

Clustering of under-five mortality in the Navrongo HDSS in the Kassena-Nankana District of northern Ghana

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Background: Under-five mortality is a major public health problem and one of the health indicators of health care in sub-Saharan Africa. In order to address inefficient health systems, there is a need to identify the spatial distribution of under-five mortality, especially areas of high mortality clustering. This study aimed to explore spatial and temporal clustering in under-five mortality in the Kassena-Nankana¹ District of the Upper East region.

Methods: We used data from the Navrongo Health and Demographic Surveillance System in the Kassena-Nankana District of northern Ghana, which had an average population of 140,000 of which about 18,400 were under five years of age. We analysed under-five mortality in 49 villages during the period 1997–2006. We calculated total under-five mortality rates and investigated their geographical distributions. A spatial scan statistic was used to test for clustering of the mortality in both space and time.

Results: Under-five mortality has been declining during the period. However, the data show a persistently higher than average clustering of mortality over the period among villages mainly in the north-eastern parts of the district.

Conclusion: There is a higher than average under-five mortality clustering in the villages in the north-east of the district and this may suggest a relatively poor health care system despite the many health interventions that took place over time in the district, including the Community Health and Family Planning Project, whose impact may not have been felt in these parts of the district between 1995 and 2004.

Keywords: *poor health care; under-five mortality; clustering; demographic surveillance; space and space-time scan statistic*

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Under-five mortality is a major public health problem in sub-Saharan Africa. Decades of sustained child mortality reductions still see the mortality levels in some parts of Africa, though decreasing generally, to be relatively high (1). In some other countries there is still an increased trend in under-five mortality (2). The reasons for this are varied: low socio-economic conditions, poor immunisation provisions, low literacy and poor access to and utilisation of health care are a few examples. Environmental conditions like access to good water and toilet facilities are also contributing factors and, in particular, poor housing conditions that predispose to crowding. Strong mortality clustering in a community may indicate the presence of an unequal

distribution of health and health-related resources and infrastructures. It also suggests a concentration of nutritional and sanitary behaviours harmful to the good health and longevity of children (3). Public health systems would need information on under-five mortality for efficient implementation of control programmes and policy (4). We set out to explore spatial and temporal clustering of under-five mortality in the Kassena-Nankana District of the Upper East region. We hypothesised that villages that had poor access to health services were more likely to have an excess of higher mortality than those with good access. The Navrongo Health and Demographic Surveillance System (NHDSS) (5) has been collecting demographic and geographic information for over 10 years and this affords the opportunity to assess spatial and temporal clustering of under-five mortality in the district. The NHDSS started with a baseline census of the rural district in 1993. The

¹In 2008, the Kassena-Nankana District was split into two districts: Kassena-Nankana West District and Kassena-Nankana East District.

Household Registration System (HRS) is the computing software used for processing and analysing the NHDSS database. All vital demographic events occurring within the district are updated through regular visits to each compound every 90 days. Thus, during these compound visits, new events such as births, deaths, marriages, in- and out-migration and obvious pregnancies are registered. Pregnancies recorded earlier are also monitored during these quarterly visits until the pregnancies are finished. This is to help improve on birth and death reporting, by capturing neonatal deaths in particular. For every vital event that is recorded, detailed information is collected using the appropriate event registration form.

By describing mortality by community and by year, we are able to identify villages with higher than average mortality. We first describe the main characteristics of the population over a 10-year period from 1997 to 2006. We then graphically highlight, through spatial and temporal analysis, villages that were clustered with higher than average mortality.

Materials and methods

Data used for the analysis presented in this paper were drawn from the NHDSS. We analysed the data on all under-fives living in the 49 villages spanning the district during the period 1997–2006. Total under-five mortality rates (MR) were calculated and their geographical distributions were investigated using a spatial scan statistic to test for clusters of higher than average under-five mortality in both space and time.

Study population

Geographical description

The study area is the Kassena-Nankana District in the Upper East region of Ghana, sharing borders with Burkina Faso (Fig. 2) (<http://www.ghanaweb.com/image-lib/dest/12307026.gif>). Ghana is located on West Africa's Gulf of Guinea, only a few degrees north of the Equator. It lies between longitudes 3°15' W and 1°12' E and latitude 4°44' S and 11°15' N. The country shares borders on the west with La Cote d'Ivoire, the east with the Republic of Togo and the north with Burkina Faso. The 2000 population census gave the population as 18,800,000 with a growth rate of 2.4% (6). Infant and under-five mortality are estimated to have worsened to 64 and 111 deaths, respectively, per 1,000 live births compared to 57 and 108 deaths in 1998, respectively (7). Ghana's (8) economy is dominated by agriculture, which contributes over 36% of gross domestic product (GDP), and about 55% of the population relies on agriculture for their income.

The Kassena-Nankana District has a rural setting with an area of 1,675 km². The population in 1999 was 140,880 with a density of 84 inhabitants per square kilometre. Of the population, 53% were female. In all, 18,400 of the population were children aged 0–4 years in

1999. These results were derived using the data from the Navrongo Demographic Surveillance systems available at the time.

Ethical issues

The Navrongo Health Research Centre sought consent from the Ministry of Health at the time of the establishment of the demographic surveillance system in 1993. Chiefs and their peoples consented verbally at durbars, and compound and household heads consented verbally at the time of every interview. The Navrongo Health Research Centre's Institutional Review Board, which monitors all research activities, also gave approval for the projects that took place afterwards in the district.

Statistical methods

Mortality rates (MR) for the HDSS data

We calculated the under-five MR by village i ($i = 1, \dots, 49$) for years j ($j = 1997, \dots, 2006$) using the formula $MR_{ij} = (d_{ij}/n_{ij})$, where n_{ij} denotes the person-years of children aged 0–4 years in village i at year j , and d_{ij} is the corresponding observed number of deaths. In order to identify villages in which the mortality rate was significantly above average for that particular year, a Poisson 95% confidence interval (CI) was calculated for each rate using Stata 9.1 (9). We considered a rate significantly above average if the lower confidence level of that rate was greater than the upper confidence level of the average rate for the respective year, a procedure commonly used in descriptive epidemiology.

Method to investigate mortality clustering

In this study, the spatial scan statistic (10) effected in SaTScan™ v7.1.0.3 (11) was used to identify clusters of deaths in the Kassena-Nankana District. SaTScan™ v7.1.0.3 identifies a cluster at any location of any size up to a maximum size, and minimises the problem of multiple statistical tests. We ran a purely spatial analysis, scanning for clusters with high rates using the Poisson model. Scanning was set to search only for villages with high proportions of deaths because we were interested in identifying the villages with higher than average mortality. No geographic overlap was used as a default setting, so secondary clusters would not overlap the most significant cluster. In order to scan for small to large clusters, the maximum cluster size was set to 50% of the total population at risk. To ensure sufficient statistical power, the number of Monte Carlo replications was set to 999, and clusters with a statistical significance of $p < 0.05$ were reported. We applied this method to the HDSS population for each year separately. We also applied the spatial scan statistic using the space–time option to the data for the time window 1997–2006.

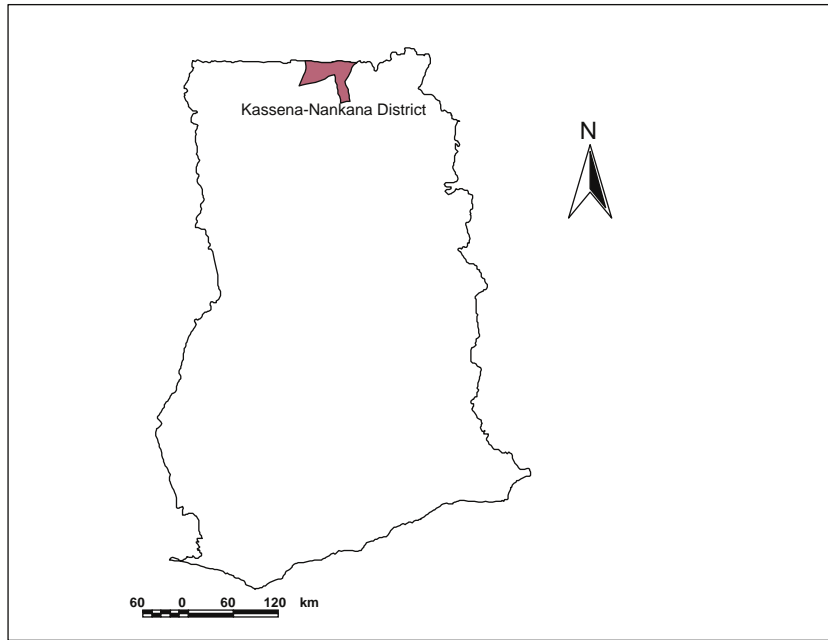


Fig. 1. Map of Ghana showing the location of the Kassena-Nankana District.

Results

Fig. 1 shows a map of the study area in relation to the national setting. Fig. 2 shows a chart of under-five mortality with Poisson 95% CI in the whole district for the period 1997–2006. There was a general decreasing trend in mortality over this period with a rate of 35.8 per 1,000 person-years in 1997 and ending with 17.3 per 1,000 person-years in 2006. However, the rate for 2000 was as high as that for 2007 which was 36.9 per 1,000 person-years. The MR with their Poisson 95% CIs for children under-five years for the period 1997–2006 for each of the 49 villages constituting the Kassena-Nankana District are shown in Table 1. MR that are significantly higher than the average rate for that year have been bolded in the table. In 1997, Kayoro in the western part of the district had a mortality rate of 67.3 (CI: 47.2, 93.2)

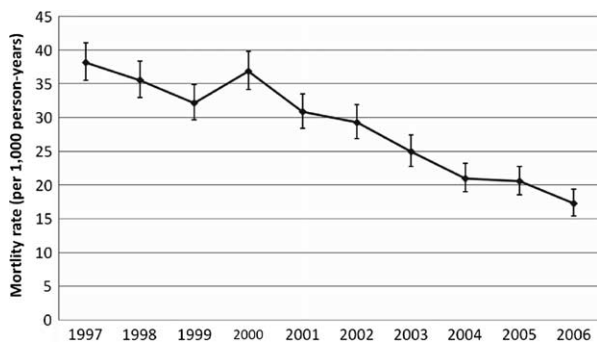


Fig. 2. Mortality rates (with 95% CI) of under-five population under surveillance from 1997 to 2006 in the Kassena-Nankana District.

deaths per 1,000 person-years compared to the district average rate of 38.2 (CI: 35.5, 41.1) deaths per 1,000 person-years. In 1998, Azeaduma with 64.7 (CI: 38.9, 101.0) deaths per 1,000 person-years and Kaasi/Akaamo with 72.3 (CI: 40.5, 119.0) deaths per 1,000 were above the average mortality rate of 35.6 (CI: 33.0, 38.4) deaths per 1,000 person-years. Both these villages are in the eastern part of the district. In 2002, two villages with mortality above the average mortality rate of 29.3 (CI: 26.9, 31.9) deaths per 1,000 person-years were Naga in the south with 57.0 (38.2, 81.9) and Navio in the north with 51.8 (CI: 34.9, 73.9) deaths per 1,000 person-years. Pungu, which is close to Navrongo, the central part of the district, had the highest mortality in 2004 with 34.1 (CI: 24.7, 45.9) deaths per 1,000 person-years compared to the average mortality rate of 21 (CI: 19.0, 23.2) deaths per 1,000 person-years. The analysis also showed two villages in 2006 with MR above the average mortality rate of 17.3 (CI: 15.4, 19.4) per 1,000 deaths person-years. These were Naga with 37.5 (CI: 21.9, 60.1) and Nakolo in the north with 37.1 (CI: 21.2, 60.2) deaths per 1,000 person-years.

Results of the space and space-time scan statistic

Using SaTScan™ v7.0.3, spatial analysis was done to identify clusters of villages with significantly higher than average mortality. Total under-five mortality in the Kassena-Nankana District between 1997 and 2006 using purely spatial analysis scanning for high rates are shown in Table 2. Statistically significant clusters of higher mortality ($p < 0.05$) were identified in 1998, 1999, 2001, 2002 and 2003. In 1998, there were 22 villages of which

Table 1. Total under-five mortality in 49 villages in the Kassena-Nankana District in the period 1997–2006

Village	Mortality rate/1,000 person-years (95% CI)										
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Abempingo	68.8 (38.5, 113.5)	53.4 (27.6, 93.3)	23.8 (7.7, 55.6)	45.5 (21.8, 83.7)	43.4 (20.8, 79.7)	34.3 (14.8, 67.7)	33.9 (14.7, 66.9)	25.8 (9.5, 56.2)	20.9 (6.8, 48.7)	8.4 (1.0, 30.3)	
Asunia	28.7 (14.8, 50.2)	27.8 (14.4, 48.6)	18.9 (8.1, 37.2)	29.5 (15.2, 51.5)	19.3 (8.3, 38.1)	12.5 (4.1, 29.1)	39.3 (22.0, 64.8)	13.2 (4.3, 30.8)	18.8 (7.5, 38.7)	20.3 (8.2, 41.8)	
Atiyoro	67.1 (27.0, 138.2)	50.3 (16.3, 117.5)	45.3 (14.7, 105.6)	108.3 (56.0, 189.2)	77.3 (33.4, 152.3)	63.8 (25.6, 131.4)	50.8 (18.6, 110.5)	33.9 (9.2, 86.7)	50.3 (18.5, 109.5)	38.7 (12.6, 90.4)	
Azaasi	41.6 (13.5, 97.0)	62.5 (25.1, 128.8)	29.9 (6.2, 87.3)	44.9 (14.6, 104.7)	18.5 (2.2, 67.0)	62.6 (25.2, 129.0)	32.6 (8.9, 83.4)	16.5 (2.0, 59.6)	0.0 (0.0, 31.9)	29.3 (6.0, 85.6)	
Azeaduma	22.4 (9.0, 46.1)	64.7 (38.9, 101.0)	40.5 (20.9, 70.7)	53.7 (31.3, 85.9)	40.2 (20.8, 70.2)	37.7 (18.8, 67.5)	25.8 (11.1, 50.8)	22.3 (9.0, 46.0)	30.7 (14.0, 58.3)	23.7 (9.5, 48.9)	
Basengo	28.0 (10.3, 61.0)	41.6 (19.0, 78.9)	55.3 (27.6, 98.9)	39.7 (17.2, 78.3)	19.5 (5.3, 49.9)	34.2 (13.8, 70.5)	34.5 (13.9, 71.2)	14.0 (2.9, 41.0)	29.9 (11.0, 65.0)	14.9 (3.1, 43.6)	
Bembisi	17.8 (4.9, 45.7)	57.1 (29.5, 99.7)	51.7 (25.8, 92.5)	47.8 (22.9, 87.8)	76.7 (41.9, 128.7)	49.1 (22.5, 93.3)	38.9 (15.6, 80.2)	26.4 (8.6, 61.5)	32.3 (11.8, 70.2)	29.4 (10.8, 64.1)	
Biu	54.0 (30.9, 87.7)	25.9 (10.4, 53.3)	26.5 (10.7, 54.6)	41.7 (20.8, 74.6)	33.0 (15.1, 62.6)	15.2 (4.1, 38.8)	12.0 (2.5, 35.0)	8.0 (1.0, 29.0)	8.1 (1.0, 29.3)	0.0 (0.0, 15.2)	
Bonia	49.4 (25.5, 86.4)	43.0 (20.6, 79.1)	27.1 (9.9, 58.9)	32.3 (13.0, 66.5)	13.1 (2.7, 38.4)	8.7 (1.1, 31.4)	32.4 (13.0, 66.8)	9.4 (1.1, 33.8)	4.6 (0.1, 25.7)	4.8 (0.1, 26.7)	
Doba	22.6 (12.4, 38.0)	40.3 (26.1, 59.5)	21.8 (11.6, 37.2)	19.6 (10.1, 34.3)	29.2 (17.3, 46.2)	29.6 (17.6, 46.8)	30.3 (18.0, 47.9)	9.7 (3.6, 21.2)	13.3 (5.8, 26.3)	13.8 (6.0, 27.2)	
Gaani	37.7 (20.1, 64.4)	28.1 (13.5, 51.6)	18.9 (7.6, 38.9)	24.5 (11.2, 46.6)	26.6 (12.7, 48.9)	16.1 (5.9, 35.0)	18.9 (7.6, 38.9)	32.5 (16.8, 56.8)	14.6 (4.7, 34.0)	9.0 (1.9, 26.3)	
Gia	24.5 (10.6, 48.3)	36.4 (18.8, 63.6)	46.5 (26.6, 75.6)	17.3 (6.3, 37.6)	20.0 (8.0, 41.2)	29.5 (14.1, 54.3)	21.2 (8.5, 43.7)	23.9 (10.3, 47.1)	25.2 (10.9, 49.8)	13.6 (3.7, 34.8)	
Gomongo	33.6 (12.3, 73.2)	46.8 (21.4, 88.9)	47.4 (21.7, 89.9)	39.6 (17.1, 78.0)	35.0 (14.1, 72.0)	33.1 (13.3, 68.2)	33.9 (13.6, 69.8)	10.2 (1.2, 36.8)	48.4 (22.1, 91.9)	27.4 (8.9, 64.1)	
Gongnia	30.3 (12.2, 62.4)	23.1 (7.5, 53.8)	32.4 (13.0, 66.8)	34.2 (14.8, 67.4)	17.6 (4.8, 45.1)	37.4 (16.1, 73.6)	28.8 (10.6, 62.6)	14.3 (2.9, 41.7)	24.6 (8.0, 57.4)	10.2 (1.2, 36.7)	
Gunwoko	36.2 (19.3, 61.9)	23.0 (9.9, 45.3)	37.3 (19.9, 63.8)	41.2 (22.5, 69.1)	34.4 (17.8, 60.1)	28.1 (13.5, 51.7)	25.6 (12.3, 47.0)	15.0 (5.5, 32.7)	26.7 (12.8, 49.1)	21.7 (9.4, 42.8)	
Janania	37.1 (7.6, 108.4)	25.7 (3.1, 92.9)	50.6 (13.8, 129.4)	56.0 (18.2, 130.6)	0.0 (0.0, 41.6)	24.8 (3.0, 89.5)	26.1 (3.2, 94.2)	12.8 (0.3, 71.4)	13.4 (0.3, 74.4)	14.2 (0.4, 78.9)	
Kaasi/Akaamo	36.1 (15.6, 71.2)	72.3 (40.5, 119.2)	37.3 (16.1, 73.5)	27.8 (10.2, 60.6)	44.8 (21.5, 82.5)	51.5 (25.7, 92.2)	46.4 (22.3, 85.4)	36.6 (15.8, 72.1)	37.0 (16.0, 72.8)	9.2 (1.1, 33.3)	
Kafania/Saboro	33.5 (13.5, 69.0)	38.7 (16.7, 76.2)	14.8 (3.0, 43.1)	21.8 (5.9, 55.8)	34.3 (12.6, 74.6)	33.1 (10.7, 77.2)	12.7 (1.5, 45.7)	30.4 (9.9, 71.0)	6.5 (0.2, 36.1)	19.8 (4.1, 57.9)	
Kalvio/Gwenia	35.6 (23.4, 51.8)	30.9 (19.6, 46.3)	23.9 (14.2, 37.8)	32.7 (21.0, 48.7)	13.4 (6.4, 24.6)	25.6 (15.4, 40.0)	17.4 (9.3, 29.8)	30.9 (19.4, 46.8)	7.4 (2.4, 17.4)	28.0 (16.6, 44.2)	
Kanania	40.1 (17.3, 79.0)	5.3 (0.1, 29.7)	36.1 (14.5, 74.3)	36.1 (14.5, 74.5)	26.5 (8.6, 61.9)	40.5 (16.3, 83.5)	33.8 (12.4, 73.6)	23.3 (6.3, 59.7)	6.2 (0.2, 34.7)	19.6 (4.0, 57.3)	
Katiu	31.0 (16.5, 53.0)	38.8 (22.2, 63.1)	36.3 (20.3, 59.9)	39.7 (22.7, 64.5)	56.3 (36.1, 83.8)	37.5 (21.0, 61.8)	34.8 (19.0, 58.4)	21.9 (10.0, 41.6)	12.7 (4.1, 29.7)	5.4 (0.7, 19.6)	
Kayoro	67.3 (47.2, 93.2)	41.2 (25.5, 62.9)	30.1 (16.8, 49.6)	58.2 (39.0, 83.6)	51.0 (33.3, 74.8)	19.1 (9.1, 35.1)	29.4 (16.8, 47.7)	31.5 (18.4, 50.4)	32.5 (19.0, 52.1)	15.6 (7.1, 29.5)	
Kologo	40.5 (27.7, 57.2)	32.5 (20.8, 48.4)	16.7 (8.6, 29.2)	35.2 (23.0, 51.6)	19.7 (11.0, 32.5)	11.0 (4.7, 21.6)	18.8 (10.3, 31.5)	19.4 (10.9, 32.1)	23.9 (14.2, 37.7)	21.0 (11.8, 34.7)	
Korania	37.5 (17.2, 71.3)	12.4 (2.6, 36.2)	38.7 (17.7, 73.5)	29.9 (12.0, 61.6)	26.0 (9.5, 56.6)	13.4 (2.8, 39.1)	22.7 (7.4, 53.0)	19.6 (5.3, 50.1)	25.3 (8.2, 59.1)	11.0 (1.3, 39.9)	
Kurugu	32.4 (13.0, 66.7)	33.3 (13.4, 68.6)	52.4 (26.2, 93.8)	61.0 (32.5, 104.3)	61.1 (32.5, 104.5)	15.2 (3.1, 44.4)	34.0 (13.7, 70.0)	27.3 (10.0, 59.4)	39.9 (18.2, 75.7)	4.7 (0.1, 26.0)	
Longo	59.7 (36.5, 92.2)	46.7 (26.2, 77.1)	18.6 (6.8, 40.4)	27.8 (12.7, 52.8)	48.7 (27.2, 80.3)	23.1 (9.3, 47.5)	29.2 (13.3, 55.4)	12.7 (3.5, 32.6)	20.0 (7.3, 43.5)	24.9 (10.0, 51.3)	
Manyoro	50.1 (34.7, 70.1)	40.8 (26.9, 59.4)	45.8 (30.9, 65.3)	38.9 (25.2, 57.5)	37.1 (23.5, 55.7)	65.0 (46.0, 89.3)	21.5 (11.1, 37.6)	22.4 (11.9, 38.3)	19.8 (9.9, 35.5)	18.4 (8.8, 33.9)	
Mirigu	38.8 (26.4, 55.1)	53.5 (38.2, 72.8)	36.4 (24.2, 52.5)	35.5 (23.8, 51.0)	45.9 (32.1, 63.5)	29.1 (18.4, 43.6)	32.5 (21.4, 47.2)	26.4 (16.5, 39.9)	16.6 (8.8, 28.3)	17.7 (9.7, 29.7)	
Nabango	44.4 (28.7, 65.5)	39.6 (24.8, 60.0)	48.7 (31.8, 71.4)	35.9 (21.6, 56.0)	33.8 (20.0, 53.3)	39.6 (24.5, 60.5)	22.2 (11.5, 38.8)	29.3 (16.8, 47.6)	22.4 (11.6, 39.1)	12.5 (5.0, 25.7)	
Naga	48.8 (31.3, 72.7)	15.0 (6.1, 31.0)	29.9 (15.9, 51.1)	37.9 (21.6, 61.5)	11.4 (3.7, 26.6)	29.9 (15.9, 51.2)	25.6 (12.8, 45.9)	13.5 (5.0, 29.4)	22.1 (10.6, 40.6)	37.5 (21.9, 60.1)	
Nakolo	27.8 (15.6, 45.8)	43.0 (26.9, 65.0)	43.9 (27.9, 65.9)	41.8 (26.2, 63.2)	43.0 (27.3, 64.6)	57.0 (38.2, 81.9)	20.7 (9.9, 38.0)	14.8 (6.0, 30.5)	21.4 (10.3, 39.4)	37.1 (21.2, 60.2)	
Nakong	50.8 (18.6, 110.5)	49.2 (18.1, 107.1)	23.5 (4.8, 68.6)	54.4 (21.9, 112.2)	23.0 (4.7, 67.2)	13.3 (1.6, 48.2)	27.8 (7.6, 71.2)	6.7 (0.2, 37.4)	19.7 (4.1, 57.5)	6.6 (0.2, 36.9)	
Namolo	67.6 (18.4, 173.1)	17.5 (0.4, 97.3)	44.4 (9.2, 129.9)	29.9 (3.6, 108.2)	47.8 (9.8, 139.6)	27.8 (3.4, 100.6)	38.6 (8.0, 112.7)	0.0 (0.0, 42.6)	33.5 (6.9, 98.0)	10.1 (0.3, 56.1)	
Nangalkinia	38.9 (17.8, 73.8)	17.9 (4.9, 45.8)	38.7 (16.7, 76.2)	15.5 (3.2, 45.2)	29.5 (10.8, 64.3)	18.8 (5.1, 48.2)	33.2 (13.3, 68.3)	14.2 (2.9, 41.5)	25.4 (8.2, 59.2)	4.7 (0.1, 26.4)	
Natugnia	45.4 (30.2, 65.6)	38.8 (24.6, 58.2)	35.8 (22.2, 54.7)	46.5 (30.9, 67.2)	31.9 (19.2, 49.8)	26.6 (15.2, 43.1)	35.1 (22.0, 53.2)	14.7 (6.7, 27.8)	24.0 (13.1, 40.3)	29.9 (17.4, 47.9)	

Table 1 (Continued)

Village	Mortality rate/1,000 person-years (95% CI)									
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Navio	50.8 (33.7, 73.4)	47.4 (31.0, 69.5)	42.4 (27.5, 62.6)	44.1 (28.8, 64.6)	40.7 (25.8, 61.1)	51.8 (34.9, 73.9)	33.4 (20.1, 52.2)	17.6 (8.4, 32.3)	21.5 (11.1, 37.6)	14.3 (6.2, 28.2)
Nawognia	21.4 (4.4, 62.7)	36.8 (13.5, 80.0)	33.7 (10.9, 78.6)	13.3 (1.6, 48.1)	13.8 (1.7, 49.8)	34.6 (11.2, 80.7)	0.0 (0.0, 27.0)	43.7 (16.0, 95.1)	0.0 (0.0, 25.8)	0.0 (0.0, 26.2)
Nayagenia	20.1 (8.7, 39.7)	28.3 (14.2, 50.7)	20.4 (8.8, 40.3)	25.7 (12.3, 47.2)	23.3 (10.7, 44.3)	14.7 (5.4, 32.0)	7.2 (1.5, 20.9)	27.2 (13.6, 48.7)	21.1 (9.1, 41.6)	21.0 (9.1, 41.4)
Nkwanta	56.4 (34.0, 88.1)	29.1 (13.3, 55.2)	26.2 (11.3, 51.6)	36.8 (18.4, 65.9)	28.9 (13.2, 54.8)	33.5 (16.1, 61.6)	38.0 (19.0, 67.9)	33.7 (16.2, 62.0)	29.5 (13.5, 56.0)	26.1 (11.3, 51.4)
Nogsinia	28.0 (20.0, 38.1)	14.1 (8.5, 22.1)	22.3 (15.1, 31.9)	23.1 (15.7, 32.8)	18.7 (12.1, 27.6)	17.1 (10.8, 25.6)	19.8 (13.1, 28.9)	19.2 (12.7, 27.9)	12.1 (7.0, 19.3)	12.0 (7.0, 19.2)
Nyangnia	38.8 (18.6, 71.4)	37.9 (17.3, 72.0)	22.2 (7.2, 51.8)	57.7 (30.7, 98.6)	25.8 (9.5, 56.1)	26.0 (9.5, 56.6)	22.2 (7.2, 51.8)	13.6 (2.8, 39.8)	8.4 (1.0, 30.5)	0.0 (0.0, 16.5)
Nyangoligo	42.2 (21.8, 73.8)	50.9 (27.1, 87.1)	23.6 (8.7, 51.3)	29.3 (12.7, 57.7)	57.1 (31.2, 95.8)	17.4 (4.8, 44.7)	41.7 (20.0, 76.6)	8.1 (1.0, 29.1)	4.0 (0.1, 22.5)	3.9 (0.1, 21.9)
Paga	31.6 (22.4, 43.4)	35.4 (25.4, 48.0)	27.4 (18.6, 38.9)	39.0 (28.5, 52.2)	28.6 (19.7, 40.2)	24.5 (16.4, 35.1)	15.6 (9.4, 24.4)	15.1 (9.1, 23.7)	21.0 (13.8, 30.6)	13.9 (8.2, 21.9)
Pindaa	89.7 (24.4, 229.6)	49.4 (6.0, 178.5)	49.9 (6.0, 180.1)	22.5 (0.6, 125.1)	90.6 (24.7, 232.1)	21.9 (0.6, 121.8)	25.8 (0.7, 143.6)	0.0 (0.0, 87.7)	0.0 (0.0, 91.7)	13.9 (1.7, 50.2)
Pungu	37.6 (28.0, 49.4)	39.1 (29.2, 51.3)	35.5 (26.0, 47.3)	40.8 (30.6, 53.4)	19.5 (12.6, 28.7)	27.5 (19.3, 38.1)	20.2 (13.2, 29.6)	34.1 (24.7, 45.9)	24.0 (16.1, 34.5)	17.1 (10.4, 26.4)
Saboro	17.4 (3.6, 50.8)	16.6 (3.4, 48.6)	39.7 (16.0, 81.8)	41.1 (16.5, 84.7)	23.1 (6.3, 59.2)	31.1 (10.1, 72.6)	18.9 (3.9, 55.2)	12.0 (1.4, 43.2)	24.0 (6.6, 62.5)	30.4 (9.9, 70.8)
Vunania	42.3 (19.3, 80.3)	35.3 (14.2, 72.7)	25.5 (8.3, 59.5)	20.3 (5.5, 51.9)	49.8 (23.9, 91.7)	47.6 (21.8, 90.3)	5.4 (0.1, 30.2)	16.2 (3.3, 47.2)	10.8 (1.3, 39.1)	18.3 (3.8, 53.6)
Wuru	50.6 (16.4, 118.0)	0.0 (0.0, 41.8)	23.4 (2.8, 84.5)	21.3 (2.6, 76.9)	19.4 (2.4, 70.2)	30.4 (6.3, 88.9)	0.0 (0.0, 40.1)	0.0 (0.0, 40.1)	34.2 (7.1, 100.0)	39.4 (8.1, 115.2)
Yua	33.4 (18.7, 55.1)	37.6 (21.5, 61.0)	43.4 (25.7, 68.5)	62.3 (40.3, 91.9)	30.6 (15.8, 53.5)	37.0 (20.2, 62.1)	24.5 (11.8, 45.1)	23.6 (11.3, 43.4)	38.5 (22.0, 62.6)	19.1 (8.3, 37.7)
Average	38.2 (35.5, 41.1)	35.6 (33.0, 38.4)	32.2 (29.7, 34.9)	36.9 (34.2, 39.8)	30.9 (28.4, 33.5)	29.3 (26.9, 31.9)	25.0 (22.8, 27.4)	21.0 (19.0, 23.2)	20.6 (18.6, 22.8)	17.3 (15.4, 19.4)
Range	[17.4, 89.7]	[0, 72.3]	[14.8, 55.3]	[13.3, 108.3]	[0, 90.6]	[8.7, 65.0]	[0, 50.8]	[0, 43.8]	[0, 50.3]	[0, 39.4]

Note: Bold numbers in cells indicate mortality rates ($p < 0.05$) significantly above average in the respective year.

Table 2. Total under-five mortality in the Kassena-Nankana District for 1997–2006 using purely spatial analysis scanning for high rates

Year	Type	Location	Observed cases	Expected cases	RR	<i>p</i> -Value
1997	Most likely	Kayoro	36	21	1.7	0.2
1998	Most likely	Basengo, Gunwoko, Nyangoligo, Yua, Bembisi, Natugnia, Longo, Kurugu, Nabango, Manyoro, Azeaduma, Gomongo, Mirigu, Kaasi/Akaamo, Azaasi, Atiyoro, Navio, Nakolo, Nkwanta, Doba, Pungu, Abempingo	412	341	1.5	0.001
1999	Most likely	Manyoro, Gomongo, Natugnia, Nakolo, Navio, Nyangoligo, Gunwoko, Mirigu, Basengo, Bembisi, Yua, Nabango, Longo Pungu, Azeaduma, Kurugu, Azaasi, Paga Saboro, Namolo, Kaasi/Akaamo	362	303	1.5	0.001
2000	Most likely	Gunwoko, Basengo, Nyangoligo, Yua, Bembisi, Natugnia, Longo, Kurugu, Nabango, Manyoro, Gomongo, Mirigu, Azeaduma, Kaasi/Akaamo, Azaasi, Atiyoro, Navio, Nakolo, Nkwanta, Pungu	371	324	1.3	0.041
2001	Most likely	Basengo, Gunwoko, Nyangoligo, Yua, Bembisi, Natugnia, Longo, Kurugu, Nabango, Manyoro, Azeaduma, Gomongo, Mirigu, Kaasi/Akaamo, Azaasi, Atiyoro, Navio, Nakolo	283	219	1.5	0.001
2002	Most likely	Basengo, Gunwoko, Nyangoligo, Yua, Bembisi, Natugnia, Longo, Kurugu, Nabango, Manyoro, Azeaduma, Gomongo, Mirigu, Kaasi/Akaamo, Azaasi, Atiyoro, Navio, Nakolo, Nkwanta, Doba, Pungu, Abempingo	347	273	1.7	0.001
2003	Most likely	Kurugu, Azeaduma, Longo, Kaasi/Akaamo, Bembisi, Nabango, Azaasi, Atiyoro, Mirigu, Nkwanta, Gunwoko, Basengo, Abempingo, Nyangoligo, Doba, Gomongo, Natugnia	200	150	1.6	0.001
2004	Most likely	Nkwanta, Atiyoro, Abempingo, Azaasi, Doba, Kaasi/Akaamo, Azeaduma, Nabango, Kurugu, Mirigu, Longo, Janania, Nayagenia, Vunania, Bembisi, Gaani, Pungu	174	140	1.4	0.053
2005	Most likely	Gunwoko, Basengo, Nyangoligo, Yua, Bembisi, Natugnia, Longo, Kurugu, Nabango, Manyoro, Gomongo, Mirigu Azeaduma, Kaasi/Akaamo, Azaasi, Atiyoro, Navio, Nakolo, Nkwanta, Pungu	342	293	1.3	0.015
2006	Most likely	Manyoro, Gomongo, Natugnia, Nakolo	62	38	1.75	0.013

20 were in the eastern part of the district. The cases observed were 412 (341 expected) with a relative risk of 1.5. Twenty-one villages with a relative risk of 1.5 were identified in 1999 with 362 cases (303 expected), 17 of the villages in the east of the district. The statistically significant clusters for 2001 and 2003 contained 18 and 17 villages, respectively, in the east of the district. The cases in 2001 were 283 (219 expected) and a relative risk of 1.5 and 200 cases (150 expected) and a relative risk of 1.6 in 2003. In 2002, the cluster identified to be statistically significant comprised 22 villages and all but one village were in the east. In 2000, the cluster comprised 20 villages, with 371 observed cases (324 expected) and a relative risk of 1.3. These villages have been consistently appearing as significant over the years. The statistically significant cluster in 2004 was not different from that in 2005, with almost the same villages featuring. However, in 2006 the statistically significant

cluster with a *p*-value of 0.013 comprised only four villages with 62 observed and 38 expected cases with a relative risk of 1.73.

Table 3 shows the total under-five mortality in the Kassena-Nankana District for 1997–2006 using space–time analysis scanning for high rates. Two villages were located in the secondary cluster with a relative risk of 1.7, whereas the 19 villages were identified within the primary cluster, also with a relative risk of 1.7 (Fig. 3). The total number of deaths observed was 1,798 for the primary cluster villages with the expected number of deaths being 1,223, whereas in the secondary cluster, 211 deaths were observed with the expected number being 124. All the villages in the primary cluster were located in the eastern part of the district, whereas the secondary cluster villages were in the west of the district. Table 4 shows the number of deaths with their person-years by village and year during the period of

Table 3. Total under-five mortality in the Kassena-Nankana District for 1997–2006 using space–time* analysis scanning for high rates

Year	Type	Location	Observed cases	Expected cases	RR	p-Value
1997–2006	Most likely	Basengo, Gunwoko, Nyangoligo, Yua, Bembisi, Natugnia, Longo, Kurugu, Nabango, Manyoro, Azeaduma, Gomongo, Mirigu, Kaasi/Akaamo, Azaasi, Atiyoro, Navio, Nakolo, Nkwanta	1,798	1,223	1.7	0.001
	Secondary	Kayoro, Katiu	211	124	1.7	0.001

*Space–time results indicate significantly higher clusters for the years 1997–2001.

the study. These data were used to calculate the rates in Table 1.

Discussion

Between 1999 and 2003, the under-five mortality rate dropped significantly from 155 per 1,000 live births to 79 per 1,000 in Upper East region, while increasing in an adjacent region with similar socio-economic conditions (12).

Analysis of the data for the period 1997–2006 showed an overall under-five mortality rate of 28.8 per 1,000 person-years for the Kassena-Nankana District. An earlier study of cause-specific mortality in the period 1999–2002 gave a crude mortality rate of 15.6 per 1,000 person-years (13). Using data from that same study, we calculated the under-five mortality as 34.1 per 1,000 person-years. However, the highest rate (38.2 per 1,000 person-years) was in 1997, while the lowest (17.3 per

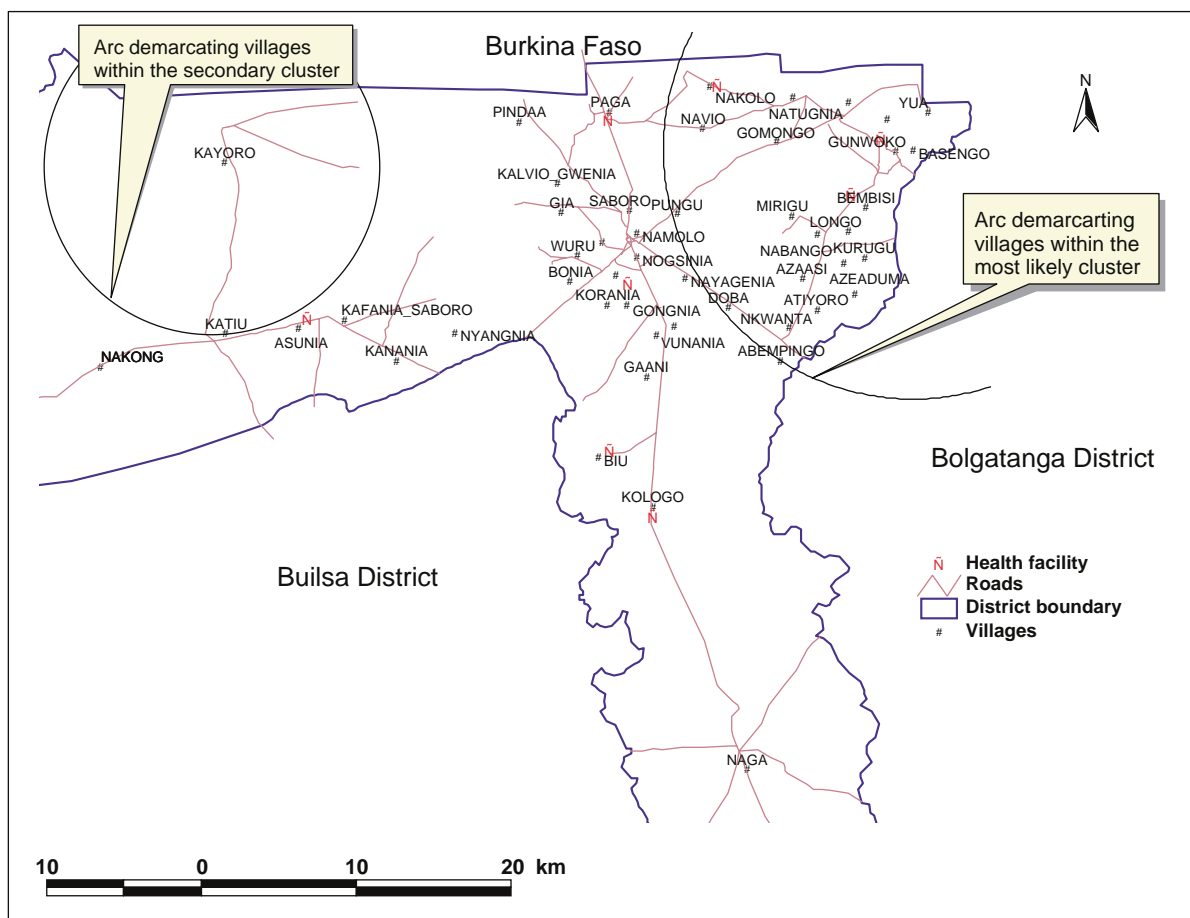


Fig. 3. Map showing the locations of significant clusters of higher total under-five mortality between 1997 and 2005 in the Kassena-Nankana District.

Table 4. A record of deaths and person-years of the 49 villages in the Kassena-Nankana District in the period 1997–2006

Village	Deaths per person-years by village during the 10-year period									
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Abempingo	15/218	12/225	5/210	10/220	10/231	8/233	8/236	6/232	5/240	2/239
Asunia	12/418	12/431	8/424	12/407	8/414	5/400	15/382	5/379	7/373	7/345
Atiyoro	7/104	5/99	5/110	12/111	8/104	7/110	6/118	4/118	6/119	5/129
Azaasi	5/120	7/112	3/100	5/111	2/108	7/112	4/123	2/121	0/116	3/102
Azeaduma	7/313	19/294	12/296	17/317	12/299	11/292	8/310	7/314	9/293	7/295
Basengo	6/214	9/217	11/199	8/201	4/205	7/204	7/203	3/214	6/201	3/201
Bembisi	4/224	12/210	11/213	10/209	14/183	9/183	7/180	5/190	6/186	6/204
Biu	16/296	7/270	7/264	11/264	9/273	4/264	3/250	2/249	2/246	0/243
Bonia	12/243	10/233	6/222	7/217	3/228	2/230	7/216	2/214	1/217	1/208
Doba	14/619	25/620	13/597	12/612	18/616	18/608	18/594	6/617	8/599	8/579
Gaani	13/345	10/356	7/371	9/367	10/376	6/374	7/371	12/369	5/343	3/333
Gia	8/327	12/330	16/344	6/347	7/350	10/339	7/330	8/334	8/317	4/294
Gomongo	6/179	9/192	9/190	8/202	7/200	7/211	7/207	2/197	9/186	5/182
Gongnia	7/231	5/217	7/216	8/234	4/227	8/214	6/209	3/210	5/203	2/197
Gunwoko	13/359	8/348	13/348	14/340	12/349	10/356	10/391	6/399	10/375	8/368
Janania	3/81	2/78	4/79	5/89	0/89	2/81	2/77	1/78	1/75	1/71
Kaasi/Akaamo	8/221	15/208	8/214	6/216	10/223	11/214	10/215	8/219	8/216	2/217
Kafania/Saboro	7/209	8/207	3/203	4/183	6/175	5/151	2/158	5/164	1/154	3/151
Kalvio/Gwenia	27/759	23/745	18/752	24/733	10/749	19/741	13/745	22/712	5/672	18/644
Kanania	8/200	1/188	7/194	7/194	5/189	7/173	6/177	4/172	1/161	3/153
Katiu	13/419	16/412	15/413	16/403	24/426	15/400	14/402	9/410	5/392	2/368
Kayoro	36/535	21/510	15/498	29/498	26/509	10/525	16/544	17/540	17/523	9/578
Kologo	32/789	24/738	12/717	26/738	15/761	8/729	14/746	15/771	18/754	15/714
Korania	9/240	3/242	9/232	7/234	6/231	3/224	5/220	4/204	5/197	2/181
Kurugu	7/216	7/210	11/210	13/213	13/213	3/197	7/206	6/220	9/226	1/214
Longo	20/335	15/321	6/323	9/323	15/308	7/303	9/308	4/314	6/300	7/281
Manyoro	34/678	27/661	30/655	25/642	23/619	38/584	12/557	13/580	11/554	10/543
Mirigu	31/799	40/748	28/770	29/817	36/785	23/791	27/832	22/834	13/785	14/792
Nabango	25/563	22/555	26/534	19/530	18/533	21/530	12/541	16/546	12/536	7/560
Naga	24/491	7/465	13/435	16/423	5/439	13/434	11/429	6/444	10/453	17/453
Nakolo	15/540	22/512	23/523	22/527	23/534	29/509	10/483	7/473	10/467	16/431
Nakong	6/118	6/122	3/128	7/129	3/130	2/150	4/144	1/149	3/153	1/151
Namolo	4/59	1/57	3/68	2/67	3/63	2/72	3/78	0/87	3/89	1/99
Nangalkinia	9/231	4/224	8/207	3/194	6/203	4/213	7/211	3/211	5/197	1/211
Natugnia	28/617	23/593	21/586	28/602	19/596	16/602	22/626	9/614	14/583	17/568

Table 4 (Continued)

Village	Deaths per person-years by village during the 10-year period									
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Navio	28/551	26/548	25/589	26/589	23/564	30/580	19/569	10/569	12/558	8/558
Nawognia	3/140	6/163	5/148	2/150	2/145	5/145	0/136	6/137	0/143	0/141
Nayagenia	8/397	11/388	8/391	10/389	9/386	6/409	3/419	11/405	8/379	8/380
Nkwanta	19/337	9/310	8/305	11/299	9/312	10/299	11/290	10/296	9/305	8/306
Nogsinia	40/1,430	19/1,344	30/1,343	31/1,342	25/1,335	23/1,348	27/1,361	27/1,406	17/1,410	17/1,415
Nyangnia	10/258	9/237	5/225	13/225	6/233	6/231	5/225	3/220	2/237	0/224
Nyangoligo	12/284	13/255	6/254	8/273	14/245	4/229	10/240	2/248	1/248	1/254
Paga	38/1,202	41/1,159	31/1,130	45/1,153	33/1,153	29/1,185	19/1,215	19/1,254	27/1,286	18/1,297
Pindaa	4/45	2/40	2/40	1/45	4/44	1/46	1/39	0/42	0/40	2/144
Pungu	51/1,358	52/1,329	46/1,298	53/1,299	25/1,284	36/1,307	26/1,287	43/1,261	29/1,206	20/1,172
Saboro	3/173	3/181	7/176	7/170	4/173	5/161	3/159	2/167	4/164	5/165
Vunania	9/213	7/198	5/196	4/197	10/201	9/189	1/184	3/186	2/185	3/164
Wuru	5/99	0/88	2/86	2/94	2/103	3/99	0/92	0/92	3/88	3/76
Yua	15/449	16/426	18/415	25/401	12/392	14/378	10/408	10/423	16/415	8/418

1,000 person-years) was in 2006, showing a relative decline in mortality over the period. A temporal trend in rates was realised after applying a Poisson regression of the number of deaths per year. The results state that for every unit increase in year, there was an 8.2% reduction, 95% CI (-9.2, -7.3) $p < 0.001$, in the number of deaths between 1997 and 2006 in the district. However, the jump in the mortality rate for 2000 compared to 1998 and 1999 may be due to the outbreak of a cerebro-spinal meningitis epidemic in the district, which also occurred in 1997. This overall decline in mortality in the district may be attributable to the many interventions being implemented in the district by the Navrongo Health Research Centre among which were the malaria intervention studies (14–16) and the Community Health and Family Planning Project (CHFP) (17–19).

At the village level, the highest rates featured Pindaa with 87.7 per 1,000 person-years for 1997 and Kassi/Akaamo with 72.3 per 1,000 person-years for 1998. For 1999, it was Basengo with 55.3 per 1,000 person-years and Atiyoro had 108.3 per 1,000 person-years for 2000. For 2001 and 2002, it was Pindaa and Manyoro with 90.6 per 1,000 person-years and 65.0 per 1,000 person-years, respectively. Atoyoro topped again in 2003 with 50.8 and Nawognia had 43.7 per 1,000 person-years in 2004. Atiyoro again had 50.3 per 1,000 person-years for 2005 and Wiru had 38.4 per 1,000 person-years for 2006. The frequency of the recurring high mortality in the villages of Pindaa and Atiyoro may indicate a problem with access to health services or a socio-cultural phenomenon that needs to be investigated further. However, there were also villages with very low rates.

The results showing the spatial distribution of the primary and secondary clusters over the period 1997–2006 indicate that the villages in the primary cluster were mainly within the areas where there was no active intervention by the CHFP project, located in the north-eastern parts of the district. The CHFP project was testing the effect of applying two different health delivery systems: putting a Community Health Officer (CHO) in the community as against putting a trained health volunteer in a 2×2 factorial design. Thus, the district was demarcated into four cells: Cell I had health volunteers only, Cell II had CHOs only, Cell III had CHOs and health volunteers and Cell IV was a comparison cell.

The higher mortality shown in the two villages in the secondary cluster was in Cell II in the west of the district and could be because even though the CHO was supposed to be living and working within the community, this did not happen in reality in the early years between 1997 and 2001. This was an area far removed from Navrongo, the capital of the district, where most of the CHOs had their families. Therefore, they were not available in the community during some days of the week to administer health service delivery.

The continued decline in mortality in the district could also be attributed to UNICEF's Accelerated Child Survival and Development Approach (ACSD), which was implemented in the Upper East region (20). However, the ACSD package was applied to the whole region and thus any spatial differences in mortality would be due to other factors. The initial hypothesis that villages that had poor access to health services were more likely to have an excess of higher mortality than those with good access had, in principle, not been rejected as villages falling outside the primary cluster coincided with the cells where intensive service delivery was taking place within active cells of the CHFP project.

The authors acknowledge their inability to compare the MR that have been reported in different units. The data quoted from the national sources are per 1,000 live births whereas those calculated using the data from the demographic surveillance system are per 1,000 person-years. Also, differences with respect to socio-economic status, ethnic groupings and religion between the villages have not been investigated. The suggested association between the clustering of under-five mortality and some of the interventions may need to be investigated further.

In conclusion, the high MR in the villages of the north-eastern part of the district may suggest a relatively poor health care system compared to the rest of the district. This may be due to the design of the CHFP project whose impact was not felt in this part of the district. This situation is hopefully changing with the new initiative by the Ghana Health Service to introducing the Community-based Health Planning and Services Initiative for scaling-up service delivery innovation (CHPS) (21) in all districts of the country.

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Conflict of interest and funding

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