) for cooking, which contributed significantly to in-door-air pollution. While during the post-COVID-19 lockdown, this figure increased to 85%. Additionally, in relation to SDG 3.9.2 indicating mortality accredited to dirty water, the findings revealed that during the pre-pandemic lockdown scenario 52.9% of the investigated families had access to many sources of non-clean water. While during the post-COVID-19 lockdown, this figure increased to 58.2%.

Moreover, relevant to SDG 6.1.1, which also indicates a share of population utilising safely managed potable water supplies, the study revealed that during the pre-COVID-19 lockdown scenario 30% of the assessed families have access to safely operated drinking water services. While during the post-COVID-19 lockdown, this figure decreased to 24.6%. The study further indicated that relevant to SDG 7.1.1, which indicates the share of residents with electricity access, Table 8 illustrates that during the pre-COVID-19 lockdown scenario, 87.3% of the participating households were associated with the general electricity network, although due to the nature of unpredictable and non-sustainable electricity supply, the electricity access index using the multi-tier framework was 1.9. While during the post-19 lockdown, the share of the households linked to the general grid decreased to 63.9% and the electricity index also dropped to 1.5. Relevant to SDG 7.1.2, which indicates a percentage of the population with top reliance on clean fuels and equipment. The data illustrate that during the pre-COVID-19 scenario, 45.5% of the investigated families were utilising non-solid fuel including electricity, cooking gas and kerosene with various respective improved cooking stoves (electric cooking stove, cooking gas stove and kerosene stove). While during the post-19 lockdown, the people with primary dependence on clean fuels and associated equipment decreased to 15.3%.

Studies (Bonn Nexus Conference, 2011; Li et al., 2021; Nkiaka et al., 2021) have identified the nexus's critical roles in achieving sustainable development. A comparative assessment of household progress towards SDG achievement revealed regression due to the pandemic. This aligns with the pandemic's influence on global goals. The international sustainable development agenda advocates for a green economy, which can help tackle long-standing threats to humanity and environmental systems.

Finally, the "Household's Food Purchase Frequencies and Ability to Pay for Food Items" section highlights the need for regional and national governments to achieve resilient societies by ensuring affordable access to food resources after undertaking food security reviews. Guaranteed all-time access to sufficient basic food items needs to be provided to reduce the likelihood of panic buying during a pandemic. Nexus- and SDG-integrated strategies and policies should be implemented by providing sustainable access to affordable basic food items at a neighbourhood scale regardless of population density.

## Conclusions and Recommendations on Policy Development

This research study examined the impact of the COVID-19 pandemic on household water, energy and food security, highlighting its threat to achieving the SDG. It suggests early resource preparations to support resilient societies and the environment during emergencies.

The COVID-19 lockdown and stay-at-home policies have negatively impacted on the household water, energy and nutrition security due to reduced income and lack of preparedness. The pandemic has highlighted the need for security reviews and re-evaluation of resource systems, particularly water, energy and food. Access to water services has dropped from 30.0 to 24.6%. The electricity index access has diminished from 1.9 to 1.5, and severe food insecurity has increased from 4.9 to 38.6%. Realising that the SDG require strategies at global, community and local levels, requiring change, transition and grass-root participation, the pandemic has negatively impacted on progress towards achieving these goals.

The nexus has been considered as part of a conceptual tool towards realising the ambitious post-2015 sustainable development agenda. Since then, the nexus has become the centre of discussion regarding the monitoring of the progress towards achieving the SDG. In line with this, the authors suggest that it is crucial to policies and planning to pay attention towards the nexus approach perspectives particularly at household scale not only to satisfy the inhabitants' basic needs, but also to make advancement towards addressing the SDG at the grass-root level.

Finally, the pandemic has been identified as a danger to the household's water energy and food security throughout the surveyed neighbourhoods. Sustainable gain of access to safely managed water services, immaculate energy sources and secured food supply was identified as the key element towards achieving sustainable and resilient communities. Critical decisions on policymaking and planning need to be made to tackle the challenges of the resource insecurity to have sustainable and resilient communities. Therefore, there is a paramount need for nexus-integrated policy and planning towards the ambitious goals in Nigeria.

As a consequence, the authors make the following clear policy recommendations and propose the corresponding actionable steps for stakeholders: (a) to achieve resilient societies by ensuring early resource preparations; (b) to re-evaluate resource systems by undertaking regular security reviews at local level; (c) to support the nexus approach in combination with the SDG by implementing policies at grass-root level; and (d) to execute timely nexus-integrated policies by providing sustainable access to water and energy sources as well as food supply on a neighbourhood level.

## Limitations

The differences in sample size between the two surveys could have impacted on the generalisation value of findings. The decreased number of households in the second survey was due to mobility, mortality and practical challenges. This may have introduced bias and affected the representativeness of the sample.

It is also essential to respect the scope of the study. Specific results and conclusions are possibly only directly applicable to the study area (Katsina State). They are unlikely to be applicable to the entire country of Nigeria or elsewhere. However, the study provided import information to the funding body (see below). Alternatively, a comparative multi-state analysis could have been performed.

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**Data Availability** All data generated and analysed throughout this investigation are included in this document.

## Declarations

**Competing Interests** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. However, the lead author was supported by the Tertiary Education Tax Fund, Nigeria. Miklas Scholz is employed by the companies Kunststoff-Technik Adams and Nexus by Sweden. Informed consent of all human participants was secured according to both Swedish and Nigerian standards.

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