Symmetrical normalisation of food insecurity challenges in developing countries

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Abstract: An inductive mixed-method research design was applied, consisting of multiple correspondence analysis. Empirical data were collected to quantify food insecurity problems and remedies into a proposed solution. A statistically significant symmetrical model was developed containing two dimensions, technology transfer and software adoption, using six of the eight factors, producing an 11% effect size. The significant factors were: farm method training, application software technology, supply chain cooperation, export market barriers, climate drought problems, and road-transportation infrastructure issues. The two insignificant factors were government corruption and farm credit financial assistance. The study will need to be replicated to build additional validity and the methods should be triangulated before these results could reliably generalise broadly to other developing countries.

Keywords: food insecurity emergency; agriculture problems; Coronavirus; consensual qualitative research; CQR; symmetrical normalisation; multiple correspondence analysis; MCA.

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1 Introduction

Food insecurity has been a longitudinal world-wide issue in developing countries but it is a relatively bigger problem in Sub-Sahara African nations (Fawole and Ozkan, 2018). Most published articles corroborate the fact that there is a global agriculture crisis faced

by approximately 815 million people or 11% of the world population (AGAR, 2018; Apanovich and Mazur, 2018). Food insecurity escalated into an emergency for many countries due to the COVID-19 global Coronavirus pandemic (WHO, 2020). More research was needed to explore solutions for this serious global problem.

In some developing countries agriculture accounts for 25% of the GDP and more than 50% of the labour force are employed in food production (Elijah et al., 2017; Nigeria-NBS, 2018, 2019). Ironically, despite high ecommerce and population growth, many developing countries have become less productive in agriculture, which in combination with weaker export trading, has further exacerbated the food insecurity crisis (Statistica, 2019; Olomola and Nwafor, 2018; UNOCHA, 2019).

There were numerous theoretical and empirical studies exploring the global food insecurity problems – the result was we now the symptoms but we do not know the underlying root causes or solutions. The common food insecurity factors include small arable land size, inadequate modern inputs, low education level, small family size, old age, low technology use, and conservative farmer attitude (Abu and Soom, 2016; Akeju et al., 2018; Awotide et al., 2019; Kazeem et al., 2017; Mafimisebi et al., 2012; Mogues and Olofinbiyi, 2018; Olawuyi, 2019; Olowogbon et al., 2019; Omotayo et al., 2018; Tsado et al., 2017). The majority of those papers were retrospective or deductive in nature.

One serious underlying food insecurity issue is the lack of good seeds and fertiliser (Che et al., 2020). They found rural farmers were not using modern fertilisers or seeds because the seeds were too expensive in the marketplace, and corrupt local dealers were supplying poor seeds along with fake fertilisers. Azih (2008) and other researchers concurred with this problem (Adesiji et al., 2014; Ashagidigbi, 2017; Bamigboye, 2016; Enesi et al., 2018; Ojo et al., 2019; Okeke and Oluka, 2017; Omorinre et al., 2018; Zhang et al., 2018). Corruption has become a highly publicised problem in African nations, especially in Sub-Saharan countries like in Nigeria (CISLAC, 2017). Azih (2008) noted that government corruption in Nigeria was a longitudinal issue. However, it was not clear if or how government corruption impacted the current food insecurity crisis. Government corruption may be an underlying problem of the food insecurity crisis. Bamigboye (2016) noted that politicians are often corrupt and operate without impartiality, channelling resources to their affiliates leaving most of the rural farmers with insufficient critical resources. As noted earlier, public and private corruption problems were identified in Nigeria (Azih, 2008; CISLAC, 2017).

According to focus group members, the agricultural development program (ADP) is mostly side-lined in the current government process for disseminating agricultural inputs (fertilisers and improved inputs), and the process is too complex. What happens is that the inputs are dispatched from the central government to the LGA then to the local government wards or ward chairman. From there, the inputs are inexplicably diverted to the markets or political favourites, but often none reaches to the farmers directly as intended. The consensus was that corruption by opportunistic politicians in the federal and local government apparatus has led to a hijacking of the inputs dissemination process to the disadvantage of rural farmers. In the past, the previous growth enhancement scheme (GES) program effectively delivered inputs to farmers across Nigeria through the ADP extension system, often free of charge or significantly subsidised. The GES was replaced with a new process requiring farmers to acquire raw agriculture inputs from unregulated dealers whose interests are limited to generating profits for themselves without genuine concern for farmers or quality. The perception of farmers and extension

workers is that the current system of inputs dissemination is severely broken, and they are powerless over the cost, quantity, and quality of the agricultural inputs they obtain. For example, farmers often must make do with less than three bags of fertiliser in situations where they used to deploy ten bags, due to the increased costs and lack of subsidies. The inputs dispatched by the Ministry of Agriculture ends up in the hands of local politicians who turn around and sell the inputs to make profits for themselves. The consensus amongst participants was that the Ministry of Agriculture has not been listening to extension workers and farmers. Individual farmers are afraid to protest against these corrupt practices, but they have been unable to organise as a group to mount an effective protest because there is no united farmers' association or a farmers' cooperative union to handle such grievances or advocate for farmers.

Che et al. (2020) found many rural farmers did not know the modern farming methods such as crop spacing to improve yield, planting to encourage maturity, as well as how to apply fertiliser mixes and alternative weed chemicals. They claimed rural farmers needed training to find and apply the relevant information to cultivate corn, maize, beans, groundnuts as well as cattle (since this provides them with free organic fertiliser). The lack of modern farming method knowledge or training in Nigeria was a common food insecurity problem reported in the literature (Abu and Soom, 2016; Aderibigbe and Ajiboye, 2013; Adetimehin et al., 2018; Akeju et al., 2018; Babatunde et al., 2018; Bamigboye, 2016; Daluba, 2013; Elijah et al., 2017; Fatusin and Oladehinde, 2018; Kassali et al., 2018; Okeke and Oluka, 2017; Okunold et al., 2018; Olowogbon et al., 2019; Omoniyi, 2016; Osa-Afiana and Kelikume, 2016; Takeshima, 2018; Yahaya and Abdulrahman, 2018).

Aderibigbe and Ajiboye (2013) concluded that rural farmers needed more training and they suggested universities could provide it. Agbo and Isa (2017) conducted an educational training experiment with rural women farmers which resulted in significant farm skill improvement. The focus group participants felt improved knowledge of farming methods would transform into higher agricultural yields for the farmers. The consensus was that rural farmers need to be taught modern or improved methods by the government, universities, or other appropriate institutions, and this would help the farmers to more readily adopt the methods to alleviate the agriculture crisis. Omoniyi (2016) pointed out that there are over 100 universities in Nigeria and many more secondary type schools, which could perform education outreach services to help rural farmers.

Rural farmers commonly do not have access to marketing data or know how to perform strategic planning (Che et al., 2020). There was a lot of evidence in the literature supporting this point (Alegwu et al., 2018; Dauda et al., 2015; Kassali et al., 2018; Magbadelo, 2018; MarketLine, 2017; Opata, 2018; Tsado et al., 2017). Olomola and Nwafor (2018) claimed that the Nigerian Government NV20:2020 strategy launched in 2009 attempted to address this problem through the agricultural transformation agenda known as the green alternative – but it failed. Adetimehin et al. (2018) emphasised the importance of agriculture extension worker role to reduce the agriculture crisis because their linear regression model indicated higher extension worker presence as mentors increased farmer productivity. Che et al. (2020) asserted the root cause of this problem in Nigeria was that extension workers have limited incentives or allowances because the government had stopped providing these allowances.

Obayelu et al. (2019) found through regression that training and access to extension worker knowledge was correlated with lower food insecurity status of rural Nigerian

farmers. Furthermore, Alabi and Ajayi (2018) asserted that extension workers need participatory needs analysis and livestock manure management training which was beyond the scope of existing pre-service training programs.

Kazeem et al. (2017) found that while farmers' attitudes towards training were positive, the content was often not relevant to the rural farmers' problems or presented to accommodate their perspectives. However, they complained that farmers were not adopting new farm management information system or smartphone applications. Che et al. (2020) found that rural farmers may not be aware of that they can freely access relevant information and knowledge through internet searches, live stream weather data, SMS messaging to outside the area, and get free access to special purpose agriculture software like crop planning applications. Badiru and Akpabio (2018) examined 150 rural Nigeria farmers' use FM broadcast stations and determined that utilisation of agriculture-related information was high (54.7%) while increased experience and slightly higher annual income were significantly related to listening to radio. Somewhat related to this, Chukwuji et al. (2019) discovered there was a high rate of climate change awareness information for farmers who listened to radio or television, and farmers were making strategic decisions on what and when to plant based on long range local forecasts. However, farmers tend to have low incomes so they cannot acquire technologies such as smartphones and laptops (Abu and Soom, 2016; Awotide et al., 2019; Michael et al., 2018; Ndubueze-Ogaraku and Andamadi, 2017; Omotayo et al., 2018).

It was clear in the literature that poor physical infrastructure was a key underlying root cause of the food insecurity crisis. Poor infrastructure slows the export of agriculture and delays the supply of inputs such as seeds or fertilisers (Che et al., 2020). They felt the training facilities were neglected. For example, one training centre building lost its roof because of the rains, but was never replaced, and there was no longer furniture to hold training. The AGAR (2018) noted the importance of maintaining and improving public infrastructure such as buildings and roads to reduce the agriculture crisis. Poor public infrastructure was a common food insecurity root cause reported in the literature (Badiru and Akpabio, 2018; Elijah et al., 2017; Idowu et al., 2012; Okeke and Oluka, 2017). For example, Idowu et al. (2012) observed that motorcycles and bicycles were used frequently by rural Nigerian farmers, who were middle aged (mean = 50 years) and needed to cover 5–10 KM but these modes were inefficient and had limited capacity, whereas cars or trucks were too expensive to purchase.

Somewhat related to poor infrastructure, Che et al. (2020) claimed rural farmers lacked safe storage facilities for agro-chemicals or and other chemical inputs. They stated farmers also lacked the knowledge about how to handle agro-chemicals. For example, some rural farmers were storing dangerous chemicals contain like DDT in their houses. They also complained rural farmers had difficulty accessing tractors, especially those who have large acreages. Sometimes, farmers had sufficient money to hire or lease tractors, but there were not enough tractors available from either the local government or private individuals. Overall, a root cause to the food insecurity was a lack of technological equipment for storing or processing farm produce, especially for perishable crops like tomatoes, onions, and others (Che et al., 2020). They explained farmers must take their crops to the market to sell them on the same day of the harvest otherwise the crops will become spoilt, especially because of the high temperatures in the area, and as such, they cannot make enough money from their produce.

Another root cause of food insecurity was farmers did not know what crops to produce because they did have access to market planning data and they did have the

means to export their products to the market (Che et al., 2020). This problem was consistent with the extant literature (Alegwu et al., 2018; Azih, 2008; Elijah et al., 2017). Elijah et al. (2017) blamed the farmer's inability to export on the quality levels required for market success as well as not having access to application technology such as internet of things or data analytics. Asenso-Okyere and Mekonnen (2018) made an interesting point by looking at how lessons from Asia could help Africa, specifically that farmers' need better access to information so they could become more competitive and productive. Che et al. (2020) claimed rural farmer associations could protect the genuine interests of well-intended farmers and reduce corruption.

Climate change, especially droughts, has also negatively impacted rural farmers and exacerbated the food insecurity crisis (Che et al., 2020). Climatic changes are unpredictable, and the rains are unreliable as compared to past years. This means rural farmers cannot plan very well without using software. To add to that, there are increased amounts of pests and diseases affecting farm yields. Increased disruptive weeds go hand in hand with the climatic change phenomenon. This is a problem also reported in the literature (Adetimehin et al., 2018; Bamigboye, 2016; Chukwuji et al., 2019; Imoloame and Ahmed, 2018; Zhang et al., 2018). Imoloame and Ahmed (2018) studied the weed problem in Nigeria and recommended an ingenious solution that the arrangement of crop types, such as 2:1 ration of maize to soybean, suppressed weeds and resulted in a higher yield. In contrast, Bamigboye (2016) reported interesting environmental friendly practices – some rural farmers in Nigeria created sustainable low-tech facilities to make herbicide lotions from their spoiled produce. Zhang et al. (2018) came to an interesting work-around for this issue in that the government ought to have an overall pest management plan and attempt to suppress weeds nation-wide which if successful would alleviate the work needed at the farm level. However that recommendation has not been implemented.

Another factor impacting food insecurity was the lack of financial credit for rural farmers (Michael et al., 2018; Ndubueze-Ogaraku and Andamadi, 2017; Osa-Afiana and Kelikume, 2016; Yustus et al., 2018). Michael et al. (2018) concluded the financial credit problem was due a lack of acceptable collateral, high interest rates, low financial literacy, and complex banking procedures. Michael et al. recommended that farming associations needed to be formed (with some government or private investor support) to provide the needed capital and banking operations ought to be simplified to suite farmers' financial literacy. Yustus et al. (2018) pointed out that rural Nigerian farmers in the Adamawa State benefited from the rotary credit union, an association with pooled resources and government funding that allows farmers to borrow limited capital for improvements. They noted often there were insufficient loan facilities to boost rural farmer productivity. A related underlying issue is many rural farmers experience land-hunger, a situation where their farm land is owned or controlled by individuals but there is no credit available to rent the land. Farmers often need to do crop rotation, but they face challenges if they do not have access to another land on which they can cultivate particular crops. At the same time, it is difficult for others to enter the farming industry because they cannot secure access to suitable land to start cultivation. These problems are inter-related. Obayelu et al. (2019) determined through regression that land ownership significantly reduced food insecurity in Nigeria.

Some authors noted growing support for farm cooperatives with credit services to agriculture producers (Adepoju and Osunbor, 2018; Ndubueze-Ogaraku and Andamadi, 2017). They claimed the government could assist in launching and funding more farmers'

cooperative unions. They recommended farmers' cooperatives could take on a coordination function to handle both agriculture input regulation and output export market promotion, possibly, at nominal self-sustaining fees. Additionally, it may be possible to establish a relationship with the African Trade Union as a means to sponsor more Nigerian knowledge transfer to farmers (MarketLine, 2017) and to better leverage export avenues through existing trade agreements (Strang and Chrysostome, 2018).

There may be complex socio-cultural factors impacting the food insecurity problem. Fasona et al. (2016) implied that NGO's such as community associations could rural farmers manage public lands for rent and resolve problems between farmers and herders. There is some correlation with the literature on this point (Awotide et al., 2019; Nwagu et al., 2017). In a qualitative focus group study grounded in Vygotsky's socio-cultural theory guide, Nwagu et al. (2017) identified nine distinct socio-cultural themes in rural Nigerians. Adesiji et al. (2014) concluded there were significant socio-cultural and gender differences related to farmer productivity, mainly that males had more effective coping strategies likely due to their experience, and vice-versa, females lacked experience and knowledge transfer.

Rural farmers face many security challenges, including kidnappings that affect farmer attitudes as well as their behaviour (Che et al., 2020). Some farmers are afraid to go out too far away farms since they are afraid of being kidnapped or killed, and they fear for family members when they are not there to protect them. Idowu et al. (2012) confirmed that that motorcycles and bicycles were used frequently by rural Nigerian farmers and they recommended security be improved for them. The root cause of the insecurity is often the Boko Haram terrorists or opportunistic criminals (Che et al., 2020). This is somewhat a cause of the lack of motorbikes and lack of fertilisers because transportation is constrained due to terrorism. There is agreement with the literature on this factor (Adelaja and George, 2019; Fasona et al., 2016; Oli et al., 2018; Tall et al., 2018). Adelaja and George (2019) analysed secondary government data on Boko Haram events in Nigeria, confirming that the macro level effects include reduced aggregate output of farm households and negatively impacted the availability of hired labour (not family labour). The Boko Haram terrorists have much different ideologies and methods as compared to the well-known global terrorists like ISIS, he former are more collective and coexist with the farming community in an unknown sociological relationship (Strang, 2015b). Interestingly, Adelaja and George (2019) claimed that rural Nigerian productivity was not impacted by the Boko Haram, only aggregate national production.

Security and socio-cultural conflict may cause food insecurity. There have been violent conflicts between farmers and nomadic Fulani herdsmen (Fasona et al., 2016; Oli et al., 2018). The Fulani herdsmen sometimes graze their cattle on the farms, often eating entire crops, so this creates conflicts with farmers. Conflicts with Fulani herdsmen are relatively uncommon but crop damage can occur during the night, so while there may be no conflict, there is still a loss of crops. There have been several studies in the literature citing this problem (Fasona et al., 2016; Oli et al., 2018). In addition to the above issues, Fasona et al. (2016) reported that herdsmen accidentally or purposefully setting fires which quickly become out of control in the dry savannah grasslands. Oli et al. (2018) recommended that the government establish cattle grazing fields in the six geo-political zones of the country, with irrigation provided, to accommodate the herdsmen, and out-law open grazing of cattle elsewhere without permits.

A few authors collected agriculture production data and published rigorous predictive regression models which unfortunately only validated what we already knew. Other

studies contained old data (e.g., Urama et al., 2019) or some researchers had surveyed farmers about what factors they thought had caused the food insecurity crisis (e.g., Zhang et al., 2018). The problem in asking farmers research questions is they have limited knowledge of the task and macro environment factors. Thus, we have polarised research ideologies about the food security crisis, some being agriculture production driven and others being farmer perception-based. Few if any researchers have analysed both evidence and perceptions, or consulted agriculture subject matter experts outside of the government. Thus, the literature gap addressed in this study was to collect factor evidence and expert opinions to normalise prescriptive remedies for overcoming the food insecurity problems in African developing nations, using Nigeria as a representative case study.

2 Empirical methods and data

The author adopted a pragmatic inductive ideology for this mixed-method study, which led to the goal of collecting empirical data along with in-depth subjective perceptions to develop solutions for the food insecurity crisis. Empirical data were collected from agriculture records. Subject perceptions were collected from agriculture extension workers, not farmers. Agriculture extension workers are considered subject matter experts with many years of agriculture experience, most have a university education and all have knowledge of economics as well as government programs.

A unique sequential mixed-methods research design was used. The consensual qualitative research (CQR) formal method was first used to collect complex focus group data. Empirical agriculture records data was added to account for production factors. Next symmetrical normalisation in multiple correspondence analysis (MCA) was used to identify the best ideas based on expert opinions and empirical data.

According to Strang (2015c), there are several appropriate formal methods to use when researchers have a pragmatic inductive ideology and intend to collect complex qualitative data – grounded theory, phenomenology, ethnography, and single/multiple case studies. Grounded theory and CQR initially met the needs of this study, but CQR was preferred.

CQR was selected as the overall method because it is inductive. CQR is similar to grounded theory which is also inductive. CQR is relatively new since it arose in the literature as a formal method just prior to 2000 for studying social science work in schools at the group level of analysis (Hill et al., 1997). CQR integrates qualitative data analysis techniques from phenomenology and grounded theory, except that CQR focuses on group perspectives (Hill et al., 1997). The inductive group level of analysis was why CQR was selected over phenomenology or grounded theory, as both are applied at the individual level of analysis (Strang, 2015c).

CQR data analysis is similar to the thematic coding procedure of grounded theory where the goal is for the researcher(s) to reduce the complexity of the data and relate the results back to the *a priori* literature where possible (Hill et al., 2005). However, in grounded theory, microanalysis is done on a word-by-word coding basis by the researcher(s), while in CQR, the focus groups members do the microanalysis through a sense making procedure. In CQR the researchers further evaluate the focus group

discourse for patterns and thematic connections (Hill et al., 2005). In CQR the emphasis is placed on synthesising the data as a whole from the group level of analysis (Hill et al., 2005; Lincoln, 2010). In grounded theory the researcher(s) iteratively analyse their themes to further identify connections or patterns. In phenomenology the researcher(s) organise the theme meanings provided by participants from their lived experiences and they do not make interpretations of the data.

The sense making activities make CQR a powerful inductive empirical technique and this is done using nominal brain storming (Strang, 2015c). According to Hill et al. (1997), CQR starts with semi-structured open-ended questions in a group setting, then the researchers will analyse the consensus data to arrive at a synthesised result, but at least one auditor (another researcher or external expert) cross-checks the data to ensure it is a consensus of the whole. Then the researcher(s) analyse the data to identify domains which can be synthesised into core themes. The themes are informed by a literature review, which is similar to how the lens works in phenomenology and how the factor linking takes place in grounded theory (Hill et al., 2005). Finally, the researcher(s) present the results back to the focus group members for validation and revision.

The CQR method is reflexive. The voice of the participants including their subjectivity must be integrated, using the group as a whole to ensure there is a consensus (Hill et al., 2005). Peer debriefing is used to ensure a consensus of the entire group and that it was accurately recorded. The generally accepted data collection approach in CQR starts with semi-structured conceptual questions grounded in the theoretical literature accompanied probes linked to the practical problem, which is followed by asking the participants to brainstorm ideas to be written on a whiteboard for group brain storming. Finally, a valuable benefit to CQR according to Hill et al. (2005) is that after data are analysed, the researchers then consider the best course of actions to disseminate their findings by asking reflexive questions like who can benefit from these findings and what populations might be impacted these results. This fits well into the scholarly duties because the conclusions of a paper ought to consider how and to whom the results generalise.

According to Strang (2015c) a mixed method approach is more rigorous in comparison to using only CQR. In this study, correspondence analysis (CA) was added to CQR. CA is situated within the family of multivariate exploratory techniques capable of producing statistical estimates and graphical diagrams of qualitative factor relationships. There are many variations in the literature including dimensional analysis, multidimensional scaling, MCA, conjoint analysis, choice modelling, discriminant analysis, Euclidian distance analysis, spatial segmentation as well as vector analysis of contingency tables (Strang, 2015c).

CA may be used to identify nominal field relationships between keywords and frequency count data. By comparison, the purpose of cluster analysis is to group similar records together, generally based on average distance of the mean within the factors, whereas CA goes a step further by identifying potential hidden relationships between factors. Cluster analysis identifies similar versus different records while correspondence determines the strength and direction of the association between nominal factors. CA and cluster analysis are capable of producing visualisation maps of the results.

While common non-parametric procedures such as chi square test of independence or goodness of fit can be used on the nominal data types, chi square methods do not indicate that nature and quality of the relationship between the content of the nominal factors, only that there may or may not be a relationship between factors in the overall model (Strang, 2015c). Also as explained earlier, cluster analysis does not examine the nature of factor relationships, only group similarity or dissimilarity.

CA calculates 'inertia' estimates of variable interdependencies and if significant a symmetric plot can be drawn by converting the inertias into Euclidian distance coordinates to visually depict the relative strength of the relationships (Strang, 2015c). According to Strang (2012), there are two basic forms of this technique, the first is simple CA (with the word simple not usually mentioned, e.g., CA) and the second is MCA; simple is used with two factors and MCA is used when there are more than two factors. MCA was ideal for this study because there were two distinct sets of data, subject matter expert opinions and agriculture production information. In SPSS, MCA version 1.1 was developed by the data theory scaling system group (DTSS), at the Faculty of Social and Behavioural Sciences in Leiden University, The Netherlands (IBM, 2013). DTSS symmetrical normalisation in SPSS because this is the best-practice method to spread the inertia evenly over the row and column factors for a two dimensional plot (IBM, 2013). Normalisation means to estimate the Euclidean distance scores or inertia (negative or positive association between factors and a centroid location). Other normalisation techniques were not ideal, such as row principle normalisation which maximises and emphasises the distances between row factors, and column principle normalisation which emphasises the same for the column factor. As mentioned earlier, two categories of collected data were being used so MCA and symmetrical normalisation were the best choices.

MCA was also preferred since it is an inductive technique because it can transform qualitative and quantitative data into relationship-interdependence patterns (Strang, 2015a). Important hidden relationships in the data can be visually highlighted by creating a multidimensional plot to make a theoretical interpretation of the data (Strang, 2012). Factors from vastly different sources that are similar to each other appear close to each other in the diagram to indicate they are related in some underlying way (Strang, 2012).

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2.1 Sampling, location and participants

Nigeria was selected as a data collection site because it was unique compared to other countries experiencing the Coronavirus pandemic and food insecurity. In addition to having a huge population and fertile land, Nigeria had severe national level factors

impacting agriculture threats including Boko Haram terrorism, climate change, corruption, economic recession and a lack of modern technology (Abu and Soom, 2016; Alegwu et al., 2018; Ashagidigbi, 2017; Bosello et al., 2018; Chukwuji et al., 2019; CISLAC, 2017; Fawole and Ozkan, 2018; Mogues and Olofinbiyi, 2018; Odudu and Omirin, 2012; Ojo et al., 2019; Olowogbon et al., 2019; Omeje et al., 2019; Omotayo et al., 2018; Owutuamor and Arene, 2018; Urama et al., 2019).

Although the Coronavirus has minimal relative effect, the food insecurity crisis in Nigeria impacted between 29% and 64% of its people during 2017–2019 (UNOCHA, 2019). Nigeria was an important democratic developing nation to study because according to the Nigeria-NBS (2019) at almost 200 million people it is the highest populated country in Africa and it is ranked the seventh populous in the world. Agriculture accounted for 25% of the Nigerian GDP and more than 50% of the labour force were employed in food production (Elijah et al., 2017; Nigeria-NBS, 2018, 2019). Nigeria had a high internet penetration of 47.1% (92.3 million citizens) which is projected to double to 187.8 million (84.5% of projected population) by five years (Statistica, 2019). Thus, Nigeria seems like it could be a formidable food production machine with a competitive e-commerce infrastructure to facilitate agriculture supply chain operations and exports although in fact it was facing one of the most serious food insecurity catastrophes, impacting up to 64% of the population in some states (Olomola and Nwafor, 2018; UNOCHA, 2019). Additionally, Nigeria has been experiencing an economic recession since 2016 resulting in high inflation rates of 16.05–18.55%, the GDP had a negative annual growth rate at approximately –1.73% and unemployment increased to 14.2% (Olomola and Nwafor, 2018). Further exacerbating the agriculture crisis is that oil generates roughly 90% of Nigeria's revenue but global crude oil prices dropped significantly during the last decade (Ukpong and Obok, 2018).

Farmers in North East Nigeria were selected for the sample because that region had been experiencing the most serious food insecurity crisis (UNOCHA, 2019). That region was also impacted by climate change, Boko Haram terrorism and corruption (Tall et al., 2018). The sample size of qualitative data collection projects, such as CQR, grounded theory, phenomenology, ethnography and multiple case studies is based on the concept of data saturation (Strang, 2015c). This means that the participants are selected dynamically until the results do not reveal any new concepts (Strauss and Corbin, 1998). Nevertheless, the generally accepted sample size of qualitative data collection such as grounded theory or a case study ranges from 1–20, whereas often 10 becomes the qualitative data collection size benchmark (Strauss and Corbin, 1998). Saturation though is the technique to indicate sample size in case studies (Strang 2015c).

In this study data were collected from the agriculture documentation in Nigeria and organised into 39 unique food insecurity factors. The factors included for example arable land size, farmer education, road infrastructure issues, Boko Haram terrorism, financial farm credit access, and so on, Then 16 agriculture extension workers were recruited on a volunteer basis across 900 farms in the North East region. After informed consent they were brought together for data collection and brain storming as part of the CQR method. The agriculture extension workers participated in a focus group to add quantitative severity and opportunity ratings in terms of causing or overcoming the food insecurity crisis. Their ideas and all quantitative were entered into a database where MCA symmetrical normalisation was performed.

3 Results and discussion

3.1 Preliminary results

The participants were evenly distributed across the 900 farms in North-East Nigeria. All participants were married, most were above age 40, 81% were male and 19% were female. Approximately half (7 of 16) of the participants had a university degree but all had at least high school education. Most were Christian religion (12) and 4 were Muslin.

Most participants (12) were active members of a farm cooperative or community association. We asked the participants how many farmers they maintained in their professional network – the mean was 169.1 (SD = 230.8) and the median was 66.5 which indicated considerable scope. Most participants communicated with their professional partners on a weekly basis (12), two did it fortnightly (bi-weekly) and two met monthly. All participants had at least 6–10 years of agriculture extension worker experience, one had 11–15 and 10 had over 15 years.

3.2 Symmetrical normalisation results

The results of the above focus group data were analysed using MCA in SPSS. Eight factors emerged as the most significant root causes and remedies for the food insecurity emergency. The eight significant factors were: farm method training, application software technology, supply chain cooperation, farm credit financial assistance, export market barriers, government corruption, climate and drought problems, and road/transportation infrastructure issues.

Symmetrical normalisation was then applied to estimate the strength and relative importance of the relationships between these eight factors. Table 1 lists the statistical estimates generated from the best model of symmetrical normalisation done with MCA. Tables 2 and 3 list the eight factors. In Table 1, the dimension column represents the model axis number, which resolved to two since there were two categories of data, food insecurity agriculture problem factors and subject matter expert factor ratings. The singular value represented the Euclidian distance scale from the origin. The inertia column shows how the data were distributed across both dimensions. According to Strang (2012, 2015c) inertia represents the normalised eigen (λ) coefficient, which may be considered similar to variance captured from a non-parametric statistical correlation technique. The proportion of inertia shows the breakdown of the association between the two dimensions, which was evenly distributed at 50% for each dimension, and the model captured 100% of the variation as seen by the total in the last row. Symmetrical normalisation constrained the model at two dimensions.

Table 1 Overall statistical estimates of MCA at dimension level

Dimension		*Singular value*	*Inertia*	*Proportion of inertia*		*Confidence singular value*	
				Accounted for	*Cumulative*	*Standard deviation*	*Correlation*
1	Knowledge	1.333	1.778	0.500	0.500	0.257	0.333
2	Technology	1.333	1.778	0.500	1.000	0.257	
Total			3.556	1.000	1.000		

Table 2 MCA symmetrical normalisation estimates for proposed remedy factors

Remedy factors	*Mass*	*Score in dimension*		*Inertia*	*Symmetric contribution*			
					Point to inertia of dimension		*Dimension to inertia of point*	
		1 Knowledge	*2 Technology*		*1 Knowledge*	*2 Technology*	*1 Knowledge*	*2 Technology*
1 Farm method training	0.250	–1.633	–0.943	1.185	0.500	0.167	0.750	0.250
2 Application software	0.250	0.000	1.886	1.185	0.000	0.667	0.000	1.000
3 Supply cooperation	0.250	1.633	–0.943	1.185	0.500	0.167	0.750	0.250
4 Financial assistance	0.250	.	.	.	.	.	.	.
Active total	1.000			3.556	1.000	1.000		

Table 3 MCA symmetrical normalisation estimates for root cause factors

Root cause factors	*Mass*	*Score in dimension*		*Inertia*	*Symmetric contribution*			
					Point to inertia of dimension		*Dimension to inertia of point*	
		1 Knowledge	*2 Technology*		*1 Knowledge*	*2 Technology*	*1 Knowledge*	*2 Technology*
1 Market barriers	0.250	0.000	1.886			0.667		1.000
2 Corruption	0.250	.	.	.	.	.	.	.
3 Climate problems	0.250	–1.633	–0.943	1.185	0.500	0.167	0.750	0.250
4 Infrastructure issues	0.250	1.633	–0.943	1.185	0.500	0.167	0.750	0.250
Active total	1.000			3.556	1.000	1.000		

The 'cumulative' inertia proportion column is redundant in this model since the two dimensions were evenly balanced. Earlier models were not able to capture sufficient inertia variance. The confidence of the singular value indicates the relationship strength. The standard deviation was relatively large at 0.257 for both dimensions indicating a beneficial result that the model factors (not yet shown) were well spread out. The correlation column estimates the overall association between the two dimensions which as +0.333 [significant according to Strang (2012)]. These two dimensions were later named knowledge transfer and technology adoption. The effect size was 11% which is considered moderate (IBM, 2013).

Table 2 contains the details of the inertia and contribution estimates for MCA symmetrical normalisation for the proposed food insecurity remedy factors while Table 3 refers to the root cause factors. These estimates were analysed and used to theoretically name the dimensions in Figure 1. The active total rows in Tables 2 and 3 are cross tabulations to show the fidelity of the model.

In Tables 2 and 3, the mass column theoretically refers to the weight of the cell in the full dimensional matrix (not just one axis). The mass for a variable is a simple calculation of the proportion of frequencies in the cell/total frequencies for the contingency matrix. A larger mass estimate would indicate a factor appeared more frequently in the data. In Tables 2 and 3 the factors were evenly distributed since the estimate was 0.25 for each one. This was partly due to constraining the model to four factors to reduce the complexity for analysis once a statistically significant result was obtained.

The 'score in dimension column' of Tables 2 and 3 are the coordinates or distances of each factor from the centroid (central position) of the dimension. These are the principal coordinates of the variable for each axis, showing the interdependence (relationship) between factors based on coordinate distance – these were used for developing the plot in Figure 1. The dimension scores represent the proportional contribution of the factor inertia to a specific axis dimension.

In Table 2 the first three factors, farm method training, application software, and supply chain cooperation significantly contributed to the overall model but the farm financial credit did not. Thus, the first three factors were used to name the dimension for the final model. This also reveals the fourth factor may have been important in the documentation of food security root causes across the 900 farms but it was not rated significantly by the subject matter experts so it did not contribute any additional statistical value to the model. In Table 3 the government corruption root cause factor did not contribute inertia to the model while factor 1 along with factor 3 and 4 contributed significantly.

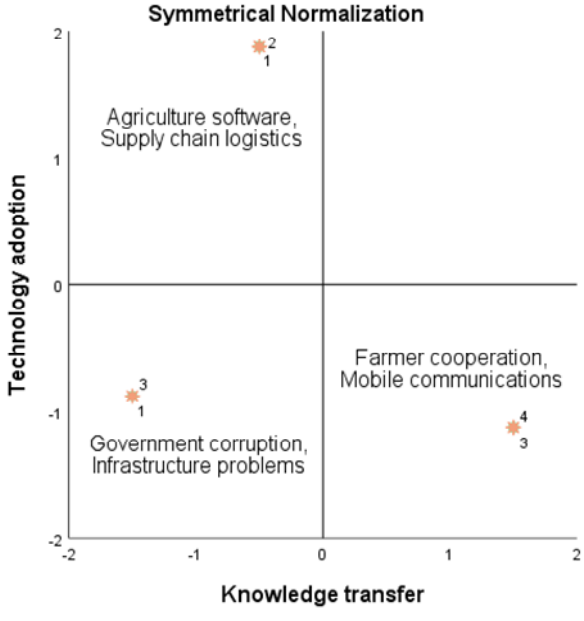
Theoretically the 'moment of inertia' in Tables 2 and 3 represents the mass and Euclidian distance of each point from the centre of gravity on the dimensional plot (centroid). Inertia is the eigen (λ), calculated by the weighted average of the chi-square distances from the axis centroid to the projections of the profiles which were later used to create the symmetrical plot. As compared to mass (which essentially measures frequencies), inertia estimates the degree of interdependence between a variable and both dimensional axis quadrants (Strang, 2015c), and is similar to the communality for a variable in factor analysis (Strang, 2012). Thus, quality is a reliability ratio (somewhat like r^2); with a minimum expectation of 0.5 but a preferred proportion is 0.7 to meet the 'strong' dimensional quality level threshold. In Table 2, the first three factors (training, software, supply cooperation) had inertia of 1.185 but the fourth (financial credit) did not capture any additional inertia. In Table 3, the second factor (corruption) did not

contribute to the model, while the other three factors (market barriers, climate drought, road infrastructure issues) did.

According to Strang (2015c) the symmetric contribution columns list estimates of the variance calculated with respect to the entire set of factors and can therefore be interpreted for relative association much like loading coefficients show how an item is loaded to a particular factor in principal component analysis. Each contribution estimate captures different parts of the relationship of each factor in the dimension. Explained factors is a term indicating a factor whose contributions to the eccentricity of one dimension are greater than a certain threshold such as 0.25 (Strang, 2015c). In other words, a researcher will consider a contribution at or over 0.25 for dimension 1 or 2 (not both) to be significant to the model. The overall contributions are like item scores in factor analysis, because they inherently suggest how related the factors on the same side of the axis are and vice versa, lack of interdependence is indicated by axis separation. The symmetric contribution coefficients are the more important estimates to explain the model and to theoretically name the dimensions.

Two food insecurity remedy factors in Table 2, farming method training (0.5) and farm application software (0.5) loaded on the knowledge transfer (dimension 1) each with some attribution of 0.17 to the technology adoption dimension, while supply chain cooperation (0.67) loaded solely on technology adoption (dimension 2). In the root cause factors (Table 3), the market barriers factor (0.67) clearly loaded on technology adoption, while climate drought problems (0.5) and road transportation infrastructure issues (0.5) loaded on knowledge transfer with minor cross-loading of 0.17 on technology adoption. Thus, the two dimensions were theoretically interpreted as knowledge transfer and technology adoption.

Figure 1 Symmetrical normalisation of food insecurity root causes and remedies ($r^2 = 0.11$) (see online version for colours)



This model was visualised by applying the dimension contribution coefficients to create the symmetric plot shown in Figure 1. The Euclidean distance coordinates were used to set the x and y axis scale, with 0, 0 being the centre of the plot, which naturally partitioned the diagram into four equal sized quadrants. The next step was to interpret the symmetric model of Figure 1. There are some rules about interpreting symmetric plots in each quadrant because according to Strang (2012) the points of a profile group situated away from the origin, but close to each other, in the same quadrant of the four quadrants, are related. Nearby points will have similar profiles in the subspace, in a geometrical sense, so in a nonlinear sense the factors close to one another in a quadrant are interdependent in an underlying way. Proximity between points on the symmetric plot does not necessarily mean strong relationships because the association is to the axis, with evidence of interdependence to other points of the same category. The strength of a relationship is measured on a symmetric plot based on the degree of similarity of the angle between points from the origin.

A theoretical model emerged from the symmetrical normalisation diagram shown in Figure 1. Interestingly, the most significant food insecurity root cause factors were paired with significant proposed remedies, in each quadrant. Starting at the upper left quadrant of Figure 1, export market barriers (0.000, 1.886) – a root cause of food insecurity – was paired with farm application software as a prescribed remedy (0.000, 1.886). This suggests if farmers were to adopt technology such as desktop farm management information systems and smartphone communication applications, they may be able to overcome market barriers through advanced production planning for expected demand. The literature review was clear that exporting was a problem in the region and farmers were not readily using FMIS programs or smartphone apps.

This nicely transitions to the second factor pairing in the lower left quadrant of Figure 1. Climate drought problems (–1.633, –0.943), another root cause of food insecurity, was matched with farming method training (–1.633, –0.943) as a proposed remedy. Training frequently arose as a panacea for agriculture and food insecurity problems, while climate change surfaced as a serious problem plaguing the Sub-Saharan agriculture region, particularly in Nigeria. Finally, in the lower right quadrant of Figure 1, supply chain cooperation (1.633, –0.943) was positioned to address the road-transportation infrastructure issues (1.633, –0.943). It was clear in the literature and from the participants that Nigeria suffered from unstable infrastructure. The novel idea was to encourage upstream and downstream supply chain partners to cooperate with farmers, and with one another, to overcome infrastructure issues. The data indicated distributors (buyers) may be able to provide better temporary storage perhaps with some cooling and use armed transportation with alternative routes to overcome road problems. One comment was that if the canals were dried up then drier earth could enable more economical direct routes across the Sub-Sahara to the sea ports for exporting.

The most unexpected finding was that while government corruption was considered a severe problem exacerbating food insecurity in Nigeria, the subject matter experts did not quantify this as a significant obstacle to future agriculture growth. The participants categorised corruption as an administrative problem created by administration, and that farmers along with the supply chain could work together to overcome it. It was also unexpected that the farm credit financial assistance remedy was not significant in the model. Although it was clear from the documentation that many farmers suffered from outdated technology and equipment, the subject matter experts stated the other knowledge transfer and technology adoption remedies particularly the applicant software

and supplier cooperation, could overcome the lack of financial credit as well as to reduce the effects of government corruption, on farming.

4 Conclusions

In this study, the goal was to inductively normalise ideas to solve the food insecurity crisis using Nigeria as a case study since it was the worst impacted of most developing nations. An inductive mixed-method research design was used, consisting of an empirical literature review, the CQR method, and MCA statistical technique. The goal was to collecting empirical data of food insecurity problems and remedies then have subject matter experts rate these data. The subject matter experts were agriculture extension workers representing 900 farms in the sample frame.

Symmetric normalisation was applied to pair potential remedies with the root causes of food insecurity. This was the result of collecting food security factor evidence along with subject matter expert ratings to quantify the problems and proposed remedies. A symmetrical normalised model was developed containing two dimensions, technology adoption and knowledge transfer, using 6 of 8 significant factors resulting in a statistical effect size of 11%. The significant factors were: farm method training, application software technology, supply chain cooperation, export market barriers, climate drought problems, and road-transportation infrastructure issues. The two insignificant factors in the model were government corruption and farm credit financial assistance.

The theoretical model which emerged from the symmetrical normalisation was interpreted to reduce the complexity of the data and to show a path forward for future researchers. The most significant food insecurity root cause factors were paired with significant proposed remedies, in each quadrant of the symmetrical normalised model. The root cause of export market barriers was paired with the proposed remedy of farm application software. The rationale for this was if farmers were to adopt technology such as desktop farm management information systems and smartphone communication applications, they may be able to overcome market barriers through advanced production planning for expected demand. The literature review was clear that exporting was a problem in the region and farmers were not readily using farm planning software or smartphone apps. The climate drought problems were matched with the suggestion of more farm method training. Training was frequently cited in the literature and by the participants as a requirement to overcome the food insecurity problems, while climate change surfaced as a serious problem plaguing the Sub-Saharan agriculture region, particularly in the Nigeria case study site. It made logical sense that better farm methods (acquired form training) could lessen the impact of climate change. Supply chain cooperation was proposed to address the poor road-transportation infrastructure. It was clear in the literature and from the participants that Nigeria suffered from unstable infrastructure. The novel idea was to encourage upstream and downstream supply chain partners to cooperate with farmers, and with one another, to overcome infrastructure issues. The data indicated distributors (buyers) may be able to provide better temporary storage perhaps with some cooling and use armed transportation with alternative routes to overcome road problems.

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categorised corruption as an administrative problem created by administration, and that farmers along with the supply chain could work together to overcome it. It was also unexpected that the farm credit financial assistance remedy was not significant in the model. Although it was clear from the documentation that many farmers suffered from outdated technology and equipment, the subject matter experts stated the other knowledge transfer and technology adoption remedies particularly the applicant software and supplier cooperation, could overcome the lack of financial credit as well as to reduce the effects of government corruption, on farming.

The two key limitations in this study are:

1 an exploratory inductive mixed method design

2 small sample size taken from one region.

The CQR method relies on subject matter expert opinions, and is therefore subjective forma scientific stand point. Although the literature and regional documentation were used to identify the food insecurity root cause factors and potential remedies, the ratings were determined by agriculture extension workers. Also, although the data represented 900 farms, the region was North-East Nigeria, and the subject matter experts were residents of Nigeria. Thus, these results may be too premature to generalise. This study needs to be replicated in other Nigerian regions and in other African countries. Additionally, a triangulation of methods needs to be achieved, by replicating the nature of this study using another research design, preferably a large survey across multiple regions and countries in Africa.

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