ENVIRONMENTAL RESEARCH
LETTERS

LETTER • OPEN ACCESS

Shocks, socio-economic status, and food security across Kenya: policy implications for achieving the Zero Hunger goal

To cite this article: Emily Mutea *et al* 2022 *Environ. Res. Lett.* **17** 094028

ENVIRONMENTAL RESEARCH
LETTERS

OPEN ACCESS

RECEIVED
5 February 2021

REVISED
18 August 2022

ACCEPTED FOR PUBLICATION
23 August 2022

PUBLISHED
7 September 2022

LETTER

Shocks, socio-economic status, and food security across Kenya: policy implications for achieving the Zero Hunger goal

Emily Mutea[1,2], **Md Sarwar Hossain**[3,*], **Ali Ahmed**[4] **and Chinwe Ifejika Speranza**[1]

[1] Institute of Geography, University of Bern, 3012 Bern, Switzerland
[2] Centre for Training and Integrated Research in ASAL Development (CETRAD), Nanyuki, Kenya
[3] Environmental Science and Sustainability, School of Interdisciplinary Studies, University of Glasgow, Dumfries, United Kingdom
[4] Initiative for Climate Change and Health, International Centre for Diarrhoeal Disease Research Bangladesh, Dhaka, Bangladesh
[*] Author to whom any correspondence should be addressed.

E-mail: MDSarwarHossain.Sohel@glasgow.ac.uk

Keywords: food security, shocks, Zero Hunger, sustainable development goals, Africa

Supplementary material for this article is available online

Abstract

This study assessed the association between shocks, socio-economic factors, and household food security across Kenya, and provided policy implications for achieving the Zero Hunger goal at national and local levels in Kenya. We analysed the Kenya Integrated Household Budget Survey 2015–16 data for 24 000 households by employing regression models. Our multiple findings show that: (a) half of the surveyed population across Kenya were food insecure; (b) large disparities in food security status exist across the country; (c) demographics (e.g. gender, urban areas), and other socio-economic aspects (e.g. education, income, remittances), positively influence food security; and (d) social and economic shocks negatively influence food security. In summary, the food security status in Kenya is not satisfactory. Our findings suggest that, in general, achieving the sustainable development goals (SDGs) Zero Hunger goal by 2030 will likely remain challenging for Kenya. Ultimately, a redoubling of efforts is required to achieve SDG 10 (reducing inequality) to ensure no one is left behind. Further, the findings could be useful in the formulation and implementation of national and regional policies for achieving the Zero Hunger goal by 2030 in Kenya.

1. Introduction

For decades, one of the most popular global goals of human society has been to reduce persistent food insecurity. Actions included the declaration of food security as a basic human right in 1948, the World Food summit of 1996, the Millennium Development Goals of 2001, and the 2015 sustainable development goals (SDGs). Despite these remarkable initiatives, the status of food security in various world regions is far from satisfactory. For example, the second SDG on Zero Hunger is behind track and will only be achieved with substantial additional efforts (United Nations Department For Economic And Social Affairs 2019). By definition, food insecurity is limited physical, economic, or social access to food, while hunger is the uneasy or painful sensation caused by insufficient consumption of food (Jones *et al* 2013, FAO 2019). The Food and Agriculture Organisation (FAO) of the United Nations (2019) frames hunger as chronic undernourishment.

According to the most recent report by the FAO, one in ten people are food insecure. More than two billion people globally are experiencing moderate or severe food insecurity, and at least 690 million people are still hungry (Davis *et al* 2020, FAO, IFAD, UNICEF, WFP & WHO 2020). While food security across the world is slowly improving, sub-Saharan Africa is the only region in the world where food insecurity has risen since 2014. More than one-quarter of the population in Eastern and Middle Africa is food insecure (Coughlan de Perez *et al* 2019, FAO 2020).

Among these Eastern African countries, Kenya is one of the most food insecure; it has made slow progress in achieving its millennium development goal targets, and its progress in achieving the SDGs (in particular the Zero Hunger goal) lags behind expected

achievements (FAO, IFAD, UNICEF, WFP & WHO 2020, Musyoka *et al* 2020). Food insecurity in Kenya affects 2.6 million people, with significant differences between counties and regions (KNBS 2018a). In general, more than half of the population in Kenya is suffering from moderate to severe food insecurity. Kenyan arid and semi-arid lands, urban slums, and rural households have high food and nutrition insecurity compared to the national averages (FAO, IFAD, UNICEF, WFP & WHO 2020). Kenya was ranked 86 out of 113 countries for food insecurity by the global food security index in 2017 (Government of Kenya—GoK 2018). Despite several national and international initiatives, Kenya still is in the level of serious hunger with a rank 84th out of the 107 countries globally in 2020 (GHI 2020).

Achieving the Zero Hunger goal by 2030 will be highly challenging due to the future impacts of climate change (Stevens and Madani 2016, Niles and Brown 2017), spatial distribution of the food insecure population (Hossain *et al* 2016), and social and economic shocks at household, local, and national levels (FAO, IFAD, UNICEF, WFP & WHO 2020, Ingram 2020). Understanding the association between food security and socio-economic characteristics is necessary to understand the way multiple factors influence food security across different scales (FAO 2013, Ingram 2020).

Shocks are additional threats to achieving household food security (DFID 2003, Ifejika Speranza *et al* 2008, Alinovi *et al* 2010). In general, shocks are events that can cause significant reduction of wellbeing such as income loss and food insecurity (Marques 2003), and typically sudden disturbing events (e.g. floods, epidemics or rapid rise in food prices), with often unpredictable and traumatic impacts such as collapse of livelihoods and economies. Further, shocks can be sudden social changes (e.g. the death of a household member) (Berend 2007, Kozel *et al* 2008) which also increase vulnerability and threats to food security (DFID 2003). Socio-economic factors, conflicts or climate trigger shocks such as a food crisis due to sudden rise in food prices and increased income inequality (FAO 2019). Economic, social, and environmental shocks prolong and exacerbate the severity of acute food insecurity (Conklin *et al* 2018, Cottrell *et al* 2019). This is because they reduce households' ability to maintain food security. If ignored, these shocks may have unpleasant effects on food insecurity in all its forms.

The FAO (2019) notes that shocks disproportionately challenge food security in places where inequalities in the distribution of socio-economic factors and other resources are profound. One way to overcome this problem is to understand better the impacts of such disparities in order to prioritise actions and implement tailored strategies depending on available resources (Hong *et al* 2019). There is thus a need to monitor all SDGs at regional and sub-regional levels to identify ways to reduce inequalities, an aspect addressed in SDG 10. In particular, reducing inequality within countries helps to ensure the progress of SDGs, leaving no one behind. Ultimately, it is important to understand the spatial pattern of food insecurity and recognise the drivers associated with the food insecure population using reliable data sets. This will help to monitor variability in food insecurity and its drivers and thus provide scientific knowledge for long-term planning to achieve Zero Hunger through geographically and socially targeted interventions.

Previous studies on food security in Kenya mostly focused on demand and access to food (Koir *et al* 2020), household vulnerability to food security shocks (Musyoka *et al* 2020), impacts of drought on food security and gender perspective (Huho and Mugalavai 2010, Kassie *et al* 2014) and basics of food consumption and poverty status (KNBS 2018b). However, it has not yet been explored how household socio-economic characteristics in the context of combined social, environmental, and economic shocks influences household food security across Kenya. Most studies are based on case studies (e.g. Ulrich *et al* 2012, Mutea *et al* 2019) of food security making it difficult to gain an overview of food security at the county and national levels. Yet, data collected for national overviews such as the Kenya Integrated Household Budget Survey 2015–16 (KIHBS), can fill this gap of gaining a national and county level overview of food security and complement insights gained from case studies. Thus, we analyse the spatial heterogeneity of food security and the associated drivers (socio-economic factors and shocks) using the 2015–16 KIHBS collected across Kenya in order to provide policy insights for achieving the Zero Hunger goal in the methods section, we explain the 2015–16 KIHBS datasets and data analysis (logistic regression) including how we define food security. Next, we explain the results focusing on food security across Kenya, and the association with shocks and socio-economic characteristics, before discussing the progress of food security and policy implications for achieving the Zero Hunger goal in Kenya. This novel study highlights the usefulness of national-level datasets for understanding food security in Kenya and could be useful in the formulation and implementation of national and regional policies for achieving the Zero Hunger goal by 2030 in Kenya and other similar East African countries.

2. Methods

2.1. Data and variables

The KIHBS 2015–16 data is a household survey that collects information from the Kenyan population in order to guide national development policy decisions (KNBS 2018a). The KIHBS questionnaire, designed by experts, is a set of modules that are administered to collect information on household characteristics,

housing conditions, education, general health characteristics, nutrition, household income and credits, household transfers, information and communication technology, domestic tourism, shocks to household welfare, and access to justice. From these key variables, we chose our outcome and predictor variables for food insecurity.

The survey was conducted by the Kenya National Bureau of Statistics from September 2015 to August 2016. Three-stage sampling was followed in order to determine sample size independently for each of the 47 Counties of Kenya, resulting in a planned national sample of 24 000 households. However, due to missing values, the total sample consists of 21 773 households. The samples are representative at the national level, the county level ($n = 47$), and the local level (urban or rural place of residence). We limited our analysis to KIHBS 2015–16, as the previous dataset KIHBS 2005–2006 is not consistent with the current dataset of KIHBS 2015–16, which has been improved in terms of indicators and data collection. For example, the number of indicators for shocks and food items are higher in KIHBS 2015–16 due to the inclusion of new variables. Some other variables such as remittances have been recently included in KIHBS 2015–16. In addition, some of the variables such as dead and stolen livestock are divided into two shocks in KIHBS 2015–16. Therefore, considering these points, we limited our approach to the cross-sectional analysis of the KIHBS 2015–16.

2.2. Data analysis

The outcome variable was household food security. We measured this variable using indicators proposed by the International Food Policy Research Institute (Smith and Subandoro 2007, Szabo *et al* 2015). The approach considered two key indicators of food security: the percentage of total household expenditure on food and the total daily calorie availability at the household level. The survey did not explicitly assess food security using these indicators, therefore, we combined variables in the dataset to compute the aforementioned food security indicators.

The share of total household expenditure (as a proxy of income) spent on food is an indicator of household food security because it is widely documented that the poorer and more vulnerable a household, the larger the share of household income spent on food. A rise in food prices results in a higher share of total household expenditure spent on food, which constrains poorer households' resources. These force poor households to spend more on basic staples, reduce the quality of their diets, or even reduce the quantity consumed of the least expensive foods, while also reducing non-food expenditures that may be equally needed such as on health and education (Lele *et at* 2016). This indicator uses the monetary value of household consumption disaggregated into food and non-food items. Thus, the share of household food expenditure is equal to the percentage of expenditure on food divided by total expenditure (Smith *et al* 2014). A household was categorised as food insecure if more than 75% of its total expenditure went on food items (Smith and Subandoro 2007).

In the calorie-based food security analysis, a household was classified as food secure if daily calorie requirements were higher than total reported energy intake per capita. We made a final categorisation based on the combination of the above two variables; a household was categorised as food secure if at least one of the above conditions was met. This study used two key categories of predictor variables: household socio-economic characteristics and shocks to household welfare that comprised 19 and 22 independent variables, respectively (table 1). On one hand, socio-economic characteristics comprise factors such as education, income and social support that influence households' wellbeing. On the other hand, shocks are sudden events such as death of household head that make households vulnerable.

We performed logistic regression modelling in order to test the main predictor variables influencing household food security. Before running the regression modelling, polychoric correlation was used as a test for independence and multicollinearity. In polychoric correlation, variables are redundant if the correlation is higher than 0.70 (Aletras *et al* 2010), As a result, we dropped the following variables: marital status, source of domestic water, electricity connection, source of cooking and lighting energy, number of livestock, and large rise in food and farm input prices.

Given that the outcome variable was dichotomous, we applied a series of logistic regression models with food security as the outcome variable in all the models to check the robustness of the final regression model. Model 1 examined the relationship between the outcome variable (food security) and 18 predictor (independent) variables defining the shocks to household welfare. The second model included the socio-economic characteristics in addition to the model 1 predictor variables (shocks). The third model included the outcome variable while the predictor variables were shocks and socio-economic characteristics excluding household remittances. The fourth model represented (Model 2 and assests) the relationship between the outcome variable and shocks, socio-economic characteristics, and assets as the predictor variables. The adjusted regression model with predicted variables was specified as follows:

$$\text{logit}\ (Y_i) = \beta_0 + \beta_1 X_{1i} + X_{2i} + X_{3i} + X_{4i} + \ldots + X_{xi}$$

where Y_i is household food security status with binary values (0 = food secure, 1 = food insecure), β_0

Table 1. Key categories of predictor variables used in regression modelling.

Variable	Indicators	Category	Description
Socio-economic characteristic	Household size	Continuous	Minimum 1 Maximum 28
	Gender of household head	Binary	Male Female
	Age of household head	Continuous	Minimum 18 Maximum 100
	Marital status	Binary	Married Not married
	Education level	Categorical	No education Primary Secondary University
	Area of residence	Categorical	Rural Peri-urban Urban
	Remittances	Binary	Receives remittances-Yes Does not receive remittances-No
	Income	Categorical	No Income ⩽100 000 100 000–200 000 200 000–300 000 300 000 and more
	Size of agricultural land	Continuous	Minimum 0 Maximum 12
	Livestock ownership	Binary	Owns livestock-Yes Does not own livestock-No
Household assets	Type of toilet facility	Categorical	Flush toilet Pit latrine/Composting toilet No facility/bush
	Source of lighting	Categorical	Electricity Generator/Solar Paraffin Others
	Type of cooking stove	Categorical	Traditional stove Improved stove
	Type of dwelling	Categorical	Grass/Thatch/Makuti Concrete Tiles
	Source of domestic drinking water	Binary	Protected- Yes Not-protected-No
	Use of solar	Binary	Uses solar-yes Does not use solar-No
	Ownership of TV	Binary	Has a TV-Yes No TV-No
	Computer ownership	Binary	Has a computer-Yes No computer-No
Economic shocks	Livestock death	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Non-agricultural business failure	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Loss of salaried employment or non-payment of salary	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Large fall in sale prices for crops	Binary	Household experience the shock-Yes Household did not experience the shock-No

(Continued.)

Table 1. (Continued.)

Variable	Indicators	Category	Description
	Large rise in food prices	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Large rise in agricultural inputs prices	Binary	Household experience the shock-Yes Household did not experience the shock-No
Social shocks	Livestock theft	Binary	Household experience the shock-Yes Household did not experience the shock-No
	End of regular assistance, aid, or remittances from external sources	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Birth in the household	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Death of household head or working member of the household	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Death of other family member	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Break-up of the household	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Breadwinner jailed	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Robbery, carjacking	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Dwelling damaged	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Eviction, conflicts	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Ethnic clashes	Binary	Household experience the shock-Yes Household did not experience the shock-No
	HIV/AIDS	Binary	Household experience the shock-Yes Household did not experience the shock-No
Environmental shocks	Fire	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Drought or floods	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Crop disease or crop pests	Binary	Household experience the shock-Yes Household did not experience the shock-No
	Severe water shortage	Binary	Household experience the shock-Yes Household did not experience the shock-No

is a constant, X_{1i} denotes shocks to household welfare, β_1 is the coefficient that shows the magnitude and direction of the relationship, and X_{2i} , X_{3i} , X_{4i} are socio-economic characteristics. The results of the logistic regression were interpreted using odds ratios (OR) and associated confidence intervals (CI). Standard post-estimation tests were applied to evaluate model fit and facilitate model selection (Szabo *et al* 2015). These included the Bayesian information criterion (BIC) and Akaike information criterion (AIC)

to compare performance of the different models. In the model selection criteria, the model with smaller values of AIC and BIC is selected as the most efficient model (Pho *et al* 2019). Thus, when considering the results of the regression tests (table 4) and the lowest values of BIC and AIC (Kuciene and Dulskiene 2019), it was concluded that Model 4 performed best and should thus be the preferred model. The results of these tests are reported in table 4. All data were analysed using STATA version 14.1.

3. Results

3.1. Food security across Kenya

The description of the studied households' characteristics is presented in the supplementary file. Overall, 52% of households were food secure. This classification was based on a combination of calorie deficiency and food expenditure indicators as explained in the data analysis section. Of the 52% food secure households, 70% and 30% were male and female-headed households, respectively and, 51%, 12% and, 37% of households were food secure respectively in rural, peri-urban and urban areas. The prevalence of food security was similar between households that did not practice agriculture and those involved in agriculture (50% and 50% respectively).

Regarding our food security indicators, calorie deficiency was the major cause of food insecurity, affecting 84% of households. The mean calorie intake per adult equivalent was 2828 $\pm$ 12 calories. Moreover, 58% of the households spent over 75% of their income on food, making them food insecure. Surprisingly, rural households spent on average 79% of their income on food, whereas for urban households this figure was 62%.

However, as shown in figure 1, there were variations across the country, with less than 50% of households found to be food insecure in almost half of the counties. Based on our analysis, households across Kenya were divided into four clusters according to food security status (10%–30%, 31%–50%, 51%–70% and 71%–90%) across the 47 counties. This aimed to simplify the food security status across counties by allowing a quick glance on counties that have similarities in terms of food security status across the country, useable for future interventions. Cluster one contained four counties (7% of the total—Nairobi, Mombasa, Machakos, and Kiambu), with over 70% of households being food secure. Most of these counties are in the central region, with one in the coastal region. Cluster two comprised 21 counties (45% of the total), where over half of households were food secure. Cluster three comprised of 20 counties (42%), where more than 50% of households were food insecure. The fourth cluster contained two counties from the north-eastern arid region (Wajir and Mandera), with 85% and 75% of households living in food insecurity respectively. Surprisingly, in Garissa County, which is also in the north-eastern arid region, 59% of households were food secure.

3.2. Association of food security with shocks and socioeconomic variables

The results of regression modelling between household food security and the predictor variables (see table 2) are shown in table 3. These results are based on Model 4. Regression analysis showed that household demographics (e.g. gender of household head, household size), socio-economic characteristics (e.g. remittances, household income, farming, cooking appliances, television), and four types of shock (death of livestock, death of household head, death of a working household member, jail term for household head) significantly influenced household food security (table 3).

Among the socio-economic variables, household income and remittances were the strongest predictors of household food security across the 47 counties. For instance, the OR (95% CI) of becoming food secure were 1.54 (1.42–1.68) from receiving remittances compared to those that did not receive remittances. The odds of becoming food secure from receiving remittances were higher in urban areas (1.86, $p = 0.00$) compared to rural (1.47, $p = 0.00$) and peri urban (1.52, $p = 0.00$) areas. The odds of food security for households increased along with household income.

Households headed by a woman were 21% (95% CI: 1.12–1.32) more likely to be food secure than male-headed households. Households with secondary education had 0.88 times the odds of households with no education for food security. The odds of food security were higher for households with primary and university education than for those with no education, but these results were not significant. In comparison to households living in rural areas, households in urban areas had higher odds (0.89, $p = 0.04$) of food security (95% CI: 0.78–0.99).

However, in terms of the age of the household head, an increase in age was only associated with a very slight increase in household food security: an OR of 1.01. The OR of food security for families that owned a television were 0.62 (95%: CI 0.55–0.69) and statistically significant ($p = 0.00$). The odds of food security for households not engaged in agriculture were 20% higher than for households in agriculture.

The regression model showed that only four shocks out of 19 (breadwinner jailed, death of household head, death of a working household member, death of livestock) were found to have a significant influence on food security. Death of livestock was found to have severely and significant influence on food security in rural areas (0.81, $p = 0.00$) compared to urban (0.79, $p = 0.23$) and peri-urban (1.01, $p = 0.92$) areas of Kenya. The majority (53%) of counties had encountered all four shocks; 34% had

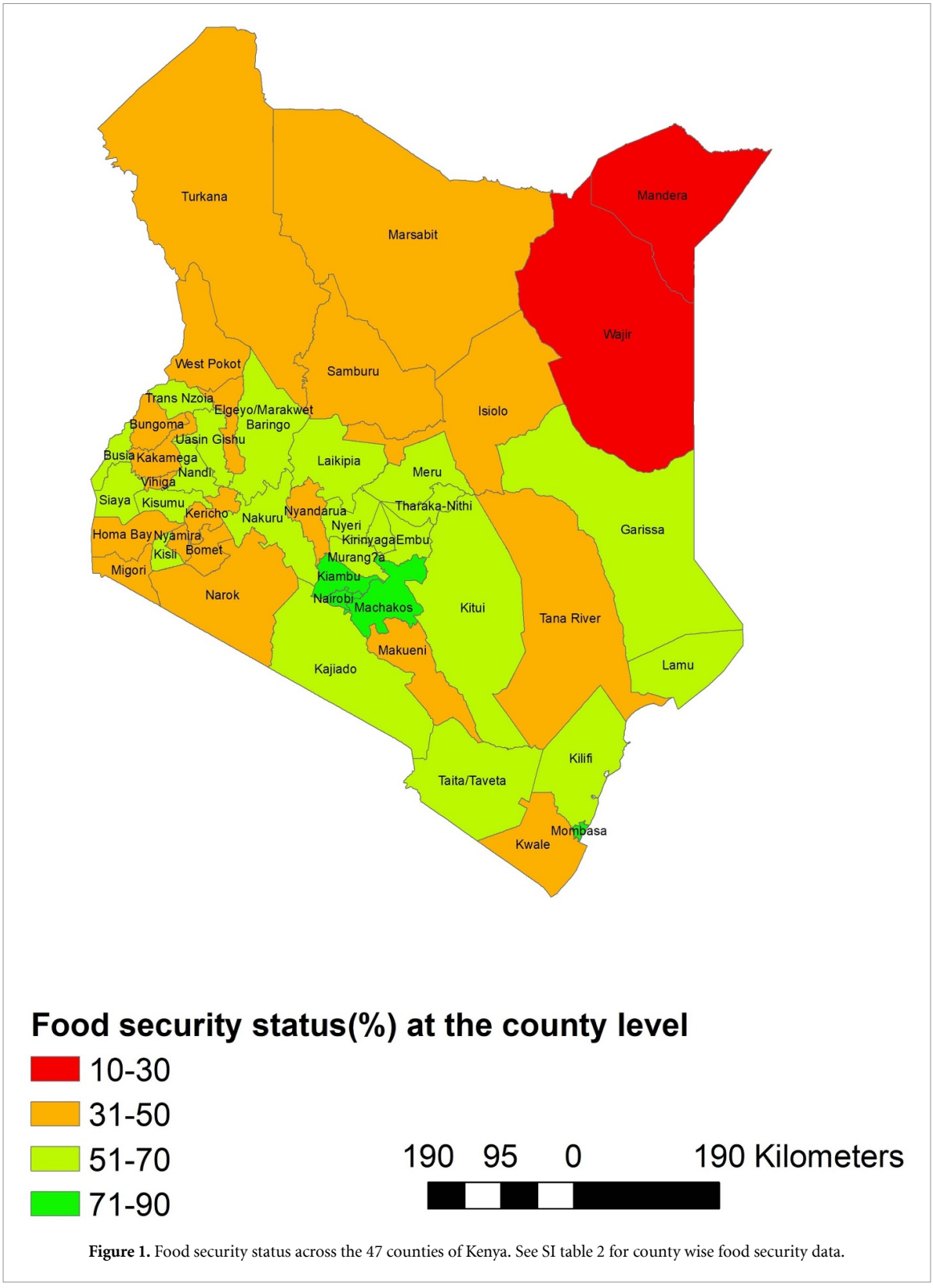

Figure 1. Food security status across the 47 counties of Kenya. See SI table 2 for county wise food security data.

been hit by three (death of household head, death of a working household member, and death of livestock); and 13% had experienced two types of shocks (death of livestock and household head). All four significant shocks were social and economic in nature and had a negative impact on household food security. Interestingly, no environmental shock had a significant effect on household food security.

The odd ratios of food security after death of livestock were 21% less than cases where no livestock had died. This result was statistically significant at p-value 0.00. The most affected region was the Rift valley, followed by Eastern and Nyanza. Similarly, households that experienced death of household head ($p = 0.00$, 95% CI: 0.58–0.91) or working household member ($p = 0.03$, 95% CI: 0.45–0.96) were ∼40%

Table 2. Regression results with household food security as the outcome variable (*0.05 **0.01 ***0.001) OR: odds ratio, CI: 95% confidence interval and $P > |z|$: significant.

Household food security		National	Urban	Peri-Urban	Rural
Household experienced droughts or floods	OR	0.93	0.91	0.89	0.98
	CI	0.83–1.03	0.67–1.23	0.63–1.25	0.87–1.11
	$P > \|z\|$	0.16	0.56	0.52	0.79
Household experienced crop pests and diseases	OR	0.90	0.80	0.77	0.95
	CI	0.79–1.03	0.67–1.23	0.54–1.09	0.82–1.10
	$P > \|z\|$	0.13	0.56	0.15	0.51
Household livestock died	OR	0.79	0.79	1.01	0.81
	CI	0.71–0.89	0.54–1.16	0.74–1.39	0.71–0.92
	$P > \|z\|$	0.00	0.23	0.92	0.00
Household livestock stolen	OR	0.90	1.17	0.93	0.95
	CI	0.75–1.09	0.65–2.09	0.58–1.50	0.76–1.18
	$P > \|z\|$	0.29	0.58	0.79	0.65
Household business failed	OR	0.99	0.76	1.22	1.06
	CI	0.84–1.16	0.58–1.00	0.79–1.88	0.85–1.32
	$P > \|z\|$	0.86	0.05	0.35	0.60
Household experienced end of regular assistance	OR	0.99	1.05	0.80	1.02
	CI	0.79–1.25	0.62–1.80	0.44–1.44	0.76–1.38
	$P > \|z\|$	0.94	0.83	0.47	0.86
Household experienced large fall of crop sale prices	OR	0.99	1.72	0.85	0.93
	CI	0.84–1.17	1.01–2.95	0.56–1.30	0.77–1.13
	$P > \|z\|$	0.92	0.04	0.47	0.50
Household experienced severe water shortage	OR	1.07	0.96	1.02	1.19
	CI	0.93–1.23	1.23	0.65–1.61	0.99–1.41
	$P > \|z\|$	0.36	0.79	0.90	0.05
Household experienced birth in the household	OR	1.24	1.68	0.91	1.07
	CI	0.96–1.61	1.03–2.74	0.45–1.84	0.75–1.51
	$P > \|z\|$	0.11	0.03	0.80	0.69
Household head died	OR	0.73	0.74	0.87	0.72
	CI	0.59–0.92	0.43–1.28	0.45–1.69	0.55–0.95
	$P > \|z\|$	0.01	0.29	0.70	0.02
Household experienced death of working household member	OR	0.66	0.59	0.47	0.83
	CI	0.45–0.96	0.26–1.36	0.18–1.22	0.51–1.34
	$P > \|z\|$	0.03	0.22	0.12	0.45
Household experienced death of other family member	OR	0.93	1.02	0.76	0.94
	CI	0.83–1.03	0.82–1.27	0.55–1.05	0.82–1.08
	$P > \|z\|$	0.18	0.80	0.09	0.39
Household experienced breakup	OR	0.90	.95	1.13	0.70
	CI	0.74–1.10	0.68–1.35	0.66–1.93	0.53–0.92
	$P > \|z\|$	0.31	0.81	0.64	0.01
Household breadwinner jailed	OR	0.53	0.47	0.38	0.54
	CI	0.31–0.90	0.21–1.04	0.08–1.63	0.24–1.18
	$P > \|z\|$	0.02	0.06	0.19	0.21
Household experienced fire	OR	1.08	1.30	0.60	1.00
	CI	0.76–1.51	0.67–2.52	0.20–1.82	0.65–1.54
	$P > \|z\|$	0.68	0.42	0.37	0.02
Household experienced robbery/burglary/assault	OR	1.00	0.86	1.28	1.04
	CI	0.84–1.19	0.66–1.12	0.77–2.12	0.81–1.34
	$P > \|z\|$	0.99	0.27	0.32	0.74
Household experienced carjacking	OR	1.43	1.75	2.19	1.36
	CI	1.01–2.03	0.77–3.94	0.73–6.52	0.89–2.09
	$P > \|z\|$	0.05	0.17	0.15	0.15
Household experienced ethnic clan clashes	OR	0.94	0.63	0.51	1.05
	CI	0.72–1.24	0.35–1.12	0.21–1.23	0.77–1.45
	$P > \|z\|$	0.67	0.12	0.13	0.72
Household experienced conflicts	OR	0.99	1.38	1.03	0.89
	CI	0.75–1.30	0.65–2.92	0.54–1.95	0.63–1.25
	$P > \|z\|$	0.93	0.38	0.92	0.51
Household member contracted HIV/AIDS	OR	0.76	0.50	0.89	0.74
	CI	0.51–1.13	0.23–1.08	0.33–2.38	0.42–1.27
	$P > \|z\|$	0.18	0.50	0.82	0.28

(Continued.)

Table 2. (Continued.)

Household food security		National	Urban	Peri-Urban	Rural
Household head is female	OR	1.21	1.29	1.19	1.21
	CI	1.11–1.31	1.09–1.53	0.92–1.53	1.08–1.34
	$P > \|z\|$	0.00	0.00	0.16	0.00
Age of household head	OR	1.01	1.00	1.01	1.01
	CI	1.00–1.01	1.00–1.01	1.00–1.02	1.01–1.01
	$P > \|z\|$	0.00	0.02	0.00	0.00
Household size	OR	0.57	0.54	0.56	0.58
	CI	0.55–0.58	0.52–0.57	0.53–0.60	0.57–0.60
	$P > \|z\|$	0.00	0.00	0.00	0.00
Education (no education)					
Primary	OR	0.95	0.96	1.02	0.89
	CI	0.84–1.06	0.73–1.27	0.71–1.47	0.77–1.02
	$P > \|z\|$	0.35	0.80	0.89	0.11
Secondary	OR	0.88	0.99	1.04	0.76
	CI	0.76–1.02	0.73–1.35	0.67–1.59	0.63–0.92
	$P > \|z\|$	0.09	0.99	0.85	0.00
University	OR	1.04	0.96	1.18	0.98
	CI	0.86–1.26	0.67–1.37	0.66–2.11	0.75–1.29
	$P > \|z\|$	0.67	0.84	0.55	0.92
Household receiving remittance	OR	1.54	1.86	1.52	1.47
	CI	1.42–1.67	1.56–2.21	1.19–1.93	1.32–1.63
	$P > \|z\|$	0.00	0.00	0.00	0.00
Household income					
⩽100 000	OR	1.58	1.27	1.62	1.71
	CI	1.41–1.76	0.98–1.64	1.16–2.28	1.49–1.96
	$P > \|z\|$	0.00	0.06	0.00	0.00
100 000–200 000	OR	10.67	5.84	11.58	14.25
	CI	9.36–12.17	4.45–7.66	7.74–17.30	12.03–16.88
	$P > \|z\|$	0.00	0.00	0.00	0.00
200 000–300 000	OR	64.59	28.02	72.00	108.33
	CI	54.16–77.03	20.18–38.90	43.25–119.85	85.07–137.95
	$P > \|z\|$	0.00	0.00	0.00	0.00
300 000 and more	OR	814.95	335.86	1748.35	1447.67
	CI	639.58–1038.40	220.79–510.91	817.14–3740.75	1018.94–2056.78
	$P > \|z\|$	0.00	0.00	0.00	0.00
Total land size	OR	1.00	0.96	0.96	1.00
	CI	0.99–1.01	0.91–1.01	0.90–1.03	0.99–1.01
	$P > \|z\|$	0.37	0.19	0.28	0.48
Household not involved in agriculture	OR	1.20	1.25	1.86	1.42
	CI	1.09–1.32	1.02–1.55	1.44–2.40	1.27–1.60
	$P > \|z\|$	0.00	0.03	0.00	0.00
Area of residence (rural)					
Peri-urban	OR	0.95			
	CI	0.85–1.07			
	$P > \|z\|$	0.39			
Urban	OR	0.89			
	CI	0.79–1.00			
	$P > \|z\|$	0.04			
Type of toilet facility (flushing toilet)					
Pit latrine/composting toilet	OR	1.13	1.21	0.91	0.85
	CI	0.97–1.31	1.00–1.45	0.52–1.57	0.60–1.20
	$P > \|z\|$	0.13	0.04	0.73	0.37
No facility/bush	OR	1.15	0.89	1.50	0.84
	CI	0.94–1.41	0.53–1.48	0.75–2.98	0.58–1.22
	$P > \|z\|$	0.18	0.66	0.24	0.38
Household using improved stove for cooking	OR	1.15	1.08	0.84	1.16
	CI	1.05–1.27	0.91–1.28	0.64–1.10	1.02–1.32
	$P > \|z\|$	0.00	0.32	0.21	0.01

(Continued.)

Table 2. (Continued.)

Household food security		National	Urban	Peri-Urban	Rural
Type of main house of household (grass/thatch/makuti/mud)					
Concrete	OR	0.97	0.93	0.99	1.01
	CI	0.84–1.11	0.61–1.41	0.62–1.57	0.86–1.18
	$P > \|z\|$	0.64	0.75	0.97	0.86
Tiles	OR	1.01	0.92	1.46	0.93
	CI	0.89–1.15	0.78–1.08	0.95–2.24	0.74–1.17
	$P > \|z\|$	0.83	0.32	0.08	0.56
Household not using protected drinking water source	OR	0.99	0.93	1.07	0.99
	CI	0.91–1.08	0.76–1.13	0.83–1.36	0.89–1.10
	$P > \|z\|$	0.82	0.49	0.58	0.94
Household owns solar	OR	0.90	1.35	0.87	0.87
	CI	0.80–1.02	0.87–2.08	0.62–1.21	0.75–1.00
	$P > \|z\|$	0.09	0.17	0.41	0.06
Household owns a computer	OR	1.05	1.31	0.50	0.88
	CI	0.81–1.35	0.93–1.85	0.24–1.05	0.56–1.38
	$P > \|z\|$	0.72	0.11	0.06	0.59
Household owns a television set	OR	0.62	0.64	0.83	0.65
	CI	0.55–0.69	0.54–0.75	0.61–1.14	0.55–0.77
	$P > \|z\|$	0.00	0.00	0.26	0.00
Household has access to internet	OR	0.91	1.11	0.83	0.76
	CI	0.81–1.01	0.93–1.32	0.61–1.14	0.64–0.89
	$P > \|z\|$	0.08	0.21	0.26	0.00
_cons	OR	1.03	0.94	0.61	0.81
	CI	0.77–1.39	0.45–1.94	0.20–1.87	0.47–1.39
	$P > \|z\|$	0.82	0.87	0.39	0.44

less food secure than households who had not experienced these shocks.

Regression Model 1 shows that nine shocks were statistically significant (table 4); in contrast, in Model 4, only four shocks remain statistically significant considering socio-economic variables. Regression Models 2, 3, and 4 showed that socio-economic variables were a strong predictor of food security. Furthermore, social and economic shocks had a stronger influence on food security than environmental shocks. Considering the lowest values of AIC and BIC from regression results, we argue that Model 4 performed best among the four models.

4. Discussion

4.1. Progress and drivers of food security

This study assessed food security status at the national level and across the 47 counties of Kenya. Additionally, we assessed the socio-economic aspects and shocks affecting household food security. Our findings show that half of the households across Kenya were food insecure. Out of the 47 counties, 25 counties were within national food security levels, while the rest were below the national average. However, our results also indicate differences in food security levels across the 47 counties in Kenya.

This study reveals a positive association between food security and socio-economic variables such as gender of household head, family size, remittance, and income. These results are in line with those of previous studies (Babatunde and Qaim 2010, Szabo *et al* 2015, Mutea *et al* 2019, Paul *et al* 2019).

Our analysis also revealed a negative significant association between household food security and socio-economic characteristics (e.g. ownership of a television set) and shocks (e.g. death of livestock, death of a working household member, death of household head).

We found that all the shocks were spread more or less equally across the 47 counties, with the most common being death of livestock. This implies that for those households owning livestock, death of livestock and by extension ownership of livestock are significant drivers of food security. Livestock keeping (e.g. sheep, goat, dairy cows and poultry) in urban areas makes important contributions to the livelihoods of urban livestock keepers (Roessler *et al* 2016, Alarcon *et al* 2017, Pablo *et al* 2017, Crump *et al* 2019). Urban livestock keeping is a source of food security due to provision of essential micronutrients to avoid malnutrition and can release pressure on poor households (that spend 60%–80% of income in food) (Alarcon *et al* 2017). Rearing livestock enables smallholders to have improved livelihoods and to avoid food insecurity through income generation and can be used as a coping strategy during times of need (Nabarro and Wannous 2014).

Kenya has addressed the issue of food security in its Vision 2030 plan and the present government's 'big four' agenda. These initiatives emphasize investing in agriculture, with the aim of transforming agriculture

Table 3. Regression results for the four models with household food security as the outcome variable (*0.05 **0.01 ***0.001).

	Household is food secure	Model 1	Model 2	Model 3	Model 4
Environmental shocks	Household experienced droughts or floods	−0.56***	−0.06	−0.04	−0.08
	Household experienced crop pests and diseases	−0.14**	−0.09	−0.09	−0.10
	Household experienced severe water shortage	0.05	0.06	0.05	0.07
	Household experienced fire	−0.16	0.07	0.05	0.07
Economic shocks	Household livestock died	−0.35***	−0.24***	−0.21***	−0.23***
	Household business failed	0.21***	−0.04	−0.02	−0.01
	Household experienced large fall of crop sale prices	−0.06	−0.02	−0.02	−0.01
Social shocks	Household livestock stolen	−0.11	−0.11	−0.08	−0.10
	Household experienced end of regular assistance	−0.06	0.01	0.09	−0.01
	Household experienced birth in the household	−0.06	0.23	0.24	0.22
	Household head died	−0.46***	−0.31**	−0.30**	−0.31**
	Household experienced death of working household member	−0.20	−0.41*	−0.39*	−0.41*
	Household experienced death of other family member	−0.03	−0.08	−0.06	−0.07
	Household experienced breakup	−0.05	−0.07	−0.07	−0.10
	Household breadwinner jailed	−0.42*	−0.64*	−0.61*	−0.64*
	Household experienced robbery/burglary/assault	0.34***	−0.01	−0.01	0.00
	Household experienced carjacking	0.14	0.38*	0.37*	0.36*
	Household experienced ethnic clan clashes	−0.67***	−0.05	0.00	−0.06
	Household experienced conflicts	−0.04	−0.00	0.08	−0.01
	Household member contracted HIV/AIDS	−0.41**	−0.27	−0.25	−0.28
Socio-economic characteristic	Household head is female		0.17***	0.24***	0.19***
	Age of household head		0.01***	0.01***	0.01***
	Household size		−0.57***	−0.56***	−0.57***
	Education (no education)		0.00	0.00	0.00
	Primary		−0.09	−0.07	−0.06
	Secondary		−0.22**	−0.19**	−0.13
	University		−0.11	−0.04	0.04
	Household receiving remittance		0.42***		0.43***
	Household income		0.00	0.00	0.00
	⩽100 000		0.45***	0.40***	0.46***
	100 000–200 000		2.31***	2.22***	2.37***
	200 000–300 000		4.06***	3.95***	4.17***
	300 000 and more		6.53***	6.39***	6.70***
	Total land size		0.00	0.00	0.00
	Household not involved in agriculture		0.19***	0.21***	0.18***
	Area of residence (rural)		0.00	0.00	0.00
	Peri-urban		−0.07	−0.06	−0.05
	Urban		−0.20***	−0.21***	−0.12*
	Type of toilet facility (flushing toilet)				0.00
	Pit latrine/composting toilet				0.12
	No facility/bush				0.14
	Household using improved stove for cooking				0.14**
	Type of main house of household (grass/thatch/makuti/mud)				0.00

(Continued.)

Table 3. (Continued.)

Household is food secure	Model 1	Model 2	Model 3	Model 4
Concrete				−0.03
Tiles				0.01
Household not using protected drinking water source				−0.01
Household owns solar				−0.11
Household owns a computer				0.05
Household owns a television set				−0.48***
Household has access to internet				−0.10
Constant	0.29***	0.20	0.26*	0.03
N (Sample size)	21 773	21 773	21 773	21 773
AIC	29 467.84	17 563.93	17 663	17 483.11
BIC	29 635.6	17 867.49	17 958.58	17 866.55

* $p < 0.01$, $p < 0.001$***

from subsistence to productive commercial farming as a pathway to food security (GoK 2007, 2018). However, our findings reveal that households not involved in agriculture are 20% more likely to be food secure. There are two possible explanations for this result.

First, most of Kenya is semi-arid and its agricultural production is challenged by climate variability and climate change, use of outdated technology, poor infrastructure (especially roads linking farmers to markets), soil degradation, regions with low cropping potential, diseases and pests, lack of fallows, and nutrient amendments (Foeken and Owuor 2008, Thornton and Herrero 2016, KARI 2019). These problems result in little or no harvest, leading to food shortage and hence food insecurity.

Surprisingly, no significant impacts on food security were found from environmental shocks such as droughts, floods, pests, and diseases, which are usually related to climate variability. This could be due to the cross-sectional datasets of KIHBS, collected from September 2015 to August 2016. Longitudinal datasets are often a prerequisite for analysing the social impacts of climate change (Geffersa and van den Berg 2015, Bahruid *et al* 2019). As droughts and floods are widespread in Kenya, they are systemic factors that can affect all inhabitants hence socio-economic characteristics becomes a differentiating and important factor in face of such system-wide exposures. This may be the reason for the non-significant association between food security and environmental shocks such as drought as the result show a non-significant possibility of 10% less food security for households experiencing drought and flood. In addition, households are also adapting to diversified livelihoods, resulting in less dependency on agriculture, where resources are becoming increasingly scarce (Babatunde and Qaim 2010, Menike and Arachchi 2016). In response to coping with drought, households mostly depend on livestock when adapting to climatic change (Ifejika Speranza 2010). Often environmental shocks (e.g. diseases, drought, floods etc) trigger livestock diseases, which may lead to livestock death, so environmental shocks can be the underlying drivers of livestock loss, which then directly affects food security.

In addition, we found that female-headed households were more likely to be food secure than male-headed households. There were no major variations across the counties in terms of gender of household head, with over 60% of households being male-headed in most counties. A possible explanation for this outcome is that women play a decisive role in dietary diversity at the household level. Other scholars have also found a significant association between the availability of a diverse diet at household level and women's participation in decision-making (Amugsi *et al* 2016). Women are also more involved in a variety of food system activities such as production and processing food, which are key in food availability and utilisation. However, such households are more often reported to be less endowed with necessary resources such as land and finances compared to male-headed households, which makes them vulnerable to food insecurity (Kassie *et al* 2014).

4.2. Policy implications for achieving the Zero Hunger goal in Kenya

The results suggest (figure 2) that given current conditions, achieving the Zero Hunger goal by 2030 is achievable for very few counties (e.g. those with 60%–70% population food secure) in Kenya; the rest (less than 40% of population food insecure) will likely continue to be food insecure for a long time if no additional efforts are put in place. These findings suggest that, in general, achieving Zero Hunger by 2030 will likely remain challenging for Kenya. This is because of the huge variations and disparities existing across the country. There are four counties that could certainly meet this goal, even before 2030. Twenty one further counties, with some effort, could feasibly be food secure by 2030. However, it is highly unlikely that the remaining 22 counties will be 100% food secure by that time. Considering the results, that social and -economic shocks had a stronger influence

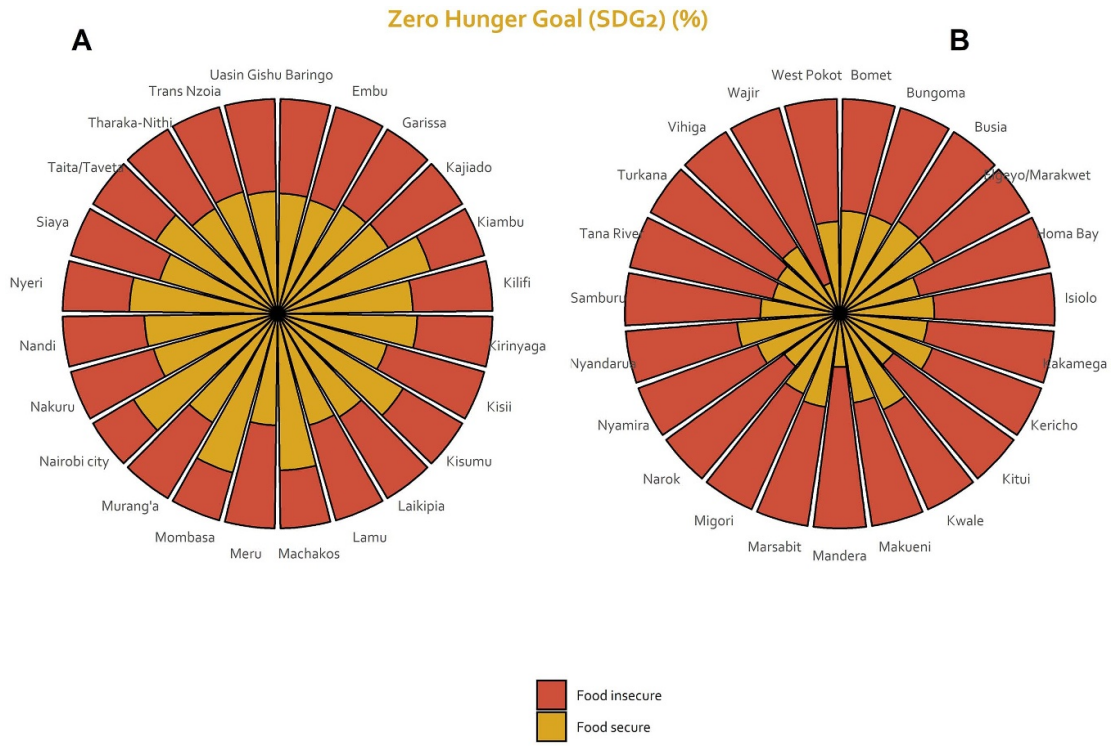

Figure 2. Progress of the Zero Hunger goal to achieve food security across counties (A > 50%, B < 50% food secure) in Kenya. See SI table 2 for county-wise food security data.

on food security than environmental shocks, holds implications for achieving the zero-hunger goal.

First, there is a need for actions to improve system-wide resilience to environmental shocks. While these shocks seem not to have significant impacts at the inter-household level, they condition the agricultural production system for all households through influencing natural production conditions. Measures are thus needed to reduce the sensitivity of crop and livestock production systems to environmental shocks. Kenya is guided by several strategic documents towards the achievement of food security: nationally by Vision 2030 and the 'big four' agenda (GoK 2007); its national adaptation plan and drought management strategies to end drought emergencies (GoK 2016), regionally by the African Union (AU) Malabo Declaration (AU 2014); and globally by the United Nations (UN) post-2015 goals (UN 2019). The effectiveness of such initiatives thus needs to be monitored to ascertain to what extent they address the systemic vulnerability underpinning food insecurity in Kenya.

Second, our results show that attaining food security for all involves more than just producing more food, even though increasing agricultural production is a big part of the solution to eradicating hunger. The results highlight the need to also address disparities in socio-economic characteristics. It is important that governments comprehensively combine sustainable agricultural investments with cross-sectoral developments (e.g. appropriate technology, market infrastructure) to improve agricultural production and to diversify and increase income levels. This approach has worked well in Ghana, leading to agricultural development (Adolph and Grieg-Gran 2013). Elsewhere, in Malawi and Bangladesh, subsidies have been effective in reducing food insecurity and contributing to environmental sustainability (Hossain *et al* 2016), hence such an option is worth exploring for Kenya.

Moreover, to ensure no one is left behind along the Zero Hunger goal pathway, it is essential to redouble efforts towards addressing the challenges that affect the most food insecure counties in terms of socio-economic characteristics. On the more challenging side, access to quality education is essential, as educated households are food secure. Our results suggest that households with secondary and other types (primary and university) of education are significant and non-significant respectively, but have a positive influence on food security in Kenya. Therefore, achieving other SDGs such as quality education (SDG 4) is necessary to end hunger across Kenya.

This study was limited to a cross-sectional (snapshot of a single moment in time) analysis, with the aim of ascertaining policy implications for achieving the Zero Hunger goal by assessing the status and drivers of food security at both national level and administrative unit (county) level. An analysis of qualitative data and a longitudinal study (repeated observations) considering seasonality of shocks may offer a deeper contextual understanding

of the impacts of environmental shocks on food security, its complexities, and its subjectivity. Further studies that extend and collect social and ecological datasets may also offer an understanding of the interactive relationships between the Zero Hunger goal and other goals, which would help to set meaningful targets and achieve these targets comprehensively. However, the result of our study will be useful for assessing how Kenya has progressed in terms of the Zero Hunger goal and for guiding national and regional policies aimed at progressing towards achieving the SDGs in Kenya and other similar East African countries by 2030.

5. Conclusion

Food security analysis across Kenya can provide important information about achieving the Zero Hunger goal; it can also be useful for decision-makers at global, national, and local levels. In this research, analysis of KIHBs datasets has shown that demographics (e.g. gender of household head, family size,) and other socio-economic characteristics (e.g. income, remittances, education) are positively associated with food security and that social and economic shocks (e.g. death of household head or livestock) are negatively associated with food security across Kenya. In general, food security status both at national and county levels is not satisfactory. It is unlikely that Kenya will be able to achieve the Zero Hunger goal by 2030, considering current food security levels, social (e.g. poverty, inequality) and environmental (e.g. climate, land degradation) challenges, and the ambitious targets set out by the SDG for Zero Hunger goal. These findings highlight the usefulness of regular (e.g. every 5 yr) collections of data sets at national-level for understanding food security, and can complement insights from household food security surveys, considering the larger efforts needed for case studies at household and local levels.

Data availability statement

The datasets used and/or analysed during the current study are available from the Kenya National Bureau of Statistics. The data that support the findings of this study are not openly available due to the copyright of Kenya National Bureau of Statistics.

No new data were created or analysed in this study.

Acknowledgments

The main author received support from the Swiss Government Excellence Scholarships for Foreign Scholars and Artists: ESKAS 2017.0930. The authors are also thankful to the Kenya national bureau of statistics for making the data available. M S H acknowledges Marie Skłodowska-Curie Grant Agreement No. 796994, under the European Union's Horizon 2020 research and innovation programme. CIS acknowledges the Swiss Programme for Global Issues on Development (r4d programme) funded by the Swiss Agency for Development and Cooperation and the Swiss National Science Foundation [Grant number 400540_152033].

Author contributions

E M and M S H conceptualized the idea for this manuscript and the data analysis plan. E M and A H analyzed the data. E M contributed to the writing of first draft manuscript, the analysis and interpretation of the data with help from M S H. M S H, A H, and C S, participated in the writing of the manuscript. All authors read and approved the final manuscript.

Conflict of interest

The authors declare no competing interests.

References

Adolph B and Grieg-Gran M 2013 *Agriculture and Food Systems for a Sustainable Future: An Integrated Approach* (London: The International Institute for Environment and Development (IIED)) (available at: https://sustainabledevelopment.un.org/content/documents/88917157IIED_Agriculture%20and%20food%20systems_post-2015.pdf)

Alarcon P, Fèvre E M, Muinde P, Murungi M K, Kiambi S, Akoko J and Rushton J 2017 Urban livestock keeping in the city of Nairobi: diversity of production systems, supply chains, and their disease management and risks *Front. Vet. Sci.* **4** 171

Aletras V H, Kostarelis A, Tsitouridou M, Niakas D and Nicolaou A 2010 Development and preliminary validation of a questionnaire to measure satisfaction with home care in Greece: an exploratory factor analysis of polychoric correlations *BMC Health Serv. Res.* **10** 1–14

Alinovi L, Mane E and Romano D 2010 Measuring household resilience to food insecurity: application to Palestinian households *Agric. Surv. Methods* 341–68

Amugsi D A, Lartey A, Kimani-Murage E and Mberu B U 2016 Women's participation in household decision-making and higher dietary diversity: findings from nationally representative data from Ghana *J. Health Popul. Nutrition* **35** 1–8

AU 2014 *Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods* (Malabo: African Union) (https://doi.org/10.1002/9780470665480.ch21)

Babatunde R O and Qaim M 2010 Impact of off-farm income on food security and nutrition in Nigeria *Food Policy* **35** 303–11

Bahruid B A, Boschid C, Birner R and Zellerid M 2019 Drought and child undernutrition in Ethiopia: a longitudinal path analysis *PLoS One* **14** e0220075

Berend I T 2007 Social shock in transforming Central and Eastern Europe *Communist Post-Communist Stud.* **40** 269–80

Capone R, Bilali H E, Debs P, Cardone G and Driouech N 2014 Food system sustainability and food security: connecting the dots *J. Food Secur.* **2** 13–22

Conklin A I, Daoud A, Shimkhada R and Ponce N A 2018 The impact of rising food prices on obesity in women: a longitudinal analysis of 31 low-income and middle-income countries from 2000 to 2014 *Int. J. Obesity* **43** 774–81

Cottrell R S *et al* 2019 Food production shocks across land and sea *Nat. Sustain.* **2** 130–7

Coughlan de Perez E, van Aalst M, Choularton R, van den Hurk B, Mason S, Nissan H and Schwager S 2019 From rain to famine: assessing the utility of rainfall observations and seasonal forecasts to anticipate food insecurity in East Africa *Food Secur.* **11** 57–68

Crump L, Mauti S, Traoré A, Shaw A, Hattendorf J and Zinnstag J 2019 The contribution of livestock to urban resilience: the case of Bamako, Mali *Trop. Animal Health Prod.* **51** 7–16

Davis K F, Downs S and Gephart J A 2020 Towards food supply chain resilience to environmental shocks *Nat. Food*

DFID 2003 *Sustainable Livelihoods: Guidance Sheets* (London: Department For International Development) (available at: www.livelihoodscentre.org/documents/114097690/114438878/Sustainable+livelihoods+guidance+sheets.pdf/594e5ea6-99a9-2a4e-f288-cbb4ae4bea8b?t=1569512091877)

FAO, IFAD, UNICEF, WFP & WHO 2020 State of food security and nutrition in the world 2020: transforming food systems for affordable. healthy diets (S.L.: FAO, IFAD, UNICEF, WFP and WHO)

FAO 2013 *The State of Food Insecurity in the World, 2013: The Multiple Dimensions of Food Security* (Rome: Food And Agriculture Organization Of The United Nations)

FAO 2019 *Safeguarding Against Economic Slowdowns and Downturns* (Rome: FAO)

FAO 2020 Regional overview of food insecurity—Africa. African food security prospects brighter than ever (FAO, IFAD, UNICEF, WFP and WHO) (https://doi.org/10.4060/ca9692en)

Foeken D W J and Owuor S O 2008 Farming as a livelihood source for the urban poor of Nakuru, Kenya *Geoforum* **39** 1978–90

Geffersa A G and van den Berg M 2015 *Effects of Climate Shocks on Household Food Security in Rural Ethiopia: Panel Data Estimation* (Wageningen University—Department of Social Sciences)

GHI 2020 Global hunger index scores by 2020 GHI rank global hunger index (GHI)—peer-reviewed annual publication designed to comprehensively measure and track hunger at the global, regional, and country levels (available at: www.globalhungerindex.org/ranking.html)

GoK 2007 Kenya vision-2030 (Government of the Republic of Kenya) (available at: http://vision2030.go.ke/inc/uploads/2018/05/Vision-2030-Popular-Version.pdf)

GoK 2016 Kenya national adaptation plan2015-2030. Enhanced climate resilience towards the attainment of vision 2030 and beyond (available at: www4.unfccc.int/sites/NAPC/Documents%20NAP/Kenya_NAP_Final.pdf)

GoK 2018 Eye on the big four: budget watch for 2018/19 and the medium term (available at: www.parliament.go.ke/sites/default/files/2018-09/Budget%20Watch%202018.pdf)

Hong S A, Winichagoon P and Khang Y-H 2019 Rural–urban differences in socioeconomic inequality trends for double burden of malnutrition in Thailand 2005–2016 *Eur. J. Clin. Nutrition* **74** 500–8

Hossain M S, Johnson F A, Dearing J A and Eigenbrod F 2016 Recent trends of human wellbeing in the Bangladesh delta *Environ. Dev.* **17** 21–32

Huho J M and Mugalavai E M 2010 The effects of droughts on food security in Kenya *Int. J. Clim. Change* **2** 61–72

Ifejika Speranza C 2010 Drought coping and adaptation strategies: understanding adaptations to climate change in agro-pastoral livestock production in Makueni district, Kenya *Eur. J. Dev. Res.* **22** 623–42

Ifejika Speranza C, Kiteme B and Wiesmann U 2008 Droughts and famines: the underlying factors and the causal links among agro-pastoral households in semi-arid Makueni district, Kenya *Glob. Environ. Change* **18** 220–33

Ingram J 2020 Nutrition security is more than food security *Nat. Food* **1** 2

Jones A D, Ngure F M, Pelto G and Young S L 2013 What are we assessing when we measure food security? A compendium and review of current metrics *Adv. Nutrition* **4** 481–505

KARI 2019 The major challenges of the agricultural sector in Kenya KARI.org (available at: www.kari.org/the-major-challenges/)

Kassie M, Ndiritu S W and Stage J 2014 What determines gender inequality in household food security in Kenya? Application of exogenous switching treatment regression *World Dev.* **56** 153–71

KNBS 2018a Economic survey 2018 Kenya National Bureau of Statistics (KNBS) (available at: www.knbs.or.ke/download/economic-survey-2018)

KNBS 2018b *Basic Report on Well-being in Kenya* (Nairobi: Kenya National Bureau of Statistics (KNBS)) (available at: https://catalog.ihsn.org/index.php/catalog/1472/download/42105)

Korir L, Rizov M and Ruto E 2020 Food security in Kenya: insights from a household food demand model *Econ. Model.* **92** 99–108

Kozel V, Fallavier P and Badiani R 2008 Risk and vulnerability analysis in world bank analytic work: FY2000-FY2007 (social protection discussion papers and notes 44780) (The World Bank) (available at: https://documents1.worldbank.org/curated/en/132701468315542069/pdf/447800NWP0Box327410B01PUBLIC10SP00812.pdf)

Kuciene R and Dulskiene V 2019 Associations between body mass index, waist circumference, waist-to-height ratio, and high blood pressure among adolescents: a cross-sectional study *Sci. Rep.* **9** 9493

Lele U, Masters W, Kinabo J, Meenakshi J, Ramaswami B, Tagwireyi J, Bell W and Goswami S 2016 Technical working group on measuring food and nutrition security measuring food and nutrition security: an independent technical assessment and user's guide for existing indicators (Rome: Food Security Information Network) (available at: www.fsincop.net/topics/fns-measurement)

Marques S J 2003 Social safety net assessments from Central America: cross-country review of principal findings *Social Protection Discussion Paper* No. SP 0316 (Washington, DC: Social Protection Unit, Human Development Network, The World Bank)

Menike L M C S and Arachchi K A G P K 2016 Adaptation to climate change by smallholder farmers in rural communities: evidence from Sri Lanka *Proc. Food Sci.* **6** 288–92

Musyoka P K, Onjala J and Mureithi L P 2020 Infrastructure growth, household vulnerability and response to shocks in Kenya *Afr. J. Econ. Rev.* **8**

Mutea E, Bottazzi P, Jacobi J, Kiteme B, Speranza C I and Rist S 2019 Livelihoods and food security among rural households in the North-Western Mount Kenya *Reg. Front. Sustain. Food Syst.* **3**

Nabarro D and Wannous C 2014 The potential contribution of livestock to food and nutrition security: the application of the one health approach in livestock policy and practice *Rev. Sci. Tech.* **33** 475–85

Niles M T and Brown M E 2017 A multi-country assessment of factors related to smallholder food security in varying rainfall conditions *Sci. Rep.* **7** 16277

Pablo A, Fèvre E M, Muinde P, Murungi M K, Kiambi S, Akoko J and Rushton J 2017 Urban livestock keeping in the city of Nairobi: diversity of production systems, supply chains, and their disease management and risks *Front. Vet. Sci.* **4** 171

Paul C J, Paul J E and Anderson R S 2019 The local food environment and food security: the health behavior role of social capital *Int. J. Environ. Res. Public Health* **16** 5045

Pho K-H, Ly S, Ly S and Lukusa T M 2019 Comparison among Akaike information criterion, Bayesian information criterion and Vuong's test in model selection: a case study of violated speed regulation in Taiwan *J. Adv. Eng. Comput.* **3** 293

Roessler R, SMpouam S E, Muchemwa T and Schlecht E 2016 Emerging development pathways of urban livestockproduction in rapidly growing West Africa Cities *Sustainability* **8** 1199

Smith L C and Subandoro A 2007 *Measuring Food Security Using Household Expenditure Surveys* (Washington, DC: International Food Policy Research Institute)
Smith L, Dupriez O and Troubat N 2014 Assessment of the reliability and relevance of the food data collected in national household consumption and expenditure surveys *International Household Survey Network (IHSN) IHSN Working Paper* No. 008 (available at: www.ihsn.org/sites/default/files/resources/IHSN_WP008_EN.pdf)
Stevens T and Madani K 2016 Future climate impacts on maize farming and food security in Malawi *Sci. Rep.* **6** 36241
Szabo S, Hossain Md S, Adger W N, Matthews Z, Ahmed S, Lázár A N and Ahmad S 2015 Soil salinity, household wealth and food insecurity in tropical deltas: evidence from south-west coast of Bangladesh *Sustain. Sci.* **11** 411–21
Thornton P and Herrero M 2016 Adapting to climate change in the mixed crop and livestock farming systems in sub-Saharan Africa *Nat. Clim. Change* **5** 830–6
Ulrich A, Ifejika Speranza C, Roden P, Kiteme B, Wiesmann U and Nüsser M 2012 Small-scale farming in semi-arid areas: livelihood dynamics between 1997 and 2010 in Laikipia, Kenya *J. Rural Stud.* **28** 241–51
United Nations Department For Economic And Social Affairs 2019 Sustainable development goals report 2019 (United Nations) (available at: https://digitallibrary.un.org/record/3812145)