Flood control embankments contribute to the improvement of the health status of children in rural Bangladesh

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Every year, Bangladesh experiences major floods that inundate about one-third of the country. Therefore, flood control projects that comprise earthen dikes and irrigation / drainage systems are built along the major rivers to protect the people living in low-lying areas, stabilize the river banks and improve agricultural productivity. However, the adverse effects of these projects are regularly emphasized, such as environmental degradation and reduction of fishing supplies.

The Demographic Surveillance System of the International Centre for Diarrhoeal Diseases Research, Bangladesh (ICDDR,B) was used to assess the effect of a flood control programme on the mortality of 0–4-year-old children residing in the Matlab study area. Adjusted mortality rates were used in comparing four adjacent child populations residing either inside or outside a flood-control embankment and according to the type of health services provided in this area.

Between the periods 1983–86 and 1989–92, the crude child mortality in the total study area decreased by 37%, from 185.9 per 1000 live births to 117.9 per 1000 live births. Following the construction of the embankment, death rates outside were up to 29% higher in 1–4-year-old children and 9% higher for 0–4-year age group compared to the flood-protected area ($P < 0.001$). Simultaneously, in the same study area, health interventions contributed to a 40% reduction in mortality among children less than 5 years of age in all causes of deaths ($P < 0.001$). Migration patterns and the effect of distances to the hospital are discussed.

Introduction

Child mortality is an appropriate indicator for measuring the impact of interventions on health and for monitoring the health status of populations (*1, 2, 3*). Although widely used as a primary objective for health and development programmes in developing countries, estimations of mortality patterns are often impossible to obtain, and therefore rarely included in project evaluations. Moreover, few studies have assessed the impact of environmental changes on the health status of populations.

Bangladesh is mostly a low-lying deltaic flood plain at the confluence of three of the world's major rivers. Between July and September, these rivers frequently overflow their banks and inundate about a third of the land surface, depositing silt on the flood plains and thus maintaining soil fertility (*4*). Besides the "normal" seasonal floods, the country regularly experiences severe floods and cyclones that cause widespread damage to crops and property (*5, 6*). Flood control projects have been undertaken in many areas exposed to the floods. These projects protect low-lying land through the construction of earthen embankments, usually in combination with irrigation and drainage components. The aims are to increase agricultural production by year-round cultivation of high-yielding varieties of rice using modern methods of cultivation and to protect the beneficiaries against extensive floods (*7*). However, such projects are criticized for many adverse effects (*8*), for example:

- restricting the seasonal deposit of sediment reduces soil fertility and leads to an intensive use of fertilizers and to further environmental degradation;
- the absence of "flushing action" by receding flood water results in contamination of surface water by fertilizers and agrochemicals;
- small fisheries are destroyed and new farming technologies are introduced which benefit wealthy farmers at the expense of poorer ones; and
- many farmers lose their land by the transfer of cultivated land to embankment infrastructure development.

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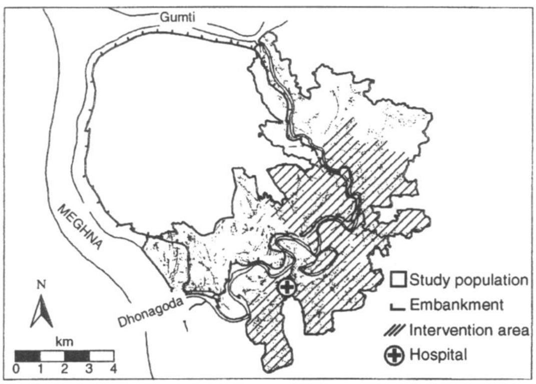
This study analysed child mortality (for children 0–4-years of age) in the Matlab study area to assess the impact of a flood control project on the health status of the beneficiaries. A secondary objective was to monitor the achievements of the maternal and child health programme by controlling the effect of the embankment.

Materials and methods

Matlab is a field study area of the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B), 55 km south-east of Dhaka. The area is a low-lying deltaic plain, intersected by numerous tidal rivers and canals. During the monsoon, almost all the land is flooded, with only clusters of homes built on earthen mounds remaining above the water level. As part of the national flood control and irrigation programme, a US$ 33 million project was carried out in the district near the confluence of two major rivers — the Meghna and the Dhonagoda (*7*). The 60-km long earth embankment was expected to provide flood protection to a gross area of 17000 hectares, including part of the Matlab study area and about 31% of its population (Fig. 1). The embankment was completed in July 1987, but was breached in August the same year and again in August 1988. The total population in the Matlab study area is about 200000, with a density of 1134 inhabitants per km^2, one of the highest in the rural world. About a third of this population lives inside the embankment. Muslims represent 85% of the population, with the rest being Hindus.

Since 1963, six cholera vaccine trials have been conducted in Matlab, and a demographic surveillance system has been in operation since 1966, consisting of periodic censuses along with a continuous household registration of all vital events such as birth, death, migration and marriage. Female community workers visit each household twice a month and report all deaths to a trained health assistant. This unique longitudinal database has been essential to studies on mortality and to services evaluation in Matlab (*9*, *10*, *11*). By introducing a geographic information system (GIS), based on the location of households, it is now possible to analyse the fluctuations in child mortality or morbidity rates over both time and space according to natural boundaries.

Fig. 1. **The flood control embankment since 1989 and Matlab study area.**



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The cause of death is assessed by an interview with the relatives of the deceased (verbal autopsy). The perception of diseases and symptoms remains traditional in this conservative society (*12*). However, local people do clearly conceptualize several diseases, for example diarrhoea (*amasha*), dysentery (*rokto amasha*), tetanus (*takuria*), and measles (*lunti* or *hum*). For all deaths, one single underlying disease is mentioned as the primary cause, and several symptoms preceding death are described in the reports for further investigation if required. The classification of the causes of death is derived from the International Statistical Classification of Diseases, Injuries and Causes of Death, 1975 Revision (*13*), and is adjusted to the context of lay reporting. The coding system was amended in 1986 by the introduction of new codes in a three-digit format. The field procedures and the management for detecting deaths and assessing the causes of death have been described extensively elsewhere (*14*).

From 1978 a comprehensive maternal and child health/family planning (MCH–FP) programme was introduced gradually in half of the Matlab study area, referred to as the "intervention area"; this programme promotes contraceptive methods, distribution of oral rehydration salts, immunization, treatment of acute respiratory illnesses (ARI), distribution of iron(II) fumarate and vitamin A, treatment of minor ailments and dysentery, and referral to the hospital. The remaining half of the study area is referred to as the "comparison area" as it receives only government health services. The treatment centre for referred patients with diarrhoea, ARI, and maternal complications is located outside the embankment and in the intervention area. It is accessible to all, and free of cost. For other diseases, patients are referred to the nearby district hospital. The impact of the health and family planning programmes on the reduction of death in the Matlab community has been described elsewhere (*15*, *16*).

Analysis

This study reports deaths in children aged 0–4 years, cumulated between January 1989 and December

1992. An average annual death rate was calculated from the ratio of the number of deaths during that period to the sum of the live births or to the mid-year populations. Mortality rates were analysed for the populations of the intervention and comparison areas according to whether they were inside or outside the embankment. As a baseline investigation, death rates were compared between the two areas during a 4-year period preceding the completion of the embankment (1983–86). The reduction in mortality and fertility due to health and family planning interventions induced changes in age structures, with proportionally more children per live birth in the intervention area (*17*). In summarizing the data, therefore, an adjustment was used in accounting for the effect of the health interventions and the resulting differences in age structures (neonates, post-neonates and 1–4-year-olds). Indirect standardization was used with one of the populations of interest as the standard population. Given that the selection of the standard population did not alter the differences in the rates, the population not exposed to floods was taken as standard. Similarly, mortality rates were compared between the health intervention and the comparison areas, adjusting in this case for the presence of the flood control programme. Standardized normal deviations were used to test for statistical differences between adjusted rates (*18*).

Causes of death were aggregated in three groups: infectious diseases including all diarrhoeas, vaccine-preventable diseases (measles, tetanus and poliomyelitis) and ARI; severe malnutrition; and other noninfectious diseases (accidental drowning and unspecified causes). However, severe malnutrition as a cause of death, and other major changes in the structure of the death-coding system were introduced in 1986. Therefore, comparison of cause-specific mortality rates between the two periods would be inappropriate.

Since the distances of the households from the nearest treatment centre are likely to affect the referral of severely sick children and thus influence mortality rates in some places, an average distance was calculated for each area. Additionally, one might expect that the construction of an embankment would induce major changes in the migration pattern in the flood-protected areas, resulting in the replacement of large sections of population; therefore, migration data were analysed between the two periods.

Results

During the 1983–86 baseline period preceding the completion of the flood control programme and the construction of the embankment, 27767 births occurred in the study area, and 5163 deaths were recorded in the population of children aged 0–4 years; the <5-year-old mortality rate was 185.9 per 1000 live births. During the 1989–92 study period, 24885 births occurred in the study area, and 2933 deaths were recorded; the <5-year-old mortality rate was 117.9 per 1000 live births.

By analysing the migration trend in the total population residing inside the embankment, the yearly out-migration rate ranged from 40.4 to 47.6 per 1000 during the 4-year baseline period, and from 41.2 to 51.1 per 1000 during the study period. The yearly in-migration rate ranged between 26.4 and 36.0 per 1000 in the baseline period and between 34.6 and 39.9 per 1000 during the study period. Between the two periods, the net out-migration decreased from 14.8 per 1000 to 7.5 per 1000.

For the baseline period, the mortality rate inside the future embankment was not significantly different from that of the population that would be outside (Table 1). Similar death rates were seen when the data were stratified by cause of death and by childhood age groups. However, following the construction of the embankment, mortality appeared to be significantly higher in the children living in areas not protected from flooding, with an excess of 159 deaths compared to the situation inside the embankment. By comparing cause-specific and age-specific rates, an excess of deaths outside the embankment for all the groups was found. The differences are particularly significant for deaths caused by infectious diseases and for the 1–4-year-old group. The average distances from households from inside and outside the embankment to the treatment centre were 5.8 km and 6.3 km, respectively; this difference was not significant.

Death rates in children aged 1–4 years living inside and outside the embankment, and according to the presence and absence of health services for both the periods are presented in Table 2. During the baseline period in the health intervention area, death rates were higher in the population that would later benefit from the flood control project. During the study period, the age-specific death rate was significantly higher outside the embankment only in the non-intervention area. In this age group (1–4-year-olds), an analysis of the cause structure of mortality revealed that the death rate for infectious diseases was 3.8 per 1000 both inside and outside the embankment (data not shown). However, death rates for severe malnutrition and accidental drowning were significantly higher outside the embankment: for severe malnutrition the death rates per 1000 live births were 2.4 inside the embankment and 3.8 outside; for accidental drowning the rates were 1.2 and 2.2 per

Table 1: **Adjusted mortality rates among 0–4-year-olds, by cause of death and age-group: comparison of populations inside and outside the Matlab embankment**

	Baseline period (1983–86)		Study period (1989–92)		
	No. of deaths inside (n = 8574)[a]	No. of deaths outside (n = 19193)[a]	No. of deaths inside (n = 7868)[a]	No. of deaths outside (n = 17017)[a]	SMR[b]
All age groups, all causes of death	1694 (197.6)[c]	3469 (193.6)	932 (118.5)	2001 (128.7)[d]	1.09
Cause-specific:					
Infectious diseases	1214 (141.6)	2381 (142.6)	340 (43.2)	645 (47.2)[d]	1.09
Diarrhoea	466 (54.4)	894 (52.4)	82 (10.4)	181 (11.8)	
Acute watery diarrhoea	94 (11.0)	201 (10.5)	61 (7.8)	122 (7.3)	
Dysentery	316 (36.9)	572 (35.4)	14 (1.8)	29 (2.1)	
Persistent diarrhoea	56 (6.5)	121 (6.5)	11 (1.4)	32 (3.1)[d]	2.24
Vaccine-preventable diseases	412 (48.1)	795 (50.0)	50 (6.4)	84 (7.6)	
Acute respiratory diseases	161 (18.8)	356 (21.4)[e]	150 (19.1)	290 (22.4)[d]	1.18
Severe malnutrition	NA[f]	NA[f]	155 (19.7)	358 (21.7)	
Other noninfectious diseases	480 (56.0)	1088 (51.8)[e]	437 (55.5)	998 (59.8)[e]	1.08
Age-specific:					
Neonates (0–28 days)	509 (59.4)	1151 (62.6)	402 (51.1)	884 (54.7)[e]	1.07
Post-neonates (29 days–11 months)	405 (47.2)	826 (43.4)[e]	285 (36.2)	576 (38.0)	
Children (1–4 years)	780 (26.4)[g]	1492 (25.3)[g]	242 (7.8)[g]	532 (9.0)[d,g]	1.15

[a] No. of live births over the 4-year period.
[b] Standard mortality ratios when differences were significant.
[c] Figures in parentheses are mortality rates per 1000 live births adjusted for age structure and location according to the health intervention, using indirect standardization with the population inside the embankment as standard.
[d] $P < 0.01$.
[e] $P < 0.05$.
[f] Data not available for baseline period.
[g] Mortality rates per 1000 children who survived the first year.

1000 live births, respectively ($P < 0.01$). Death rates for noninfectious disease, other than malnutrition and drowning, were similar (1.0 per 1000).

In Table 3, the cause-specific and age-specific death rates according to the type of health services available are compared. The rates were adjusted for whether the area of residence was inside or outside the flood control embankment. The overall death rate was 36% higher in the comparison area with an excess of 667 deaths over the 4 years. The differences in mortality rates between the intervention and comparison areas increased with the age of the children. The cause-specific death rates were consistently higher for the comparison area when compared to the intervention area; the differences were especially great for diseases preventable by vaccination. The mean distance of the households to the treatment centre was 5.1 ± 3.1 km in the health intervention area and 7.1 ± 3.9 km in the comparison area.

Table 2: **Deaths among children aged 1–4 years, by type of heath care service provided and whether they live inside or outside the embankment**

	Baseline period (1983–86)			Study period (1989–92)		
	No. of deaths inside	No. of deaths outside	SMR[a]	No. of deaths inside	No. of deaths outside	SMR[a]
Health intervention area	175 (20.8)[b]	653 (18.3)[c]	0.9	50 (6.0)	224 (6.0)	
Comparison area	605 (28.6)	839 (29.6)		192 (8.5)	308 (10.9)[c]	1.29

[a] Standard mortality ratios when differences were significant.
[b] Figures in parentheses are mortality rates per 1000 children.
[c] $P < 0.01$.

Table 3: **Adjusted mortality rates among 0–4-year-old children, by cause of death and age-group: Matlab health intervention and comparison areas over the period 1989–92**

	Intervention area (n = 11 196)[a]	Comparison area (n = 13 689)[a]	
	No. of deaths	No. of deaths	SMR[b]
All age groups, all causes of death	1 133 (101.2)[c]	1 800 (137.5)[d]	1.36
Cause-specific:			
Infectious diseases	298 (26.6)	687 (54.3)[d]	2.04
Diarrhoea	100 (8.9)	163 (12.7)[d]	1.43
Acute watery diarrhoea	69 (6.2)	114 (8.0)[d]	1.30
Dysentery	18 (1.6)	25 (2.2)	1.37
Persistent diarrhoea	14 (1.3)	29 (3.2)[d]	2.59
Vaccine-preventable diseases	14 (1.3)	120 (9.6)[d]	7.70
Acute respiratory diseases	134 (12.0)	306 (25.8)[d]	2.15
Severe malnutrition	194 (17.3)	319 (23.6)[d]	1.36
Other noninfectious diseases	641 (57.3)	794 (77.4)[d]	1.35
Age-specific:			
Neonates (0–28 days)	529 (47.2)	757 (56.3)[d]	1.19
Post-neonates (29 days–11 months)	325 (29.0)	536 (40.4)[d]	1.39
Children (1–4 years)[e]	274 (6.0)	500 (9.8)[d]	1.64

[a] Total number of live births.
[b] Standard mortality ratios when differences were significant.
[c] Figures in parentheses are mortality rates per 1000 live births adjusted for age structure and location according to the health intervention, by using indirect standardization.
[d] $P < 0.01$.
[e] Mortality rates per 1000 children who survived the first year.

Discussion

Over the last decade, overall mortality in children aged 0–4 years decreased dramatically in many developing countries. This was confirmed in Bangladesh by a countrywide survey (*19*), and has been attributed to measles and tetanus immunization and to family planning activities (*10*). The data from the present study reveal that in Matlab mortality dropped from an average of 186 per 1000 to 118 per 1000 live births. The downward trend was similar in both the health intervention and comparison areas. However, the data on mortality for the period 1989–92 show a large variation among the four adjacent sectors, even though the study area is less than 200 km^2.

Preventive health care and family planning in Matlab has been sustained and strengthened since 1978, and its impact on child survival has been demonstrated. In agreement with that reported from earlier periods (*20*), the present study shows that between 1989 and 1992, the overall under-5-year-old mortality in the comparison area, covered only by government facilities, was 30–40% higher than that of the intervention area. With the construction of the 60-km embankment in 1987, major environmental and seasonal changes were introduced in Matlab. The continuous reporting of death by the Demographic Surveillance System (DSS) coupled with GIS permitted the assessment of mortality rates for children residing either inside or outside the embankment area at any point of time. The analysis suggested that rates for under-5-year-olds were consistently lower inside the flood-protected areas than outside. A 15% difference was particularly indicative for the 1–4-year-old group. Besides, in the population covered only by the government health facilities (comparison area), the difference rose up to almost 30%.

How these differences in mortality are caused was not revealed by this study. Since the primary objective of flood control and irrigation projects is to optimize agricultural and fisheries' production, an expected outcome might be a reduction of malnutrition. Indeed, this study suggests that fewer children died of severe malnutrition inside the protected areas. In addition, accidental drowning was also lower in these areas.

It has been suggested that in Bangladesh the embankment would induce major changes in the traditional agricultural structures and thus favour people of higher socioeconomic status. This could have led the fishermen and the poorest farmers to move outside the flood-protected area, or conversely, they may have benefited from a higher demand for their labour from more intensive farming. The data on migration trends in the flood-protected area of Matlab suggest that out-migration remained almost stable after the construction of the embankment, whereas the number of immigrants increased slightly, possibly because the lack of flooding allowed more land to be used for homesteads. This may have induced changes in the socioeconomic conditions and social welfare of individuals, although the contribution of migration to the population size remained insignificant during the two periods.

It should be noted from the map (Fig. 1) that the study population lives on one edge of the total flood-protected area. There might be a boundary effect in which privileged families benefit from the higher return from crops inside the embankment and from the fishing activities outside the embankment.

In this study, average mortality rates represent those for a 4-year period following the construction of the embankment. The impact of the flood control project was measured in a period starting less than 2 years after the completion of the embankment and only 1 year after consolidation of the breaches. Since the project induced changes in the health status of the children by way of nutrition, more benefits are expected after a longer follow-up period. In addition, further improvements in socioeconomic status might be expected.

Geographical accessibility to the treatment centre is another important factor that affects attendance and mortality (*21*). Although the difference in average distance from the houses on either side of the embankment to the treatment centre is not significant, better land communications throughout the year resulting from the flood control project may have facilitated both referral of severely sick children to the treatment centre and routine home visits by community workers.

We conclude, according to our data, that while embankments induce adverse effects on the environment, flood control programmes reduce mortality in young children. The mechanisms involved ought to be investigated by studying morbidity and by performing more in-depth analyses of the migration patterns. The situation needs to be monitored for a longer period, and villages far from the main rivers and the embankment should be included in future studies.

Owing to the careful management of the death reports by the demographic surveillance system, this study presents accurate data on mortality. However, the causes of death need to be considered carefully, because they are reported based on parents' statements. For most of the diseases, and particularly for malnutrition, deaths may be related to multiple symptoms or diseases. Nevertheless, a previous study pointed out that the symptoms of malnutrition were well perceived by the parents in 86% of the cases (*10*). In future, population-based studies in Matlab where mortality and morbidity are being compared between the intervention and comparison areas, the presence of the embankment is a potential confounder.

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Résumé

Digues de protection contre les inondations et amélioration de l'état sanitaire des enfants dans le Bangladesh rural

Chaque année le Bangladesh connaît des inondations importantes qui envahissent environ un tiers du pays. C'est pourquoi des projets de protection ont vu le jour le long des principales rivières, sous la forme de digues en terre ou de systèmes d'irrigation et de drainage, afin de protéger les populations vivant dans les basses terres, de stabiliser les berges et d'améliorer la productivité agricole. On souligne néanmoins régulièrement les effets nocifs de ces projets, tels que la dégradation de l'environnement et la réduction des ressources halieutiques.

Il a été fait appel au Système de surveillance démographique de l'International Centre for

Diarrhoeal Diseases Research au Bangladesh (ICDDR,B) pour évaluer les effets du programme de protection contre les inondations sur la mortalité des enfants de 0 à 4 ans, résidant dans la région d'étude de Matlab. On a utilisé les taux de mortalité ajustés pour comparer les populations d'enfants de quatre zones voisines résidant soit à l'intérieur, soit à l'extérieur du site protégé, en fonction également du type de services de santé qui y sont disponibles.

Entre les périodes 1983–1986 et 1989–1992, le taux brut de mortalité infantile dans toute la zone étudiée a diminué de 37%, passant de 185,9 à 117,8 pour mille naissances vivantes. A la suite de la construction de la digue, le surcroît de mortalité en dehors de la zone protégée allait jusqu'à 29% pour les enfants de 1 à 4 ans et 9% pour les enfants de 0 à 4 ans ($p < 0,001$). Dans le même temps, les interventions dans le domaine de la santé ont contribué à réduire la mortalité de 40% dans la même zone chez les enfants de moins de 5 ans, toutes causes de décès confondues ($p < 0,001$). L'article comprend également une discussion sur les effets des mouvements migratoires et de l'éloignement de l'hôpital.

Cette étude montre comment les indicateurs bruts de mortalité peuvent varier dans une zone très limitée mais densément peuplée. Elle arrive également à la conclusion que les effets bénéfiques pour la santé semblent compenser les inconvénients de la construction de digues anti-inoxidations. D'autres études sur la morbidité et les modifications socio-économiques sont nécessaires pour comprendre les mécanismes impliqués.

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