

## **Supplementary files**

### **Armed conflicts and national trends in reproductive, maternal, newborn and child health in sub-Saharan Africa: what can national health surveys tell us?**

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#### **Appendix**

- A Country grouping**
- B Methods used to estimate subregional trends**
- C Country summaries with trends**
- D Tables with individual country data for Figures 1-3**

## **Appendix A: Regional classification of countries, using the UNICEF region 2 classification**

Countries were classified into two UNICEF regions in sub-Saharan Africa: ESA: Eastern and Southern Africa and WCA: West and Central Africa.

**Eastern and Southern Africa:** Angola, Burundi, Botswana, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Lesotho, Madagascar, Mozambique, Mauritius, Malawi, Namibia, Rwanda, Somalia, South Sudan, Swaziland, Seychelles, United Republic of Tanzania, Uganda, South Africa, Zambia and Zimbabwe

**West and Central Africa:** Benin, Burkina Faso, Central African Republic, Cote d'Ivoire, Cameroon, Democratic Republic of the Congo, Congo, Cabo Verde, Gabon, Ghana, Guinea, Gambia, Guinea-Bissau, Equatorial Guinea, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Sao Tome and Principe, Chad and Togo.

## Appendix B: Description of the model utilized for regional estimation, 1990-2016

### Data identification, access and inclusion

The distribution of key indicators considered for comparative analysis include the Countdown Composite Coverage Index (CCI), stunting and wasting. CCI refers to the weighted average of the percentage of eight interventions along the four of the continuum of care, and that include: family planning (demand satisfied with modern methods) coverage (DFPSm); skilled attendant at birth (SBA); at least one antenatal care visit by a skilled provider (ANC1); Bacilli Calmette-Guerin (BCG) vaccination; three diphtheria-tetanus-pertussis (DPT3) vaccinations; measles vaccination (MSL); oral rehydration solution (ORS) therapy for infant diarrhoea and care-seeking for child pneumonia (CAREP). Data on CCI was computed from DHS and MICS data.



- Weighted average of 8 interventions
  - Four stages of the continuum of care

$$CCI = \frac{1}{4} \left( DFPSm + \frac{ANC1 + SBA}{2} + \frac{BCG + 2 \times DPT3 + MSL}{4} + \frac{ORS + CAREP}{2} \right)$$

DFPSm = demand for family planning satisfied with modern methods; ANC1 = 1+ antenatal care visits; SBA = skilled birth attendant; BCG, DTP3, measles vaccines; ORS = oral rehydration salts; CAREP = careseeking for suspected pneumonia



Data on stunting and wasting – defined as low height-for-age and low weight-for-height, respectively -, among children under five years of age were extracted from the UN Joint Malnutrition Estimate data sets.<sup>1</sup> These indicators refer to percentages of children aged 0-59 months who are below 2 standard deviations of the WHO Child Growth Standard median. For the analysis we limited the subregional reference curves to the data points obtained from the DHS and MICS surveys.

We only included national level data and identified and removed duplicate data. From MICS and DHS surveys we used data points with two or three-year recall periods to obtain recent statistics from the

<sup>1</sup> WHO, UNICEF and World Bank. Joint malnutrition estimates.  
<http://www.who.int/nutgrowthdb/estimates2016/en/> (accessed June 8 2018)

survey (instead of 5-year recall periods) and minimize the sampling error (which would have been large with single year data). We excluded data with no clear primary data source. Data were collected on or after 1990, but also data points prior to 1990 were included and used for analysis, particularly for data imputation. For regional trend analyses, in addition to countries with no data, those with either only one data point or all pre-2000 data points were excluded. As a result, data from Cape Verde and Mauritius were excluded from analysis. We located all survey data points in the middle of the reference period, taking the period of data collection and the length of the reference period into account. For instance, if a survey was conducted in 2016 and the reference period for the indicator was three years, we used 2015 as the year for the indicator's data point.

There were 276 (48.6% in ESA and 51.4% in WCA) stunting and wasting data points for 47 countries (24 in ESA and 23 in WCA), while a total of 156 (48.7% in ESA and 51.3% in WCA) CCI data points for 37 countries (17 in ESA and 20 in WCA). All but 5 countries had three or more stunting and wasting data points, with at least one data point after 2000, and were included in the analysis. We located all survey data points in the middle of the reference period, taking the period of data collection and the length of the reference period into account.

## **Modeling**

Pre-1990 data points were used to assign values for missing data points for the period 1990-2016. Countries with no data points within the period 2000-2015 were excluded from the analysis, including Cape Verde and Mauritius which only had pre-2000 data points. For each country, missing data points were assumed missing at random and multiple imputation technique was utilized to impute missing data. For each country, four scenarios were considered to impute data for the missing years:

- 1) if pre-1990 data were available, most recent pre-1990 data was used as prior information and we linearly interpolate to the first data point with the period 1990-2016 to estimate the data point in 1990.
- 2) if there were no pre-1990 data points available, we performed that the indicator exhibits an increasing trend and backward extrapolation from the first data point after 1990 to obtain the data point for the year 1990.
- 3) if there was no data point available on or after 2016, we linearly extrapolated using all available pre-2016 (i.e., all post-1990) data points to obtain estimates for the year 2016. For countries with only one post-1990 data point, the trend was assumed linear.
- 4) For missing data points between 1990 and 2016 (excluding the two extremes), multiple imputation technique was utilized to estimate missing data points of the indicator between two data points in a sequence of values. This method is described below and was used for all countries with at least one missing data point in between 1990 and 2016.

## **Systematic and random measurement errors**

Empirical data obtained from different sources are most likely to suffer from different errors, and that includes random errors in sample surveys or systematic errors. In order to better account for random and systematic biases of different types of empirical data inputs, we utilized the multiple imputation technique using a multivariate normal distribution assumption to impute missing data so that multiple data values are imputed rather than a single value to reflect the uncertainty range around the true value. Ten imputations were used, with missing data points assumed as missing at random. Variables describing country and time were considered as covariates. Convergence of imputed variables were assessed using trace plots.

## **Estimation of regional and global levels and trends of stunting, wasting and CCI**

In an effort to first identify whether or not a trend exists, we conducted Mann-Kendall trend test – a non-parametric test for monotonic trends that provides an indication of whether the trend exists and whether the trend is positive or negative. In all scenarios of global and regional trends of the indicators, results indicated that the stunting and wasting levels are decreasing over time for a significant trend, while CCI was increasing ( $p < 0.05$ ).

Regional and global levels and trends of each indicator (CCI, stunting and wasting) were estimated with the penalized B-splines of degree 3 with 3 knots, and a penalty of lambda range (range; 1 to  $10^6$ ) specified to control the smoothness of the fit, in order to model the regression function. Knot locations were decided by the models. For each indicator estimates, the spline regression models are fitted to all data inputs in each subregion (i.e., subregion-year data points). In the spline regression, each data point of stunting and wasting is weighted by country-year population of children under five years, while we weighted each data point of CCI by total live births in each country (i.e., country-year total births) for the reference year, obtained from the UN population division.

Uncertainty ranges were derived from regression models that we utilized using values generated through multiple imputation. Note that the penalized B-spline function is typically much smoother than a model using spline transformation or a B-spline expansion since the changes in the coefficients of the basis are penalized to make a smoother fit<sup>2</sup>. For each analysis, the dependent variable is specified with an identity transformation and analyzed as is (i.e., with no transformations). The independent variable, year, is specified with penalized B-spline transformation, so a penalized B-spline model is fit. Furthermore, Schwarz Bayesian Criterion (SBC) along with smoothing parameter, requesting for a penalized B-spline analysis minimizing the SBC criterion, was utilized to produce smoother estimates. Uncertainty ranges around the estimated value were obtained from the penalized B-spline regression model. Our estimation did not extend beyond 2015 as only few countries had a data point after 2015. The analysis was conducted using SAS version 9.4 using TRANSREG (transformation regression) procedure<sup>3</sup>. The code is available upon request from the corresponding author.

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<sup>2</sup> Eilers, P.H.C. and Marx, B.D. Flexible Smoothing with B-splines and penalties. *Statistical Sciences*; 1996; 11(2): 89-121.

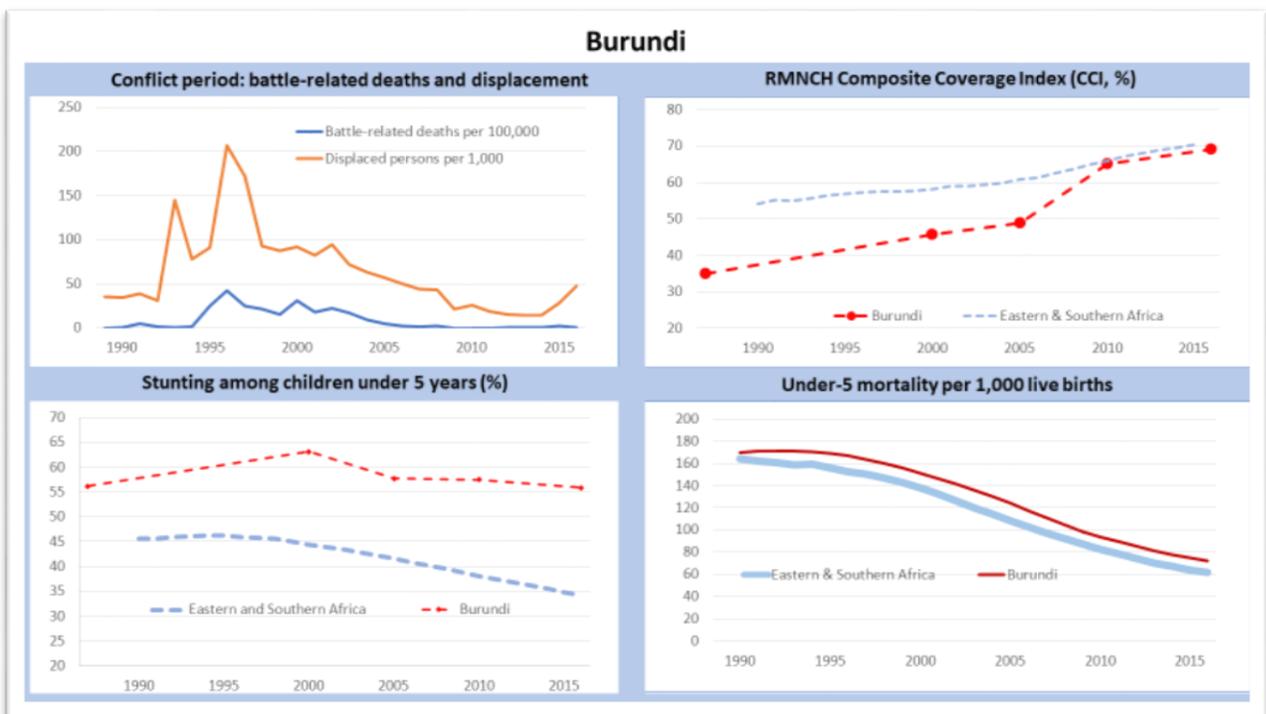
<sup>3</sup> SAS Institute Inc., SAS 9.4 Help and Documentation, Cary, NC: SAS Institute Inc., 2002-2015.

## Appendix C Country summaries with trends

### Burundi

Burundi has suffered on and off from political instability driven by Hutu-Tutsi ethnic clashes since independence in 1962. In *Burundi*, battle-related mortality rates were high during 1995-2005 and displacement rates were extremely high in the mid nineties and continued to be high until 2010. Four national surveys have been conducted and none reported sample problems. The CCI increased from 35% to 46% during 1987-2005 but was considerably lower than the subregional CCI for eastern and southern Africa. After the end of the civil war, the CCI in Burundi increased rapidly, almost at the same pace as Rwanda during 2005-2010, to almost 70% by 2015. The effect of the civil war on stunting is large with no decline in the past decades at levels of 55%.

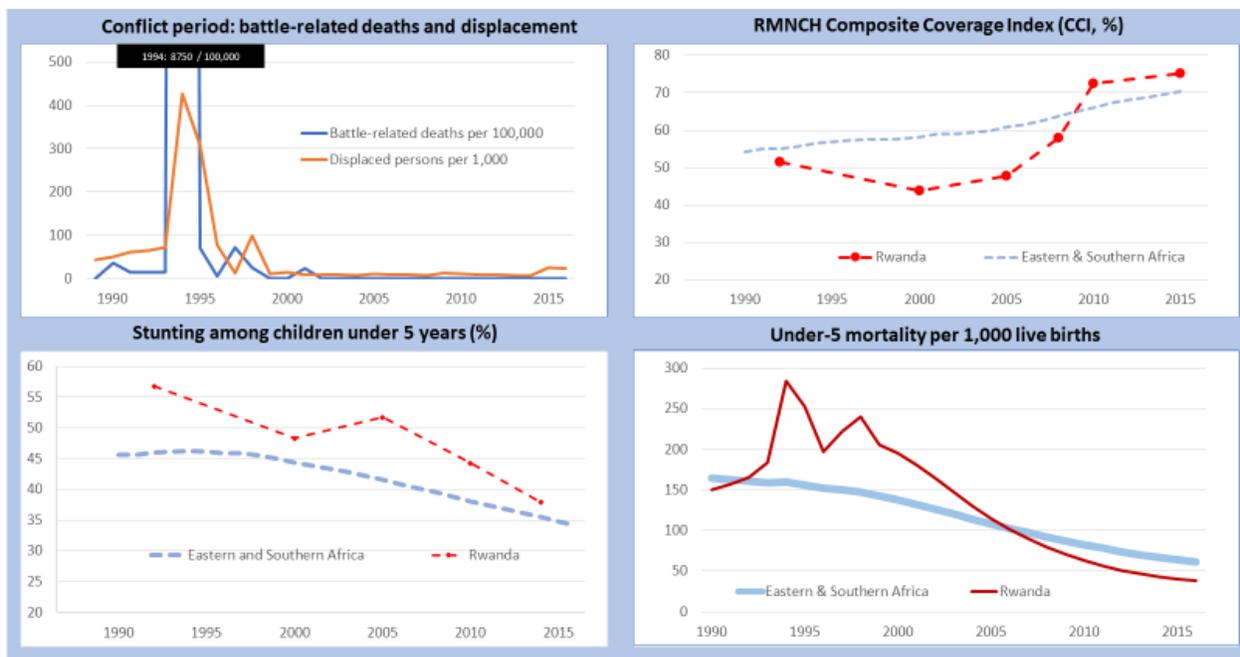
Figure 1: Battle-related deaths per 100,000 population and displaced persons per 1,000 population, RMNCH composite coverage index (CCI, %), stunting and under-5 mortality per 1,000 live births, 1989-2016.



## Rwanda

Rwanda has suffered on and off from political instability driven by Hutu-Tutsi ethnic clashes since independence in 1962. The genocide in 1994 was by far the most severe event during the past few decades in sub-Saharan Africa, with over 500,000 battle-related deaths in the UCDP database which considerably underestimates the actual death toll.<sup>1</sup> Battle-related mortality and displacement rates were elevated a longer period (1990-2002). All surveys in Rwanda were based on nationally representative samples, except in 1992 where 3% of the population had to be excluded due to the civil war in the north. The impact of the civil war on coverage trends, stunting and child mortality was large. The post-conflict improvements were very large but only gained pace after 2005.

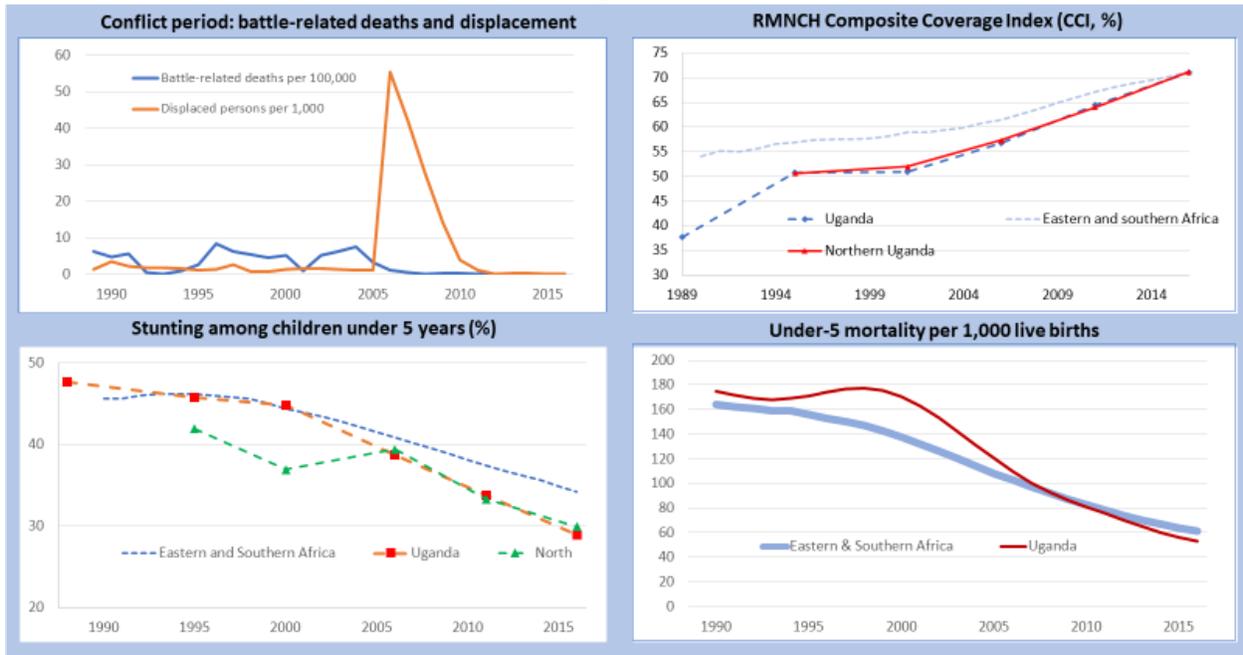
## Rwanda



## Uganda

*Uganda* went through a prolonged period of political instability and conflict, which after 1986 was concentrated in the north and west along the Congolese border, and continued until a peace agreement with the LRA in 2006. Internally displaced population numbers surged in 2006, according to the UNHCR database (Figure 1c). Several national surveys excluded part of the North because of insecurity, including the whole region except West Nile in 1988/89, one district in 1995 (Kitgum), two of the ten northern districts in 2001 (Kitgum, Gulu). Even without these most-affected populations, Uganda's CCI was considerably lower than the subregional CCI and only caught up after 2010. Post conflict Uganda's under-five mortality and stunting declined rapidly from 2000. Within Uganda, there is no clear evidence that the CCI in the North was lower than in the West or East, but the exclusion of the most affected districts has to be considered. If no woman or child received any intervention in the clusters excluded for security reasons in the 1995 and 2001 surveys, the CCI in North Uganda would drop by 7 percentage points to 44% in 1995 and by 10 percentage points to 42% in 2001.

## Uganda

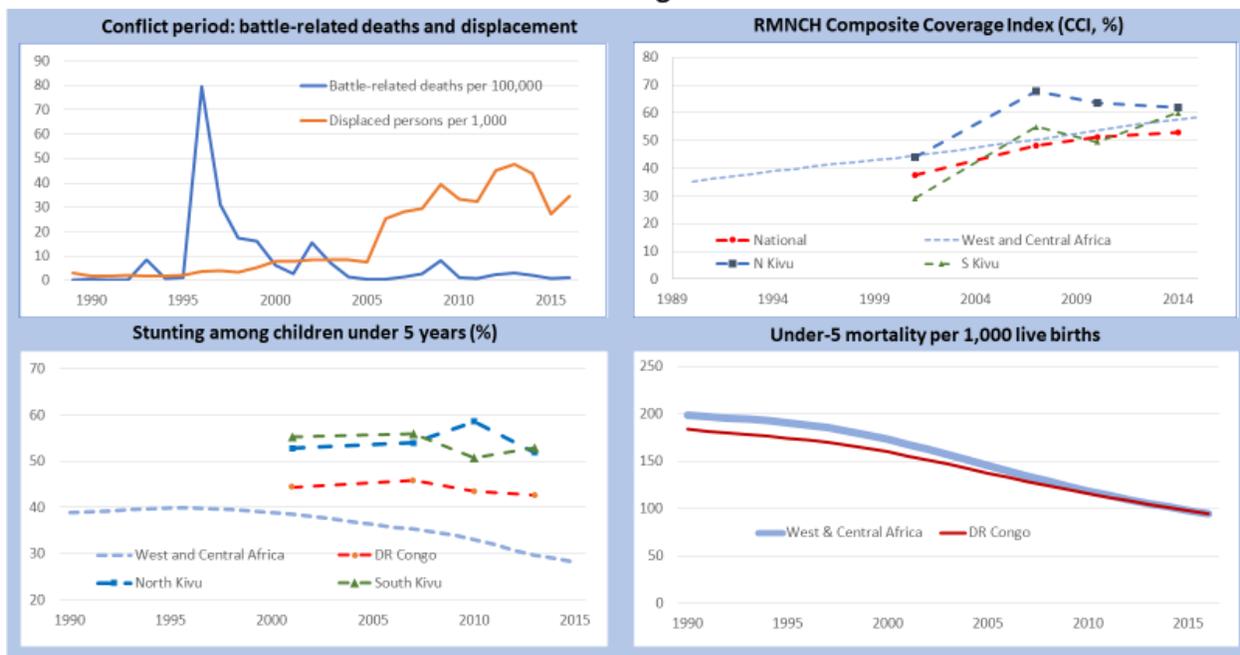


## DR Congo

*DR Congo* has been affected by war and political instability since the first Congo war in 1996-97 with the Rwanda-Uganda invasion to depose president Mobutu and the second Congo war from 1998-2002/03 with most of the fighting occurring in five eastern provinces. Since then, until today, political stability in particularly eastern Congo has been challenged by multiple incidents and militias fighting the government and increasing numbers of displaced populations. North and South Kivu provinces (estimated population 6.7 and 5.8 million respectively in 2015) were particularly affected, as well as Ituri region in Orientale province, Katanga, and more recently Kasai. The analysis focused on North and South Kivu.

Four national surveys were conducted in 2001, 2007, 2010 and 2013/14. Exclusion of selected clusters was only a problem in the 2001 MICS survey, where 32 of 365 clusters (9%) could not be visited because of security problems or could not be found. The report does not provide information on the location of these clusters. The DHS 2013/14 reported that four out of 430 clusters could not be visited, including one out of 32 clusters in North Kivu. The impact on the results is likely to be small. National coverage increased gradually and was slightly below the West and Central Africa CCI (Figure 1d). The coverage in North Kivu was on or above the national average in all surveys, although there was a decline in the more recent surveys. South Kivu had the lowest CCI in the country in 2001 but increased rapidly and was close to the national average in all other surveys. Stunting levels were very high and did not decline during 2001-2013. Under-5 mortality in DR Congo was slightly lower than the average for West and Central Africa, especially during the nineties. The mortality levels in North and South Kivu were below the national average according to the DHS 2007 and 2013.

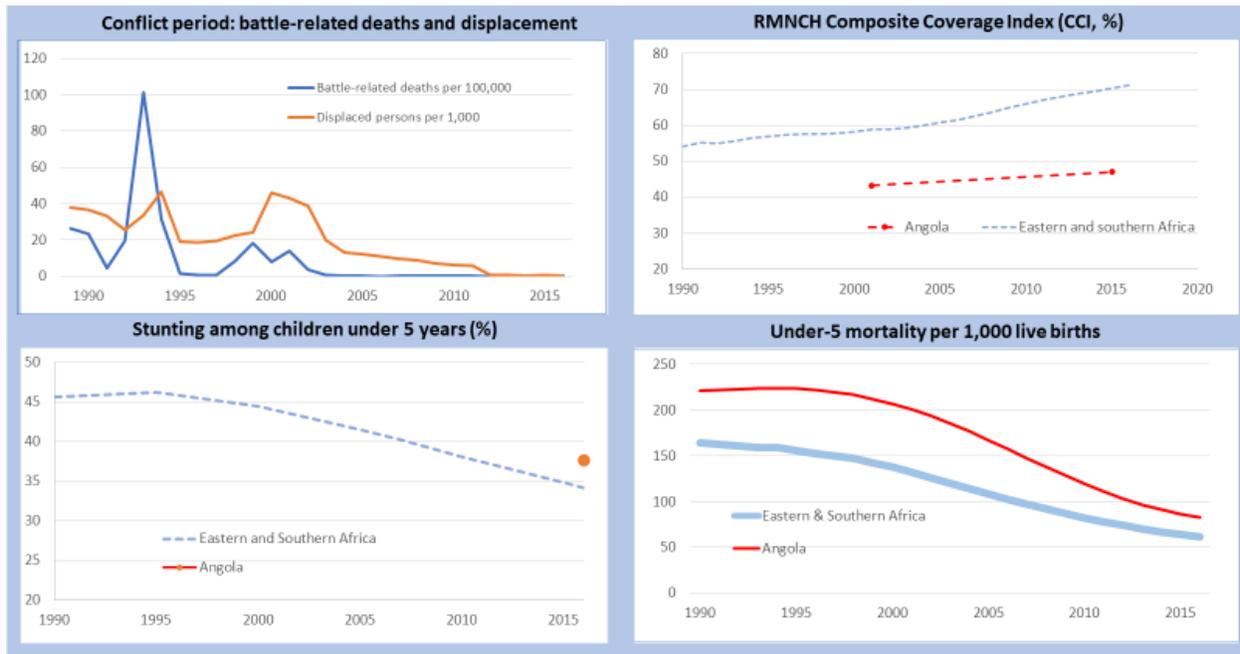
## DR Congo



## Angola

Angola became independent in 1975. Fighting between different political factions, most notably MPLA and Frelimo, continued until 2002, only temporarily interrupted by fragile periods of peace, with displaced persons gradually returning in the subsequent decade. Angola conducted its first national survey in 2001, resulting in a CCI of 49%. According to the second survey in 2016, the CCI hardly increased and the gap with the regional average grew. Stunting rates were also above regional rates in 2016 (Figure 1e). Angola's under-5 mortality rate was considerably higher than subregional average, especially during the civil war. After the civil war Angola's mortality decline was faster than for the subregion (AARR 6.3% and 5.3% respectively).

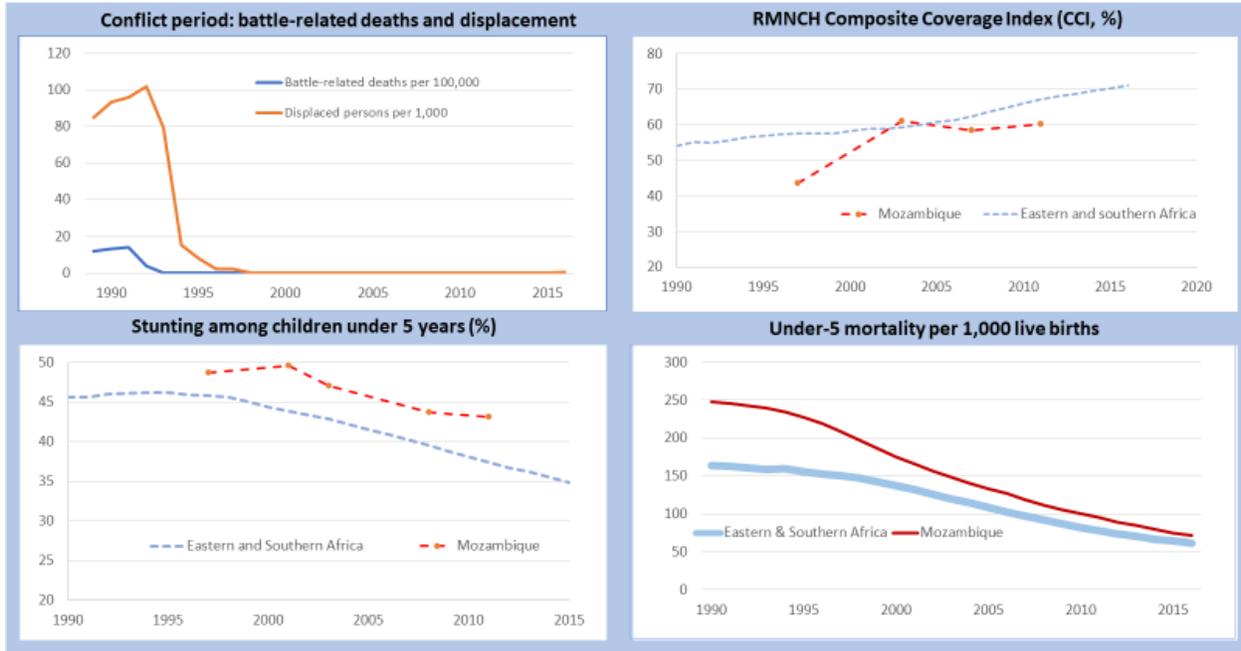
## Angola



## Mozambique

Mozambique became independent in 1975. The civil war between Frelimo and Renamo ran from 1977-1992, with displacement ending in the subsequent five years. Four post-conflict surveys in Mozambique showed a low CCI in 1997, a rapid increase in 2003 and little progress in the following period until the 2011 DHS (Figure 1f). Stunting levels remained higher than the regional average. Child mortality levels were much higher than the subregional average at the end of the civil war in 1992 and caught up about only 15 years later.

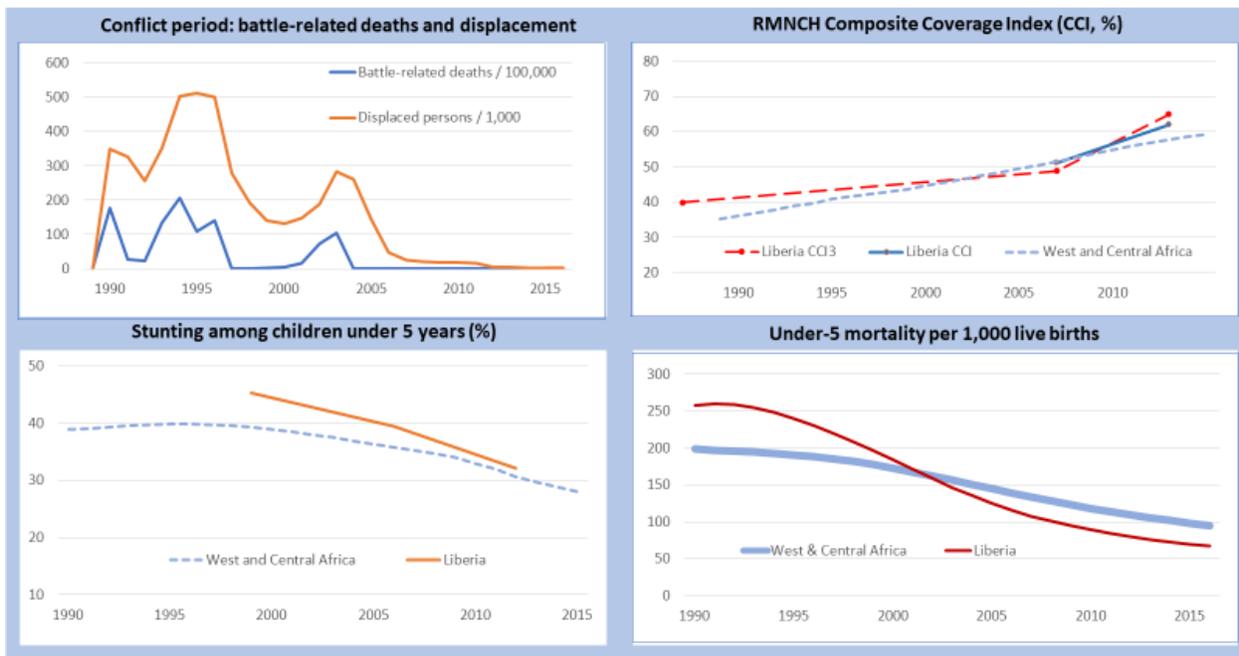
## Mozambique



## Liberia

Liberia went through civil wars during 1989-97 and 2001-2003 with multiple warring factions throughout the country and had massive numbers of displaced persons until 2005. Liberia conducted a DHS in 1987, 2007 and 2013 with no sample implementation problems reported. The 1987 survey did not provide comparable data on childhood illness treatment. Therefore, the index is shown for family planning, maternal and newborn care and immunization only (referred to as CCI3), as well as the full CCI for the recent surveys (Figure 1g). Despite the protracted civil war, the CCI3 was 10 percentage points higher in 2007 than two decades earlier and close to other countries in West and Central Africa with surveys during 2005-2009. From 2007 a very rapid increase occurred to 62% in 2013. Child mortality trends did not show any impact of the civil war. In 1990, Liberia's mortality level was considerably higher than in the region, but it declined at a faster pace than the regional average (AARR 4.2% and 1.9% respectively) during 1990-2003. Stunting levels were higher than the regional average.

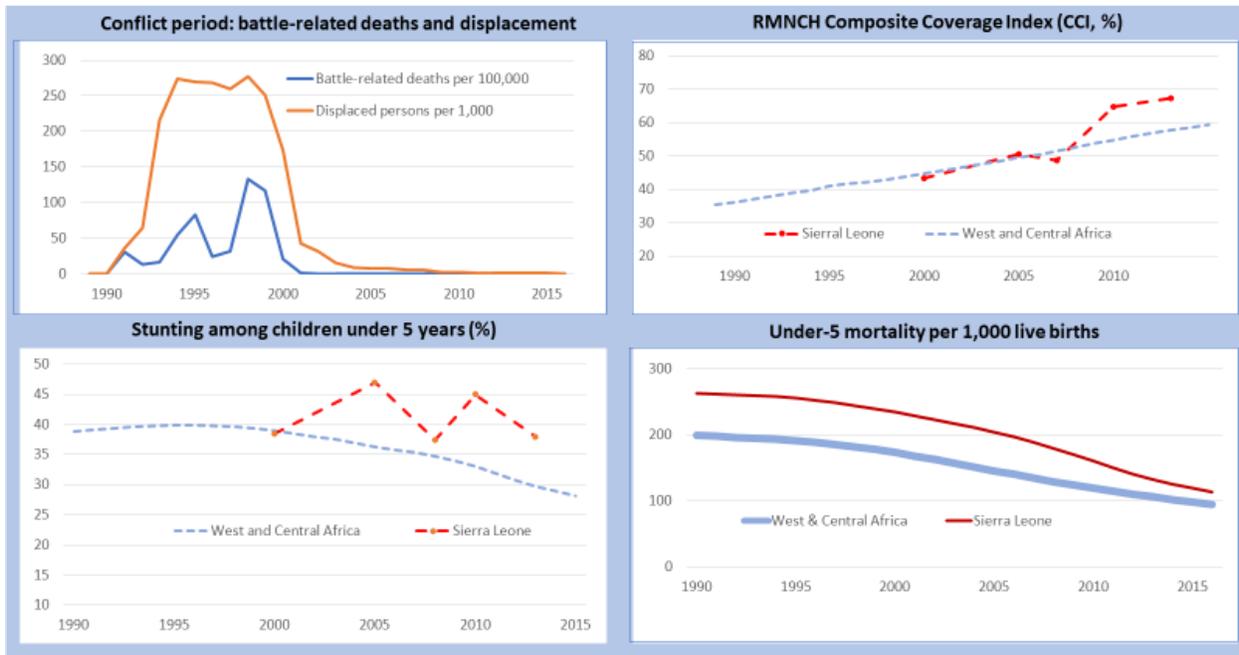
## Liberia



## Sierra Leone

Sierra Leone's civil war began in 1991 and ended in 2001 when the peace accord was signed. The results of the first survey in 2000 must be interpreted with caution, as 17 of the 225 selected clusters were excluded because of inaccessibility or hostilities between government and rebels. The CCI in 2000 was 44% in 2000 (40% if we assume zero coverage in the excluded clusters) and increased by 7 percentage points to about 51% during 2005-2007, close to the average for the West and Central African region (Figure 1h). During 2008-2013, Sierra Leone's CCI increased rapidly to 68%, well above the regional average. Stunting levels were higher than the region, but increasingly so during the post-conflict period. Under-5 mortality was very high in 1990 but declined faster than the regional pace during the civil war (AARR 3.9% and 1.7% respectively) and even more so after the civil war (AARR 4.8% and 1.4% respectively).

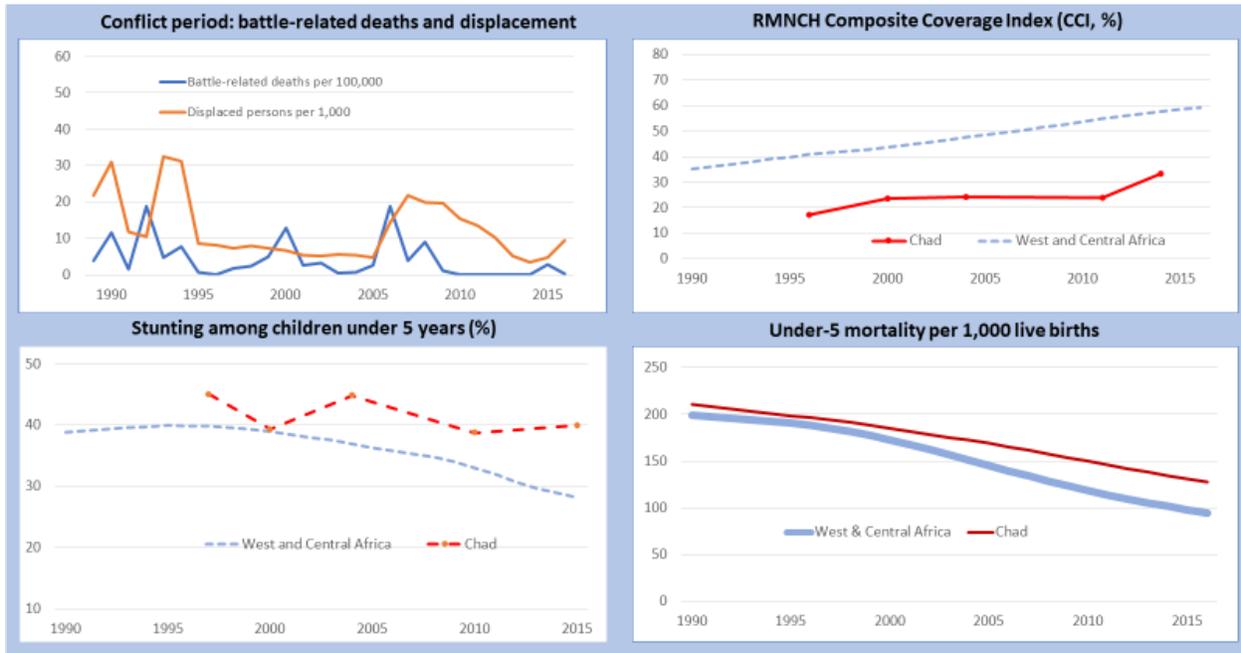
## Sierra Leone



## Chad

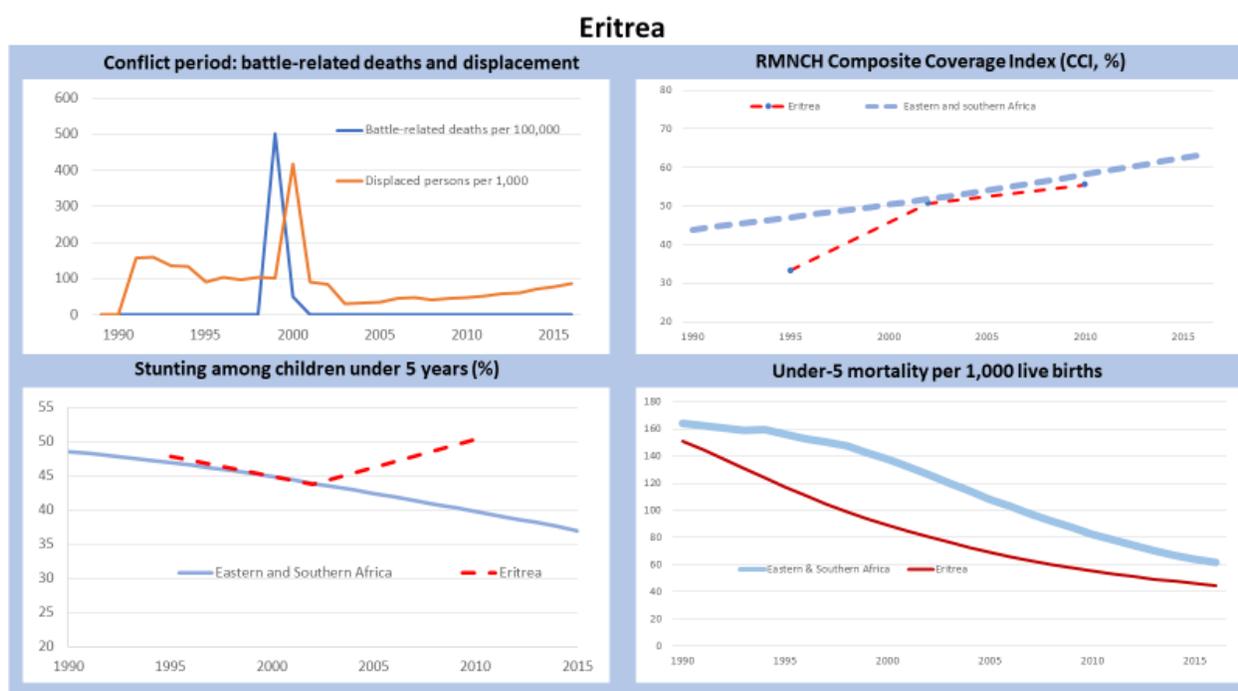
*Chad* has been affected by decades of civil strife and at times war with Libya, as well as a large influx of refugees from neighbouring Sudan. Battle-related mortality and displacement rates for 1989-2009 indicated continued fighting during most years at different locations in Chad. Five national surveys were conducted during 1996-2014, which all reported that more than 98% of the selected clusters were visited. The CCI in Chad was below 20%, one of the lowest in Africa, in the mid-nineties and only marginally increased to 24% by 2011 (Figure 1i). Only in the DHS 2014 an increase to 33% was observed. Stunting levels were high and not declining. Chad's under-5 mortality was just above the West and Central Africa regional value in the early nineties but declined at a considerably slower pace during the period of conflict.

## Chad



## Eritrea

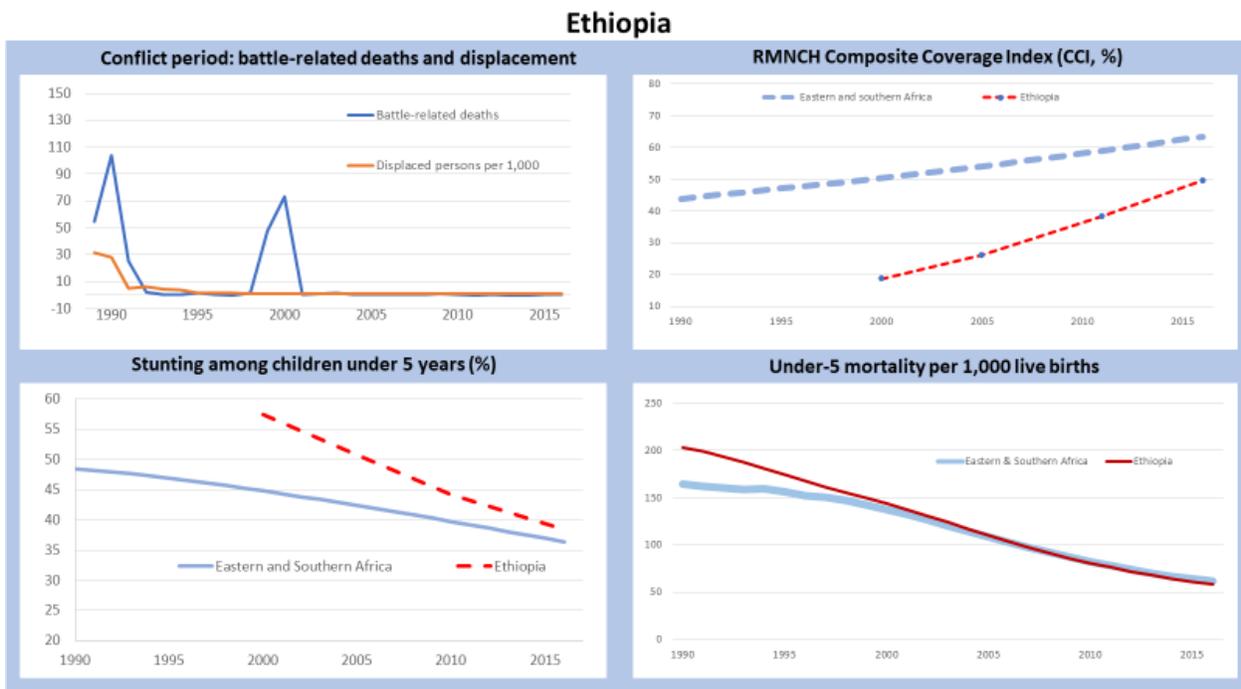
The war between *Eritrea and Ethiopia* about the location of the border began in May 1998 and lasted until June 2000, with nearly 100,000 battle-related deaths. In the following years, rates of displacement remained high according to the UNHCR database, notably out-migration. Eritrea conducted DHS surveys in 1995 and 2002 and a Population and Demographic and Health Survey which was very similar to a regular DHS in 2010. The two early DHS surveys showed little impact of the war on the CCI which increased from a very low 32% in 1995 to 49% in 2002. After 2002 the increase was much smaller to 56% by 2010, but the pace of increase stayed close to the subregional average. There was little impact on national stunting rates during 1995-2002, but in the 2010 survey stunting levels were over 50%, one of the highest in the region. The birth history data from the three surveys provide little evidence of impact of the conflict on child mortality.



## Ethiopia

Ethiopia had suffered a major civil war during 1989-1991, had an extremely low CCI of 15% in 2000 and increased to 21% by 2005, followed by a decade of major increases. The impact of the war between Eritrea and Ethiopia about the location of the border began in May 1998 and lasted until June 2000, on population rates of battle-related deaths and displacement were much smaller for Ethiopia than for Eritrea given its much larger population, even though actual numbers of casualties were high on the Ethiopian side.

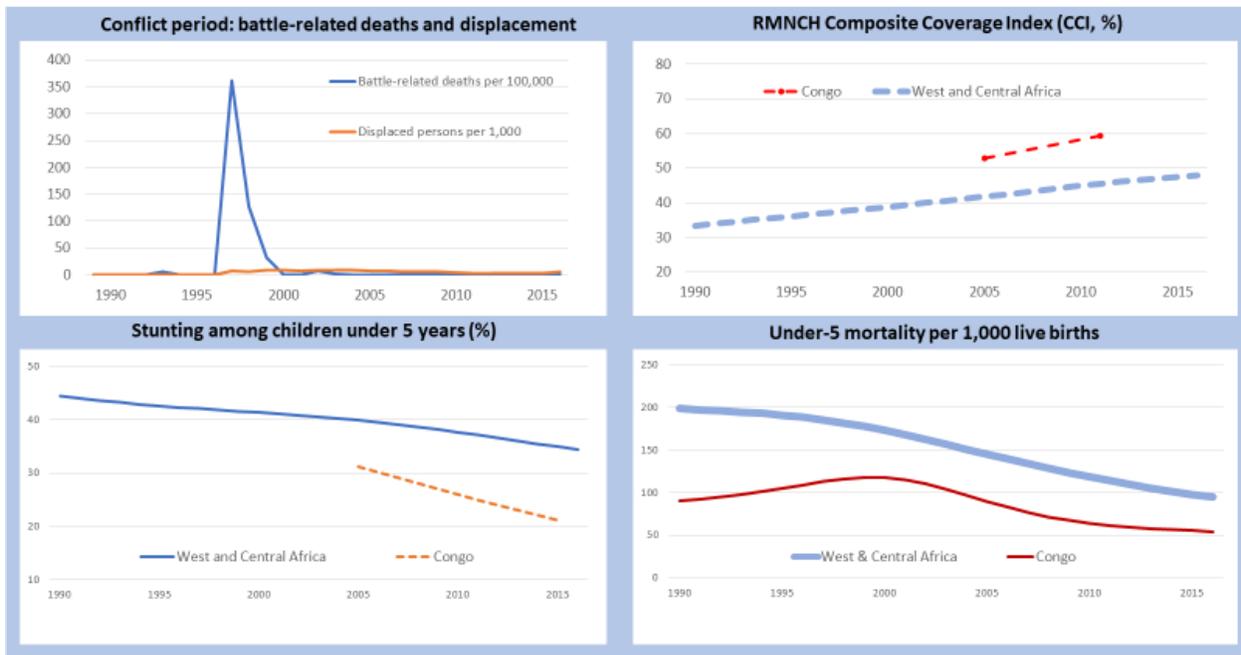
Ethiopia conducted its first DHS survey in 2000, just after the conflict. The survey showed a very low CCI (19%) with an enormous deficit compared with the subregion, which was reduced gradually in subsequent DHS in 2005, 2010 and 2016 to a gap of just over 10%. Ethiopian children had much higher stunting levels (57%) than the subregion in 2000 (45%) but experienced much greater improvements since then and the absolute gap reduced gradually over time. The child mortality trend based on the UN IGMR estimates from all surveys shows little national impact of the conflict.



## Congo (Brazzaville)

The Republic of the Congo experienced civil wars during 1993-94 and 1997-99, with three parties involved, often concentrated in the cities, especially Brazzaville, but affecting the whole country. The second civil war had very high rates of battle-related mortality. The first DHS was conducted several years post conflict in 2005, followed by surveys in 2011 and 2015. For all three indicators DR Congo has better statistics than the average for West and Central Africa. The first survey in 2005 shows considerably higher CCI and lower stunting levels than the rest of the subregion. The child mortality trend however shows a major impact on the trend in under-five mortality during the nineties, albeit at much lower levels than the subregion. The decline in mortality started after 2000 according to the UN IGME estimates from all available data.

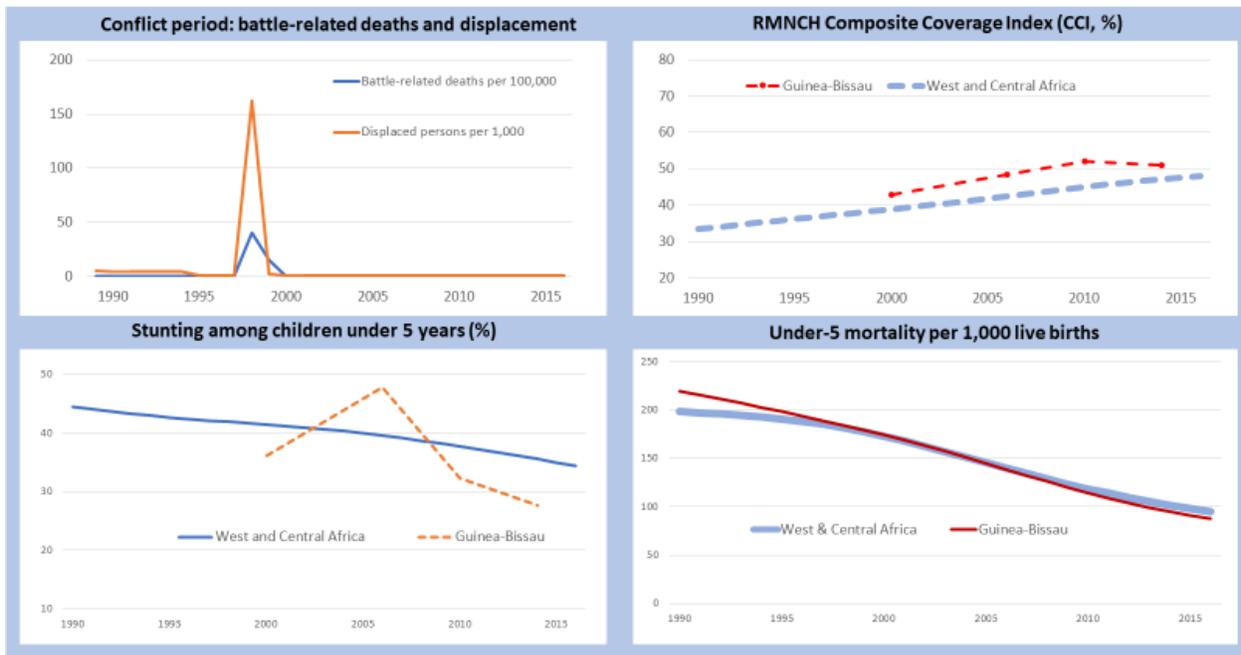
## Congo (Brazzaville)



## Guinea-Bissau

An attempted coup d'état triggered the Guinea-Bissau civil War in June 1998 which was fought for nearly a year. The peace agreement was signed in November 1998, even though there was still a brief outbreak of fighting in May 1999. Guinea-Bissau conducted its first MICS shortly after the war ended in 2000, followed by surveys in 2006, 2010 and 2014. The MICS 2000 showed slightly higher CCI than the subregional average and a faster increase than the subregion during 2000-2010. Stunting levels were below the subregional average in 2000, and even more so by 2010. The findings in the MICS 2006 showed a large increase in the first five years post-war and then a rapid decline to restore levels again well below the subregional average. The child mortality trend seemed unaffected by the civil war.

## Guinea-Bissau



## Appendix D: Data by country for Figures 1-3

**Table: RMNCH Composite Coverage Index (CCI) in conflict-affected countries based on surveys conducted during conflict phase, within 5 years post-conflict and 5-9 years post-conflict: absolute difference of country CCI and subregional estimates for eastern and southern Africa and for West and Central Africa for the survey year.**

	During conflict	Post 0-4 years	Post 5-9 years
<b>Eastern and Southern Africa</b>			
Angola	-7.8		-15.5
Burundi	-4.6	7.0	5.8
Eritrea		-1.1	-2.7
Ethiopia	-31.6	-28.0	-20.7
Mozambique		-4.7	8.6
Rwanda	-6.4	-6.3	14.3
Uganda	-0.1	1.8	5.3
<b>West and Central Africa</b>			
Chad	-15.6	-17.5	-13.3
Congo		-3.0	13.9
DR Congo	-1.8	5.2	6.3
Guinea-Bissau		-7.5	-6.4
Liberia		7.4	14.8
Sierra Leone	4.5	8.7	19.8
Median	-5.5	-2.1	5.8
Median (7, 3 data points)	-4.6	1.8	5.8
Median (first, last)	-4.6		5.3
Median (2nd, last)		-1.1	5.8

**Table: Stunting and wasting among children under 5 years in conflict-affected countries based on surveys conducted during conflict phase, within 5 years post-conflict and 5-9 years post-conflict: absolute difference of country value and subregional estimates for eastern and southern Africa and for West and Central Africa for the survey year.**

### Stunting

	During conflict	Post 0-4 years	Post 5-9 years
<b>Eastern &amp; Southern Africa</b>			
Angola			2.0
Burundi	15.3	18.4	20.3
Eritrea		-0.4	11.2
Ethiopia	12.3	8.3	5.1
Mozambique		2.1	3.5
Rwanda	3.2	9.3	5.2
Uganda	-0.3	-3.1	-4.7
<b>West and Central Africa</b>			
Chad	-2.1	4.4	5.3
Congo		-8.9	-11.2
DR Congo	3.2	6.5	6.0
Guinea-Bissau		-5.3	8.0
Liberia		-0.3	-4.1
Sierra Leone	-3.0	6.8	7.4
Median	3.2	3.3	5.2
Mean (7, 3 data points))	3.2	7.6	5.6
Mean (first, last)	3.2		5.6
Mean (2nd, last)		3.3	5.2

### Wasting

	During conflict	Post 0-4 years	Post 5-9 years
<b>Eastern &amp; Southern Africa</b>			
Angola			-1.6
Burundi	1.0	-1.4	-1.4
Eritrea		6.7	7.8
Ethiopia	3.9	4.3	2.6
Mozambique		1.0	-2.8
Rwanda	0.2	-3.2	-4.5
Uganda	-3.5	-1.6	-2.6
<b>West and Central Africa</b>			
Chad	1.1	4.0	3.7
Congo		-4.0	-4.6
DR Congo	8.3	2.3	-2.6
Guinea-Bissau		-1.0	-3.0
Liberia		-4.1	-4.9
Sierra Leone	-1.2	-1.8	-1.9
Median	1.0	-1.2	-2.6
Mean (7, 3 data points))	0.6	-1.5	-2.2
Mean (first, last)	0.6		-2.2
Mean (2nd, last)		-1.2	-2.6

**Table: Difference of the average annual rate of change (AARC) in under-five mortality between conflict-affected country and the subregional trends for eastern and southern Africa or West and Central Africa (e.g. negative value indicates absolute percent slower decline than subregion).**

Country	Main period of conflict*	Before conflict	During conflict	Post-conflict: first 5 years	Post-conflict: second 5 years	Strength of evidence of impact of conflict#
Rwanda	1990-2001	-	-3.6	6.9	6.7	strong
Uganda	1990-2004	-	-3.2	3.2	2.1	strong
Burundi	1995-2005	-0.9	0.2	-0.8	-0.5	moderate
Eritrea	1999-2000	3.9	1.5	-0.1	-1.2	weak
Ethiopia	1999-2000		0.5	0.6	0.7	none
Angola	1990-2001	-	-1.1	-0.2	1.6	strong
Mozambique	1990-1993	-	-0.2	1.7	2.4	strong
Sierra Leone	1991-2000	-	-2.9	-0.7	2.4	moderate
Liberia	1990-2003	-	2.6	3.8	1.6	weak
DR Congo	1996-2003	-0.1	-0.5	-0.6	-0.3	weak
Chad	2006-2008	-	-0.9	-1.7	-	none
Congo	1997-2003	-4.1	-2.2	3.6	1.2	strong
Guinea-Bissau	1999-2000	1.0	0.1	0.3	0.9	weak
	Median*		-1.1	1.7	1.6	

\*Includes main as well as lingering conflict phase, based on criteria described in the Methods section; # Qualitative assessment of authors; \*\* Excluding Chad and the three short term conflict countries (Eritrea, Ethiopia, Guinea-Bissau)

The qualitative assessment by the authors was entirely based on the extent to which the indicator trends during the different phases related to the conflict corresponded with the temporality, intensity and severity of the conflict. No formal analysis was attempted given the relatively small number of countries and the heterogeneity of the countries in terms of conflicts (including the often complex situations related to displacement) and surveys.

<sup>i</sup> Verpoorten M. Le coût en vies humaines du génocide rwandais : le cas de la province de Gikongoro. *Population* 2005, 60: 331-367.