The determinants of food security in Sudan: the case of Kassala state

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Abstract

Purpose – This paper aims to discuss the determinants of food security in Kassala state using the measurement of Household Food Insecurity Access Scale (HFIAS). We use the measurement of HFIAS and use new primary data from a food security household survey in Kassala state (2019).

Design/methodology/approach – This paper focuses on the determinants of food security in Kassala state using the measurement of Household Food Insecurity Access Scale (HFIAS), using new primary data from a food security household survey in Kassala state (2019) and using the multinomial logistic regression analysis and both ordered logit and ordered probit regression to examine the determinants of food security.

Findings – Our results are in support of our hypothesis that the significant determinants of household food insecurity are family-owned production (that negatively affects the probabilities of household being food insecure), household income (that negatively affects HFIAS). We observe that the effects of family-owned production on household food insecurity are particularly significant in the case of mildly and moderately food insecurity. We explain that the other factors that affect the household food insecurity include improvement in the level of agricultural services, marketing, banking services and road characteristics that reduce HFIAS. We find a gender gap related to food security in the sense that male-headed households produce more food compared to female-headed households and also families headed by males are more likely food secure. Therefore, the major policy implication from our results is the importance of increasing households income and enhancing family own production of food to eliminate food insecurity.

Originality/value – This paper provides a significant contribution to the Sudanese and international literature because it discusses the determinants of food security in Kassala state. Different from the two other accompanying papers that focused on the incidence of food security in Kassala state using the measurement of Household Food Insecurity Access Scale (HFIAS) and the determinants of production of food and consumption of food in Kassala state, this paper focuses on the determinants of food security in Kassala state using the measurement of HFIAS and using new primary data from a food security household survey in Kassala state (2019). We fill the gap in the Sudanese literature because we provide a more interesting analysis of the determinants of food security in Kassala state. Our analysis is useful from policy perspective since we provide useful policy recommendations to enhance food security through agricultural development in Kassala state.

Keywords Sudan, Food security, Food production, Agricultural development, Kassala

Paper type Research paper

1. Introduction, conceptual framework and literature review

This research aims to discuss the determinants of food security in Kassala state in Eastern Sudan.

It would be interesting to begin with the conceptual framework and the definition of the concepts of food security and agricultural development, to discuss the most common measures used in the international literature and then review the literature on the relationship between agricultural development and food security.

The literature widely used the concepts agricultural development and food security. The concept agricultural development can be defined as a process that creates the conditions for the fulfillment of agricultural potential to serve the needs of local communities and the state. The creation of conditions includes accumulation of knowledge, availability of technology and allocation of inputs and outputs.

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The concept food security has evolved over the past decades and has been widely used in the international literature (cf. Clay, 2002; Heidhues *et al.*, 2004). The term first originated in the mid-1970s, when the World Food Conference defined food security in terms of food supply – assuring the availability and price stability of basic foodstuffs at the international and national level: *"Availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices"*. In 1983, Food and Agriculture Organization (FAO) analysis focused on food access, leading to a definition based on the balance between the demand and supply side of the food security equation: *"Ensuring that all people at all times have both physical and economic access to the basic food that they need"* (FAO, 1983). The widely accepted definition of World Food Summit (1996) indicates that "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). This widely accepted definition reinforces the different dimensions of food security and includes food access, availability, food use and stability: *food availability*: the availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid); *food access*: access by individuals to adequate resources (income) for acquiring appropriate foods for a nutritious diet; *utilization*: utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met. This brings out the importance of nonfood inputs in food security; *stability:* to be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). The concept of stability refers to both the availability and access dimensions of food security.

Several studies in the international literature use several indicators to measure various aspects of food security. For instance, Barrett (2010) discusses measuring food insecurity and argues that because indicators inform action, much current research focuses on improving food insecurity measurement. Several studies in the international literature use Household Food Insecurity Access Scale (HFIAS) to measure food insecurity. According to Tiwari *et al.* (2013) HFIAS is a measure developed by FANTA to assess food access problems faced by households during a recall period of 30 days. It aims to capture the changes in food consumption patterns and reflect the severity of food insecurity faced by households due to lack of or limited resources to access food. It is composed of nine questions, and these questions relate to three different domains of the access component food insecurity: anxiety and uncertainty about household food access, insufficient quality and insufficient food intake (Swindindale *et al.*, 2006). Each question has four response options: never, rarely, sometimes and often, which are coded 0, 1, 2 and 3 in order of increasing frequency. Responses to these nine questions are summed to construct a food insecurity score, with a maximum score of 27 indicating most food insecure households [1].

Abegaz (2017) discusses the status and determinants of food security in Ethiopia using pooled cross-sectional data obtained from the sixth and seventh round of the Ethiopia Rural Household Survey (ERHS), and binary multivariable logistic regression was employed to identify the determinants of food security. The study finds that in Ethiopia food security was significantly determined by rain shock, lack of off-farm income and region of the households. To assure food security, the farmers should have to consider every rain seasons in the farming activity, and the availability of off-farm income-generating activities should have to be enhanced. Mota *et al.* (2019) assess food insecurity and its determinants in the rural households in Damot Gale Woreda, Wolaita zone, southern Ethiopia. They use cross-sectional household survey and use primary data from 155 randomly selected households and use HFIAS and use bivariate and multivariate logistic regression analyses. The results of

the study revealed that the majority (71.6%) of rural households in the study area were food insecure. The HFIAS shows that HH cannot cover the required daily food from the production generated from their agriculture as well as other activities. Households with large family size, households who cannot read and write and old household heads are more likely to be food insecure than their counterparties. Similarly low land size, lack of livestock, not having confidence to overcome food insecurity of HH, borrowing money from informal rural money lenders and not using farm input by the HH are significantly associated with food insecurity. Finally, promoting income-generating activities, enhancing the micro-financing efficiency, initiating family planning, strengthening the interresettlement programs, enhancing saving habits, creating employment opportunities at local areas to deter unskilled labor migration on-farm diversification.

Obayelu (2012) analyze the determinants of household food security status in the North–Central Nigeria. This study employed a cross-sectional survey of 396 households in the North–Central Nigeria and use multivariate-ordered logit analyses. The results from the ordered logit revealed that geographical location, marital status, gender of the household head, household size, food dietary diversity, total household expenditure, level of education, occupation of household head, household dependency ratio, social capital and agricultural land-holding size significantly affect households' food security status. Oke (2015) examines the determinants of national food security in Nigeria. The study found out that the various problems encountered by the food sector in the economy include policy ineffectiveness, high cost of production, high exchange rate, increasing population, etc. These factors cause inflationary pressures on food prices, and they are the reasons why food security in Nigeria has worsened in the country over the years. Muktar (2011) investigates the determinants of food insecurity in Nigeria, using application of binary choice modeling technique; it estimates the likelihood of food insecurity among some selected households in Kano State of Nigeria using the binary choice modeling technique, specifically the logit. The result obtained showed that household income, educational qualification, gender, size of household, assets owned by households and access to credits are among the major determinants of food insecurity. Amaza *et al.* (2006) identify and analyze food security measures in Borno State, Nigeria, using a multi-stage sampling technique and using the logit model method as analytical techniques for the study. Major determinants of this food insecurity factors are, household size, gender, educational level, farm size and type of household farm enterprise.

Mustapha *et al.* (2016) discuss the determinants of household food insecurity in Northern Ghana, using an ordered probit approach. The study extends the study on food insecurity by examining the relative occurrence of food insecurity using the classification of food insecurity as mild/very low, moderate/low and severe and using ordered probit model and analyzing data from 4,288 households in northern Ghana. The study shows that for each of these categories households' rural dwelling, age, land size and access to credit significantly increase food insecurity whilst maize crop output and marital status decrease food insecurity. This study reveals that food insecurity is a rural and productivity problem and not a poverty issue (or inadequate credit). Mensah *et al.* (2013) assess the determinants of household food security among 100 randomly selected rural households in Sekyere-Afram Plains District of Ghana, using the logistic regression model to examine the determinants of food security among the households surveyed. Among the variables considered in the model, household size, farm size, off-farm income, credit access and marital status were found to significantly influence household food security. Consistent with *a priori* expectation, larger households were found to be food insecure compared with households with smaller sizes, ceteris paribus. Also, consistent with findings from previous empirical studies, farm size, off-farm income and credit access were found to have significant positive effect on household food security.

Akbar *et al.* (2020) discuss the determinants of households' food insecurity with severity dimensions in Pakistan, using varying estimates using partial proportional odds model.

The study shows the impact of some selected socioeconomic and demographic factors on households' food insecurity in Pakistan using the national-level survey, Household data Integrated Income and Consumption Survey 2015–2016. There was inclusion of gender dimensions of some important factors and estimation of varying estimates at four severity levels of households' food insecurity status using partial proportional odds model. They find that household's income, employment, agricultural income, donations, parental education level and some households' characteristics are important factors for improving food security in Pakistan. Maternal education and maternal paid employment compared to paternal education, and paternal paid employment shows strong positive effects to improve severe food insecurity. Couple-paid employment, livestock ownership and operating agricultural land seem to have the most effective role for improving food security. Social welfare programs and religious institution of Zakat are helpful to cope with severe food insecurity in Pakistan. Khan *et al.* (2012) explain the determinants of food security in rural areas of Pakistan. The paper examines the determinants of three aspects of food security in rural areas of Pakistan, i.e. food availability, accessibility and absorption. To estimate the determinants of each component, a series of models is created, in which each component of food security is a function of socio-economic variables. Ordinary least square regression is used to estimate the coefficients. The results show that the production of wheat, rice, maize, pulses, oilseeds, poultry meat and fish at the district level is found to affect food availability positively. In the food accessibility, electrification and adult literacy emerged as the factors having negative effect. Child immunization, safe drinking water and number of hospitals have shown positive effect on food absorption. Since long the potential role of agricultural development to achieve food security has been widely recognized in developing countries including Arab countries and Sudan. For instance, Sudan was considered by the Arab Gulf countries as the "breadbasket" of the Arab World in the 1970s. More recently, the emphasis on agricultural development and food security was recognized in the UN Declaration of Sustainable Development Goals (SDGs) in 2015. In September 2015, the global community adopted the 17 SDGs Global Goals for Sustainable Development to be achieved by 2030. Sudan is committed to achieve sustainable development goals (2030), including goal 2 – zero hunger – committed to end hunger, achieve food security, improve nutrition and promote sustainable agriculture as in most other developing countries in Sudan the achievement of SDG2 implies that achieving food security relies heavily on sustainable food production systems, resilient agricultural practices, boosting agricultural productivity and increasing investments in agriculture, both public and private, from domestic and foreign sources.

Based on the above and given the high poverty and undernourishment rates in Eastern Sudan (cf. Abdalla *et al.*, 2016), it is relevant to investigate the issues of food security and agricultural development in Kassala state as a case study of Eastern Sudan. Previous studies in the Sudanese literature examine some issues related to agriculture and food security in Kassala state. For instance, Abdalla *et al.* (2016) investigate the effect of rural nonfarm activities on households' food security in Kassala state. They find that the majority (about 61%) of population engages in one form of nonfarm activities and that nonfarm income has a positive and significant impact on food security in the state.

This paper focuses on the determinants of food security; we use the measurement of (HFIAS), we use new primary data from a Food Security Household Survey in Kassala State (2019) and we use multinomial logistic regression analysis and both ordered logit and ordered probit regression to examine the determinants of food security. This paper differs from our paper that focused on the incidence of food security; we use the measurement of HFIAS, we use new primary data from a Food Security Household Survey in Kassala State (2019) and we use the descriptive analysis to discuss the measurement of HFIAS, the incidence of food security, the variation in households' food insecurity between localities and the adaptation and survival strategy in Kassala state. This paper also differs from our paper that focused on

agricultural development, production of food, consumption of food and food security in Sudan; we use new primary data from a Food Security Household Survey in Kassala State (2019), and we use the OLS estimation to estimate the determinants of production of food and consumption of food and to discuss the importance of agricultural development, the determinants of supply of food (production of food) and demand for food (consumption of food) and food security food in Kassala state. This paper examines the research hypothesis concerning the determinants of food security in Kassala state. The main research question investigated in this paper is: what are the major determinants of food security in Kassala state in Sudan?

Different from the previous studies in the Sudanese literature, this paper aims to examine the interaction between food security and agricultural development in Kassala state as a case study of Sudan. We fill the gap in the Sudanese literature because we provide a more interesting analysis of the determinants of food security in Kassala state. Our analysis is useful from policy perspective since we provide useful policy recommendations to enhance food security through agricultural development in Kassala state.

The significance and relevance of focusing our analysis on the case of Kassala state is demonstrated from the fact that Kassala state is widely considered to be an important agricultural center and source of border trade for Sudan; the total cultivable area in Kassala state is around 4m feddans or 40.5% of the state's total land (Abdalla *et al.*, 2016). The potential agricultural endowments in Kassala, such as abundant water resources, arable land and livestock, render it a suitable place for agrarian activities in Eastern Sudan. Despite the abundance of natural resources in Kassala state in terms of cultivable land and water, food security and agricultural development remain important problems in Kassala state.

Based on the above, the central theme discussed in this research is the interaction between food security and agricultural development in Kassala state. In particular, the main objectives are to provide an economic analysis of the four key dimensions or pillars of food security (availability, stability, access and utilization of food) in Kassala. It is also to examine the factors that determine food security in Kassala, and finally, to provide useful policy recommendations to enhance food security through agricultural development in Kassala.

The limitation of this study is that it focuses only on the determinants of food security only in Kassala State. To deal with this limitation our future research will extend the current study and provide a more comprehensive study covering all states in Sudan.

Regarding the structure, this paper is organized as follows. Section 1 present introduction and the conceptual framework and literature review on food security. Section 2 shows the challenges related to food security in Sudan and Kassala state. . Section 3 explains the methodology (method of data collection and data analysis). Section 4 shows the results and discussion concerning the determinants of food security and relationship between food security and agricultural development in Kassala. Finally, Section 5 provides the conclusions and policy recommendations.

2. Food security in Sudan

Although Sudan is endowed with vast and diverse agricultural resource base that provides various means of sustaining livelihood and despite the importance of the agricultural sector for Sudan economy and the potential opportunities for achieving food security in Sudan as explained above, unfortunately Sudan suffers from serious food insecurity problem and failure to achieve food and nutrition security for the whole population. According to USAID (2019), chronic food insecurity in Sudan threatens lives, livelihoods and stability. Due to prolonged conflict, environmental deterioration and other disasters such as drought and floods, many of Sudan's people are at risk of food insecurity. According to the World Food Programme (2019), approximately 5.5m people were food insecure in early 2018 – up from 3.8m in 2017.

According to Famine Early Warning Systems Network (2018) "Sudan Food Security Outlook," food security would deteriorate across the country with more households facing stressed (IPC phase 2) and crisis (IPC phase 3) outcomes. Although parts of North Darfur, parts of West Kordofan, North Kordofan and South Kordofan, southern Blue Nile, northern Kassala and much of Red Sea states would remain areas of greatest concern, food security would also deteriorate in other areas.

According to IPC (2018) people in (IPC Phase 3+) are considered as people facing severe acute food insecurity and in need of urgent action. IPC explains the intensity, severity and geographical distribution of people facing severe acute food insecurity and in need of urgent action in the periods October to December 2018 and January to March 2019 (see Figure 1). For instance, in the period (October–December 2018), 5.67m people (representing 12.8% of the analyzed population) are estimated to be in crisis and emergency (IPC phases 3 and 4). Almost 1m people (representing 2.2% of the population analyzed) are in IPC phase 4 (emergency) and more than 4.5m people (representing 10.6% of the population analyzed) are in IPC phase 3 (crisis). In the projected period, (January–March 2019), 5.76m people (representing 13% of the

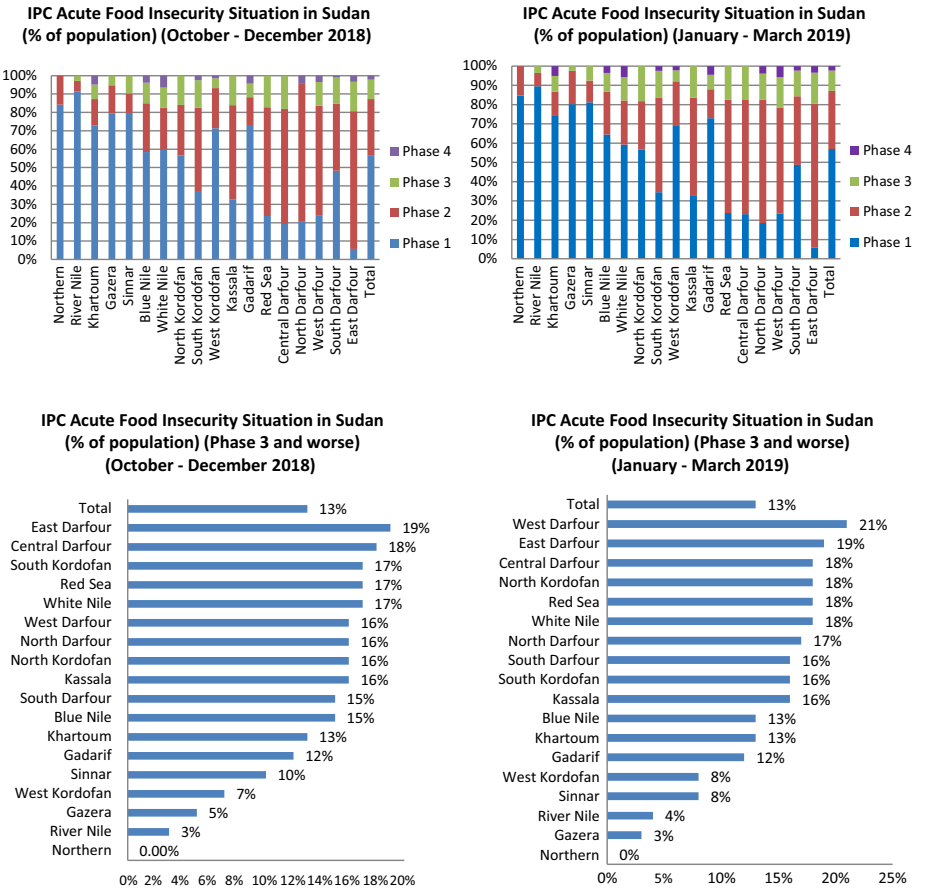

Figure 1.
IPC acute food insecurity situation in Sudan (2018–2019) (% of population)

Source(s): Adapted from IPC (2018), p.4

analyzed population) are estimated to be in crisis and emergency (IPC phases 3 and 4). More than 1m people (representing 2.4% of the population analyzed) are in IPC phase 4 (emergency) and more than 4.67m people (representing 10.5% of the population analyzed) are in IPC phase 3 (crisis). Regarding the geographical distribution, 171 localities were classified in all states in Sudan. 33 localities are estimated to be in IPC phase 3 (crisis) in Blue Nile, White Nile, Southern Kordofan, Kassala, Gedaref, Red Sea and Darfur states. Darfur accounts for about 45% of the population in IPC phase 3 and 4; however there has been no area classified in IPC phase 4 (emergency). The highest prevalence of population in IPC phase 3 (crisis) and IPC phase 4 (emergency) are in the states of Khartoum and South Darfur.

Like other eastern states in Sudan, Kassala has been exposed to chronic poverty, lack of adequate access to basic services such as, healthcare and education (WFP, 2012). High levels of food insecurity and malnutrition as well as unemployment are widespread problems in the state. The World Food Program (WFP) most recent comprehensive food security assessment showed that about 2% of the households in Kassala state are suffering from acute food insecurity and 4.5% are vulnerable to acute food insecurity (WFP, 2012). Regarding the chronic food insecurity, the report reveals that 22% of households in Kassala state are suffering from chronic food insecurity, while 26% are chronically moderately food insecure. The main factors related to food insecurity include poverty, lack of education, unsustainable livelihood activities (unskilled labor, collection of wood/grass) and to a certain extent, isolation and cultural practices (WFP, 2012). Furthermore, the problem of maluntrition in Kassala is attributed to many factors that include inadequate intake of nutrients, diseases, inadequate access to portable water and preventive health services, poor child care, poor hygiene and sanitation practices and household food insecurity (Sudan Nutrition Sector Bulletin, 2015).

According to IPC Acute Food Insecurity Analysis in Sudan (2018) in the period (October–December 2018), Kassala state together with North Kordofan, North Darfour and West Darfour States reported that 16% of their analysed population are estimated to be in crisis and emergency (IPC phases 3 and 4) (people facing severe acute food insecurity); they are ranked third after the Red Sea, South Kordofan and White Nile and Central Darfour States.

3. Methodology (Method of data collection and data analysis)

Based on the conceptual framework and the literature review on agricultural development and food security presented above in the previous section, this section discusses the methodology for measurement of food security in Sudan, with particular reference to Kassala state.

Regarding the research method, this research uses primary data, qualitative and quantitative data and the descriptive method to discuss the determinants of food security in Kassala state. The secondary data were obtained from relevant national and international sources. The primary data were obtained through a survey questionnaire that was distributed among 500 households to represent different areas in Kassala state during April 10–20, 2019. The research covers both rural and urban areas in Kassala state in Eastern Sudan. The sample included in the study was 500 households in total covering both rural and urban areas in Kassala. Regarding the sample, the survey covered five areas or localities out of 11 localities in Kassala State. In particular, the survey included New Halfa locality, Rural Aroma, Kassala locality, Rural Kassala locality and Waldel Helew or Khasm Algirba locality. The rationale for selection of these five localities in Kassala is that they reflect the diversity of agricultural activities defined by type of irrigation (including gravity irrigated area, flood irrigated land, Basin irrigated areas and rain fed areas). Another criteria for selection is the contribution of these five localities in food production and employment of population in Kassala state.

We use the descriptive method of analysis and use FAO definition and conceptual framework that often used in the international literature that defined the multidimensional nature of food security that includes food access, availability, food use and stability. We use statistical analysis; mainly we use the multinomial logistic regression analysis and use both ordered logit and probit regression to examine the determinants of food security (HFIAS), and the relationship between household food insecurity score index and size of agricultural land cultivated, household income and size of household family. Mainly we test the hypothesis that the household food insecurity score index is affected by the size of agricultural land cultivated, own production, household income and size of household family and other household and village characteristics.

The descriptive analysis was used to discuss the determinants of food security (HFIAS) that was also used in our other paper on the incidence of food security in Kassala state. We measure food insecurity using HFIAS that has been widely used as a more universal method for measuring food insecurity in several studies in the international literature (see Bertelli and Macours, 2014; Tiwari *et al.*, 2013).

According to Tiwari *et al.* (2013), the HFIAS is a measure developed by FANTA to assess food access problems faced by households during a recall period of 30 days. It aims to capture the changes in food consumption patterns and reflect the severity of food insecurity faced by households due to lack of or limited resources to access food. It is composed of nine questions, and these questions relate to three different domains of the access component food insecurity: anxiety and uncertainty about household food access, insufficient quality and insufficient food intake. Each question has four response options: never, rarely, sometimes and often, which are coded 0, 1, 2 and 3 in order of increasing frequency (see Table 1). Responses to these nine questions are summed to construct a food insecurity score, with a maximum score of 27 indicating most food insecure households [2].

3.1 Sample and data

The empirical analysis of this study is based on primary sources of data collected through a survey that was conducted focusing on rural areas where agricultural activities are the main source of livelihoods. Likewise, the five localities selected for the survey reflect the diversity of agricultural activities defined by type of irrigation system, in addition to contribution of these localities in food production and employment of population in Kassala state. The two-stage cluster sampling procedure was used to draw out ten villages/ quarters from each locality. Proportional random samples of households were drawn from each village/ quarter based on the number of households as reported in recent population statistics; therefore, a sample of five hundred households was settled.

3.2 Model specification

There are several ways to model econometrically the factors that affect food security status of household. The key aspect is whether the options are ordered or unordered. The multinomial logistic model assumes that data are case-specific; that is, each independent variable has a single value for each case. If the multinomial logit is used to model choices, it relies on the assumption of independence of irrelevant alternatives, which is not always desirable. If the multinomial logit is used to model choices, it may in some situations impose too many constraints on the relative preferences between the different alternatives. Multinomial logistic regression is used when an outcome variable consists of discrete but unordered categories.

To use information about ordering in the data, there are several alternatives such as ordered logit and ordered probit models. Just like the binary choice models, the central idea behind the ordinal outcome is that there is a latent continuous (Y^*) underlying the observed

No	Questions	Response	Code
1	In the past [four weeks/30 days] did you worry that your household would not have enough food?	0 = no (Skip to Q2) 1 = yes	|___|
1.a	How often did this happen in the past [4 weeks/30 days]?	1 = rarely (1–2 times) 2 = sometimes (3–10 times) 3 = often (more than 10 times)	|___|
2	In the past [four weeks/30 days] were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	0 = no (Skip to Q3) 1 = yes	|___|
2.a	How often did this happen in the past [four weeks/30 days]?	1 = rarely (1–2 times) 2 = sometimes (3–10 times) 3 = often (more than 10 times)	|___|
3	In the past [four weeks/30 days] did you or any household member have to eat a limited variety of foods due to a lack of resources?	0 = no (Skip to Q4) 1 = yes	|___|
3.a	How often did this happen in the past [four weeks/30 days]?	1 = rarely (1–2 times) 2 = sometimes (3–10 times) 3 = often (more than 10 times)	|___|
4	In the past [four weeks/30 days] did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	0 = no (Skip to Q5) 1 = yes	|___|
4.a	How often did this happen in the past [four weeks/30 days]?	1 = rarely (1–2 times) 2 = sometimes (3–10 times) 3 = often (more than 10 times)	|___|
5	In the past [four weeks/30 days] did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	0 = no (Skip to Q6) 1 = yes	|___|
5.a	How often did this happen in the past [four weeks/30 days]?	1 = rarely (1–2 times) 2 = sometimes (3–10 times) 3 = often (more than 10 times)	|___|
6	In the past [four weeks/30 days] did you or any other household member have to eat fewer meals in a day because there was not enough food?	0 = NO (Skip to Q7) 1 = Yes	|___|
6.a	How often did this happen in the past [four weeks/30 days]?	1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	|___|
7	In the past [four weeks/30 days] was there ever no food to eat of any kind in your household because of lack of resources to get food?	0 = NO (Skip to Q8) 1 = Yes	|___|
7.a	How often did this happen in the past [four weeks/30 days]?	1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	|___|

(*continued*)

Table 1.
HFIAS questionnaire module

No	Questions	Response	Code
8	In the past [four weeks/ 30 days] did you or any household member go to sleep at night hungry because there was not enough food?	0 = NO (Skip to Q9) 1 = Yes	|___|
8.a	How often did this happen in the past [four weeks/30 days]?	1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	|___|
9	In the past [four weeks/30days] did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = NO (questionnaire is finished) 1 = Yes	|___|
9.a	How often did this happen in the past [four weeks/30 days]?	1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	|___|

Table 1. **Source(s)**: Coates *et al.* (2007), cited in Tiwari *et al.* (2013), pp. 41–42

responses (Gujarati, 2004; Greene, 2012). Therefore, both the ordered probit and ordered logit models were used to identify the determinants of household food security status and estimated by employing the maximum likelihood method.

Although the coefficients of logit and probit models are different, the interpretation of coefficients is similar. It should be noted that only sign of the logit and probit models are interpreted but not the magnitude. However, marginal effects of probit and logit models are similar. The main difference between logit and probit models is that the logistic distribution has slightly flatter tails. Therefore, there is no reason for choosing one model over another.

With respect to food security status, the dependent variable in the model, based on HFIAS method, can have four different levels of food security that are defined as follows: 0 = food secure; 1 = mildly food insecure ; 2 = moderately food insecure and 3 = severe food insecure.

Food security status will be dented by Y_i^*, The question that would be explored is how food security is affected by socioeconomic characteristics. That is, a model to estimate the probability of food security status conditional upon socioeconomic characteristics (X_i) is needed.

Modeling of food security status of household, using the ordered probit model, requires the following steps:

$$y_i^* = X_i^{'}\beta + \varepsilon_i$$

where, y_i^* is the latent unobserved variable, X = socioeconomic and demographic characteristics affecting food security status of household; ε_i: errors, assumed normally distributed and $i = 1, \ldots, N$.

As usual, y_i^* is unobserved, what observed is:

$$\begin{aligned} Y &= 0 \quad \text{if} \quad Y^* \leq 0 \\ &= 1 \quad \text{if} \quad 0 < Y^* \leq \mu_1 \\ &= 2 \quad \text{if} \quad \mu_1 < Y^* \leq \mu_2 \\ &= J \quad \text{if} \quad \mu_{j-1} \leq Y^* \end{aligned}$$

The μs are unknown parameters to be estimated with β.

Then, the probabilities for the four choices are determined as follows:

$$\begin{aligned} P_1\,(y=0|X) &= \theta\,(-X^{'}B) \\ P_2\,(Y=1|X) &= \theta\,(\mu_1 - X^{'}B) - \theta\,(-X^{'}B) \\ P_3\,(Y=2|X) &= \theta\,(\mu_2 - X^{'}B) - \theta\,(\mu_1 - X^{'}B) \\ P_4\,(Y=3|X) &= 1 - \theta\,(\mu_3 - X^{'}B) \end{aligned} \quad (1)$$

For all the probabilities to be positive, we must have

$$0 < \mu_1 < \mu_2 < \mu_3$$

In the case of logit the probability model is

$$P\,(Y \leq j|X) = \Lambda(\mu - X^{'}B) \quad \text{for} \quad j = 1 \ldots J-1$$

For the ordered probit, θ is the standard normal CDF, while Λ is the logistic CDF for the ordered logit. where θ represents the standard normal distribution function and βs are vectors of the model parameters.

θ could be written explicitly in the present context as:

$$\theta\left(y_i^*\right) = 1/\sqrt{2}\int e^{-z2/2}dz = 1/\sqrt{2\pi}\int e^{-z2/2}dz \quad (2)$$

and the integral is definite from $-\infty$ to y_i^* where y_i^* is a latent variable representing the household's food security status i.e. the dependent variable.

X is the vector containing the explanatory variables as stated above and z is the standard normal variable, i.e. $Z \sim N(0,\ \sigma^2)$. To obtain the model equation we take the inverse of (y_i^*):

$$y_i^* = \theta^{-1}\left(y_i^*\right) = \theta^{-1}(P_i) = X_i^{'}\beta \quad (3)$$

where θ^{-1} is the inverse of the normal CDF.

With regard to independent variables, the core explanatory variables include size of agricultural land owned, own production, household income, size of household family size and other household and village characteristics.

4. Results and discussion

This section shows the results and discussion of the Food Security Household Survey conducted in Kassala State in April (2019); we begin by explaining the general characteristics and background information about the households families included in the survey. Next we discuss the determinants of the determinants of food security (HFIAS) in Kassala State (2019).

4.1 The determinants of household food insecurity score index (HFIAS)

We examine the relationship between household food insecurity score index and the size of agricultural land, household income and size of household family (Tables 2–6). Tables (2–4) show the multinomial logistic regression analysis, in which the dependent variable takes the values of one, two and three if the household is mildly, moderately or severe food insecure respectively and zero if it is food secure. The core explanatory variables include size of agricultural land cultivated, own production, household income and size of household family and other household and village characteristics. In general, most of the estimated coefficients are not significant, except for own production and access to markets. Our results from the regression analysis verify part of our research hypothesis that implies that the

Explanatory variables	Coefficient	*Z*-Statistic	Prob.
Constant	11.20***	13.63	0.000
Sex of HH	−0.622	0.721	0.396
Age of HH	0.023	1.393	0.238
Dependency ratio	1.001	1.292	0.256
Family production[b]	−0.719***	9.664	0.002
Family size	−0.19	0.038	0.845
Cultivated land	−0.324	1.168	0.28
Household income	−0.112	0.124	0.726
Non-farm income	−0.099	0.161	0.688
Livestock	−0.075	0.449	0.503
Health services	−0.19	0.296	0.586
Education services	0.338	0.854	0.355
Marketing services	−1.034***	18.869	0.000
Road characteristics	−0.873***	14.63	0.000
Banking services	−0.449	0.82	0.365
Agricultural services	−0.953*	2.896	0.086
Housing			
– Family-owned house	−0.101	0.019	0.889
– Bricks built (Ref: Interim materials)	−1.30	2.597	0.107
Water services: (Ref: Tanker)			
– Piped in to dwelling	1.357**	5.764	0.016
– Piped out dwelling	1.004	1.194	0.274
– Well	−19.84	0.00	0.995
N		269	

Table 2.
Multinomial logistic regression of HFIAS P1: Probability of household being severe food insecure [HFIAS (15–27)][a]

Note(s): [a]We use HFIAS directly as the dependent variable; it is a probability variable takes only four values, 0, 1, 2 and 3. In this case and where all options open to household simultaneously, a multinomial choice model is used
[b]We define family production by the total or sum of value of all household products (each product is defined by product value in SDG)
*, ** , and *** indicate significant at the 10, 5, and 1 percent level, respectively

significant determinants of household food insecurity score index are aggregate value of family own production which increases the probabilities of household being food secure. Also household income has a positive effect on food security although only for the case of mildly and moderately food insecurity. In addition, the improvement in the level of agricultural services, marketing, banking services and road characteristics reduces HFIAS. Unexpectedly, concerning the sources of drinking water, piped into dwelling was expected to reduce the probability of food insecurity. These results are not in line with the expectation.

While we above estimated separate regression models for each level of food insecurity (as compared to food secure), using the multinomial logistic regression model, we will now estimate a single model, where the outcomes are ordered (using both ordered logit and probit regression) to examine the determinants of food security (HFIAS), (see Tables 5 and 6) [3]. We find that using both ordered logit and ordered probit regression implies that the male-headed households are likely to decrease the probability of reporting food insecurity (from severe, moderately, mildly to food secure) by 0.631 points, when holding other variables constant. We observe that family production of food is in favor of improving food security because an increase in family production by one unit will decrease the probability of food insecurity by 0.136 points. We find that the status of food security is likely to decrease with the dependency ratio; improve with family production; agricultural land; livestock and availability of good marketing services and road characteristics.

Explanatory variables	Coefficient	*Z*-Statistic	Prob.
Constant	7.971***	7.091	0.008
Sex of HH	−0.749	1.225	0.268
Age of HH	0.009	0.226	0.634
Dependency ratio	1.248	2.280	0.131
Family production	−0.618***	8.615	0.003
Family size	−0.078	0.694	0.405
Cultivated land	0.129	0.223	0. 637
Household income	−0. 549*	3.000	0.083
Non-farm income	0.317	1.887	0.170
Livestock	−0.176	1.849	0.174
Health services	0.162	0.264	0.607
Education services	0.025	0.006	0.938
Marketing services	−0.100	0.244	0.621
Road characteristics	−0.281	1.611	0.204
Banking services	−0.792*	3.077	0. 079
Agricultural services	−0.116	0.063	0.802
Housing			
– Family-owned house	0.673	0.818	0.366
– Bricks built (Ref: interim materials)	0.130	0.041	0. 840
Water services: (Ref: Tanker)			
– Piped in to dwelling	0.721	2.230	0.135
– Piped out dwelling	0.206	0.036	0.849
– Well	−0.920	0.749	0.387
N		269	

Note(s): * and *** indicate significant at the 10 and 1 percent level, respectively

Table 3.
P2: Probability of household being moderately food insecure [HFIAS (8–14)]

Therefore, we find support for part of our research hypothesis that the household food insecurity score index is affected by the size of agricultural land, own production, household income and size of household family and other household and village characteristics. Our results are consistent with the earlier results in the international literature, in particular, the results that food security was significantly determined by off-farm income in Ethiopia (Abegaz, 2017) and HFIAS are significantly associated with family size, land size, livestock in Ethiopia (Mota *et al.*, 2019). Our results are consistent with the earlier results in the international literature, mainly, the results that household size, household dependency ratio and agricultural land-holding size significantly affect households food security status in Nigeria (Obayelu. 2012), the results that household income, and size of household are among the major determinants of food insecurity in Nigeria (Muktar, 2011) and the result that household size and farm size are the major determinants of food insecurity in Nigeria (Amaza *et al.*, 2006). Our findings are consistent with the findings in the international literature, mainly the findings that land size significantly increases food insecurity in Ghana (Mustapha *et al.*, 2016), the findings that household size, farm size, and off-farm income were found to significantly influence household food security in Ghana (Mensah *et al.*, 2013). Our findings are also consistent with the findings in the international literature, mainly the findings that household's income, agricultural income and some households' characteristics, livestock ownership and operating agricultural land are important factors for improving food security in Pakistan (Akbar *et al.*, 2020).

Therefore, one major policy implication from our results is the importance of both improvement of households income and enhancing family-owned production of food to satisfy households consumption of food, to eliminate food insecurity and therefore to achieve food security in Kassala and in Sudan.

Explanatory variables	Coefficient	*Z*-Statistic	Prob.
Constant	−4.855	1.854	0.173
Sex of HH	−01.111	2.168	0.141
Age of HH	0.002	0.004	0.949
Dependency ratio	0.733	0.512	0.474
Family production	−0.879***	11.179	0.001
Family size	−0.158	1.625	0.202
Cultivated land	0.124	0.131	0.718
Household income	−0.642*	2.750	0.097
Non-farm income	0.171	0.351	0.553
Livestock	0.013	0.012	0.912
Health services	−0.085	0.048	0. 826
Education services	0.32	0.635	0.426
Marketing services	−0.372	2.152	0.142
Road characteristics	0.090	0.098	0.755
Banking services	−0. 206	0.188	0.665
Agricultural services	−0.702	1.250	0.264
Housing			
– Bricks built(Ref: Interim materials)	0.255	0.114	0.736
Water services: (Ref: Tanker)			
– Piped in to dwelling	1.290*	3.809	0.051
– Piped out dwelling	0.255	0.036	0.85
– Well	−0.717	0.244	0. 621
N	269		

Note(s): ***, ** and * indicate significant at the 1%, 5% and 10% level, respectively
#Multinomial logistic model fitting criteria
−2 log likelihood: 537.325
Significant: 0.000
R square
Cox and Snell: 0.487
Ngelkerke: 0.524

Table 4.
P3: Probability of household being mildly food insecure [HFIAS (2–7)]

5. Conclusions and policy recommendations

This research discusses the determinants of food security in Kassala state in Eastern Sudan.

Our results from the regression analysis verify part of our research hypothesis that implies that the significant determinants of household food insecurity score index are family-owned production which is negatively affecting the probabilities of household being food insecure. Also household income is negatively influencing HFIAS, particularly in the case of mildly and moderately food insecurity. In addition, the improvement in the level of agricultural services, marketing, banking services and road characteristics reduce HFIAS. Also, we explain the gender gap related to food security that implies that the sex of household head is significant and negatively affecting HFIAS, implying that the greater the family is headed by male the greater will be the probability of being food secure.

Therefore, the major policy implication from our results is the importance of increasing households income and enhancing family-owned production of food to eliminate food insecurity. We recommend increasing households income, enhancing family own production, enhancing agricultural land ownership, increasing the size of cultivated land, diversification of agricultural food crops, improvement of irrigation systems, enhancing female participation in agricultural activities and food security, improvement of agricultural services, mainly, agricultural services related to technology, creation of appropriate housing status, quality, environment, services and infrastructure to support food security in Kassala state.

Explanatory variables	Coefficient	*Z*-Statistic	Prob.	95% conf.	Interval
Sex of HH	−0.631**	2.01	0.044	−1.246	−0.0163
Dependency ratio	1.297***	2.90	0.004	0.419	2.176
Family production	−0.247***	3.07	0.002	−0.405	−0.0894
The owned agricultural land	−0.218**	2.46	0.044	−0.392	−0.044
Family labor	0.110*	1.82	0.069	0.008	0.2297
Livestock	−0.088**	2.23	0.026	−0.166	−0.010
Marketing services	−0.443***	4.29	0.000	−0.645	−0.2410
Road characteristics	−0.50***	5.16	0.000	−0.696	−0.3131
Water services: (Ref: Tanker)					
– Well	−1.89***	3.90	0.000	−2.845	0.9399
/cut1	−5.209			−6.947	−3.471
/cut2	−4.406			−6.120	−2.693
/cut3	−2.919			−4.60	−1.232
N			348		

Note(s): ***, ** and *, indicate significant at the 1, 5 and 10 percent level respectively
#Ordered logistic model fitting criteria
Log likelihood: −405.323
LR chi^2 (9): 126.38
Prob > chi^2: 0.000
Pseudo *R* square: 0.134

Table 5.
The ordered logistic regression results: the determinants of (HFIAS)

Explanatory variables	Coefficient	*Z*-Statistic	Probability	95% confidence	Interval
Sex of HH	−0.631**	2.01	0.044	−1.246	−0.0163
Dependency ratio	0.708***	2.72	0.006	0.198	1.217
Family production	−0.136***	3.10	0.002	−0.223	−0.050
The owned agricultural land	−0.138***	2.65	0.008	−0.241	−0.036
Family labor	0.069*	1.93	0.054	0.0012	0.140
Livestock	−0.055***	2.60	0.009	−0.096	−0.013
Marketing services	−0.243***	4.13	0.000	−0.359	−0.128
Road characteristics	−0.287***	5.04	0.000	−0.399	−0.175
Water services: (Ref: Tanker)					
– Well	−1.083***	3.73	0.000	−1.652	0.514
/cut1	−2.956			−3.9003	−2.124
/cut2	−2.480			−3.4135	−1.5476
/cut3	−1.601			−2.5269	−0.6759
N			348		

Note(s): ***, ** and *, indicate significant at the 1, 5 and 10 percent level respectively
#Ordered probit model fitting criteria
Log likelihood: −406.2046
LR chi^2 (9): 124.61
Prob > chi^2: 0.000
Pseudo *R* square: 0.133

Table 6.
The ordered probit regression results: the determinants of HFIAS

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Notes

1. See Tiwari *et al.* (2013), p. 11.
2. See Tiwari *et al.* (2013), p. 11.
3. The ordered logit and probit model in its contemporary regression based form was proposed by Mc Elvey and Zavoina (1971, 1975) for the analysis of ordered, categorical, nonquantitative choices, outcomes and responses; the mode is used to describe the data-generating process for a random outcome that takes one of a set of discrete, ordered outcomes (Greene and Hensher, 2009).

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