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Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from 291 cross-sectional surveys

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ABSTRACT

Background: More than two decades of conflict and natural disasters in Somalia have resulted in one of the largest and longest running humanitarian crises in the world. Nutrition data has been collected over the years despite challenges to inform programmatic action. This paper explores malnutrition and morbidity trends in Somalia during the last decade, disaggregated by geographical zone and livelihood system.

Methods: We used data from 291 cross-sectional surveys conducted in children aged 6-59 months between 2007 and 2016 in Somalia. Wasting, morbidity and stunting prevalences over time were analysed by geographic area, livelihood system and season. Logistic regressions were used to test trends.

Results: Morbidity showed a declining trend, although with multiple peaks depicting disease outbreaks. Stunting also declined for all groups and in all zones, but with more consistent patterns in northern Somalia. The wasting trends show a striking peak in 2011, more marked in southern and central Somalia (SCZ) and coinciding with the famine declaration. A slight decreasing trend is observed thereafter although not consistent across all zones and livelihoods, and with a raising slope in 2016, especially among Internally Displaced Persons (IDPs).

Pastoralist showed the lowest stunting estimates overall, while agrarian populations showed the lowest prevalence of wasting and morbidity. IDPs were the most affected by all outcomes. Seasonality affected the three outcomes differently by livelihood system. Stunting rates increased after the 2011 famine for all age groups within children under five years.

Conclusions: Despite the continuous complex situation in Somalia, there has been a sustained decline in stunting and morbidity in the last decade. Wasting trends have

remained at very high levels especially in north-east and the south zones of Somalia. The findings support the importance of performing trend analyses disaggregated by zone and livelihood groups within countries, to better identify priorities for program intervention.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- The sample characteristics in terms of size and number of surveys allowed for a high precision in the analysis and for the stratification by livelihood system. However, despite the enhanced precision of the estimates of malnutrition and morbidity showed by the narrow confidence intervals, due to the effects of confounding and bias (measurement and or recall bias) inherent in cross sectional and nutritional surveys, the analysis may produce spuriously precise but biased estimates of association and stability.
- The so called IDPs livelihood was over-represented in the overall population as recent data indicated that the proportion of IDPs in Somalia population was around 14% (36), thus the importance of the stratified analysis.
- Data were collected in field conditions, which may have an impact on the accuracy of measurements, although the FSNAU survey enumerators' long-time experience and routinely training may have minimized this limitation.
- Accurate age estimation is a major problem as there are no accurate records of birth and age determination mostly relies on maternal recall. As a result, recall bias in child morbidity and stunting could have occurred due to reliance on maternal recall.

BACKGROUND

Somalia has been experiencing one of the longest-running humanitarian crises in the world. It has suffered protracted war and conflict, political instability, disruption of economy and humanitarian assistance, and extreme climatic conditions since collapse of state institutions in 1991, resulting in large-scale food and nutrition security crises. In 2011 the country suffered a famine, more than 250,000 people are estimated to have died of starvation and approximately 53% of the population experienced food crisis. An estimated 200,00 people had also died during a previous famine in 1991/1992 (1).

On top of the two mentioned famines, the rates of acute malnutrition have remained at very high levels since the start of the conflict, and they are among the highest in the world today. The causes of different forms of malnutrition in Somalia are multi-factorial and linked not only to food insecurity but also to morbidity and inadequate caring practices, all of them related to the disruption of peoples livelihood, destitution, large-scale population displacement and the limited access to basic services (2) (3) (4) (5).

Nutrition response programming has been taking place in Somalia for decades, in the form of live-saving interventions like distribution of food and cash, treatment of acute malnutrition, targeted supplementary feeding, and emergency public health measures during disease outbreaks, as well as in the form of livelihoods, recovery and development programmes in agriculture, livestock, water, and environment in order to improve resilience among vulnerable populations (6). However, effectiveness of humanitarian assistance continues to be constrained by prevailing insecurity which restricts access and delivery of aid to some areas.

The Food Security and Nutritional Analysis Unit (FSNAU) has been conducting national nutrition surveillance in Somalia since the year 2000 in order to monitor the nutritional

status of the population and inform program interventions. FSNAU has been collecting data through different surveillance systems including nutrition surveys, rapid Mid-Upper Arm Circumference (MUAC) assessments, passive health facility-based screening and at some times and places by sentinel site surveillance. In 2009 FSNAU carried out a meta-analysis study including a systematic review of findings and raw data analysis of surveys conducted by FSNAU and partners in Somalia for the period 2001-2008 focusing on wasting trends and casual factors (7). In addition, in 2012 WFP released a report analysing trends of food and nutrition insecurity in Somalia for the period 2007-2012 (8). Since then, no other systematic review of the nutrition data collected by FSNAU has been published.

The reports circulated by FSNAU in the 2007-2016 period have been exhaustive in describing the nutrition situation in regular periods (monthly, bimonthly, quarterly or twice yearly depending on the year). They combine results from different data collection methods to assess the overall nutrition situation, and focus on the identification of malnutrition hotspots and on closely following up specific population groups such as IDP settlements or particular livelihood zones (9).

The three geographic zones of Somalia have been affected differently by the conflict, being the South-central zone (SCZ) historically the most affected one, whereas the North West (NWZ) and the North East zones (NEZ) have been generally more stable, with better governance and institutional capacities. Three main livelihood systems are present in Somalia: pastoralists, agro-pastoralists and riverine. The North west, east and central parts of the country are predominantly pastoral, while some regions in the south in addition to pastoralists also have agro-pastoral and riverine livelihood systems (10). The prevailing insecurity in the SCZ also triggered large-scale displacement of population and according to the latest United Nations High Commissioner for Refugees (UNHCR) Forced

Displacement report, among the 1.5 million IDPs estimated in 2016, 893,000 were located in the SCZ (11).

Food security and nutrition outcomes are importantly affected by seasonality in Somalia as well, with annual crop and livestock production dependent on the two main rainy seasons: *Gu* (April-June) and *Deyr* (October-December). Seasonality impacts the general availability of food and the rates of infection, among other things. Thus, understanding the typical seasonal fluctuations is useful for predicting changes in malnutrition and morbidity rates (12).

The aim of this study is to explore and interpret observed trends in malnutrition (wasting and stunting) and morbidity by zone, livelihood system and season of analysis for the 2007-2016 period, giving special attention to the effects of the 2011 famine on the malnutrition outcomes for the rest of the period.

METHODS

The data used for this study were obtained from 291 surveys undertaken by FSNAU and partners working in Somalia. All surveys included in this study had similar design (two stage cross-sectional surveys) and comparable probability sampling methods. They were carried out biannually in the *Gu* and in the *Deyr* seasons, from year 2007 to 2016.

There are four main seasons defined by rainfall patterns in Somalia: the *Gu,* the main rainy season (April to June), the *Hagaa,* a short and cool dry season (July to September), the *Deyr,* the short rainy season (October to December), and the long and hot dry season called the *Jilaal* (January to March) (13). Only surveys conducted in the *Gu* or in the *Deyr* seasons were taken into account for the analysis.

Somalia has been divided into three main UN operational zones: Northwest, Northeast and South-Central, with varied social, livelihood and economic structures. These zones generally correspond to current administrative and political designations known, respectively, as Somaliland, Puntland and other Federal Member States of the Federal Government of Somalia. The North West zone comprising the pre-war regios of Woqooyi Galbeed, Awdal, Togdheer, Sool and Sanaag regions; the North East zone that includes the pre-war regions of Bari and Nugal and the South Central zone comprising Mudug, Galgadud, Hiran, Bakool, Bay, Middle and Lower Shabelle, Middle and Lower Juba, Gedo and Banadir regions.

There are three main livelihoods in the country, broadly defined by common characteristics of the household's economy: pastoralists rear livestock and are nomadic; agro-pastoralists practise mixed crop and livestock production; and riverine live in the South Central irrigated zones along the Shabelle and Juba rivers and are mainly agrarian (13). Agropastoralists and riverine livelihoods are classified as Agropastoral in this analysis as both are mainly sedentary and share similar characteristics in terms of their primary dependence on crop cultivation as opposed to reliance on rearing livestock. Because of the presence of a significant proportion of internally displaced population in the country, FSNAU also collects data on IDPs. Surveys of main IDP settlements were included, and these were coded as a further livelihood category, although it does not constitute a livelihood system in *sensu stricto*. Although FSNAU also collects data on selected urban populations (mostly Kismayo and Mogadishu), these were not included in our analysis.

Since 2007 and for both technical and operational purposes, FSNAU has conducted rural livelihood-based surveys as opposed to administrative boundary-based surveys. A livelihood zone map of Somalia was created based on climate, topography, natural resources and local livelihood patterns, resulting into 32 rural livelihood zones. In 2015, the

32 rural livelihood zones were consolidated into 18, reasonably homogenous rural livelihood zones. See maps attached in Annex 1 (14).

The surveys were conducted at livelihood zone level or main IDP settlement based on multi-stage cluster sampling with probability proportional to size (PPS) design covering all livelihood zones that were accessible at the time of the survey. The primary sampling units were the villages which were selected randomly from a list of all the villages in each livelihood, and the second unit of analysis were the households within the sample villages, which were randomly selected using the Standardized Methodology for Survey in Relief and Transition (SMART). Sample selection and sizes of the surveys (number of households and number of children) were calculated using the Emergency Nutrition Assessment (ENA) software (Version 2011, July 9, 2015). Previous estimations of wasting measured by weight-for-height and crude mortality rates for the surveyed areas were used for the sample size calculations, separately for anthropometry and mortality. The higher of these two sample sizes was used to determine the final sample size as the surveys integrate both anthropometry and mortality. An additional 2-3% was added to the sample size to allow for dropout or refusal to participate

As there are livelihood zones that geographically cross the three operational zones taken into account for this analysis (like Coastal Deeh crossing the SCZ and the NEZ or Hawd Pastoral crossing the SCZ and the NWZ, see maps in Annex 1), we went down to the villages level in order to allocate children surveyed to the corresponding operational zone according to the geographical location. In each zone, surveys were aggregated according to the livelihood system of the livelihood zone they represented (example, West Golis Pastoral and Guban Pastoral livelihood zones in the NWZ would be aggregated in the Pastoral sub-sample of the NWZ, according to 2014 livelihood zone distribution).

Although in most of the time points (season/year) of the study period we had representative data for each livelihood, due to field work restrictions in some specific season/years not all livelihoods systems were covered. Therefore, and in order to construct the trends for the whole period of analysis the missing values in-between the trend were imputed. The imputation method we used was logistic regression to calculate the predictions and the residuals. Missing values in the beginning of the trend (year 2007 and 2008) were not imputed. Out of 159 time points analysed, only 24 estimations were imputed. Supplementary Table 1 in Annex 2 presents the compiled sample sizes of the population analysed in each time point, disaggregated by livelihood and zone.

The data were cleaned by deleting the records of individual children with any of the following criteria: age < 6 months(n=5), age > 59 months (n=6), and missing age (n=1137), sex (n=1222), weight (n=1134), height (n=1143) or oedema (n=1802). Weight-for-height z-score (WHZ) and length/height-for-age z-score (HAZ) were calculated using World Health Organization (WHO) Anthro (version 3.2.2, January 2011) and Macros using WHO 2006 growth standards. Extreme biologically implausible values were excluded based on WHO standards with recommended flag limits of WHZ (n=545) and HAZ (n=824) scores below -5 or above +5 (15).

Nutritional status indicators used were *wasting* defined as weight-for-height below -2 Z-scores and/or the presence of nutritional oedema; and *stunting* or chronic malnutrition defined as height-for-age below -2 Z-scores (16). Child morbidity was assessed based on a 2-week recall of the incidence of diarrhoea, acute respiratory infection (ARI) and febrile illness and 30-days recall for suspected measles. A new variable called morbidity was created and coded as 1 if the child had a positive response to at least one of the four illnesses and as 0 if the child had a negative response to all of the four illnesses. We calculated the prevalence of wasting, morbidity and stunting for each of the surveys

separately and provided the levels of uncertainty in the estimates with the 95% confidence intervals (CI).

We graphed the estimations and confidence intervals of wasting, stunting and morbidity for each year and season disaggregated by livelihood group and geographical zone for the patterns comparison over the 10-year time period.

In order to analyse the observed trends, we created two differentiated time periods, one before the famine of 2011 (including data from 2007 to 2010), and another one covering the time period after the famine (2012-2016). Logistic regressions were used to test the change of the nutrition and health outcomes with each additional year in each of the two periods, and to model the association of the outcomes with the *Gu* and *Deyr* seasons for the overall period. All analyses were stratified by livelihood system and geographical zone. Odd ratios (ORs) and confidence intervals (CI) were calculated.

To explore the potential impact of the wasting peaks recorded during the 2011 famine on the subsequent stunting estimations, we created six artificial cohorts based on the children's year of birth. We constructed the cohort of 2007 (Cohort07) by selecting children who were 6-12 months in the year 2007, children that were 13-24 months in 2008, 25-36 months in 2009, 37-48 months in 2010 and 49-59 months in 2011. The 2008 cohort (Cohort08) was constructed by selecting children that were 6-12 months in the year 2008, 13-24 months in 2009, 25-36 months in 2010, 37-48 months in 2011 and 49-59 months in 2012. Following the corresponding procedure, we constructed the rest of the cohorts for the years 2009 (Cohort09), 2010 (Cohort10), 2011 (Cohort11) and 2012 (Cohort12), and we graphed the prevalence of stunting (y-axis) for each cohort according to the age of the child (x-axis), highlighting the position of the 2011 famine in order to facilitate the interpretation of results. Due to data availability this analysis was restricted to the agropastoral and pastoralists populations of the South Central zone.

Stata 15 (StataCorp, College Station, Texas, USA) was used for statistical analysis.

Ethical approval

Ethical approval was provided through permission by the Ministry of Health (MOH) Somalia, Transitional Federal Government of Somalia Republic, Ref: MOH/WC/XA/146./07, dated 02/02/07. Subsequent survey plans and protocols were presented and discussed with MOH and partners prior to the conduct of each seasonal assessment. Owing to the high illiteracy rate of the population, informed verbal consent was sought from all participating households and individuals.

RESULTS

A total of 282 514 measurements of children aged 6 to 59 months from 291 surveys were examined from 2007 to 2016. The North West and North East zones of the country were mainly composed of pastoral livelihood zones with a large proportion of IDPs. The South Central zone, in addition to pastoralists and IDPs, also included agro-pastoral and riverine livelihoods (See Table 1).

Of the children surveyed, 69 275 (24%) children were located in the North East zone, 49 585 (18%) in the North East zone and 163 654 (58%) in the South Central zone of Somalia Supplementary Table 1 in the Annex 2 summarizes the survey data by zone, season and period of analysis. The assessments were equally distributed in relation to the *Gu* (50.7%) and the *Deyr* (49.3%) seasons. Around 36% of the children were surveyed before the 2011 year of famine, and 64% after year 2011.

In Table 1 are summarized the children's characteristics by zone.

Table 1. Characteristics of children 6 to 59 months in Somalia (n=282 514)

	North West (n=49 585) 17.5%	North East (n=69 275) 24.5%	South Central (n=163 654) 57.9%
Sex			
Male	50.9	50.6	50.8
Female	49.1	49.4	49.2
Age			
<24 months	35.7	34.9	35.8
≥24 months	64.3	65.1	64.2
Wasting			
Weight-for-height <-2 z-scores	12.7	17.0	19.3
Severe wasting			
Weight-for-height <-3 z-scores	2.5	4.0	5.7
Stunting			
Height-for-age <-2 z-scores	7.3	22.1	23.8
Morbidity	*24.4*	*39.2*	*39.5*
Diarrhoea	11.3	14.6	16.4
Acute respiratory infection	8.4	14.1	16.0
Febrile illness	12.9	25.7	22.7
Measles	2.5	4.1	3.9
Morbidity overall[1]	24.4	39.2	39.5
Livelihood system			
Agro-pastoralists	12.6	-	26.2
Pastoralists	46.6	33.6	30.7
Riverine	-	-	20.0
Internally displaced persons	40.8	66.4	23.1

[1]Morbidity variable integrating the diseases described in the table. See Methods section for details.

Trends in morbidity

The mean prevalence of reported morbidity for the overall period of analysis was 24.4% in the NWZ, 39.2% in the NEZ and 39.5% in the SCZ.

In Figure 1 we observe the jagged patterns of morbidity estimations, with peaks over 50% in several time points (season/year) for the pastoralists and IDP populations.

Pastoralists showed in the NWZ a significant increase in morbidity for each additional year until 2010 (Table 2) and two important peaks in the *Deyr* seasons of 2015 and 2016, while in the NEZ values for pastoralists have been steadily between 30 and 40% since Deyr

2012. In the SCZ, however, there was a significant decrease of morbidity during the whole period of analysis for pastoralists, more marked during the second period (0.8 decrease per each additional year, see Table 2), although with a steep rise at the end of the period, in year 2016.

Agropastorals on the other hand, showed a decreasing trend in the two periods and zones where they are present, although with a marked increase in year 2016 as well.

Among IDPS morbidity has been decreasing significantly since 2012 both in the North West and South Central zones but remaining stagnant at levels around 40% in the NEZ.

For agropastoral and pastoralists' populations morbidity was higher during the *Deyr* season, while for IDPs in the NWZ and SCZ it was higher during the *Gu* seasonal analysis.

Table 2. Trend analysis on morbidity per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.70 (0.55-0.89)	1.5 (1.4-1.6)	1.00 (0.86-1.15)
2012-2016	0.90 (0.83-0.99)	1.0 (1.0-1.1)	0.77 (0.74-0.80)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.77 (0.67-0.88)	0.86 (0.81-0.91)	1.29 (1.20-1.38)
North East Zone			
Trend per year			
2007-2010		0.99 (0.89-1.1)	0.85 (0.81-0.89)
2012-2016		1.04 (1.01-1.06)	0.99 (0.97-1.00)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	0.79 (0.74-0.83)	0.94 (0.90-0.98)
South Central Zone			
Trend per year			
2007-2010	0.95 (0.93-0.97)	0.89 (0.87-0.92)	0.78 (0.74-0.82)
2012-2016	0.85 (0.83-0.87)	0.81 (0.78-0.83)	0.82 (0.80-0.83)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.84 (0.80-0.87)	1.01 (0.98-1.05)	1.38 (1.32-1.44)

Trends in wasting

The mean prevalence of wasting for the overall period of study was 13%, 17% and 19 % for the NWZ, NEZ and SCZ respectively.

Figures 2 shows, in the NWZ, a steady decline in wasting estimates for all livehoods and periods of analysis. Agropastorals' estimates declined to around 5% at the end the period, although with a steep increase above 10% in *Gu* 2016. Wasting among IDPs also increased sharply in 2016 in this particular zone.

In the NEZ, there was an important decrease in wasting estimates for each additional year until 2010 (OR=0.75 and OR=0.80 for pastorals and IDPs respectively) see Table 3, although estimates raised at above 20% in 2011. Since 2012 wasting prevalence has remained above 10% among pastoralists and above 15% among IDPs (Figure 2B).

Figure 2C shows the wasting estimates for the SCZ above 15% for the three livelihoods in most of the years, and the peak of wasting prevalence above 35% in year 2011 for agropastorals and IDPs. This peak was less pronounced among pastoralists, although it was sustained longer in time. In the second period of analysis, starting in 2012, there was a slight decrease on wasting for each additional year (see Table 3).

In all zones, wasting was higher during the *Gu* seasonal analysis for all livelihoods, although the difference was more marked for pastoralists and IDPs.

Table 3. Trend analysis on wasting per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.59 (0.42-0.84)	0.87 (0.78-0.97)	1.10 (1.0-1.5)
2012-2016	0.90 (0.81-1.01)	0.91 (0.87-0.95)	0.98 (0.95-1.0)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.06 (0.88-1.26)	1.15 (1.06-1.24)	1.23 (1.16-1.29)
North East Zone			
Trend per year			
2007-2010		0.75 (0.66-0.86)	0.80 (0.75-0.84)
2012-2016		1.00 (0.96-1.03)	0.96 (0.94-0.99)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	1.26 (1.16-1.36)	0.96 (0.95-0.97)
South Central Zone			
Trend per year			
2007-2010	1.03 (1.0-1.06)	1.00 (0.98-1.04)	1.07 (1.00-1.15)
2012-2016	0.93 (0.91-0.96)	0.94 (0.92-0.97)	0.98 (0.95-1.00)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.07 (1.01-1.13)	1.15 (1.1-1.2)	1.23 (1.17-1.30)

Trends in stunting

For the first period of analysis (2007-2010) the stunting estimates have decreased significantly for each additional year in the three zones and all livelihoods (See Figure 3 and Table 4) although in the NWZ there was a peak for pastoralists observed in Gu 2010, and for all livelihoods in Deyr 2008 in the other two zones (NEZ and SCZ).

During the second period of analysis, there was a small peak of stunting in year 2012 in the NWZ for all livelihoods but ever since estimates have been declining steadily in this zone, reaching estimates below 5% at the end of the period. In the NEZ the peak was observed for all livelihoods at the end of 2011 and early 2012, with a subsequent decrease thereafter reaching a prevalence around 5% for pastoralists and 15% among IDPs (Figure 3 B). The stunting estimates among pastoralists are approximately a third of the IDPs in this zone during the whole period of analysis.

Stunting trends in the SCZ increased sharply in 2011, and then again in 2013 for agropastorals and IDPs only. After that rates decreased to below 5% for pastoralists, below 10% for agropastorals and only slightly, to around 25% for IDPs in 2016. Pastoralists show the lower stunting rates overall.

Stunting rates were consistently higher in the *Gu* season except for the NEZ pattern.

Table 4. Trend analysis on stunting per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.53 (0.37-0.78)	0.79 (0.72-0.88)	0.33 (0.27-0.40)
2012-2016	0.92 (0.77-1.10)	0.82 (0.77-0.88)	0.86 (0.81-0.91)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.32 (0.1-1.64)	1.15 (1.04-1.27)	1.90 (1.70-2.12)
North East Zone			
Trend per year			
2007-2010		0.59 (0.51-0.69)	0.84 (0.80-0.88)
2012-2016		0.87 (0.83-0.91)	0.86 (0.84-0.88)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	0.89 (0.85-0.89)	0.96 (0.93-1.00)
South Central Zone			
Trend per year			
2007-2010	0.88 (0.86-0.90)	0.92 (0.89-0.95)	0.65 (0.61-0.70)
2012-2016	0.72 (0.70-0.74)	0.89 (0.86-0.92)	0.96 (0.94-0.98)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.04 (1.00-1.10)	1.35 (1.29-1.41)	1.29 (1.23-1.36)

Figure 4 represent the growth patterns based on height for age, showing the stunting rates by age group for the six self-constructed cohorts in the agro-pastoral and pastoral livelihoods of the SCZ (See Methods section for details). In both livelihoods and all cohorts, we observe a peak in stunting at 24 months of age, which declines thereafter in most of the cohorts. Exceptions to this pattern are, among the agro-pastoralists, the Coh2009 and the Coh2010 which experience an increase in stunting prevalence after the initial peak at 24 months, and the Coh2008 which despite initial decline after the 24 months' peak, experiences a later increase among the children 49-59 months of age. Among the pastoralists exceptions to the observed pattern were the Coh07 and the Coh09 for which the stunting prevalence increased or decreased only slightly respectively after the first 24 months' peak.

The cohort of children born in 2012 (Coh12) showed the growth patterns with sharper declines in stunting prevalence after initial peak at 13-24 months of age and throughout all the older age groups.

DISCUSSION

To our knowledge, this is the first study analysing malnutrition and morbidity trends comprehensively during the period 2007-2016 in Somalia. We observe a decreasing trend in morbidity overall, although with multiple peaks depicting disease outbreaks. Stunting also declined for all groups and in all zones, but with more consistent patterns in the northern ones. The wasting trends show a striking peak in 2011, more marked in the SCZ and coinciding with the famine declaration. A slight decreasing trend is observed thereafter although not consistent across all zones and livelihoods, and with a raising slope in 2016, especially among IDPs.

Since early nineties, the food security and nutrition situation in Somalia has been characterised by protracted and recurrent emergency situations resulting from repeated episodes of drought, flooding, conflict and large-scale population displacement. The frequency and severity of these crises have been exacerbated by the absence of strong government and lack of humanitarian space (17). Food insecurity and conflict have been shown to have a direct and independent impact on malnutrition (18),but also infectious diseases are identified as main drivers of malnutrition in Somalia (2) (9).

Our results show that even if morbidity declined during the period of analysis, prevalence were still high, especially among IDPs. Pervasive morbidity is associated with limited access and utilisation of basic health and water services and IDPs reside in temporary infrastructures and crowded conditions, which exacerbate their vulnerability to infectious diseases(19). Also, and for all the livelihood groups, the morbidity trends showed numerous peaks reflecting disease outbreaks such as measles, polio, acute watery diarrhoea and cholera almost every year since 2007. Somalia is one of the acute watery diarrhoea/ cholera-endemic countries in the world and according to UNICEF, contains “the largest known reservoir of unvaccinated children in a geographic area in the world”

(around half a million children)(20). The rise in morbidity observed in 2016 corresponds with the cholera and measles outbreaks occurring in that year (21) (22) which further contributed to the rise in acute malnutrition and mortality which reached near-famine thresholds at the start of 2017, only averted by the large-scale and sustained humanitarian actions (23).

In relation to wasting, we observe the rising trend in 2009-2010 coinciding with the slow onset of drought driven by four consecutive rain failures, which together with some of the most violent conflict and restricted humanitarian access in Somalia's history contributed to the 2011 famine, reflected in our results with wasting peaks above 35% among IDPS and agro-pastoralists in the SCZ and above 20% among pastoralists and IDPS in the NEZ. The situation was further aggravated by the economic crisis, characterized by currency devaluation, disrupted trade and market activities, and hyperinflation of basic food and non-food items (24), and by al-Shabaab's blocking of humanitarian operations in areas under their control (25). It is estimated that nearly 260 000 people died during the 2011 famine(26), half of them children.

After the 2011 peak the wasting prevalence dropped from the extremely high levels registered in the SCZ and NEZ to around 15%, at the level it remained for the rest of the period, still a very high prevalence which flags the threshold for emergency according to the World Health Organization (27). The pronounced decrease was the result of the intense humanitarian actions but could also be reflecting the increased under five mortality in 2011, which affected severely acutely malnourished children primarily, and that peaked at 5.83 deaths per 10,000 in the South Central zone (28). The SCZ was the most affected by the 2011 famine and shows the highest wasting levels for all livelihoods in the consequent years. This zone is impacted by higher intensity of conflict, flooding of the riverine areas, continued displacements, restrictions of movements and goods due to clan

and religious insurgency, and low availability and poor quality of health services (29). Moreover, the IDPs show consistently the highest estimates of wasting in all zones. They are considered to be among the poorest population groups in the country and their vulnerability to malnutrition is highly linked to poor access to food, income, health care, and safe water coupled with high morbidity burden (30). In this group, our results show the raising trend in wasting in early 2016 which resulted in a declaration of high famine risk in early 2017 (23) previously mentioned. Stunting estimates are also consistently higher among IDPs, especially in the NEZ and the SCZ.

Nevertheless, the overall pattern of stunting is a declining trend for all livelihood groups in the three zones. Pastoralists' children seem to be more resilient to stunting, with estimates consistently lower, reaching very low levels (below 5%) in all three zones at the end of the period. Other studies have suggested this is a result of the physical stature of Somali pastoralists as tall and lean, which may mask the actual estimates of chronic malnutrition (31), but decreasing trends are clear nonetheless. Another potential explanation for this differentiation is that pastoral groups have relatively better asset base and access to animal products, especially milk and cow's blood, which provide high protein diets even when food is scarce. This type of diet, also rich in iron, calcium and other micronutrients will favour continued height growth rather than soft tissue. The opposite applies for agriculturalists as energy may be provided by cereals but protein and micronutrient intake may be compromised, favouring stunting but less wasting (32).

Also important to notice is the stunting peak consistently shown for all livelihoods in the immediate years after the famine, probably reflecting the effects in stunting of the extremely high rates of wasting.

These same observations are replicated in the results of the agro-pastoralists and pastoralists artificial cohorts we created for the SCZ. The stunting rates are consistently

lower and the stunting fluctuations consistently softer among the pastoralists' cohorts as compared to the agro-pastoral ones, and a relation is observed between the high wasting peak in 2011 and the stunting in the subsequent years.

The overall growth pattern we observe in our cohorts, with stunting peaks within the 13-24 months of age, is consistent with the growth faltering observed in other deprived populations of the world, which show a stunting crowning around 24 months of age which decreases thereafter (33). The interpretation of childhood catch-up after 24 months is that a combination of the normal postnatal maturation of the children's immune systems and the development of a broad range of adaptive responses against previously encountered pathogens reduces the frequency and severity of growth-impairing infections (34). This is the observed pattern in most of the pastoralists' cohorts we created in the SCZ. However, among the agro-pastorals the only cohort that follows that clear pattern is the Coh2012, which encompasses the children born after the 2011 famine. In all the rest of the cohorts the growth pattern changes, as the stunting prevalence experiences a sharp increase a year after the children have experienced the 2011 famine, independently of the age of the children during that period. This suggests a strong impact of the high wasting rates in the subsequent stunting prevalences. This association has been shown in longitudinal studies that have reported that children with wasting or negative changes in weight for height are at greater risk of linear growth retardation (35).

CONCLUSIONS

The international community has been implementing humanitarian, recovery and development programmes for the Somali population in a complex and varied environment for the last decade, with ambivalent results.

Although wasting and morbidity prevalence remained high during the period of analysis there was a slight but clear decreasing trend for both indicators, only reversed at the end

of the period, 2016, when severe drought conditions impacted most parts of the country. Furthermore, the decrease in stunting for the 2007-2016 period is remarkable.

The association found between high wasting prevalence and subsequent high stunting estimates calls for a more holistic response which addresses humanitarian life-saving needs and development work simultaneously.

Moreover, the focus on reducing malnutrition in Somalia clearly needs to move away from the short-term response aimed at addressing acute food insecurity and treatment of acutely malnourished children to a more integrated response that includes access to clean water, the promotion of hygiene and sanitation, and the improvement of access to basic health services among its priorities.

Authors' contributions

RCM & EC were involved in all stages from the conception and design, data acquisition, analysis and interpretation. FK and DB contributed to the study design, the data analysis and interpretation. DM & AY were responsible for conducting the surveys and managing the data. All authors have critically reviewed and approved the final version of the article.

Competing interests

The authors declare that they have no competing interests.

Funding

Not applicable.

Availability of data and material

The data that support the findings of this study are available from FSNAU but restrictions apply to the availability of these data, which were used under license for the current study,

and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of FSNAU.

Patient and Public Involvement

Not patients were involved in the study. Results of the nutrition and mortality surveys conducted in Somalia are used for programmatic actions targeting the study participants (children under 5 years of age), but due to the characteristics of the study population there is no specific action planned to disseminate results directly to them.

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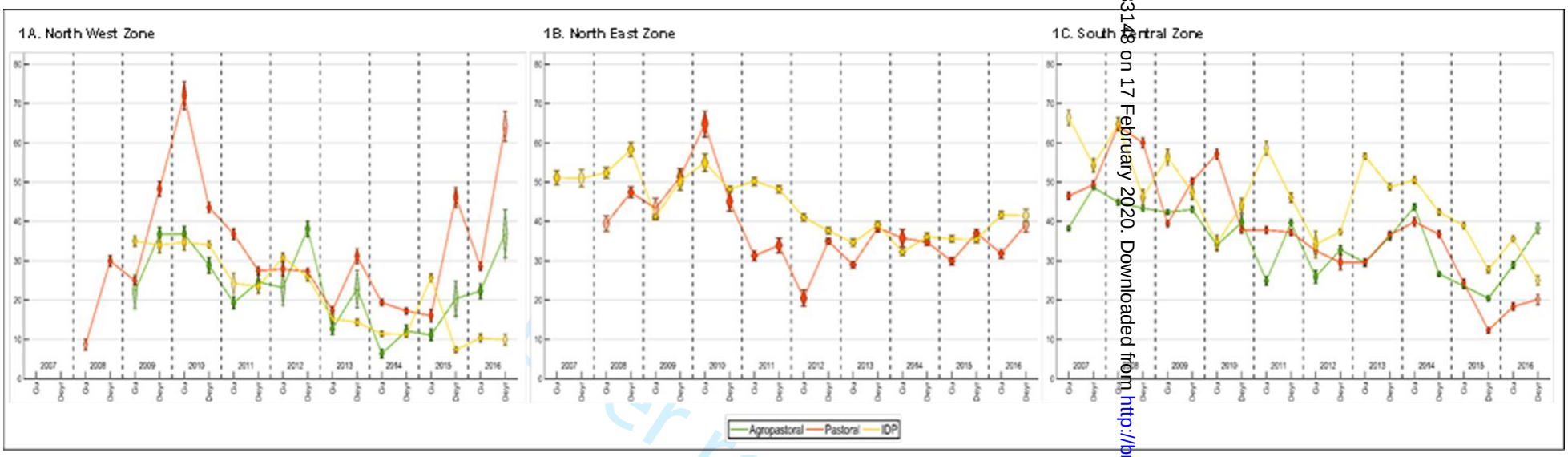
FIGURE'S LEGENDS

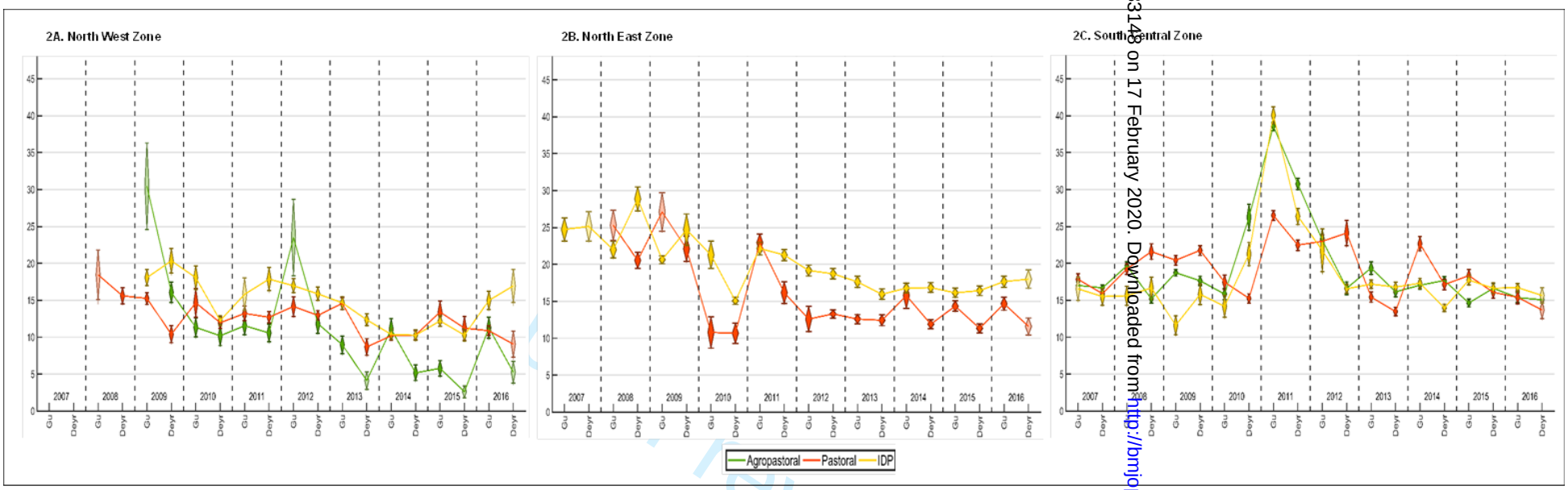
Figure 1: Morbidity estimates and confidence intervals at 95% by year and season of analysis for each livelihood and disaggregated in the three operational zones (NWZ, NEZ and SCZ).

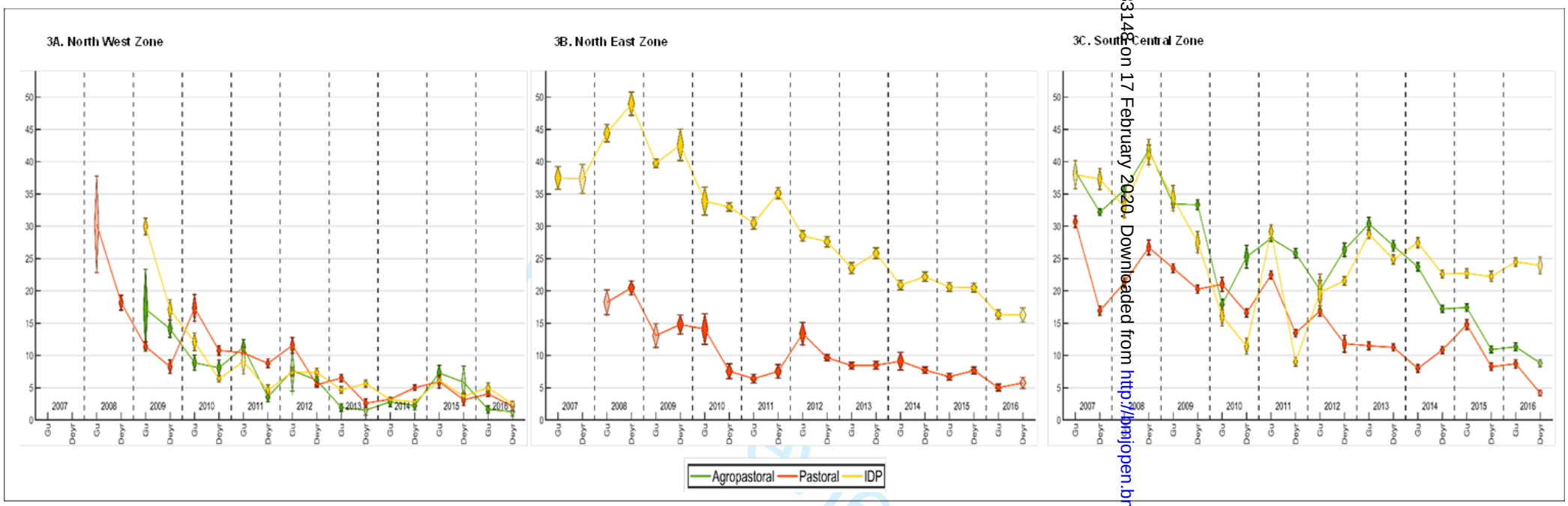
Figure 2: Wasting estimates and confidence intervals at 95% by year and season of analysis for each livelihood and disaggregated in the three operational zones (NWZ, NEZ and SCZ).

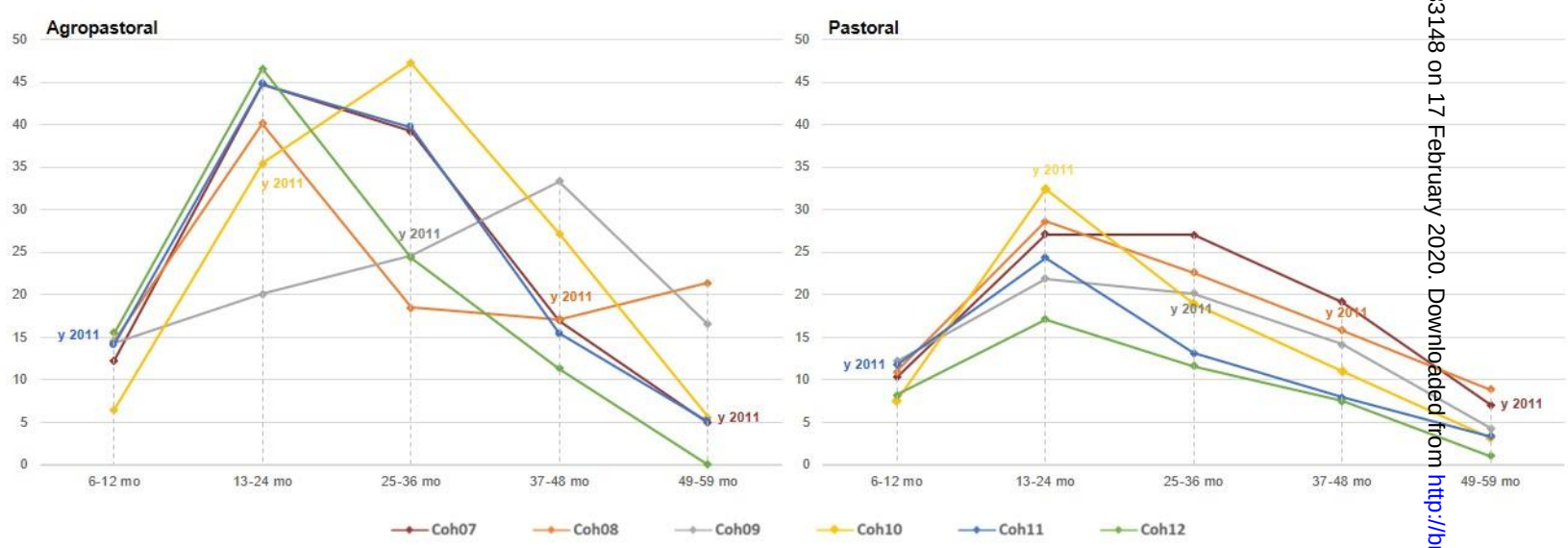
Figure 3. Estimates of stunting with 95% confidence intervals by year and season of analysis, for each livelihood disaggregated in the three operational zones (NWZ, NEZ and SCZ).

Figure 4. Growth patterns cohorts of children 6-59 months in agro-pastoralists and pastoralists populations in the South Central zone of Somalia









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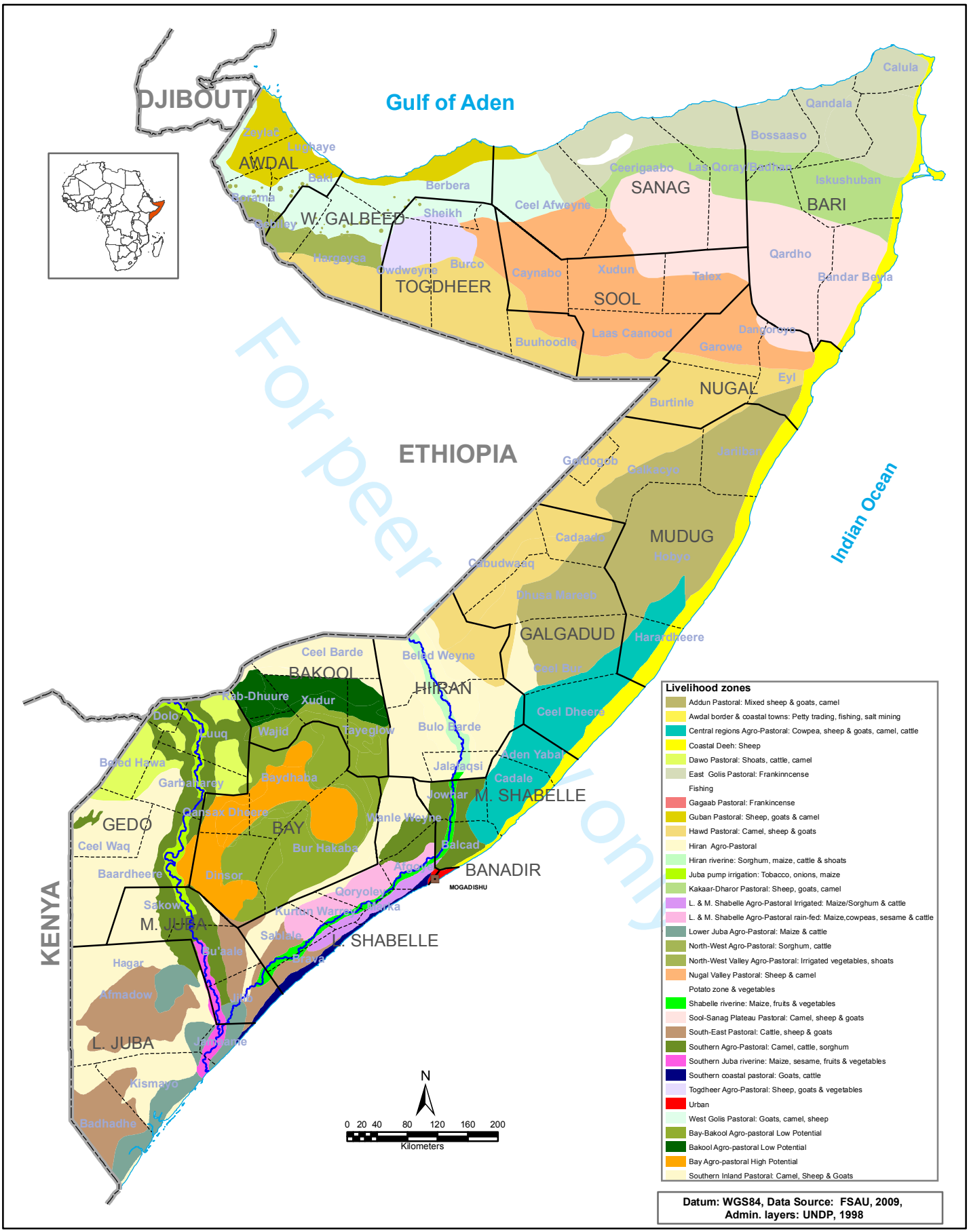

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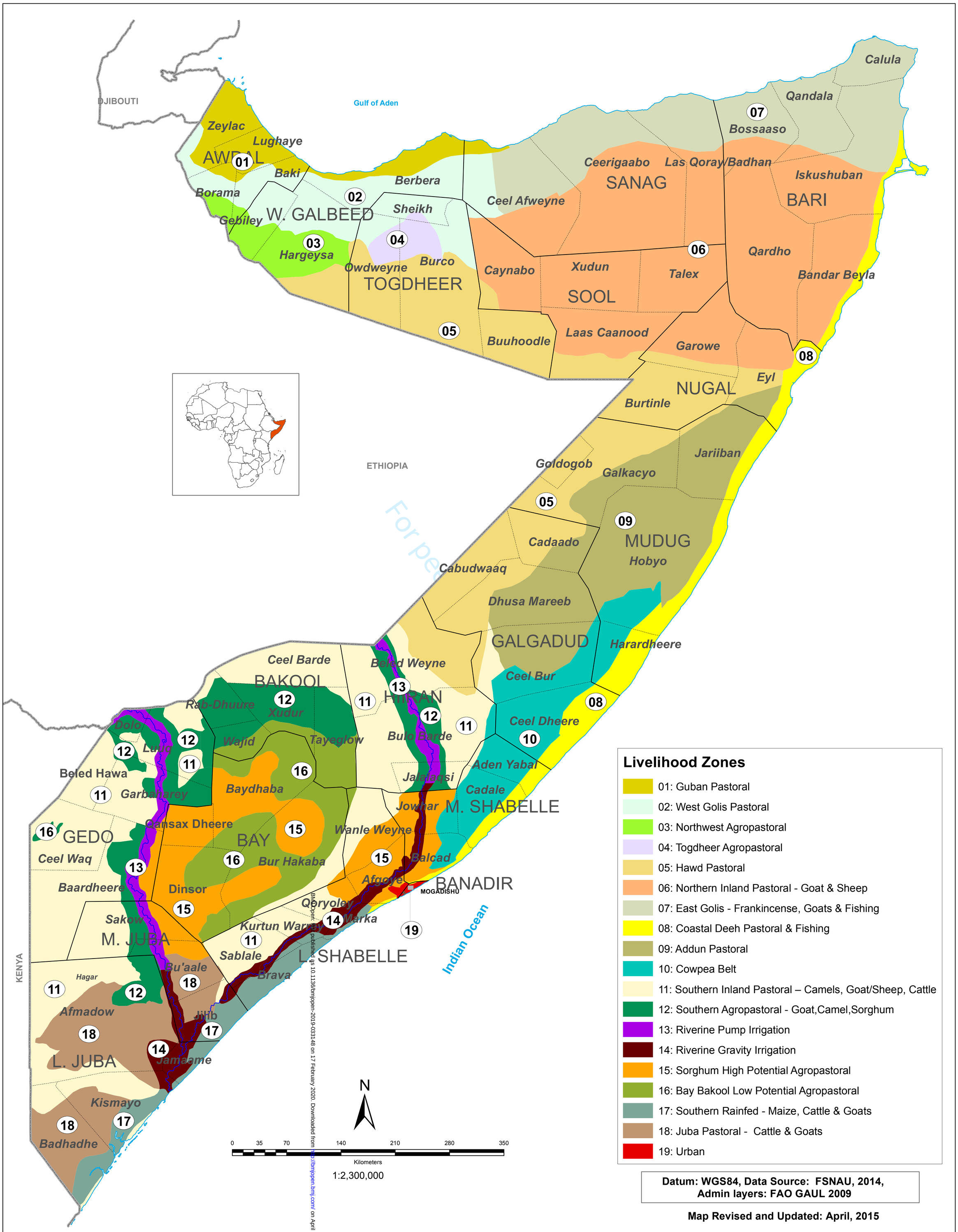

Datum: WGS84, Data Source: FSNAU, 2014, Admin layers: FAO GAUL 2009

Map Revised and Updated: April, 2015

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Annex 2

Supplementary Table 1: Sample size of the study by zone and livelihood system.

Zones	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016	Total
	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	
North West																				**49585**
Agropastoral						716	609	520	684	643		617	568		496	445	467		488	6253
Pastoral				1128	2045	702	334	1781	1203	1937	692	2594	1892	611	2639	2361	537	383	2253	23092
IDP					1251	585	570	2497		610	1597	1651	1713	1716	1975	1743	2179	1352	801	20240
North East																				**69275**
Pastoral				1407		588	213	516	1294	637	381	3701	2763	2083	450	2832	2383	2426	1614	23288
IDP	760		1333	772	5165	413	484	5314	2365	2844	3015	3176	2376	2656	2913	3210	3393	3222	2574	45987
South Central																				**163654**
Agrop+Riverine	6,421	8,273	4,984	3,652	7,159	3,730	2241	617	7,416	3,726	764	1810	2127	2,756	4,314	5,005	4,174	3,682	2,753	75,598
Pastoral	2,713	2,837	2,956	1,542	3,853	3,988	1,461	3,244	4,484	3,359	2,262	618	2,799	3,196	1,903	2,960	2,252	2,177	1,688	50,295
IDP		903	794	624	594	734	578	682	1,874	1,684	202	3,703	4,043	3,419	3,183	4,648	3,309	2,646	4,141	37,761
Total	9894	12013	10067	9125	20067	11456	6490	15171	19320	15440	8913	17870	18281	16439	17873	23204	18694	15888	16312	**282514**

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-11
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-11
Bias	9	Describe any efforts to address potential sources of bias	3 &10
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	

		which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from 291 cross-sectional surveys

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Primary Subject Heading:	Global health
Secondary Subject Heading:	Emergency medicine, Nutrition and metabolism
Keywords:	wasting, stunting, morbidity, Somalia

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Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from 291 cross-sectional surveys

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§The first two authors have contributed equally to the manuscript.

ABSTRACT

Background: More than two decades of conflict and natural disasters in Somalia have resulted in one of the longest running humanitarian crises in the world. Nutrition data has been collected over the years despite challenges to inform programmatic action. This paper explores malnutrition and morbidity trends in Somalia during the last decade, disaggregated by geographical zone and livelihood system.

Methods: We used data from 291 cross-sectional surveys conducted in children aged 6-59 months between 2007 and 2016 in Somalia. Wasting, morbidity and stunting prevalences over time were analysed by geographic area, livelihood system and season. Logistic regressions were used to test trends.

Results: The wasting trends show a striking peak in 2011, more marked in southern and central Somalia (SCZ) and coinciding with the famine declaration. The trend declines slightly thereafter although not consistently across all zones and livelihoods, and it raises again in 2016 especially among Internally Displaced Persons (IDPs). Stunting declined for all groups and in all zones, but with more consistent patterns in northern Somalia.

Morbidity also showed a declining trend, although with multiple peaks depicting disease outbreaks.

Pastoralist showed the lowest stunting estimates overall, while agrarian populations showed the lowest prevalence of wasting and morbidity. IDPs were the most affected by all outcomes. Seasonality affected the three outcomes differently by livelihood system. Stunting rates increased after the 2011 famine for all age groups within children under five years.

Conclusions: Despite the continuous complex situation in Somalia, there has been a sustained decline in stunting and morbidity in the last decade. Wasting trends have

remained at very high levels especially in north-east and the south zones of Somalia. The findings support the importance of performing trend analyses disaggregated by zone and livelihood groups within countries, to better identify priorities for program intervention.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- The sample characteristics in terms of size and number of surveys allowed for a high precision in the analysis and for the stratification by livelihood systems, although the so called IDPs livelihood was over-represented
- Data were collected in field conditions, which may have an impact on the accuracy of measurements, although survey teams were consistently trained and equipment precision regularly monitored to avoid it.
- Accurate age estimation was problematic as there were no accurate records of birth and age determination mostly relied on maternal recall.
- Data quality validation was carried out daily by running the ENA plausibility checks and after each data collection data vetting was conducted by the Assessment and Information Management Working Group in Somalia.

BACKGROUND

Somalia has been experiencing a long humanitarian crisis for the past two decades. It has suffered protracted war and conflict, political instability, disruption of economy and humanitarian assistance, and extreme climatic conditions since collapse of state institutions in 1991, resulting in large-scale food and nutrition security crises. In 2011 the country suffered a famine, more than 250,000 people are estimated to have died of starvation and approximately 53% of the population experienced food crisis. An estimated 200,000 people had also died during a previous famine in 1991/1992 (1).

On top of the two mentioned famines, the rates of acute malnutrition have remained at very high levels since the start of the conflict, and they are among the highest in the world today. The causes of different forms of malnutrition in Somalia are multi-factorial and linked not only to food insecurity but also to morbidity and inadequate caring practices, all of them related to the disruption of peoples livelihood, destitution, large-scale population displacement and the limited access to basic services (2) (3) (4).

Nutrition response programming has been taking place in Somalia for decades, in the form of live-saving interventions like distribution of food and cash, treatment of acute malnutrition, targeted supplementary feeding, and emergency public health measures during disease outbreaks, as well as in the form of livelihoods recovery and development programmes in agriculture, livestock, water, and environment in order to improve resilience among vulnerable populations (5). However, effectiveness of humanitarian assistance continues to be constrained by prevailing insecurity which restricts access and delivery of aid to some areas.

The Food Security and Nutritional Analysis Unit (FSNAU) is an FAO project with the mission to conduct national nutrition surveillance in Somalia since the year 2000 in order

to monitor the nutritional status of the population and inform program interventions. FSNAU has been collecting data through different surveillance systems including nutrition surveys, rapid Mid-Upper Arm Circumference (MUAC) assessments, passive health facility-based screening and, at some times and places, by sentinel site surveillance.

In 2009 FSNAU carried out a meta-analysis study including a systematic review of findings and raw data analysis of surveys conducted by FSNAU and partners in Somalia for the period 2001-2008 focusing on wasting trends and casual factors (6). In addition, in 2012 WFP released a report analysing trends of food and nutrition insecurity in Somalia for the period 2007-2012 (7). Since then, no other systematic review of the nutrition data collected by FSNAU has been published.

The reports circulated by FSNAU in the 2007-2016 period have been exhaustive in describing the nutrition situation in regular periods (monthly, bimonthly, quarterly or twice yearly depending on the year). They combine results from different data collection methods to assess the overall nutrition situation, as well as to identify malnutrition hotspots and to closely follow-up specific population groups such as internally displaced populations (IDP) or particular livelihood zones (8).

The three operational zones of Somalia have been affected differently by the conflict, being the South-central zone (SCZ) historically the most affected one, whereas the North West (NWZ) and the North East zones (NEZ) have been generally more stable, with better governance and institutional capacities. The three main livelihood systems present in Somalia are unevenly distributed across the country. Pastoralists are mainly distributed in the north west, east and central parts, while agro-pastoralists and riverine livelihood systems mostly in the South. (9). The prevailing insecurity has also triggered large-scale displacement of populations, and settlements of internally displaced populations (IDPs) are

found all over Somalia, but in the SCZ predominantly. According to the latest United Nations High Commissioner for Refugees (UNHCR) Forced Displacement report, among the 1.5 million IDPs estimated in 2016, 893,000 were located in the SCZ (10).

Food security and nutrition outcomes are importantly affected by seasonality in Somalia as well, with annual crop and livestock production dependent on the two main rainy seasons (*Gu* and *Deyr*). Seasonality impacts the general availability of food and the rates of infection, among other things. Thus, understanding the typical seasonal fluctuations is useful for predicting changes in malnutrition and morbidity rates (11).

Assessing the fluctuations in malnutrition by season within the year, over time year-to-year, and differentiated by livelihood group is essential to facilitate interpretation of the situation and target effective interventions, as shown by a similar exercise conducted in the Greater Horn of Africa region (12).

The aim of this study is to explore and interpret observed trends in malnutrition (wasting and stunting) and morbidity by operational zone, livelihood system and season of analysis for the 2007-2016 period, giving special attention to the effects of the 2011 famine on the malnutrition outcomes for the rest of the period.

METHODS

The data used for this study were obtained from 291 surveys undertaken by FSNAU and partners working in Somalia. All surveys included in this study had similar design (two stage cross-sectional surveys) and comparable probability sampling methods. They were carried out biannually in the *Gu* and in the *Deyr* seasons, from year 2007 to 2016.

There are four main seasons defined by rainfall patterns in Somalia: the *Gu,* the main rainy season (April to June), the *Hagaa,* a short and cool dry season (July to September), the

Deyr, the short rainy season (October to December), and the long and hot dry season called the *Jilaal* (January to March) (13). Only surveys conducted in the *Gu* or in the *Deyr* seasons were taken into account for the analysis.

Somalia has been divided into three main UN operational zones: Northwest, Northeast and South-Central, with varied social, livelihood and economic structures. These zones generally correspond to current administrative and political designations known, respectively, as Somaliland, Puntland and other Federal Member States of the Federal Government of Somalia. The North West zone comprising the pre-war regions of Woqooyi Galbeed, Awdal, Togdheer, Sool and Sanaag regions; the North East zone that includes the pre-war regions of Bari and Nugal and the South Central zone comprising Mudug, Galgadud, Hiran, Bakool, Bay, Middle and Lower Shabelle, Middle and Lower Juba, Gedo and Banadir regions.

The three main livelihoods in the country are broadly defined by common characteristics of the household's economy: pastoralists rear livestock and are nomadic; agro-pastoralists practise mixed crop and livestock production; and riverine live in the South Central irrigated zones along the Shabelle and Juba rivers and are mainly agrarian (13). Agropastoralists and riverine livelihoods are classified as *Agropastoral* in this analysis as both are mainly sedentary and share similar characteristics in terms of their primary dependence on crop cultivation as opposed to reliance on rearing livestock. Because of the presence of a significant proportion of internally displaced population in the country, FSNAU also collects data on IDPs. Surveys of main IDP settlements were included, and these were coded as a further livelihood category, although it does not constitute a livelihood system in *sensu stricto*. Although FSNAU also collects data on selected urban populations (mostly Kismayo and Mogadishu), these were not included in our analysis.

Since 2007 and for both technical and operational purposes, FSNAU has conducted rural livelihood-based surveys as opposed to administrative boundary-based surveys. A livelihood zone map of Somalia was created based on climate, topography, natural resources and local livelihood patterns, resulting into 32 rural livelihood zones. In 2015, the 32 rural livelihood zones were consolidated into 18, reasonably homogenous rural livelihood zones. Detailed maps can be found at http://www.fsnau.org/products/maps/livelihood-maps (14).

The surveys were conducted at livelihood zone level or main IDP settlement based on multi-stage cluster sampling with probability proportional to size (PPS) design covering all livelihood zones that were accessible at the time of the survey. The primary sampling units were the villages (clusters) which were selected randomly from a list of all the villages in each livelihood zone, and the second unit of analysis were the households within the sample villages, which were randomly selected using the Standardized Methodology for Survey in Relief and Transition (SMART). Households and villages were assumed to follow the livelihood of the livelihood zone in which they were located. Sample selection and sizes of the surveys (number of households and number of children) were calculated using the Emergency Nutrition Assessment (ENA) software (Version 2011, July 9, 2015). Previous estimations of wasting measured by weight-for-height and crude mortality rates for the surveyed areas were used for the sample size calculations, separately for anthropometry and mortality. The higher of these two sample sizes was used to determine the final sample size as the surveys integrate both anthropometry and mortality. An additional 2-3% was added to the sample size to allow for dropout or refusal to participate

As there are livelihood zones that geographically cross the three operational zones taken into account for this analysis (like Coastal Deeh crossing the SCZ and the NEZ or Hawd Pastoral crossing the SCZ and the NWZ, see maps in

http://www.fsnau.org/products/maps/livelihood-maps), we went down to the clusters level in order to allocate children surveyed to the corresponding operational zone according to the geographical location. In each zone, surveys were aggregated according to the livelihood system of the livelihood zone they represented (example, West Golis Pastoral and Guban Pastoral livelihood zones in the NWZ would be aggregated in the Pastoral sub-sample of the NWZ, according to 2014 livelihood zone distribution).

Although in most of the time points (season/year) of the study period we had representative data for each livelihood, due to field work restrictions in some specific season/years not all livelihoods systems were covered. Therefore, and in order to construct the trends for the whole period of analysis the missing values in-between the trend were imputed. The imputation method we used was logistic regression to calculate the predictions and the residuals. Missing values in the beginning of the trend (year 2007 and 2008) were not imputed. Out of 159 time points analysed, only 24 estimations were imputed. Supplementary Table 1 in Annex 1 presents the compiled sample sizes of the population analysed in each time point, disaggregated by livelihood and zone.

Data was collected by FSNAU survey enumerators, who are recruited locally from health centers, clinics etc. and are trained for five days before every survey as part of FSNAU's quality assurance process. FSNAU surveys are coordinated by FSNAU Nutrition Field Analysts and technical experts from the Ministries of Health, and data quality is validated in a daily basis by running the ENA plausibility checks. At the end of data collection there is a technical vetting conducted by the Assessment and Information Management Working Group established under the Somalia Nutrition Cluster for data coordination and quality control of nutrition surveys.

The data were cleaned by deleting the records of individual children with any of the following criteria: age < 6 months (n=5), age > 59 months (n=6), and missing age

(n=1137), sex (n=1222), weight (n=1134), height (n=1143) or oedema (n=1802). Weight-for-height z-score (WHZ) and length/height-for-age z-score (HAZ) were calculated using World Health Organization (WHO) Anthro (version 3.2.2, January 2011) and Macros using WHO 2006 growth standards. Extreme biologically implausible values were excluded based on WHO standards with recommended flag limits of WHZ scores below -5 or above +5 (n=545) and HAZ scores below -6 or above +6 (n=824)(15).

Nutritional status indicators used were *wasting* defined as weight-for-height below -2 Z-scores and/or the presence of nutritional oedema; and *stunting* or chronic malnutrition defined as height-for-age below -2 Z-scores (16). *Severe wasting* is defined as WHZ below -3 and/or the presence of nutritional oedema, thus severe wasting is included in the wasting definition. We provide the severe wasting estimates independently in Table 1 but the rest of the tables and figures only report wasting which includes both moderate and severe forms.

Child morbidity was assessed based on a 2-week recall of the incidence of diarrhoea, acute respiratory infection (ARI) and febrile illness and 30-days recall for suspected measles. A new variable called morbidity was created and coded as 1 if the child had a positive response to at least one of the four illnesses and as 0 if the child had a negative response to all of the four illnesses. We calculated the prevalence of wasting, morbidity and stunting for each of the surveys separately and provided the levels of uncertainty in the estimates with the 95% confidence intervals (CI).

We graphed the estimations and confidence intervals of wasting, stunting and morbidity for each year and season disaggregated by livelihood group and geographical zone for the patterns comparison over the 10-year time period.

In order to analyse the observed trends, we created two differentiated time periods, one before the famine of 2011 (including data from 2007 to 2010), and another one covering the time period after the famine (2012-2016). Logistic regressions were used to test the change of the nutrition and health outcomes with each additional year in each of the two periods, and to model the association of the outcomes with the *Gu* and *Deyr* seasons for the overall period. All analyses were stratified by livelihood system and geographical zone. Odd ratios (ORs) and confidence intervals (CI) were calculated.

To explore the potential impact of the wasting peaks recorded during the 2011 famine on the subsequent stunting estimations, we created six artificial cohorts based on the children's year of birth. We constructed the cohort of 2007 (Cohort07) by selecting children who were 6-12 months in the year 2007, children that were 13-24 months in 2008, 25-36 months in 2009, 37-48 months in 2010 and 49-59 months in 2011. The 2008 cohort (Cohort08) was constructed by selecting children that were 6-12 months in the year 2008, 13-24 months in 2009, 25-36 months in 2010, 37-48 months in 2011 and 49-59 months in 2012. Following the corresponding procedure, we constructed the rest of the cohorts for the years 2009 (Cohort09), 2010 (Cohort10), 2011 (Cohort11) and 2012 (Cohort12), and we graphed the prevalence of stunting (y-axis) for each cohort according to the age of the child (x-axis), highlighting the position of the 2011 famine in order to facilitate the interpretation of results. Due to data availability this analysis was restricted to the agropastoral and pastoralists populations of the South Central zone.

Stata 15 (StataCorp, College Station, Texas, USA) was used for statistical analysis.

Public and patient involvement

Not patients were involved in the study. Results of the nutrition and mortality surveys conducted in Somalia are used for programmatic actions targeting the study participants

(children under 5 years of age), but due to the characteristics of the study population there is no specific action planned to disseminate results directly to them.

Access to survey sites was agreed with local authorities and community leaders in the districts where the clusters were sampled. Verbal consent for all caregivers of the sampled children was sought before administration of the questionnaire. Children who were found as severely malnourished or with any other medical problem during the survey were referred to the nearest health facility for medical attention and appropriate treatment using referral form.

Ethical approval was provided through permission by the Ministry of Health (MOH) Somalia, Transitional Federal Government of Somalia Republic, Ref: MOH/WC/XA/146./07, dated 02/02/07. Subsequent survey plans and protocols were presented and discussed with MOH and partners prior to the conduct of each seasonal assessment.

RESULTS

A total of 282 514 measurements of children aged 6 to 59 months from 291 surveys were examined from 2007 to 2016. The North West and North East zones of the country were mainly composed of pastoral livelihood zones with a large proportion of IDPs. The South Central zone, in addition to pastoralists and IDPs, also included agro-pastoral and riverine livelihoods (See Table 1).

Of the children surveyed, 69 275 (24%) children were located in the North East zone, 49 585 (18%) in the North East zone and 163 654 (58%) in the South Central zone of Somalia Supplementary Table 1 in the Annex 2 summarizes the survey data by zone, season and period of analysis. The assessments were equally distributed in relation to the *Gu* (50.7%)

and the *Deyr* (49.3%) seasons. Around 36% of the children were surveyed before the 2011 year of famine, and 64% after year 2011.

In Table 1 are summarized the children's characteristics by zone.

Table 1. Characteristics of children 6 to 59 months in Somalia (n=282 514)

	North West (n=49 585) 17.5%	North East (n=69 275) 24.5%	South Central (n=163 654) 57.9%
Sex			
Male	50.9	50.6	50.8
Female	49.1	49.4	49.2
Age			
<24 months	35.7	34.9	35.8
≥24 months	64.3	65.1	64.2
Wasting			
Weight-for-height <-2 z-scores	12.7	17.0	19.3
Severe wasting			
Weight-for-height <-3 z-scores	2.5	4.0	5.7
Stunting			
Height-for-age <-2 z-scores	7.3	22.1	23.8
Morbidity	*24.4*	*39.2*	*39.5*
Diarrhoea	11.3	14.6	16.4
Acute respiratory infection	8.4	14.1	16.0
Febrile illness	12.9	25.7	22.7
Measles	2.5	4.1	3.9
Morbidity overall[1]	24.4	39.2	39.5
Livelihood system			
Agro-pastoralists	12.6	-	26.2
Pastoralists	46.6	33.6	30.7
Riverine	-	-	20.0
Internally displaced persons	40.8	66.4	23.1

[1]Morbidity variable integrating the diseases described in the table. See Methods section for details.

Trends in wasting

The mean prevalence of wasting for the overall period of study was 13%, 17% and 19 % for the NWZ, NEZ and SCZ respectively.

Figure 1 shows in the first graph, for the NWZ, a steady decline in wasting estimates for all livehoods and periods of analysis. Agropastorals' estimates declined to around 5% at the

end the period, although with a steep increase above 10% in *Gu* 2016. Wasting among IDPs also increased sharply in 2016 in this particular zone.

In the NEZ, there was an important decrease in wasting estimates for each additional year until 2010 (OR=0.75 and OR=0.80 for pastorals and IDPs respectively) see Table 2, although estimates raised at above 20% in 2011. Since 2012 wasting prevalence has remained above 10% among pastoralists and above 15% among IDPs (second graph of Figure 1).

The third graph of Figure 1 shows the wasting estimates for the SCZ above 15% for the three livelihoods in most of the years, and the peak of wasting prevalence above 35% in year 2011 for agropastorals and IDPs. This peak was less pronounced among pastoralists, although it was sustained longer in time. In the second period of analysis, starting in 2012, there was a slight decrease on wasting for each additional year (see Table 2).

In all zones, wasting was higher during the *Gu* seasonal analysis for all livelihoods, although the difference was more marked for pastoralists and IDPs.

Table 2. Trend analysis on wasting per period of analysis and season

		Agropastoral	Pastoral	IDPs
North West Zone				
Trend per year				
	2007-2010	0.59 (0.42-0.84)	0.87 (0.78-0.97)	1.10 (1.0-1.5)
	2012-2016	0.90 (0.81-1.01)	0.91 (0.87-0.95)	0.98 (0.95-1.0)
Season				

Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.06 (0.88-1.26)	1.15 (1.06-1.24)	1.23 (1.16-1.29)
North East Zone			
Trend per year			
2007-2010		0.75 (0.66-0.86)	0.80 (0.75-0.84)
2012-2016		1.00 (0.96-1.03)	0.96 (0.94-0.99)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	1.26 (1.16-1.36)	0.96 (0.95-0.97)
South Central Zone			
Trend per year			
2007-2010	1.03 (1.0-1.06)	1.00 (0.98-1.04)	1.07 (1.00-1.15)
2012-2016	0.93 (0.91-0.96)	0.94 (0.92-0.97)	0.98 (0.95-1.00)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.07 (1.01-1.13)	1.15 (1.1-1.2)	1.23 (1.17-1.30)

Trends in stunting

For the first period of analysis (2007-2010) the stunting estimates have decreased significantly for each additional year in the three zones and all livelihoods (See Figure 2 and Table 3) although in the NWZ there was a peak for pastoralists observed in Gu 2010, and for all livelihoods in Deyr 2008 in the other two zones (NEZ and SCZ).

During the second period of analysis, there was a small peak of stunting in year 2012 in the NWZ for all livelihoods but ever since estimates have been declining steadily in this zone, reaching estimates below 5% at the end of the period. In the NEZ the peak was observed for all livelihoods at the end of 2011 and early 2012, with a subsequent decrease thereafter reaching a prevalence around 5% for pastoralists and 15% among IDPs (Figure 2). The stunting estimates among pastoralists are approximately a third of the IDPs in this zone during the whole period of analysis.

Stunting trends in the SCZ increased sharply in 2011, and then again in 2013 for agropastorals and IDPs only. After that rates decreased to below 5% for pastoralists, below 10% for agropastorals and only slightly, to around 25% for IDPs in 2016. Pastoralists show the lower stunting rates overall.

Stunting rates were consistently higher in the *Gu* season except for the NEZ pattern.

Table 3. Trend analysis on stunting per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			

Trend per year			
2007-2010	0.53 (0.37-0.78)	0.79 (0.72-0.88)	0.33 (0.27-0.40)
2012-2016	0.92 (0.77-1.10)	0.82 (0.77-0.88)	0.86 (0.81-0.91)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.32 (0.1-1.64)	1.15 (1.04-1.27)	1.90 (1.70-2.12)
North East Zone			
Trend per year			
2007-2010		0.59 (0.51-0.69)	0.84 (0.80-0.88)
2012-2016		0.87 (0.83-0.91)	0.86 (0.84-0.88)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	0.89 (0.85-0.89)	0.96 (0.93-1.00)
South Central Zone			
Trend per year			
2007-2010	0.88 (0.86-0.90)	0.92 (0.89-0.95)	0.65 (0.61-0.70)
2012-2016	0.72 (0.70-0.74)	0.89 (0.86-0.92)	0.96 (0.94-0.98)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.04 (1.00-1.10)	1.35 (1.29-1.41)	1.29 (1.23-1.36)

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Figure 3 represent the growth patterns based on height for age, showing the stunting rates by age group for the six self-constructed cohorts in the agro-pastoral and pastoral livelihoods of the SCZ (See Methods section for details). In both livelihoods and all cohorts, we observe a peak in stunting at 24 months of age, which declines thereafter in most of the cohorts. Exceptions to this pattern are, among the agro-pastoralists, the Coh2009 and the Coh2010 which experience an increase in stunting prevalence after the initial peak at 24 months, and the Coh2008 which despite initial decline after the 24 months' peak, experiences a later increase among the children 49-59 months of age. Among the pastoralists exceptions to the observed pattern were the Coh07 and the Coh09 for which the stunting prevalence increased or decreased only slightly respectively after the first 24 months' peak.

The cohort of children born in 2012 (Coh12) showed the growth patterns with sharper declines in stunting prevalence after initial peak at 13-24 months of age and throughout all the older age groups.

Trends in morbidity

The mean prevalence of reported morbidity for the overall period of analysis was 24.4% in the NWZ, 39.2% in the NEZ and 39.5% in the SCZ.

In Figure 4 we observe the jagged patterns of morbidity estimations, with peaks over 50% in several time points (season/year) for the pastoralists and IDP populations.

Pastoralists showed in the NWZ a significant increase in morbidity for each additional year until 2010 (Table 4) and two important peaks in the *Deyr* seasons of 2015 and 2016, while in the NEZ values for pastoralists have been steadily between 30 and 40% since Deyr 2012. In the SCZ, however, there was a significant decrease of morbidity during the whole period of analysis for pastoralists, more marked during the second period (0.8 decrease

per each additional year, see Table 4), although with a steep rise at the end of the period, in year 2016.

Agropastorals on the other hand, showed a decreasing trend in the two periods and zones where they are present, although with a marked increase in year 2016 as well.

Among IDPS morbidity has been decreasing significantly since 2012 both in the North West and South Central zones but remaining stagnant at levels around 40% in the NEZ.

For agropastoral and pastoralists' populations morbidity was higher during the *Deyr* season, while for IDPs in the NWZ and SCZ it was higher during the *Gu* seasonal analysis.

Table 4. Trend analysis on morbidity per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.70 (0.55-0.89)	1.5 (1.4-1.6)	1.00 (0.86-1.15)
2012-2016	0.90 (0.83-0.99)	1.0 (1.0-1.1)	0.77 (0.74-0.80)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.77 (0.67-0.88)	0.86 (0.81-0.91)	1.29 (1.20-1.38)
North East Zone			
Trend per year			
2007-2010		0.99 (0.89-1.1)	0.85 (0.81-0.89)
2012-2016		1.04 (1.01-1.06)	0.99 (0.97-1.00)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	0.79 (0.74-0.83)	0.94 (0.90-0.98)
South Central Zone			
Trend per year			
2007-2010	0.95 (0.93-0.97)	0.89 (0.87-0.92)	0.78 (0.74-0.82)
2012-2016	0.85 (0.83-0.87)	0.81 (0.78-0.83)	0.82 (0.80-0.83)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.84 (0.80-0.87)	1.01 (0.98-1.05)	1.38 (1.32-1.44)

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DISCUSSION

To our knowledge, this is the first study analysing malnutrition and morbidity trends comprehensively during the period 2007-2016 in Somalia. We observe a decreasing trend in morbidity overall, although with multiple peaks depicting disease outbreaks. Stunting also declined for all groups and in all zones, but with more consistent patterns in the northern ones. The wasting trends show a striking peak in 2011, more marked in the SCZ and coinciding with the famine declaration. A slight decreasing trend is observed thereafter although not consistent across all zones and livelihoods, and with a raising slope in 2016, especially among IDPs.

Since early nineties, the food security and nutrition situation in Somalia has been characterised by protracted and recurrent emergency situations resulting from repeated episodes of drought, flooding, conflict and large-scale population displacement. The frequency and severity of these crises have been exacerbated by the absence of strong government and lack of humanitarian space (17). Conflict related violence and insecurity prevent the delivery of humanitarian aid,disrupts livelihoods and breaks down familial and community networks that can provide the necessary support and guidance needed for looking after young children, including their nutritional requirements (18) Food insecurity and conflict have been shown to have a direct and independent impact on malnutrition (19),but also infectious diseases are identified as main drivers of malnutrition in Somalia (20).

In relation to wasting, we observe the rising trend in 2009-2010 coinciding with the slow onset of drought driven by four consecutive rain failures, which together with some of the most violent conflict and restricted humanitarian access in Somalia's history contributed to the 2011 famine, reflected in our results with wasting peaks above 35% among IDPS and agro-pastoralists in the SCZ and above 20% among pastoralists and IDPS in the NEZ. The

situation was further aggravated by the economic crisis, characterized by currency devaluation, disrupted trade and market activities, and hyperinflation of basic food and non-food items (21), and by al-Shabaab's blocking of humanitarian operations in areas under their control (22). It is estimated that nearly 260 000 people died during the 2011 famine(23), half of them children.

After the 2011 peak the wasting prevalence dropped from the extremely high levels registered in the SCZ and NEZ to around 15%, at the level it remained for the rest of the period, still a very high prevalence which flags the threshold for emergency according to the World Health Organization (24). The pronounced decrease was mainly the result of the intense humanitarian actions but could also be reflecting the increased under five mortality in 2011, which affected severely acutely malnourished children primarily, and that peaked at 5.83 deaths per 10,000 in the South Central zone (25) (26). The SCZ was the most affected by the 2011 famine and shows the highest wasting levels for all livelihoods in the consequent years. This zone is impacted by higher intensity of conflict, flooding of the riverine areas, continued displacements, restrictions of movements and goods due to clan and religious insurgency, and low availability and poor quality of health services (27). Moreover, the IDPs show consistently the highest estimates of wasting in all zones. They are considered to be among the poorest population groups in the country and their vulnerability to malnutrition is highly linked to poor access to food, income, health care, and safe water coupled with high morbidity burden (28). In this group, our results show the raising trend in wasting in early 2016 which resulted in a declaration of high famine risk in early 2017 (29) previously mentioned. Stunting estimates are also consistently higher among IDPs, especially in the NEZ and the SCZ.

Nevertheless, the overall pattern of stunting is a declining trend for all livelihood groups in the three zones. Pastoralists' children seem to be more resilient to stunting, with estimates

consistently lower, reaching very low levels (below 5%) in all three zones at the end of the period. Other studies have suggested this is a result of the physical stature of Somali pastoralists as tall and lean, which may mask the actual estimates of chronic malnutrition (30), but decreasing trends are clear nonetheless. Another potential explanation for this differentiation is that pastoral groups have relatively better asset base and access to animal products, especially milk and cow's blood, which provide high protein diets even when food is scarce. This type of diet, also rich in iron, calcium and other micronutrients will favour continued height growth rather than soft tissue. The opposite applies for agriculturalists as energy may be provided by cereals but protein and micronutrient intake may be compromised, favouring stunting but less wasting. The higher rates of malnutrition observed among pastoralists in the analysis after the Gu rains may be associated with the restricted access to their typical diet in the precedent Jilal season. During that extended dry season from mid-January to mid-April the pastoralists adult male and adolescent boys migrate with the livestock to distant grazing areas, leaving women and young children behind with limited access to milk and other animal source products (31). And this is consistent with findings from pastoralist populations of other countries in the region (12). And although this may have a more clear impact on wasting as an indicator sensitive to short term changes, our results show the same seasonal fluctuations in stunting estimates, and recent studies are highlighting the role of seasonality as potential risk factor to poor growth among young infants (32).

Also important to notice is the stunting peak consistently shown for all livelihoods in the immediate years after the famine, probably reflecting the effects in stunting of the extremely high rates of wasting.

These same observations are replicated in the results of the agro-pastoralists and pastoralists artificial cohorts we created for the SCZ. The stunting rates are consistently

lower and the stunting fluctuations consistently softer among the pastoralists' cohorts as compared to the agro-pastoral ones, and a relation is observed between the high wasting peak in 2011 and the stunting in the subsequent years.

The overall growth pattern we observe in our cohorts, with stunting peaks within the 13-24 months of age, is consistent with the growth faltering observed in other deprived populations of the world, which show a stunting crowning around 24 months of age which decreases thereafter (33). The interpretation of childhood catch-up after 24 months is that a combination of the normal postnatal maturation of the children's immune systems and the development of a broad range of adaptive responses against previously encountered pathogens reduces the frequency and severity of growth-impairing infections (34). This is the observed pattern in most of the pastoralists' cohorts we created in the SCZ. However, among the agro-pastorals the only cohort that follows that clear pattern is the Coh2012, which encompasses the children born after the 2011 famine. In all the rest of the cohorts the growth pattern changes, as the stunting prevalence experiences a sharp increase a year after the children have experienced the 2011 famine, independently of the age of the children during that period. This suggests a strong impact of the high wasting rates in the subsequent stunting prevalence. This association has been shown in longitudinal studies that have reported that children with wasting or negative changes in weight for height are at greater risk of linear growth retardation (32) (35), and the differentiated patterns for children among pastoralists and agropastoralists populations are consistent with similar studies conducted in the region (12).

In relation to morbidity, although it declined during the period of analysis, prevalence were still high, especially among IDPs. Pervasive morbidity is associated with limited access and utilisation of basic health and water services and IDPs reside in temporary infrastructures and crowded conditions, which exacerbate their vulnerability to infectious

diseases (36). Also, and for all the livelihood groups, the morbidity trends showed numerous peaks reflecting disease outbreaks such as measles, polio, acute watery diarrhoea and cholera almost every year since 2007. Somalia is one of the acute watery diarrhoea/ cholera-endemic countries in the world and according to UNICEF, contains "the largest known reservoir of unvaccinated children in a geographic area in the world" (around half a million children). The rise in morbidity observed in 2016 corresponds with the cholera and measles outbreaks occurring in that year (37) (38) which further contributed to the rise in acute malnutrition and mortality which reached near-famine thresholds at the start of 2017, only averted by the large-scale and sustained humanitarian actions (29).

As already shown by other studies, the provision of malnutrition and morbidity estimates, when seen in the context of historical values and viewed as specific to different livelihood groups can provide useful timely warning of the need for intervention to mitigate developing nutritional crises (12).

Limitations and strengths of the study

The sample characteristics in terms of size and number of surveys allowed for a high precision in the analysis and for the stratification by livelihood system. However, despite the enhanced precision of the estimates of malnutrition and morbidity showed by the narrow confidence intervals, due to the effects of confounding and bias (measurement and or recall bias) inherent in cross sectional and nutritional surveys, the analysis may produce spuriously precise but biased estimates of association and stability.

The so called IDPs livelihood was over-represented in the overall population as recent data indicated that the proportion of IDPs in Somalia population was around 14% (36), thus the importance of the stratified analysis.

Data were collected in field conditions, which may have an impact on the accuracy of measurements, although the FSNAU survey enumerators' long-time experience and routinely training may have minimized this limitation.

Imputed values have to be interpreted with caution as they can introduce a bias. However, as shown in the figures the imputed values are randomly distributed in the years, zones and livelihood groups studied thus we do not consider they are impacting the trends patterns in a systematic way

Accurate age estimation can be a major problem as there are no accurate records of birth in Somalia and age determination mostly relies on maternal recall. However, FSNAU conducted the ENA plausibility checks on every survey to minimize any potential bias and the age distribution in the sample shows the expected distribution.

CONCLUSIONS

The international community has been implementing humanitarian, recovery and development programmes for the Somali population in a complex and varied environment for the last decade, with ambivalent results.

Although wasting and morbidity prevalence remained high during the period of analysis there was a slight but clear decreasing trend for both indicators, only reversed at the end of the period, 2016, when severe drought conditions impacted most parts of the country. Furthermore, the decrease in stunting for the 2007-2016 period is remarkable.

The association found between high wasting prevalence and subsequent high stunting estimates calls for a more holistic response which addresses humanitarian life-saving needs and development work simultaneously.

Moreover the focus on reducing malnutrition in Somalia clearly needs to move away from the short-term response aimed at addressing acute food insecurity and treatment of acutely malnourished children to a more integrated response that includes access to clean water, the promotion of hygiene and sanitation, and the improvement of access to basic health services among its priorities.

Finally, the households' vulnerability towards morbidity and malnutrition varies according to the type of livelihoods they pursue. Significant improvements can only be realized taking into account the specific challenges and opportunities within the various livlihoods across Somalia.

Authors' contributions

RCM & EC were involved in all stages from the conception and design, data acquisition, analysis and interpretation. FK and DF contributed to the study design, the data analysis and interpretation. DM & AY were responsible for conducting the surveys and managing the data. All authors have critically reviewed and approved the final version of the article.

Competing interests

The authors declare that they have no competing interests.

Funding

Not applicable.

Availability of data and material

The data that support the findings of this study are available from FSNAU but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of FSNAU.

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Not applicable.

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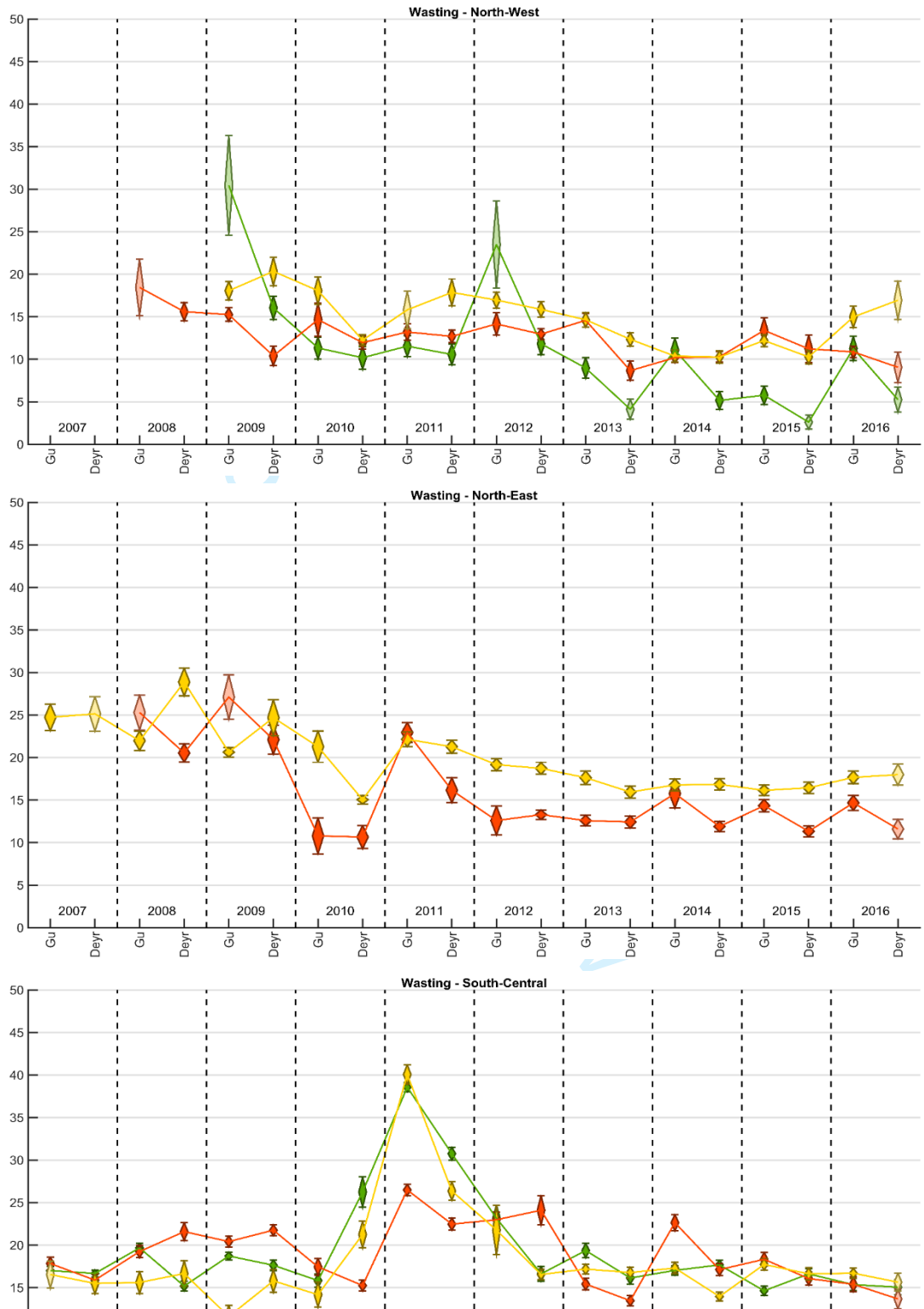
FIGURE'S LEGENDS

Figure 1: Wasting estimates and confidence intervals at 95% (diamond shapes) by year and season of analysis for each livelihood and disaggregated in the three operational zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were imputed.

Figure 2. Stunting estimates and confidence intervals at 95% (diamond shapes) by year and season of analysis for each livelihood and disaggregated in the three operational zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were imputed.

Figure 3. Growth patterns cohorts of children 6-59 months in agro-pastoralists and pastoralists populations in the South Central zone of Somalia

Figure 4: Morbidity estimates and confidence intervals at 95% (diamond shapes) by year and season of analysis for each livelihood and disaggregated in the three operational zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were imputed.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Wasting - North-East
Wasting - South-Central
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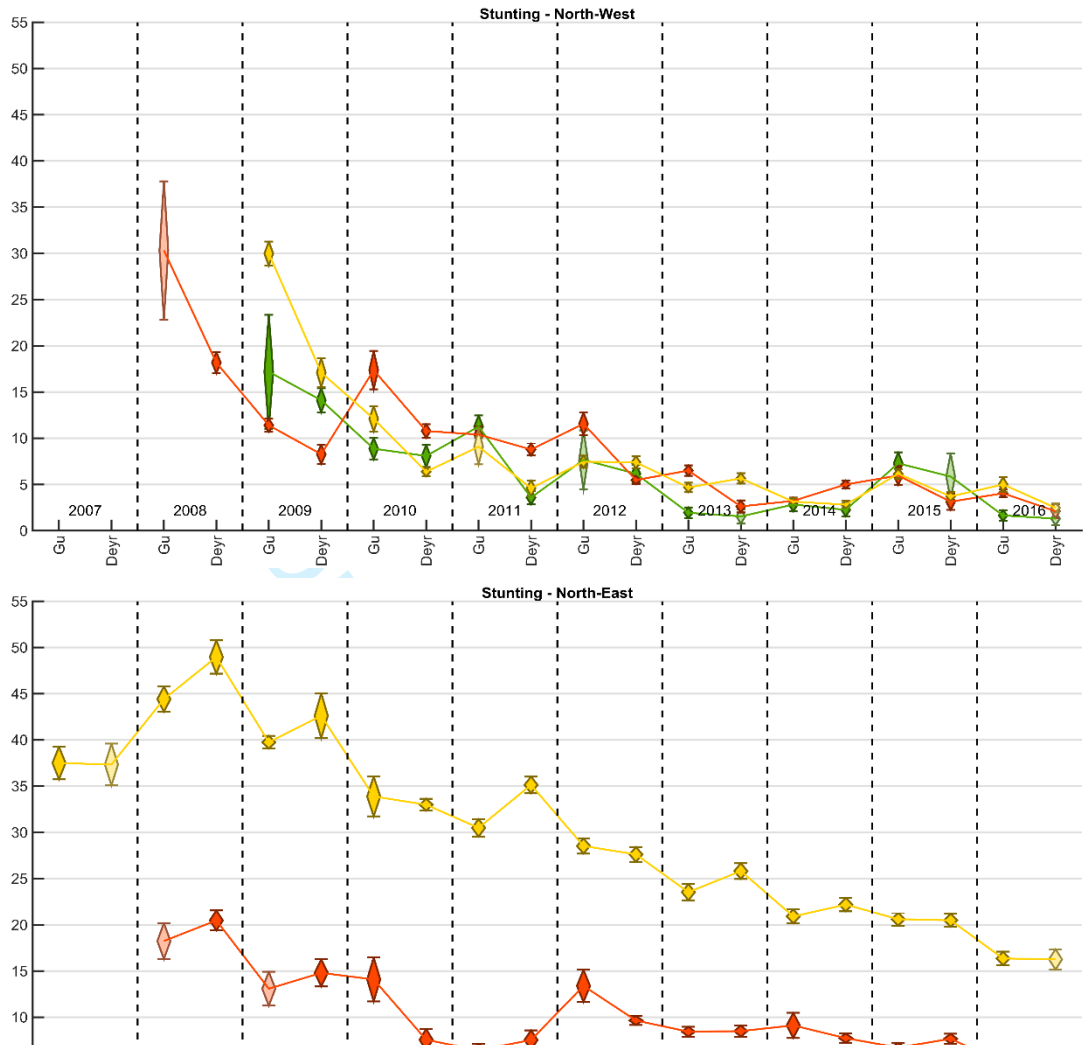
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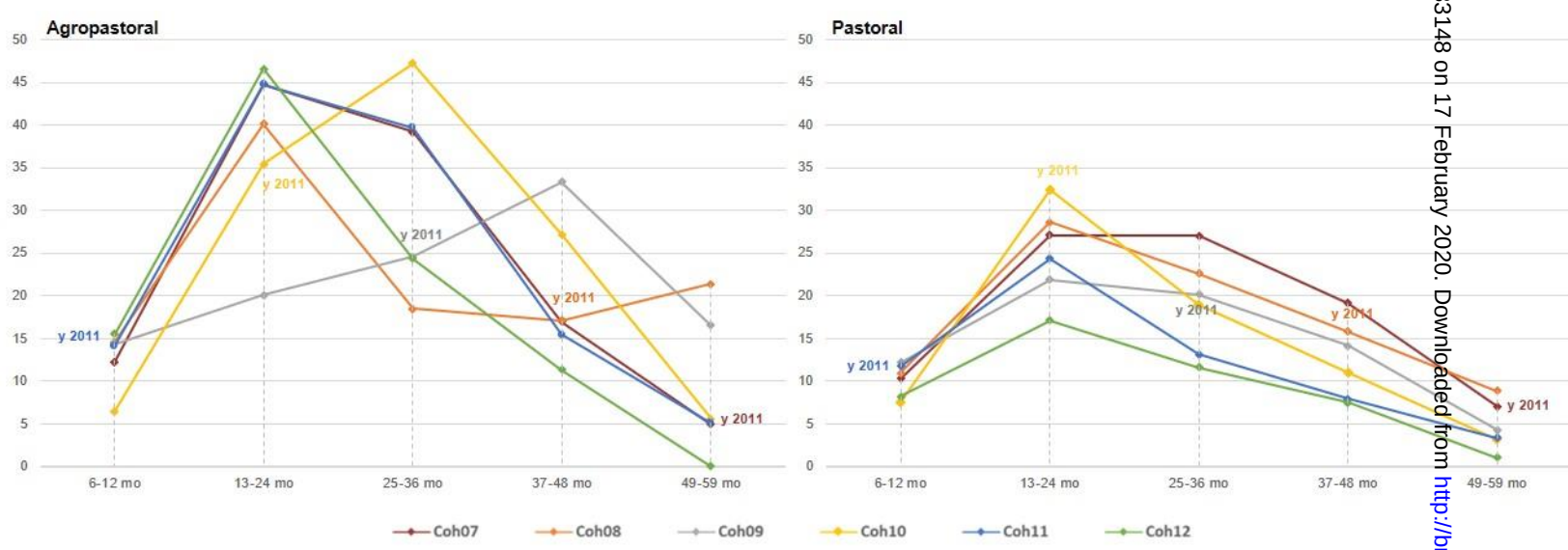

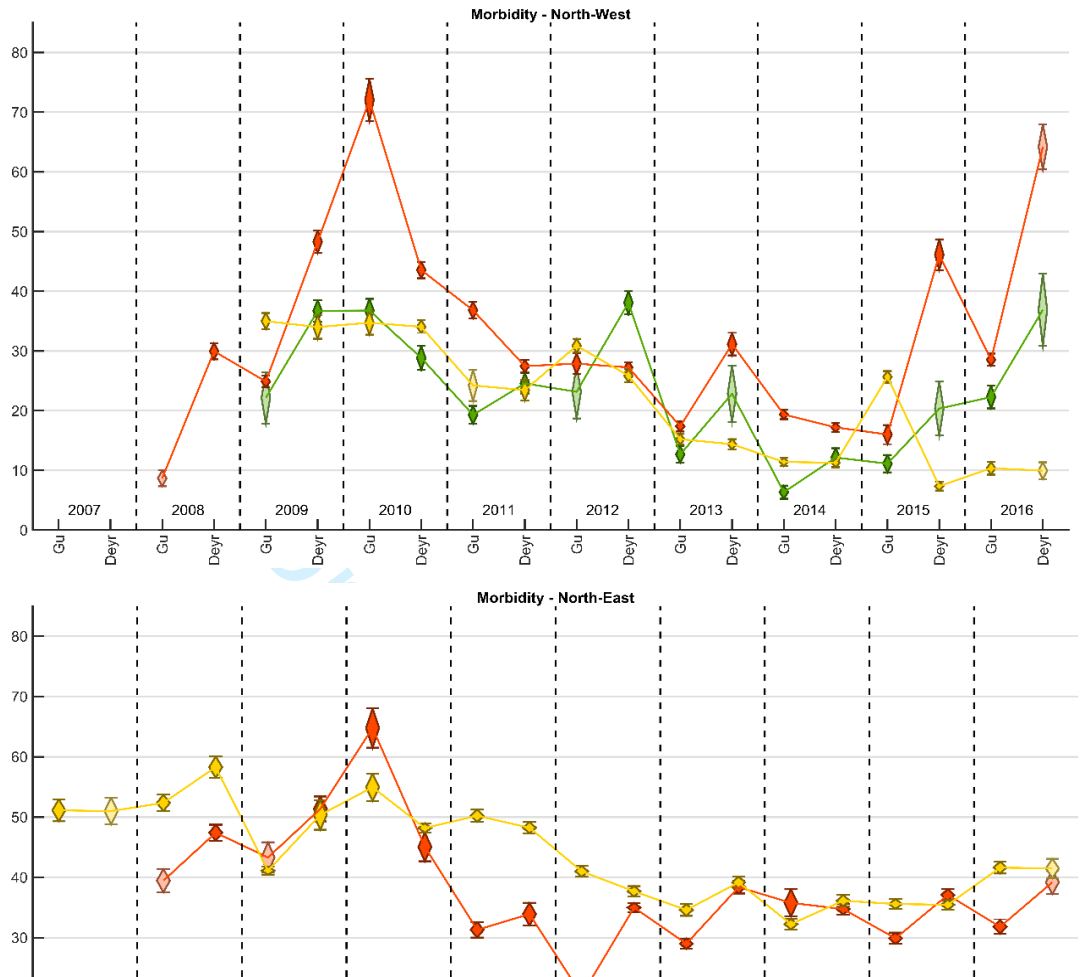
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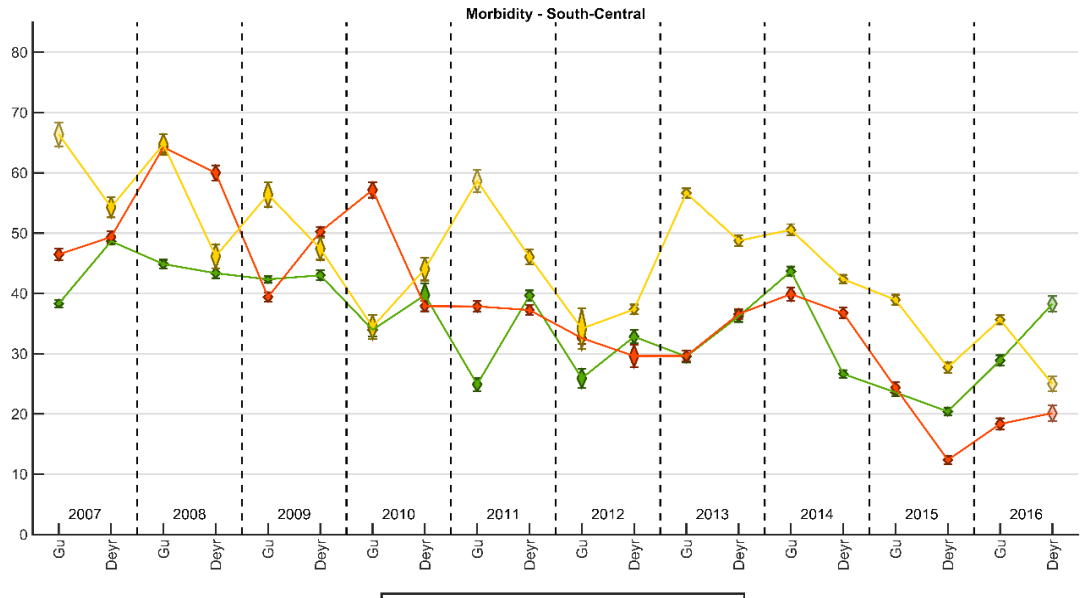
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Annex 1. Sample size of the study by zone and livelihood system.

Zones	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016	Total
	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	
North West																				**49585**
Agropastoral						716	609	520	684	643		617	568		496	445	467		488	6253
Pastoral				1128	2045	702	334	1781	1203	1937	692	2594	1892	611	2639	2361	537	383	2253	23092
IDP					1251	585	570	2497		610	1597	1651	1713	1716	1975	1743	2179	1352	801	20240
North East																				**69275**
Pastoral				1407		588	213	516	1294	637	381	3701	2763	2084	450	2832	2383	2426	1614	23288
IDP	760		1333	772	5165	413	484	5314	2365	2844	3015	3176	2376	2658	2913	3210	3393	3222	2574	45987
South Central																				**163654**
Agrop+Riverine	6,421	8,273	4,984	3,652	7,159	3,730	2241	617	7,416	3,726	764	1810	2127	2,750	4,314	5,005	4,174	3,682	2,753	75,598
Pastoral	2,713	2,837	2,956	1,542	3,853	3,988	1,461	3,244	4,484	3,359	2,262	618	2,799	3,196	1,903	2,960	2,252	2,177	1,688	50,295
IDP		903	794	624	594	734	578	682	1,874	1,684	202	3,703	4,043	3,419	3,183	4,648	3,309	2,646	4,141	37,761
Total	9894	12013	10067	9125	20067	11456	6490	15171	19320	15440	8913	17870	18281	16436	17873	23204	18694	15888	16312	**282514**

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-11
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-11
Bias	9	Describe any efforts to address potential sources of bias	3 &10
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10
		(*b*) Describe any methods used to examine subgroups and interactions	10
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8-9
		(*e*) Describe any sensitivity analyses	n.a.
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-11
		(b) Give reasons for non-participation at each stage	n.a.
		(c) Consider use of a flow diagram	n.a.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-12
		(b) Indicate number of participants with missing data for each variable of interest	9
Outcome data	15*	Report numbers of outcome events or summary measures	12-18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15-19 and 31

		(*b*) Report category boundaries when continuous variables were categorized	12-18
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n.a.
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-18
Discussion			
Key results	18	Summarise key results with reference to study objectives	19
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	3
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	19-23
Generalisability	21	Discuss the generalisability (external validity) of the study results	19-23
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	27

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from 291 cross-sectional surveys

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Primary Subject Heading:	Global health
Secondary Subject Heading:	Emergency medicine, Nutrition and metabolism
Keywords:	wasting, stunting, morbidity, Somalia

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Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from 291 cross-sectional surveys

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ABSTRACT

Background: More than two decades of conflict and natural disasters in Somalia have resulted in one of the longest running humanitarian crises in the world. Nutrition data has been collected over the years despite challenges to inform programmatic action. This paper explores malnutrition and morbidity trends in Somalia during the last decade, disaggregated by geographical zone and livelihood system.

Methods: We used data from 291 cross-sectional surveys conducted in children aged 6-59 months between 2007 and 2016 in Somalia. Wasting, morbidity and stunting prevalences over time were analysed by geographic area, livelihood system and season. Logistic regressions were used to test trends.

Results: The wasting trends show a striking peak in 2011, more marked in southern and central Somalia (SCZ) and coinciding with the famine declaration. The trend declines slightly thereafter although not consistently across all zones and livelihoods, and it raises again in 2016 especially among Internally Displaced Persons (IDPs). Stunting declined for all groups and in all zones, but with more consistent patterns in northern Somalia.

Morbidity also showed a declining trend, although with multiple peaks depicting disease outbreaks.

Pastoralist showed the lowest stunting estimates overall, while agrarian populations showed the lowest prevalence of wasting and morbidity. IDPs were the most affected by all outcomes. Seasonality affected the three outcomes differently by livelihood system. Stunting rates increased after the 2011 famine for all age groups within children under five years.

Conclusions: Despite the continuous complex situation in Somalia, there has been a sustained decline in stunting and morbidity in the last decade. Wasting trends have

remained at very high levels especially in north-east and the south zones of Somalia. The findings support the importance of performing trend analyses disaggregated by zone and livelihood groups within countries, to better identify priorities for program intervention.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- The sample characteristics in terms of size and number of surveys allowed for a high precision in the analysis and for the stratification by livelihood systems, although the so called IDPs livelihood was over-represented
- The data collected at village level was aggregated at the operational zone level and stratified by livelihood systems providing a broad perspective relevant for policy analysis and programming
- Data were collected in field conditions, which may have an impact on the accuracy of measurements, although survey teams were consistently trained and equipment precision regularly monitored to avoid it.
- Accurate age estimation was problematic as there were no accurate records of birth and age determination mostly relied on maternal recall.
- Data quality validation was carried out daily by running the ENA plausibility checks and after each data collection data vetting was conducted by the Assessment and Information Management Working Group in Somalia.

BACKGROUND

Somalia has been experiencing a long humanitarian crisis for the past two decades. It has suffered protracted war and conflict, political instability, disruption of economy and humanitarian assistance, and extreme climatic conditions since collapse of state institutions in 1991, resulting in large-scale food and nutrition security crises. In 2011 the country suffered a famine, more than 250,000 people are estimated to have died of starvation and approximately 53% of the population experienced food crisis. An estimated 200,000 people had also died during a previous famine in 1991/1992 (1).

On top of the two mentioned famines, the rates of acute malnutrition have remained at very high levels since the start of the conflict, and they are among the highest in the world today. The causes of different forms of malnutrition in Somalia are multi-factorial and linked not only to food insecurity but also to morbidity and inadequate caring practices, all of them related to the disruption of peoples livelihood, destitution, large-scale population displacement and the limited access to basic services (2) (3) (4).

Nutrition response programming has been taking place in Somalia for decades, in the form of live-saving interventions like distribution of food and cash, treatment of acute malnutrition, targeted supplementary feeding, and emergency public health measures during disease outbreaks, as well as in the form of livelihoods recovery and development programmes in agriculture, livestock, water, and environment in order to improve resilience among vulnerable populations (5). However, effectiveness of humanitarian assistance continues to be constrained by prevailing insecurity which restricts access and delivery of aid to some areas.

The Food Security and Nutritional Analysis Unit (FSNAU) is an FAO project with the mission to conduct national nutrition surveillance in Somalia since the year 2000 in order

to monitor the nutritional status of the population and inform program interventions. FSNAU has been collecting data through different surveillance systems including nutrition surveys, rapid Mid-Upper Arm Circumference (MUAC) assessments, passive health facility-based screening and, at some times and places, by sentinel site surveillance.

In 2009 FSNAU carried out a meta-analysis study including a systematic review of findings and raw data analysis of surveys conducted by FSNAU and partners in Somalia for the period 2001-2008 focusing on wasting trends and casual factors (6). In addition, in 2012 WFP released a report analysing trends of food and nutrition insecurity in Somalia for the period 2007-2012 (7). Since then, no other systematic review of the nutrition data collected by FSNAU has been published.

The reports circulated by FSNAU in the 2007-2016 period have been exhaustive in describing the nutrition situation in regular periods (monthly, bimonthly, quarterly or twice yearly depending on the year) and by livelihood zone. They combine results from different data collection methods to assess the overall nutrition situation, as well as to identify malnutrition hotspots and to closely follow-up specific population groups such as internally displaced populations (IDP) or particular livelihood zones (8). However, these data and results are not compiled and disseminated within the global nutrition reports due to having results aggregated at the livelihood zone level and not by any type of administrative divisions.

The three operational zones of Somalia have been affected differently by the conflict, being the South-central zone (SCZ) historically the most affected one, whereas the North West (NWZ) and the North East zones (NEZ) have been generally more stable, with better governance and institutional capacities. To show the malnutrition outcomes aggregated by

operational zone adds to the results provided by FSNAU reports and allows for interpreting the trends within each zone historical context.

On the other hand, the three main livelihood systems present in Somalia are unevenly distributed across the country. Pastoralists are mainly distributed in the north west, east and central parts, while agro-pastoralists and riverine livelihood systems mostly in the South. (9). The prevailing insecurity has also triggered large-scale displacement of populations, and settlements of internally displaced populations (IDPs) are found all over Somalia, but in the SCZ predominantly. According to the latest United Nations High Commissioner for Refugees (UNHCR) Forced Displacement report, among the 1.5 million IDPs estimated in 2016, 893,000 were located in the SCZ (10). Showing malnutrition outcomes and trends by type of livelihood is highly relevant, as the coping strategies to prevent and overcome malnutrition differ depending on the livelihoods and/or displacement situation of populations

Finally, food security and nutrition outcomes are importantly affected by seasonality in Somalia as well, with annual crop and livestock production dependent on the two main rainy seasons (*Gu* and *Deyr*). Seasonality impacts the general availability of food and the rates of infection, among other things. Thus, understanding the typical seasonal fluctuations is useful for predicting changes in malnutrition and morbidity rates (11).

Assessing the fluctuations in malnutrition by season within the year, over time year-to-year, and differentiated by livelihood group is essential to facilitate interpretation of the situation and target effective interventions, as shown by a similar exercise conducted in the Greater Horn of Africa region (12).

The aim of this study is to explore and interpret observed trends in malnutrition (wasting and stunting) and morbidity by operational zone, livelihood system and season of analysis

for the 2007-2016 period, giving special attention to the effects of the 2011 famine on the malnutrition outcomes for the rest of the period.

METHODS

The data used for this study were obtained from 291 surveys undertaken by FSNAU and partners working in Somalia. All surveys included in this study had similar design (two stage cross-sectional surveys) and comparable probability sampling methods. They were carried out biannually in the *Gu* and in the *Deyr* seasons, from year 2007 to 2016.

There are four main seasons defined by rainfall patterns in Somalia: the *Gu,* the main rainy season (April to June), the *Hagaa,* a short and cool dry season (July to September), the *Deyr,* the short rainy season (October to December), and the long and hot dry season called the *Jilaal* (January to March) (13). Only surveys conducted in the *Gu* or in the *Deyr* seasons were taken into account for the analysis, as data collected in *Hagaa* or *Jilal* seasons was only available for years 2007 and 2009. Although the *Gu* and the *Deyr* seasons are both rainy seasons they represent different times of the year and have specific characteristics impacting food and security outcomes, as the *Gu* is preceded by the long hot dry season whereas the *Deyr* follows a short and cool dry one.

Somalia has been divided into three main UN operational zones: Northwest, Northeast and South-Central, with varied social, livelihood and economic structures. These zones generally correspond to current administrative and political designations known, respectively, as Somaliland, Puntland and other Federal Member States of the Federal Government of Somalia. The North West zone comprising the pre-war regions of Woqooyi Galbeed, Awdal, Togdheer, Sool and Sanaag regions; the North East zone that includes the pre-war regions of Bari and Nugal and the South Central zone comprising Mudug,

Galgadud, Hiran, Bakool, Bay, Middle and Lower Shabelle, Middle and Lower Juba, Gedo and Banadir regions.

The three main livelihoods in the country are broadly defined by common characteristics of the household's economy: pastoralists rear livestock and are nomadic; agro-pastoralists practise mixed crop and livestock production; and riverine live in the South Central irrigated zones along the Shabelle and Juba rivers and are mainly agrarian (13). Agropastoralists and riverine livelihoods are classified as *Agropastoral* in this analysis as both are mainly sedentary and share similar characteristics in terms of their primary dependence on crop cultivation as opposed to reliance on rearing livestock. Because of the presence of a significant proportion of internally displaced population in the country, FSNAU also collects data on IDPs. Surveys of main IDP settlements were included, and these were coded as a further livelihood category, although it does not constitute a livelihood system in *sensu stricto*. The FSNAU also collects data on selected urban populations (mostly Kismayo and Mogadishu), but not as comprehensively and consistently as on rural and IDP populations, thus we did not include them in this analysis.

Since 2007 and for both technical and operational purposes, FSNAU has conducted rural livelihood-based surveys as opposed to administrative boundary-based surveys. A livelihood zone map of Somalia was created based on climate, topography, natural resources and local livelihood patterns, resulting into 32 rural livelihood zones. In 2015, the 32 rural livelihood zones were consolidated into 18, reasonably homogenous rural livelihood zones. Detailed maps can be found at http://www.fsnau.org/products/maps/livelihood-maps (14).

The surveys were conducted at livelihood zone level or main IDP settlement based on multi-stage cluster sampling with probability proportional to size (PPS) design covering all livelihood zones that were accessible at the time of the survey. The primary sampling units

were the villages (clusters) which were selected randomly from a list of all the villages in each livelihood zone, and the second unit of analysis were the households within the sample villages, which were randomly selected using the Standardized Methodology for Survey in Relief and Transition (SMART). All children aged 6 to 59 months living in the selected household were measured and the child section of the survey questionnaire administered to the child caregiver or household head. Households and villages were assumed to follow the livelihood of the livelihood zone in which they were located. Sample selection and sizes of the surveys (number of households and number of children) were calculated using the Emergency Nutrition Assessment (ENA) software (Version 2011, July 9, 2015). Previous estimations of wasting measured by weight-for-height and crude mortality rates for the surveyed areas were used for the sample size calculations, separately for anthropometry and mortality. The higher of these two sample sizes was used to determine the final sample size as the surveys integrate both anthropometry and mortality. An additional 2-3% was added to the sample size to allow for dropout or refusal to participate

In order to show results at the operational zone level we had to aggregate the data collected at the livelihood zone level and allocate them to the corresponding operational zone based on its location. However, as there are livelihood zones that geographically cross the three operational zones taken into account for this analysis (like Coastal Deeh crossing the SCZ and the NEZ or Hawd Pastoral crossing the SCZ and the NWZ, see maps in http://www.fsnau.org/products/maps/livelihood-maps), we went down to the clusters level in order to allocate children surveyed to the corresponding operational zone according to the cluster (village) geographical location. In each zone, surveys were aggregated according to the livelihood system of the livelihood zone they represented (example, West Golis Pastoral and Guban Pastoral livelihood zones in the NWZ would be

aggregated in the Pastoral sub-sample of the NWZ, according to 2014 livelihood zone distribution).

Although in most of the time points (season/year) of the study period we had representative data for each livelihood, due to field work restrictions in some specific season/years not all livelihoods systems were covered. Therefore, and in order to construct the trends for the whole period of analysis the missing values in-between the trend were imputed. The imputation method we used was logistic regression to calculate the predictions and the residuals. Missing values in the beginning of the trend (year 2007 and 2008) were not imputed. Out of 159 time points analysed, only 24 estimations were imputed. Supplementary Table 1 in Annex 1 presents the compiled sample sizes of the population analysed in each time point, disaggregated by livelihood and zone.

Data was collected by FSNAU survey enumerators, who are recruited locally from health centers, clinics etc. and are trained for five days before every survey as part of FSNAU's quality assurance process. As FSNAU nutrition surveys are conducted regularly (i.e. every season), only the best performing enumerators and supervisors are retained but they still have to undergo the mandatory five-day training before conducting each survey. FSNAU surveys are coordinated by FSNAU Nutrition Field Analysts and technical experts from the Ministries of Health, and data quality is validated in a daily basis by running the ENA plausibility checks. At the end of data collection there is a technical vetting conducted by the Assessment and Information Management Working Group established under the Somalia Nutrition Cluster for data coordination and quality control of nutrition surveys.

The data were cleaned by deleting the records of individual children with any of the following criteria: age < 6 months (n=5), age > 59 months (n=6), and missing age (n=1137), sex (n=1222), weight (n=1134), height (n=1143) or oedema (n=1802). Weight-for-height z-score (WHZ) and length/height-for-age z-score (HAZ) were calculated using

World Health Organization (WHO) Anthro (version 3.2.2, January 2011) and Macros using WHO 2006 growth standards. Extreme biologically implausible values were excluded based on WHO standards with recommended flag limits of WHZ scores below -5 or above +5 (n=545) and HAZ scores below -6 or above +6 (n=824)(15).

Nutritional status indicators used were *wasting* defined as weight-for-height below -2 Z-scores and/or the presence of nutritional oedema; and *stunting* or chronic malnutrition defined as height-for-age below -2 Z-scores (16). *Severe wasting* is defined as WHZ below -3 and/or the presence of nutritional oedema, thus severe wasting is included in the wasting definition. We provide the severe wasting estimates independently in Table 1 but the rest of the tables and figures only report wasting which includes both moderate and severe forms.

Child morbidity was assessed based on a 2-week recall of the incidence of diarrhoea, acute respiratory infection (ARI) and febrile illness and 30-days recall for suspected measles. A new variable called morbidity was created and coded as 1 if the child had a positive response to at least one of the four illnesses and as 0 if the child had a negative response to all of the four illnesses. We calculated the prevalence of wasting, morbidity and stunting for each of the surveys separately and provided the levels of uncertainty in the estimates with the 95% confidence intervals (CI).

We graphed the estimations and confidence intervals of wasting, stunting and morbidity for each year and season disaggregated by livelihood group and geographical zone for the patterns comparison over the 10-year time period.

In order to analyse the observed trends, we created two differentiated time periods, one before the famine of 2011 (including data from 2007 to 2010), and another one covering the time period after the famine (2012-2016). Logistic regressions were used to test the

change of the nutrition and health outcomes with each additional year in each of the two periods, and to model the association of the outcomes with the *Gu* and *Deyr* seasons for the overall period. All analyses were stratified by livelihood system and geographical zone. Odd ratios (ORs) and confidence intervals (CI) were calculated.

To explore the potential impact of the wasting peaks recorded during the 2011 famine on the subsequent stunting estimations, we created six artificial cohorts based on the children's year of birth. We constructed the cohort of 2007 (Cohort07) by selecting children who were 6-12 months in the year 2007, children that were 13-24 months in 2008, 25-36 months in 2009, 37-48 months in 2010 and 49-59 months in 2011. The 2008 cohort (Cohort08) was constructed by selecting children that were 6-12 months in the year 2008, 13-24 months in 2009, 25-36 months in 2010, 37-48 months in 2011 and 49-59 months in 2012. Following the corresponding procedure, we constructed the rest of the cohorts for the years 2009 (Cohort09), 2010 (Cohort10), 2011 (Cohort11) and 2012 (Cohort12), and we graphed the prevalence of stunting (y-axis) for each cohort according to the age of the child (x-axis), highlighting the position of the 2011 famine in order to facilitate the interpretation of results. Due to data availability this analysis was restricted to the agropastoral and pastoralists populations of the South Central zone.

Stata 15 (StataCorp, College Station, Texas, USA) was used for statistical analysis.

Public and patient involvement

Not patients were involved in the study. Results of the nutrition and mortality surveys conducted in Somalia are used for programmatic actions targeting the study participants (children under 5 years of age), but due to the characteristics of the study population there is no specific action planned to disseminate results directly to them.

Access to survey sites was agreed with local authorities and community leaders in the districts where the clusters were sampled. Verbal consent for all caregivers of the sampled children was sought before administration of the questionnaire. Children who were found as severely malnourished or with any other medical problem during the survey were referred to the nearest health facility for medical attention and appropriate treatment using referral form.

Ethical approval was provided through permission by the Ministry of Health (MOH) Somalia, Transitional Federal Government of Somalia Republic, Ref: MOH/WC/XA/146./07, dated 02/02/07. Subsequent survey plans and protocols were presented and discussed with MOH and partners prior to the conduct of each seasonal assessment.

RESULTS

A total of 282 514 measurements of children aged 6 to 59 months from 291 surveys were examined from 2007 to 2016. The North West and North East zones of the country were mainly composed of pastoral livelihood zones with a large proportion of IDPs. The South Central zone, in addition to pastoralists and IDPs, also included agro-pastoral and riverine livelihoods (See Table 1).

Of the children surveyed, 69 275 (24%) children were located in the North East zone, 49 585 (18%) in the North East zone and 163 654 (58%) in the South Central zone of Somalia Supplementary Table 1 in the Annex 2 summarizes the survey data by zone, season and period of analysis. The assessments were equally distributed in relation to the *Gu* (50.7%) and the *Deyr* (49.3%) seasons. Around 36% of the children were surveyed before the 2011 year of famine, and 64% after year 2011.

In Table 1 are summarized the children's characteristics by zone.

Table 1. Characteristics of children 6 to 59 months in Somalia (n=282 514)

	North West (n=49 585) 17.5%	North East (n=69 275) 24.5%	South Central (n=163 654) 57.9%
Sex			
Male	50.9	50.6	50.8
Female	49.1	49.4	49.2
Age			
<24 months	35.7	34.9	35.8
≥24 months	64.3	65.1	64.2
Wasting			
Weight-for-height <-2 z-scores	12.7	17.0	19.3
Severe wasting			
Weight-for-height <-3 z-scores	2.5	4.0	5.7
Stunting			
Height-for-age <-2 z-scores	7.3	22.1	23.8
Morbidity	*24.4*	*39.2*	*39.5*
Diarrhoea	11.3	14.6	16.4
Acute respiratory infection	8.4	14.1	16.0
Febrile illness	12.9	25.7	22.7
Measles	2.5	4.1	3.9
Morbidity overall[1]	24.4	39.2	39.5
Livelihood system			
Agro-pastoralists	12.6	-	26.2
Pastoralists	46.6	33.6	30.7
Riverine	-	-	20.0
Internally displaced persons	40.8	66.4	23.1

[1]Morbidity variable integrating the diseases described in the table. See Methods section for details.

Trends in wasting

The mean prevalence of wasting for the overall period of study was 13%, 17% and 19 % for the NWZ, NEZ and SCZ respectively.

Figure 1 shows in the first graph, for the NWZ, a steady decline in wasting estimates for all livehoods and periods of analysis. Agropastorals' estimates declined to around 5% at the end the period, although with a steep increase above 10% in *Gu* 2016. Wasting among IDPs also increased sharply in 2016 in this particular zone.

In the NEZ, there was an important decrease in wasting estimates for each additional year until 2010 (OR=0.75 and OR=0.80 for pastorals and IDPs respectively) see Table 2,

although estimates raised at above 20% in 2011. Since 2012 wasting prevalence has remained above 10% among pastoralists and above 15% among IDPs (second graph of Figure 1).

The third graph of Figure 1 shows the wasting estimates for the SCZ above 15% for the three livelihoods in most of the years, and the peak of wasting prevalence above 35% in year 2011 for agropastorals and IDPs. This peak was less pronounced among pastoralists, although it was sustained longer in time. In the second period of analysis, starting in 2012, there was a slight decrease on wasting for each additional year (see Table 2).

In all zones, wasting was higher during the *Gu* seasonal analysis for all livelihoods, although the difference was more marked for pastoralists and IDPs.

Table 2. Trend analysis on wasting per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.59 (0.42-0.84)	0.87 (0.78-0.97)	1.10 (1.0-1.5)
2012-2016	0.90 (0.81-1.01)	0.91 (0.87-0.95)	0.98 (0.95-1.0)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.06 (0.88-1.26)	1.15 (1.06-1.24)	1.23 (1.16-1.29)
North East Zone			
Trend per year			
2007-2010		0.75 (0.66-0.86)	0.80 (0.75-0.84)
2012-2016		1.00 (0.96-1.03)	0.96 (0.94-0.99)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	1.26 (1.16-1.36)	0.96 (0.95-0.97)
South Central Zone			
Trend per year			
2007-2010	1.03 (1.0-1.06)	1.00 (0.98-1.04)	1.07 (1.00-1.15)
2012-2016	0.93 (0.91-0.96)	0.94 (0.92-0.97)	0.98 (0.95-1.00)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.07 (1.01-1.13)	1.15 (1.1-1.2)	1.23 (1.17-1.30)

Trends in stunting

For the first period of analysis (2007-2010) the stunting estimates have decreased significantly for each additional year in the three zones and all livelihoods (See Figure 2 and Table 3) although in the NWZ there was a peak for pastoralists observed in Gu 2010, and for all livelihoods in Deyr 2008 in the other two zones (NEZ and SCZ).

During the second period of analysis, there was a small peak of stunting in year 2012 in the NWZ for all livelihoods but ever since estimates have been declining steadily in this zone, reaching estimates below 5% at the end of the period. In the NEZ the peak was observed for all livelihoods at the end of 2011 and early 2012, with a subsequent decrease thereafter reaching a prevalence around 5% for pastoralists and 15% among IDPs (Figure 2). The stunting estimates among pastoralists are approximately a third of the IDPs in this zone during the whole period of analysis.

Stunting trends in the SCZ increased sharply in 2011, and then again in 2013 for agropastorals and IDPs only. After that rates decreased to below 5% for pastoralists, below 10% for agropastorals and only slightly, to around 25% for IDPs in 2016. Pastoralists show the lower stunting rates overall.

Stunting rates were consistently higher in the *Gu* season except for the NEZ pattern.

Table 3. Trend analysis on stunting per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.53 (0.37-0.78)	0.79 (0.72-0.88)	0.33 (0.27-0.40)
2012-2016	0.92 (0.77-1.10)	0.82 (0.77-0.88)	0.86 (0.81-0.91)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.32 (0.1-1.64)	1.15 (1.04-1.27)	1.90 (1.70-2.12)
North East Zone			
Trend per year			
2007-2010		0.59 (0.51-0.69)	0.84 (0.80-0.88)

2012-2016		0.87 (0.83-0.91)	0.86 (0.84-0.88)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	0.89 (0.85-0.89)	0.96 (0.93-1.00)
South Central Zone			
Trend per year			
2007-2010	0.88 (0.86-0.90)	0.92 (0.89-0.95)	0.65 (0.61-0.70)
2012-2016	0.72 (0.70-0.74)	0.89 (0.86-0.92)	0.96 (0.94-0.98)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.04 (1.00-1.10)	1.35 (1.29-1.41)	1.29 (1.23-1.36)

Figure 3 represent the growth patterns based on height for age, showing the stunting rates by age group for the six self-constructed cohorts in the agro-pastoral and pastoral livelihoods of the SCZ (See Methods section for details). In both livelihoods and all cohorts, we observe a peak in stunting at 24 months of age, which declines thereafter in most of the cohorts. Exceptions to this pattern are, among the agro-pastoralists, the Coh2009 and the Coh2010 which experience an increase in stunting prevalence after the initial peak at 24 months, and the Coh2008 which despite initial decline after the 24 months' peak, experiences a later increase among the children 49-59 months of age. Among the pastoralists exceptions to the observed pattern were the Coh07 and the Coh09 for which the stunting prevalence increased or decreased only slightly respectively after the first 24 months' peak.

The cohort of children born in 2012 (Coh12) showed the growth patterns with sharper declines in stunting prevalence after initial peak at 13-24 months of age and throughout all the older age groups.

Trends in morbidity

The mean prevalence of reported morbidity for the overall period of analysis was 24.4% in the NWZ, 39.2% in the NEZ and 39.5% in the SCZ.

In Figure 4 we observe the jagged patterns of morbidity estimations, with peaks over 50% in several time points (season/year) for the pastoralists and IDP populations.

Pastoralists showed in the NWZ a significant increase in morbidity for each additional year until 2010 (Table 4) and two important peaks in the *Deyr* seasons of 2015 and 2016, while in the NEZ values for pastoralists have been steadily between 30 and 40% since Deyr 2012. In the SCZ, however, there was a significant decrease of morbidity during the whole period of analysis for pastoralists, more marked during the second period (0.8 decrease

per each additional year, see Table 4), although with a steep rise at the end of the period, in year 2016.

Agropastorals on the other hand, showed a decreasing trend in the two periods and zones where they are present, although with a marked increase in year 2016 as well.

Among IDPS morbidity has been decreasing significantly since 2012 both in the North West and South Central zones but remaining stagnant at levels around 40% in the NEZ.

For agropastoral and pastoralists' populations morbidity was higher during the *Deyr* season, while for IDPs in the NWZ and SCZ it was higher during the *Gu* seasonal analysis.

Table 4. Trend analysis on morbidity per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.70 (0.55-0.89)	1.5 (1.4-1.6)	1.00 (0.86-1.15)
2012-2016	0.90 (0.83-0.99)	1.0 (1.0-1.1)	0.77 (0.74-0.80)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.77 (0.67-0.88)	0.86 (0.81-0.91)	1.29 (1.20-1.38)
North East Zone			
Trend per year			
2007-2010		0.99 (0.89-1.1)	0.85 (0.81-0.89)
2012-2016		1.04 (1.01-1.06)	0.99 (0.97-1.00)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	0.79 (0.74-0.83)	0.94 (0.90-0.98)
South Central Zone			
Trend per year			
2007-2010	0.95 (0.93-0.97)	0.89 (0.87-0.92)	0.78 (0.74-0.82)
2012-2016	0.85 (0.83-0.87)	0.81 (0.78-0.83)	0.82 (0.80-0.83)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.84 (0.80-0.87)	1.01 (0.98-1.05)	1.38 (1.32-1.44)

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DISCUSSION

To our knowledge, this is the first study analysing malnutrition and morbidity trends comprehensively during the period 2007-2016 in Somalia. We observe a decreasing trend in morbidity overall, although with multiple peaks depicting disease outbreaks. Stunting also declined for all groups and in all zones, but with more consistent patterns in the northern ones. The wasting trends show a striking peak in 2011, more marked in the SCZ and coinciding with the famine declaration. A slight decreasing trend is observed thereafter although not consistent across all zones and livelihoods, and with a raising slope in 2016, especially among IDPs.

Since early nineties, the food security and nutrition situation in Somalia has been characterised by protracted and recurrent emergency situations resulting from repeated episodes of drought, flooding, conflict and large-scale population displacement. The frequency and severity of these crises have been exacerbated by the absence of strong government and lack of humanitarian space (17). Conflict related violence and insecurity prevent the delivery of humanitarian aid,disrupts livelihoods and breaks down familial and community networks that can provide the necessary support and guidance needed for looking after young children, including their nutritional requirements (18) Food insecurity and conflict have been shown to have a direct and independent impact on malnutrition (19),but also infectious diseases are identified as main drivers of malnutrition in Somalia (20).

In relation to wasting, we observe the rising trend in 2009-2010 coinciding with the slow onset of drought driven by four consecutive rain failures, which together with some of the most violent conflict and restricted humanitarian access in Somalia's history contributed to the 2011 famine, reflected in our results with wasting peaks above 35% among IDPS and agro-pastoralists in the SCZ and above 20% among pastoralists and IDPS in the NEZ. The

situation was further aggravated by the economic crisis, characterized by currency devaluation, disrupted trade and market activities, and hyperinflation of basic food and non-food items (21), and by al-Shabaab's blocking of humanitarian operations in areas under their control (22). It is estimated that nearly 260 000 people died during the 2011 famine(23), half of them children.

After the 2011 peak the wasting prevalence dropped from the extremely high levels registered in the SCZ and NEZ to around 15%, at the level it remained for the rest of the period, still a very high prevalence which flags the threshold for emergency according to the World Health Organization (24). The pronounced decrease was mainly the result of the intense humanitarian actions but could also be reflecting the increased under five mortality in 2011, which affected severely acutely malnourished children primarily, and that peaked at 5.83 deaths per 10,000 in the South Central zone (25) (26). The SCZ was the most affected by the 2011 famine and shows the highest wasting levels for all livelihoods in the consequent years. This zone is impacted by higher intensity of conflict, flooding of the riverine areas, continued displacements, restrictions of movements and goods due to clan and religious insurgency, and low availability and poor quality of health services (27). Moreover, the IDPs show consistently the highest estimates of wasting in all zones. They are considered to be among the poorest population groups in the country and their vulnerability to malnutrition is highly linked to poor access to food, income, health care, and safe water coupled with high morbidity burden (28). In this group, our results show the raising trend in wasting in early 2016 which resulted in a declaration of high famine risk in early 2017 (29) previously mentioned. Stunting estimates are also consistently higher among IDPs, especially in the NEZ and the SCZ.

These results are in line with the FSNAU annual technical reports when compared to specific years or populations groups (to be found at http://www.fsnau.org), as could not be

otherwise, but adding the broad perspective of data aggregated at the operational zone level and by livelihood system thus helping to interpret the impact of policies already implemented and to better target future interventions based on operational zones and type of livelihood.

The overall pattern of stunting is a declining trend for all livelihood groups in the three zones. This decline had been projected by policy reports and international tracking tools (30) (31) based on data collected in 2009. Our results shows the trends with data collected in the period 2007-2016 by operational zones and by livelihood systems which can help to better target the efforts needed to maintain a stunting declining trend as to reach the World Health Assembly targets by 2025.

Pastoralists' children seem to be more resilient to stunting, with estimates consistently lower, reaching very low levels (below 5%) in all three zones at the end of the period. Other studies have suggested this is a result of the physical stature of Somali pastoralists as tall and lean, which may mask the actual estimates of chronic malnutrition (32), but decreasing trends are clear nonetheless. Another potential explanation for this differentiation is that pastoral groups have relatively better asset base and access to animal products, especially milk and cow's blood, which provide high protein diets even when food is scarce. This type of diet, also rich in iron, calcium and other micronutrients will favour continued height growth rather than soft tissue. The opposite applies for agriculturalists as energy may be provided by cereals but protein and micronutrient intake may be compromised, favouring stunting but less wasting. The higher rates of malnutrition observed among pastoralists in the analysis after the *Gu* rains may be associated with the restricted access to their typical diet in the precedent *Jilal* season. During that extended dry season from mid-January to mid-April the pastoralists adult male and adolescent boys migrate with the livestock to distant grazing areas, leaving women and young children

behind with limited access to milk and other animal source products (33). And this is consistent with findings from pastoralist populations of other countries in the region (12). Also the amount and intensity of the Gu rains tends to be high in the NWZ and SCZ which can lead to increased morbidity among IDPS due to increased contamination and infections. And although this may have a more clear impact on wasting as an indicator sensitive to short term changes, our results show the same seasonal fluctuations in stunting estimates, and recent studies are highlighting the role of seasonality as potential risk factor to poor growth among young infants (34).

Also important to notice is the stunting peak consistently shown for all livelihoods in the immediate years after the famine, probably reflecting the effects in stunting of the extremely high rates of wasting.

These same observations are replicated in the results of the agro-pastoralists and pastoralists artificial cohorts we created for the SCZ. The stunting rates are consistently lower and the stunting fluctuations consistently softer among the pastoralists' cohorts as compared to the agro-pastoral ones, and a relation is observed between the high wasting peak in 2011 and the stunting in the subsequent years.

The overall growth pattern we observe in our cohorts, with stunting peaks within the 13-24 months of age, is consistent with the growth faltering observed in other deprived populations of the world, which show a stunting crowning around 24 months of age which decreases thereafter (35). The interpretation of childhood catch-up after 24 months is that a combination of the normal postnatal maturation of the children's immune systems and the development of a broad range of adaptive responses against previously encountered pathogens reduces the frequency and severity of growth-impairing infections (36). This is the observed pattern in most of the pastoralists' cohorts we created in the SCZ. However, among the agro-pastorals the only cohort that follows that clear pattern is the Coh2012,

which encompasses the children born after the 2011 famine. In all the rest of the cohorts the growth pattern changes, as the stunting prevalence experiences a sharp increase a year after the children have experienced the 2011 famine, independently of the age of the children during that period. This suggests a strong impact of the high wasting rates in the subsequent stunting prevalence. This association has been shown in longitudinal studies that have reported that children with wasting or negative changes in weight for height are at greater risk of linear growth retardation (34) (37), and the differentiated patterns for children among pastoralists and agropastoralists populations are consistent with similar studies conducted in the region (12).

In relation to morbidity, although it declined during the period of analysis, prevalence were still high, especially among IDPs. Pervasive morbidity is associated with limited access and utilisation of basic health and water services and IDPs reside in temporary infrastructures and crowded conditions, which exacerbate their vulnerability to infectious diseases (38). Also, and for all the livelihood groups, the morbidity trends showed numerous peaks reflecting disease outbreaks such as measles, polio, acute watery diarrhoea and cholera almost every year since 2007. Somalia is one of the acute watery diarrhoea/ cholera-endemic countries in the world and according to UNICEF, contains “the largest known reservoir of unvaccinated children in a geographic area in the world” (around half a million children). The rise in morbidity observed in 2016 corresponds with the cholera and measles outbreaks occurring in that year (39) (40) which further contributed to the rise in acute malnutrition and mortality which reached near-famine thresholds at the start of 2017, only averted by the large-scale and sustained humanitarian actions (29).

As already shown by other studies, the provision of malnutrition and morbidity estimates, when seen in the context of historical values and viewed as specific to different livelihood

groups can provide useful timely warning of the need for intervention to mitigate developing nutritional crises (12).

Limitations and strengths of the study

The sample characteristics in terms of size and number of surveys allowed for a high precision in the analysis and for the stratification by livelihood system. However, despite the enhanced precision of the estimates of malnutrition and morbidity showed by the narrow confidence intervals, due to the effects of confounding and bias (measurement and or recall bias) inherent in cross sectional and nutritional surveys, the analysis may produce spuriously precise but biased estimates of association and stability.

The aggregation of the data at the operational level and by livelihood system permitted the analysis from a different perspective and additional insights for policy makers. The so called IDPs livelihood was over-represented in the overall population as recent data indicated that the proportion of IDPs in Somalia population was around 14% (38), thus the importance of the stratified analysis.

Although the data was collected at village level and could have the potential to derive the impact of locality and environmental conditions on individual outcomes the geo-localization of the clusters surveyed was challenging due to a lack of updated Somalia cartography and changes in villages names and spelling over the years during the period of study.

Data were collected in field conditions, which may have an impact on the accuracy of measurements, although the FSNAU survey enumerators' long-time experience and routinely training may have minimized this limitation.

Imputed values have to be interpreted with caution as they can introduce a bias. However, as shown in the figures the imputed values are randomly distributed in the years, zones

and livelihood groups studied thus we do not consider they are impacting the trends patterns in a systematic way

Accurate age estimation can be a major problem as there are no accurate records of birth in Somalia and age determination mostly relies on maternal recall. However, FSNAU conducted the ENA plausibility checks on every survey to minimize any potential bias and the age distribution in the sample shows the expected distribution.

Finally, the construction of artificial cohorts to assess the impact in growth retardation of the wasting peaks during the 2011 famine showed interesting results. We recommend to apply this methodology when longitudinal data is not existent but repeated cross-sectional data are available for the population of study.

CONCLUSIONS

The international community has been implementing humanitarian, recovery and development programmes for the Somali population in a complex and varied environment for the last decade, with ambivalent results.

Although wasting and morbidity prevalence remained high during the period of analysis there was a slight but clear decreasing trend for both indicators, only reversed at the end of the period, 2016, when severe drought conditions impacted most parts of the country. Furthermore, the decrease in stunting for the 2007-2016 period is remarkable.

The association found between high wasting prevalence and subsequent high stunting estimates calls for a more holistic response which addresses humanitarian life-saving needs and development work simultaneously.

Moreover the focus on reducing malnutrition in Somalia clearly needs to move away from the short-term response aimed at addressing acute food insecurity and treatment of acutely malnourished children to a more integrated response that includes access to clean

water, the promotion of hygiene and sanitation, and the improvement of access to basic health services among its priorities.

Finally, the households' vulnerability towards morbidity and malnutrition varies according to the type of livelihoods they pursue. Significant improvements can only be realized taking into account the specific challenges and opportunities within the various livlihoods across Somalia.

Authors' contributions

RCM & EC were involved in all stages from the conception and design, data acquisition, analysis and interpretation. FK and DF contributed to the study design, the data analysis and interpretation. DM & AY were responsible for conducting the surveys and managing the data. All authors have critically reviewed and approved the final version of the article.

Competing interests

The authors declare that they have no competing interests.

Funding

Not applicable.

Availability of data and material

The data that support the findings of this study are available from FSNAU but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of FSNAU.

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Not applicable.

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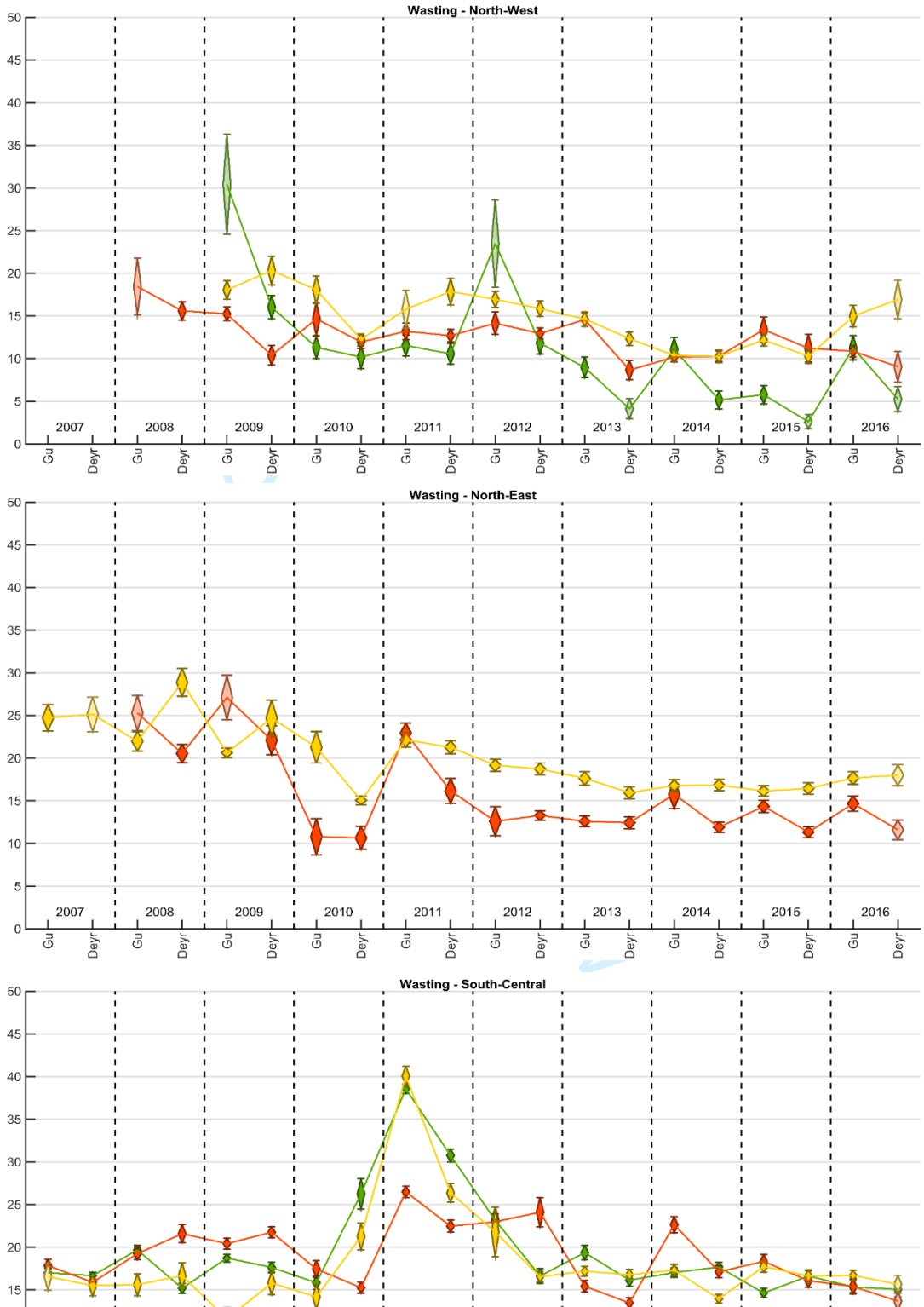
FIGURE'S LEGENDS

Figure 1: Wasting estimates and confidence intervals at 95% (diamond shapes) by year and season of analysis for each livelihood and disaggregated in the three operational zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were imputed.

Figure 2. Stunting estimates and confidence intervals at 95% (diamond shapes) by year and season of analysis for each livelihood and disaggregated in the three operational zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were imputed.

Figure 3. Growth patterns cohorts of children 6-59 months in agro-pastoralists and pastoralists populations in the South Central zone of Somalia

Figure 4: Morbidity estimates and confidence intervals at 95% (diamond shapes) by year and season of analysis for each livelihood and disaggregated in the three operational zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were imputed.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Wasting - North-East
Wasting - South-Central
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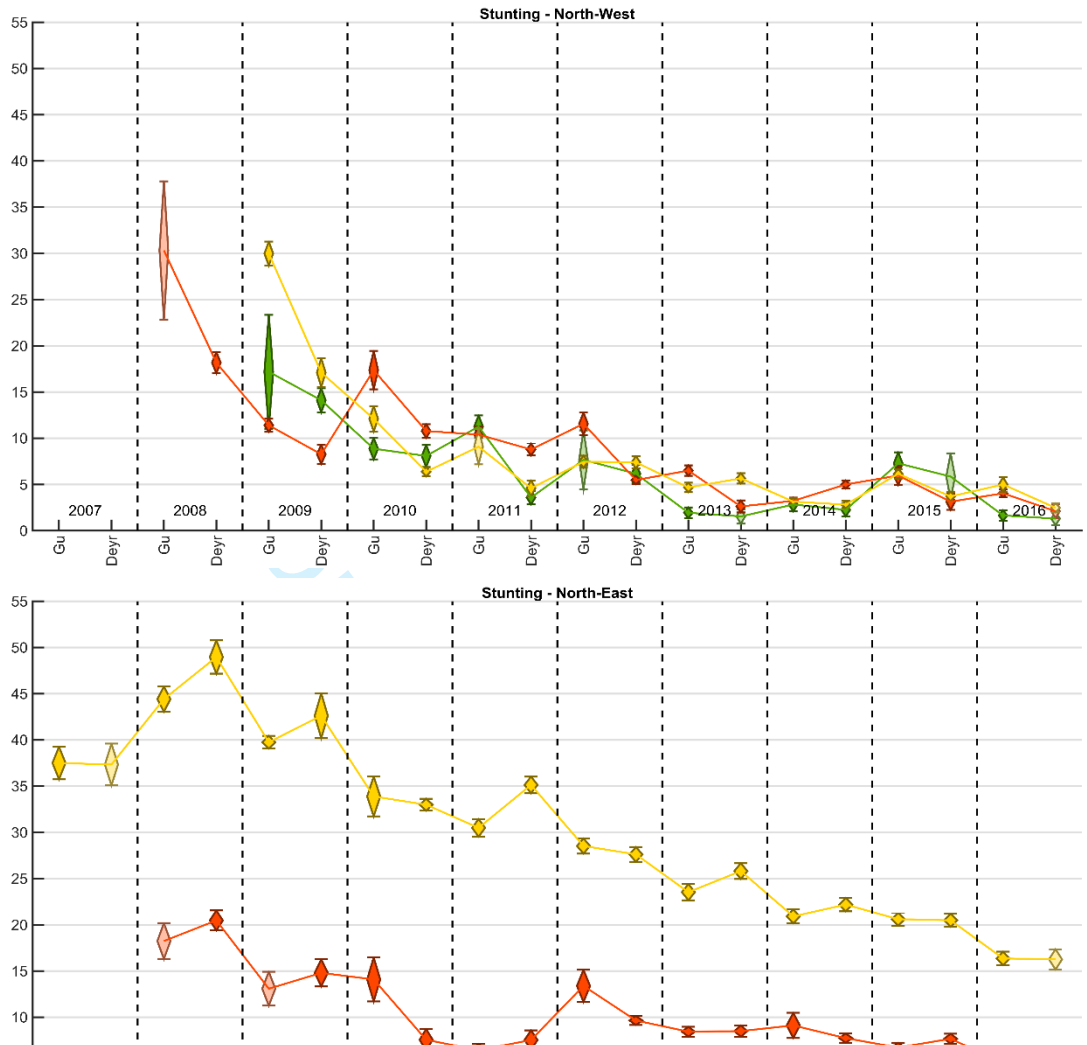
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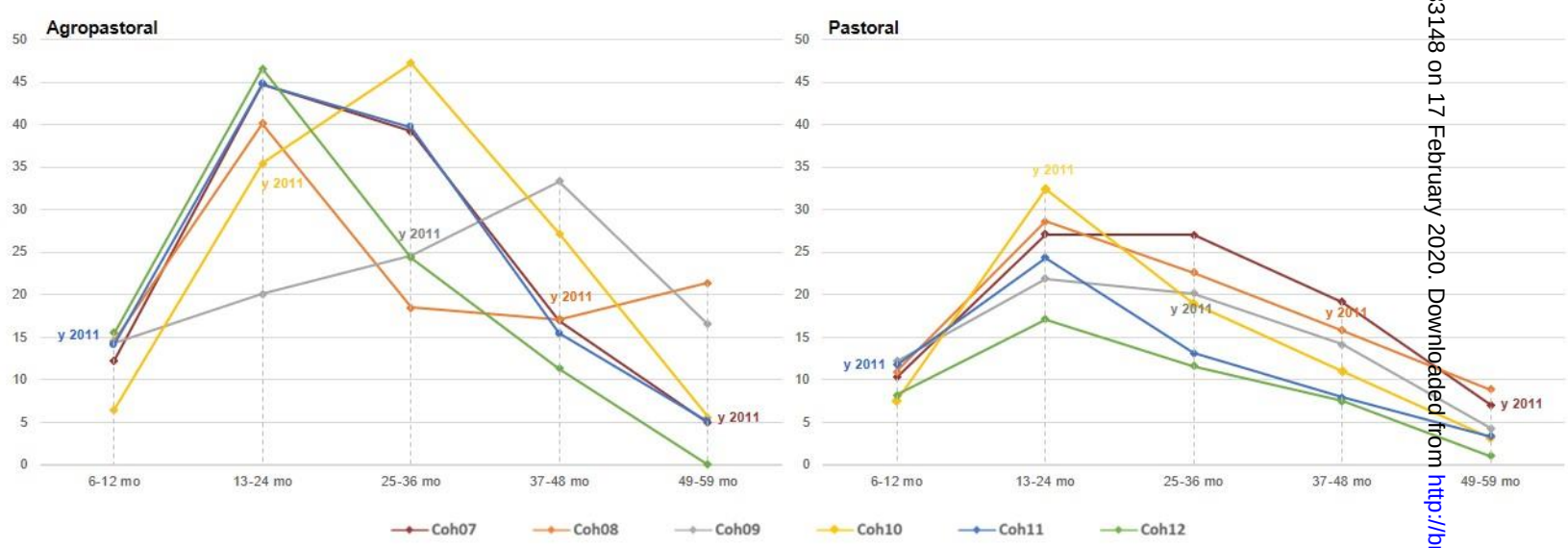

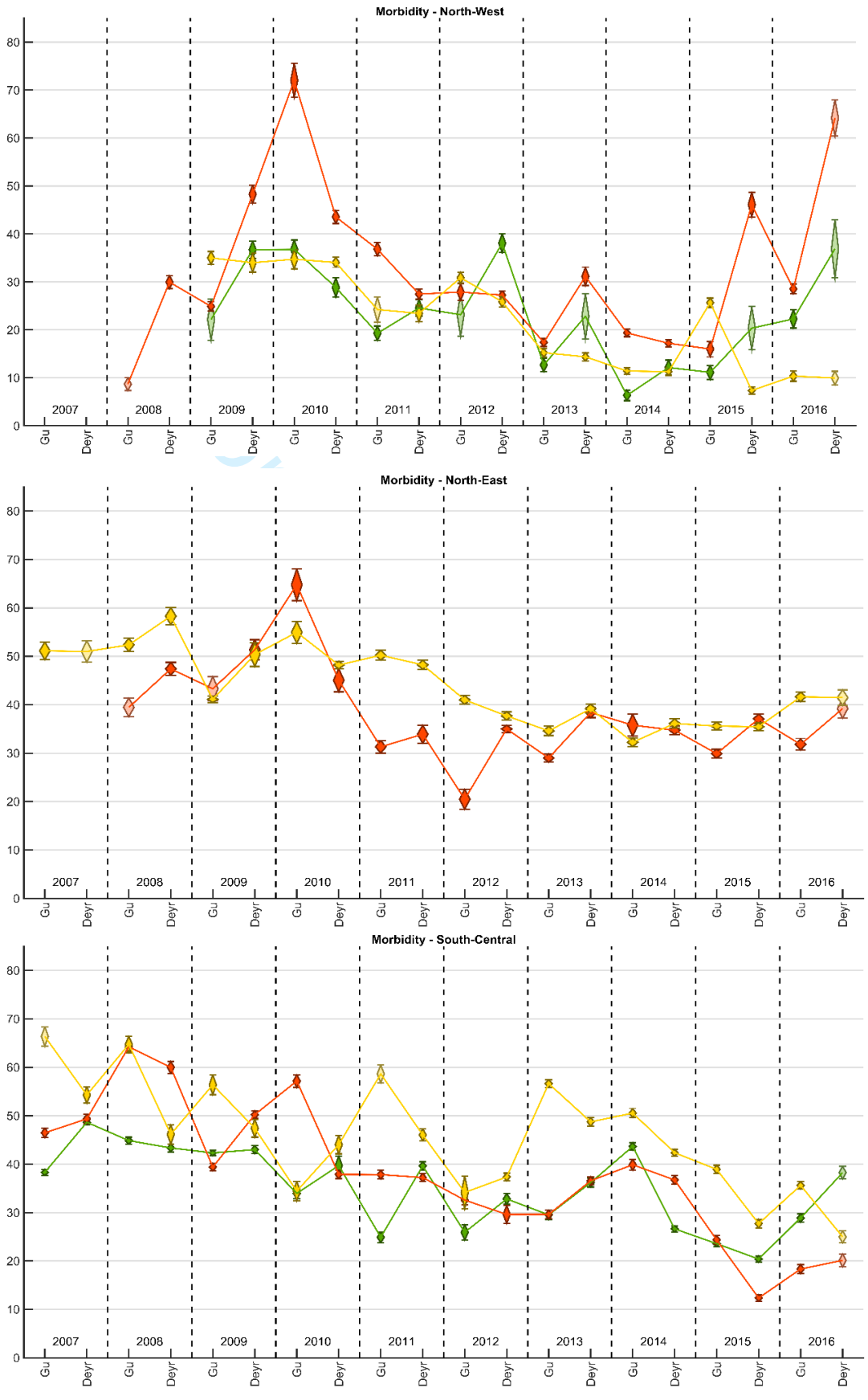
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Morbidity - North-East
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Annex 1. Sample size of the study by zone and livelihood system.

Zones	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016	Total
	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	
North West																				**49585**
Agropastoral						716	609	520	684	643		617	568		496	445	467		488	6253
Pastoral				1128	2045	702	334	1781	1203	1937	692	2594	1892	611	2639	2361	537	383	2253	23092
IDP					1251	585	570	2497		610	1597	1651	1713	1716	1975	1743	2179	1352	801	20240
North East																				**69275**
Pastoral				1407		588	213	516	1294	637	381	3701	2763	2084	450	2832	2383	2426	1614	23288
IDP	760		1333	772	5165	413	484	5314	2365	2844	3015	3176	2376	2658	2913	3210	3393	3222	2574	45987
South Central																				**163654**
Agrop+Riverine	6,421	8,273	4,984	3,652	7,159	3,730	2241	617	7,416	3,726	764	1810	2127	2,750	4,314	5,005	4,174	3,682	2,753	75,598
Pastoral	2,713	2,837	2,956	1,542	3,853	3,988	1,461	3,244	4,484	3,359	2,262	618	2,799	3,196	1,903	2,960	2,252	2,177	1,688	50,295
IDP		903	794	624	594	734	578	682	1,874	1,684	202	3,703	4,043	3,419	3,183	4,648	3,309	2,646	4,141	37,761
Total	9894	12013	10067	9125	20067	11456	6490	15171	19320	15440	8913	17870	18281	16436	17873	23204	18694	15888	16312	**282514**

Annex 2

Supplementary Table 1: Sample size of the study by zone and livelihood system.

Zones	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016	Total
	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	
North West																				**49585**
Agropastoral						716	609	520	684	643		617	568		496	445	467		488	6253
Pastoral				1128	2045	702	334	1781	1203	1937	692	2594	1892	611	2639	2361	537	383	2253	23092
IDP					1251	585	570	2497		610	1597	1651	1713	1716	1975	1743	2179	1352	801	20240
North East																				**69275**
Pastoral				1407		588	213	516	1294	637	381	3701	2763	2083	450	2832	2383	2426	1614	23288
IDP	760		1333	772	5165	413	484	5314	2365	2844	3015	3176	2376	2656	2913	3210	3393	3222	2574	45987
South Central																				**163654**
Agrop+Riverine	6,421	8,273	4,984	3,652	7,159	3,730	2241	617	7,416	3,726	764	1810	2127	2,756	4,314	5,005	4,174	3,682	2,753	75,598
Pastoral	2,713	2,837	2,956	1,542	3,853	3,988	1,461	3,244	4,484	3,359	2,262	618	2,799	3,196	1,903	2,960	2,252	2,177	1,688	50,295
IDP		903	794	624	594	734	578	682	1,874	1,684	202	3,703	4,043	3,419	3,183	4,648	3,309	2,646	4,141	37,761
Total	9894	12013	10067	9125	20067	11456	6490	15171	19320	15440	8913	17870	18281	16439	17873	23204	18694	15888	16312	**282514**

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-11
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-11
Bias	9	Describe any efforts to address potential sources of bias	3 &10
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10
		(*b*) Describe any methods used to examine subgroups and interactions	10
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8-9
		(*e*) Describe any sensitivity analyses	n.a.
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-11
		(b) Give reasons for non-participation at each stage	n.a.
		(c) Consider use of a flow diagram	n.a.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-12
		(b) Indicate number of participants with missing data for each variable of interest	9
Outcome data	15*	Report numbers of outcome events or summary measures	12-18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15-19 and 31

		(*b*) Report category boundaries when continuous variables were categorized	12-18
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n.a.
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-18
Discussion			
Key results	18	Summarise key results with reference to study objectives	19
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	3
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	19-23
Generalisability	21	Discuss the generalisability (external validity) of the study results	19-23
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	27

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.