

**Successes and failures in the fight against child mortality in Sub-Saharan Africa:  
Lessons from Senegal, a country with low AIDS prevalence**

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Paper submitted to the European Population Conference

Stockholm, 13-16 June 2012

(Draft, 13-10-2011)

## **ABSTRACT**

Child mortality has declined in Sub-Saharan Africa over the last 60 years but the decrease has not been regular. It has accelerated over some periods, as during the last decade, and slowed down during others. Mortality has even increased during some periods, as in the 1990s. This was not solely attributable to AIDS. In order to determine any other diseases or factors that also played a part, Senegal was chosen for study – a country with very low AIDS prevalence but where trends in child mortality have closely resembled those of the whole region. In addition, Senegal has the advantage of possessing relatively numerous information sources available for tracing the evolution of child mortality on a national scale, as well as three demographic surveillance sites in a rural area where child mortality could be followed and the causes of deaths studied in detail over almost 25 years.

The decline in child mortality in Senegal in the 1970s and 1980s is attributable to the reduction in deaths from infectious diseases, thanks largely to vaccinations. The situation reversed in the 1990s due to a combination of several factors: the development of chloroquine resistance leading to many malaria deaths; inefficiencies in the health services leading to failures in basic services, including vaccination; and an adverse economic climate. Mortality decline resumed rapidly in the 2000s due also to a combination of factors, among which the renewal of vaccination efforts and investments in anti-malaria programs played an important role. These factors are common to many countries in Sub-Saharan Africa and explain why many of them experienced the health crisis in the 1990s and the renewal of progress in the 2000s, irrespective of whether or not they were hit by the AIDS epidemic.

## INTRODUCTION

Life expectancy at birth worldwide has increased considerably over the last century, due mainly to a marked reduction in child mortality. This has also been the case in sub-Saharan Africa, although this region has the highest mortality rates in the world.

Over the last 60 years, infant mortality (1q0) has declined in sub-Saharan Africa, falling from a level of roughly 180 per 1,000 in 1950-54 to 85 per 1,000 in 2005-2009 as indicated by the United Nations Population Division (2011). According to the UN statistics, the decline occurred at a steady rate until the late 1980s, slowed down during the 1980s and the 1990s, and then resumed during the last decade (figure 1).

Although the decline in sub-Saharan Africa over these sixty years seems high in absolute figures, it has been slower than in Asia. If we compare, for example, sub-Saharan Africa with India, which have around 1 billion inhabitants each (respectively 0.9 and 1.2 billion in 2011), infant mortality in 1950-54 was nearly at the same level in both (177 and 165 per thousand respectively in sub-Saharan Africa and in India according to UN figures). By contrast, in 2005-2009 it was more than 50% higher in sub-Saharan Africa (85 per thousand, as against 53 per thousand in India). The rate of fall was quite steady in Indian with a slight acceleration over time, particularly during the 1970s and the 1980s. Over the same period, the decline slowed down in sub-Saharan Africa and the gap with India increased. And even though the decline has resumed during the last decade in sub-Saharan Africa, the gap with India is still increasing.

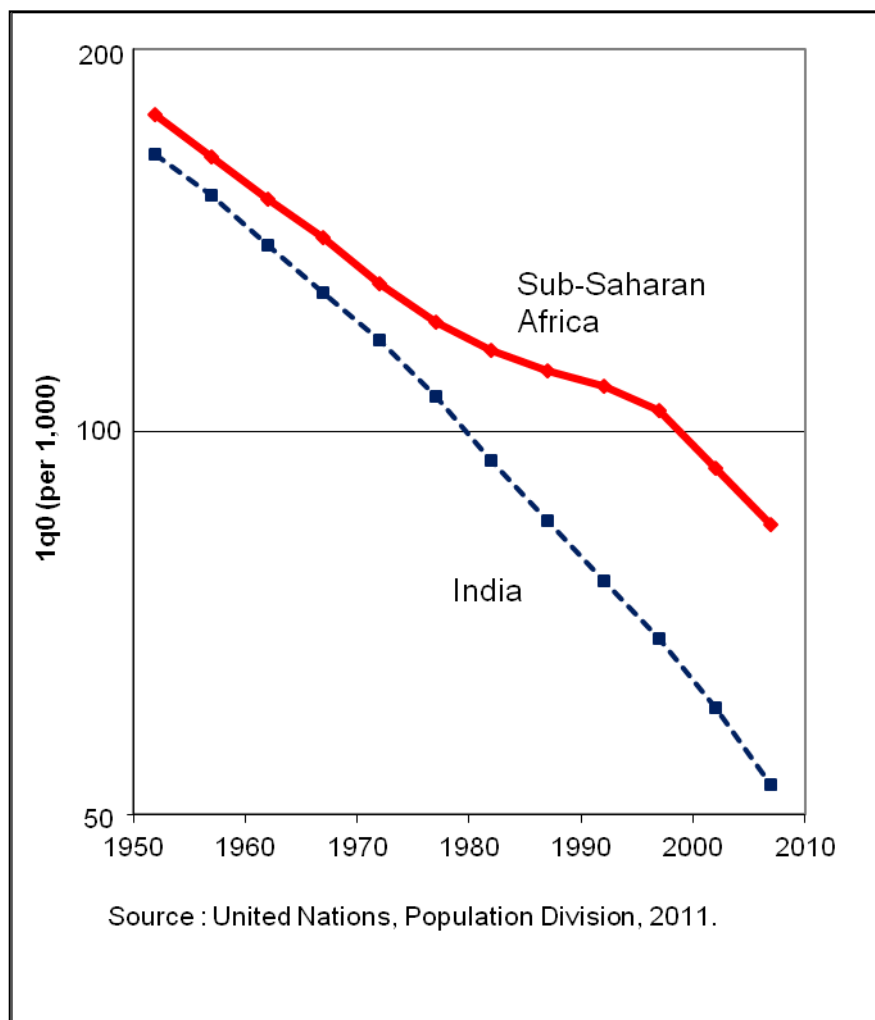
The rapid fall in Africa from 1950 to 1980 can doubtless be attributed to the same causes as in other parts of the world where mortality was very high. Progress in infrastructure and in health programmes led to the spread of vaccination and effective treatments and to the consequent reduction in the infectious diseases that were chiefly responsible for child deaths. Socio-economic progress, especially in education, played an important part here in enabling all population groups to benefit from progress in health.

It appears that the slowdown of mortality decline over the 1980s and 1990s seen in sub-Saharan Africa but not in Asia was due to a phenomenon unique to Africa: the AIDS epidemic being the first factor that comes to mind. The disease is certainly highly prevalent in Sub-Saharan Africa, with a major impact on mortality. Substantial efforts have been made over the last decade to fight the disease. It appears that the resumption of the child mortality decline at the beginning of the twenty-first century is a consequence of this effort.

The question remains as to whether the principal factor accounting for the halt in the reduction of child mortality and the recent resumption of progress is linked to AIDS, or whether other diseases or factors are also involved.

Figure 1. Infant mortality (1q0) trends in India and in the whole of sub-Saharan Africa between 1950 and 2010.

(1q0: probability for a new-born child of dying before age 1)



To better understand the reasons for the irregular pace of child mortality decline in Sub-Saharan Africa since the mid-twentieth century, particularly the rapid fall in child mortality from the 1950s to 1980s, the subsequent ten- to twenty-year slowdown in progress, and the recent resumption of rapid decline, we shall examine in detail the case of Senegal. This country offers the following four advantages:

- child mortality has evolved there in a way that is typical of the whole region, and especially includes a rapid fall followed by a ten- to fifteen-year stagnation and a subsequent return to rapid decline;

- up to the present, the country has not been severely affected by AIDS: the proportion of persons aged 15-49 infected by HIV is estimated at 0.7% and did not change much between 2005 and 2010 (Ndiaye et Ayad 2006 ; ANSD 2011).
- sources of information there are relatively numerous and child mortality trends on a national scale can be tracked quite accurately;
- the country also possesses three demographic surveillance sites in rural areas that have monitored child mortality and its causes in detail over a long period.

## **A. CHILD MORTALITY DECLINE AND EVOLUTION OF HEALTH CONDITIONS IN SENEGAL**

### ***1. Child mortality decline in Senegal since 1945***

Ten surveys supply data that can be used to estimate the national level of child mortality in Senegal. We use here as an indicator of child mortality the probability that a newborn will die before the age of 5 (5q0). Figure 2 shows 5q0 estimates for Senegal since 1946. According to these data, in the 60 years following the end of the Second World War, 5q0 decreased nearly six-fold. The decline appears to have occurred rather slowly until the early 1970s, with a 25% drop in 25 years (from 373 per 1,000 in 1946 to 280 per 1,000 in 1970), and to have accelerated thereafter, with 5q0 falling by 75% in 35-40 years (down to 70 per 1,000 in 2008). However, during this second period of rapid fall, the decline appears to have halted at the turn of the 1980s and the 1990s, and mortality to have stagnated at the level of 140 per thousand during the 1990s. At the end of the 1990s or the early 2000s, the decline resumed with 5q0 falling rapidly by 50% in the next 10 years (to a level of 70 per 1,000 during the second part of the 2000s).

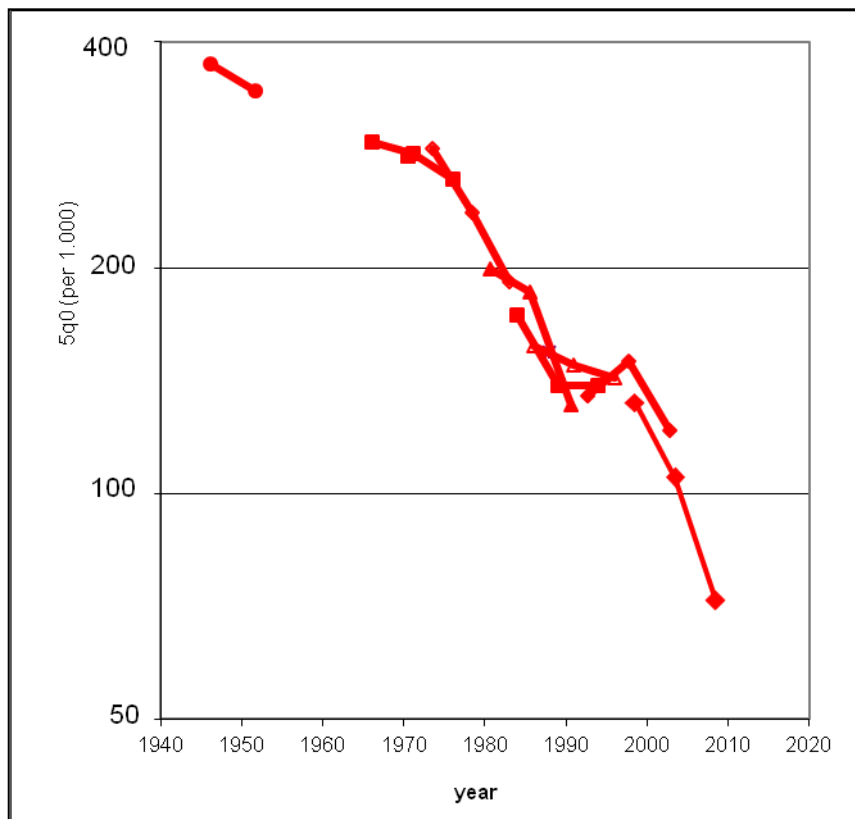
The trend shown by figure 2 raises several questions:

1 – Are the trends real or artefacts ? In particular, did mortality decline really level off during the 1990s ? The type and quality of data gathered varies across the surveys, as do the methodologies employed. However we chose to focus on a simple, robust indicator of child mortality, 5q0. The different measurements are fairly consistent. And a similar stagnation is also observed over the same period in the three demographic surveillance sites in rural areas (see below).

2 – What are the factors behind the decline in child mortality in Senegal since the mid 20th century? In this country, as in most other countries, it is probably related to economic development and the improvement in health conditions which took place after the end of the Second World War. In this paper we try to determine more precisely what has been the contribution of different factors: (1) changes in the epidemiological context (with new or resurgent infections), (2) the development of health infrastructures (number of hospitals, maternity clinics, health personnel, etc.) and their distribution across the country, (3) health programmes (vaccinations, programmes to control particular diseases – HIV infection, malaria, etc..). We examine in particular whether the changes in the pace of child mortality

decline (acceleration, or slowdown, stagnation or reversal) are concomitant with changes in the epidemiological context or in health infrastructures and programmes.

Figure 2. Child mortality (5q0) trends in Senegal between 1945 and the period 2006-2010 (5q0: probability for a new-born child of dying before age 5)



Sources of figure 2 :

- Hill, 1989
- Sénégal, 1971.
- Rutstein, 1984
- Ndiaye et al., 1988 (Enquête démographique et de santé, 1986)
- Pison et al., 1995
- Ndiaye et al., 1994 (Enquête démographique et de santé II, 1992-3)
- Ndiaye et al., 1997 (Enquête démographique et de santé III, 1997)
- Sow et al., 2000 (Enquête sénégalaise sur les indicateurs de santé, 1999)
- Ndiaye et al., 2006 (Enquête démographique et de santé IV, 2005)
- ANSD, 2011 (Enquête démographique et de santé à indicateurs multiples, 2010-2011)

3 – To better understand the reasons for the successes and failures of efforts to lower child mortality in Senegal, we examine in detail the changes in causes of death. As there are no sufficiently reliable statistics on causes of death at the national level, we examine changes in three Senegalese rural areas: Bandafassi, Mlomp and Niakhar. The populations of these areas have been monitored for more than twenty-five years and changes in child mortality and causes of child death have been documented precisely.

## ***2. Changes in health infrastructure and health programmes in Senegal since 1945***

Until 1978, Senegal's health infrastructure (hospitals, maternity clinics) was focused on the cities. Public health programmes to improve sanitary conditions and control disease were developed primarily in the towns, building on these infrastructures. The poorly served rural areas received only periodic visits of mobile teams from the Major Endemic Diseases Department (Service des Grandes Endémies), whose activities began to decline following independence in 1960. In 1978, following the recommendations made at the World Health Conference in Alma Ata in 1977, Senegal introduced primary health care. Paralleling the effort towards decentralization of the major health facilities (hospitals and dispensaries), this policy led to the training of community health workers and the establishment of village health centres and maternity clinics. Using these new village-based infrastructures, several mother and child health care (MCH) programmes were initiated to provide vaccinations, malaria prevention, rehydration of children suffering from diarrhoea, pregnancy monitoring and assistance in delivery, and food supplements for young children.

### **a. Health infrastructures**

The number of hospitals increased three-fold between 1960 and 1988, reflecting the policy to equip each region with a hospital and to divide some hospitals in the cities into two separate entities (Pison et al., 1995). The number of hospitals increased only slightly thereafter, by 25% from 1988 to 2008 (from 16 to 20). The number of hospital beds has not grown proportionally however, and has not even kept pace with population growth. Thus, the supply of beds per inhabitant has halved since 1988.

The number of health centres has doubled over the last 50 years while the population has quadrupled. These health centres are normally run by a physician and are equipped with hospital beds. The number of dispensaries has been multiplied by five over the same period. Operated by nurses, these dispensaries are found throughout the country. They are generally located in the district (arrondissement) capitals or rural communities.

Maternity clinics were rare and, until 1977, concentrated in the towns. Beginning in 1978, the primary health care policy led to the construction of a large number of such clinics in rural areas. In 1988, there were almost as many rural maternity clinics as there were dispensaries.

In 1960, the Dakar region, which accounted for 14% of the population, had three-fifths of the country's hospitals and the vast majority of its hospital beds. In 1988, it had 22% of the

population, but only 6 out of 16 hospitals and half the hospital beds. Twenty years later, in 2008, the proportion had not changed much : it still had 22% of the population, 8 out of 20 hospitals and half of the hospital beds. The distribution of facilities between Dakar and the rest of the country is still unequal. It improved considerably in the 1960s and the 1970s, but the progress seems to have slowed since then. Health personnel remain very concentrated in Dakar, where two-thirds of the country's physicians, pharmacists and dentists and half of its nurses and midwives are to be found.

## **b. Health programmes**

Numerous programmes were implemented before 1978, each one having a specific scope of action. They were carried out either by MCH centres in urban settings, or by mobile teams (smallpox eradication and control of leprosy). After 1978, these programmes were integrated into the general primary health care programme carried out by the dispensaries and mobile vaccination teams. Two of these specific programmes, vaccinations and the antimalaria campaign, are discussed in greater detail below.

### **— Vaccinations**

Initiated in Senegal in 1981, the Expanded Programme for Immunization (EPI) was designed to extend vaccination coverage to rural areas, which were at that time not well served, and to improve coverage in urban areas. Its objective was to protect children against seven diseases: tuberculosis, diphtheria, tetanus, pertussis, polio, measles and yellow fever.

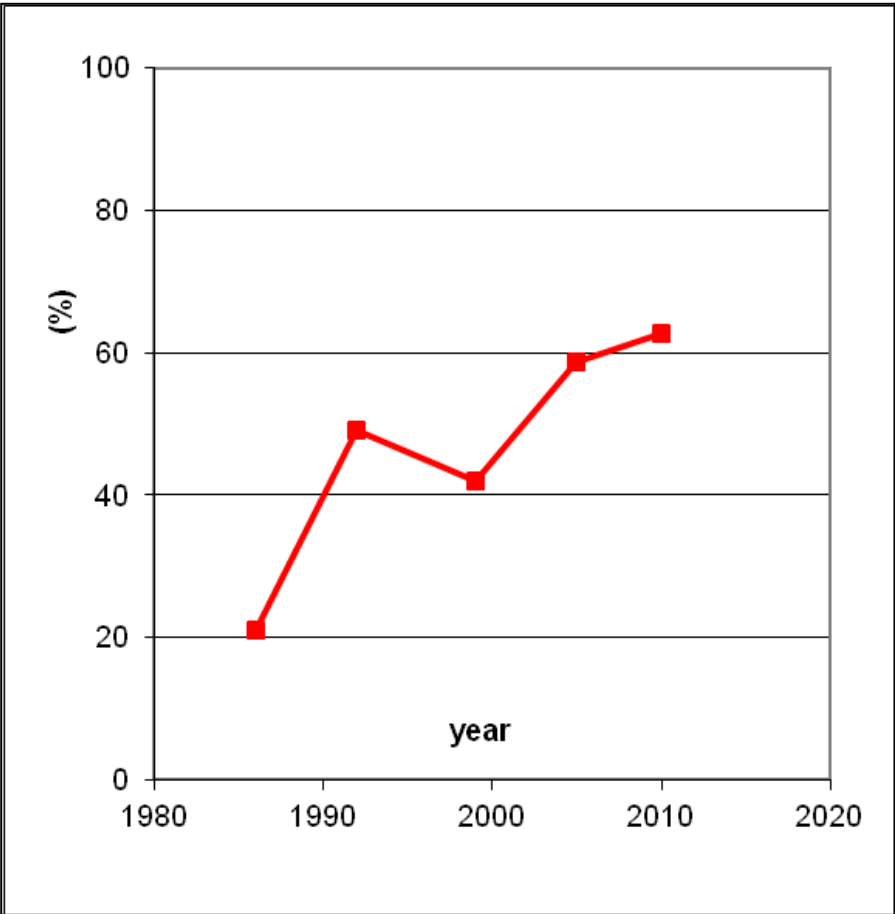
The programme targeted young children and also pregnant women, who were given tetanus vaccinations to protect their newborns against neonatal tetanus.

Since the EPI first began, its activities have varied in intensity, with periods of accelerated efforts followed by periods of lesser activity. Each acceleration led to the training and mobilization of administrative and health personnel, media information campaigns (especially by radio), and the provision of new equipment for dispensaries. There was a major acceleration effort, for example, in the first quarter of 1987, when it was decided to improve coverage in poorly provided rural areas. Substantial efforts were also made at the end of the 1990s and in the 2000s, linked to the world effort to eradicate polio. In particular, polio vaccinations (with measles vaccine and vitamin A supplements) were given to children during “Polio days”.

Vaccination coverage declined rather than continuing to increase in the 1990s. The proportion of fully vaccinated children aged 12-23 months decreased from 49% in 1992 to 42% in 1999 (figure 3). Subsequent to the resumption of vaccination efforts that year and in the 2000s, vaccination coverage rose again, with respectively 59% and 63% of fully vaccinated children aged 12-23 months in 2005 and 2010 (Ndiaye et Ayad 2006 ; ANSD 2011).

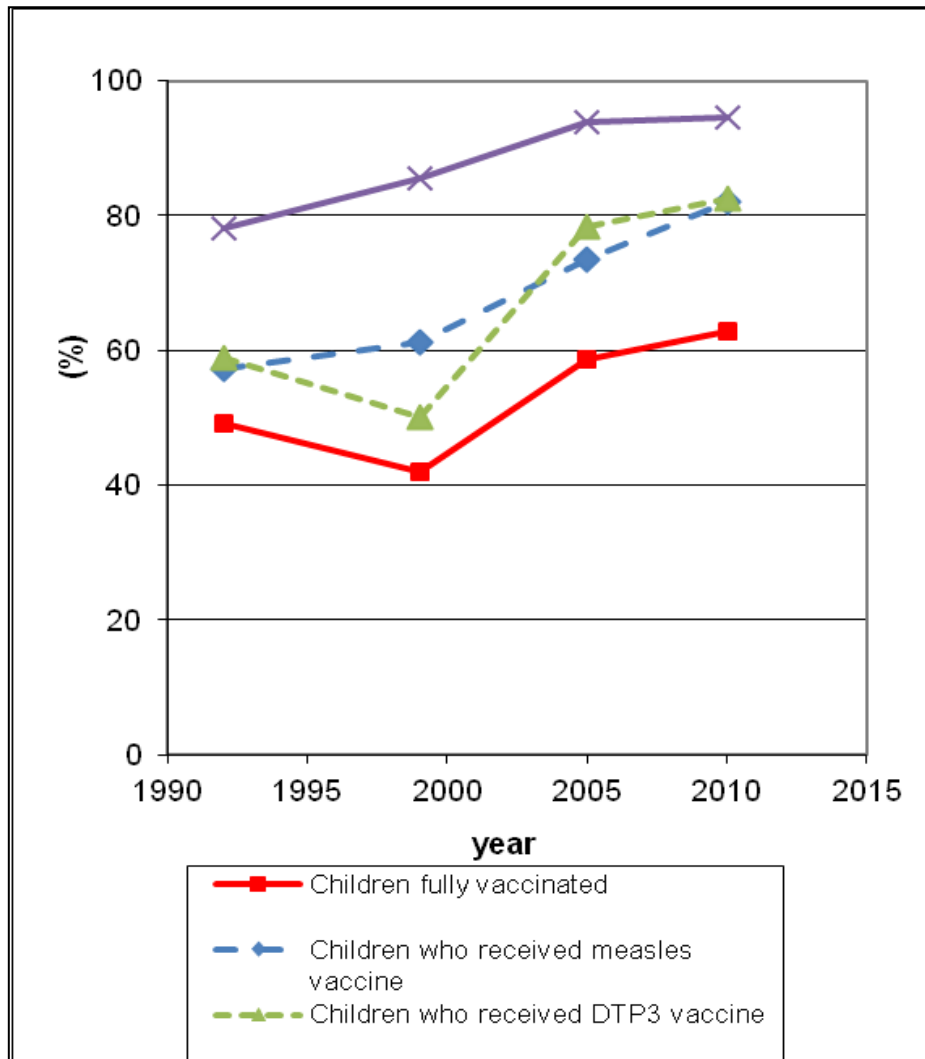


Figure 3. Change in the proportion of fully vaccinated children aged 12-23 months in Senegal



Source : DHS surveys in Senegal

Figure 4. Changes in the proportion of children aged 12-23 months who received specific vaccines (polio 1, measles vaccine, DTP3) during the 1990s and the 2000s in Senegal



Source : DHS surveys in Senegal

Figure 4 shows the changes in the proportion of children aged 12-23 months who received specific vaccines (polio 1, measles vaccine, DTP3) during the 1990s and the 2000s. Vaccination coverage for polio and measles seems to have remained stable in the 1990s. The point at the end of the 1990s corresponds to the estimate provided by the 1999 DHS survey which took place just after efforts began in 1999 to increase polio vaccine coverage, linked to the world effort to eradicate polio. During the preceding years, coverage for measles and polio vaccines had also declined, however. Thanks to the major effort to increase polio coverage which started in 1999, nearly 95% of children had received the polio1 vaccine in 2005 and 2010. As measles vaccination and vitamin A supplements were often given with polio during

the “polio days” and, after 2005, during “*Journées de la survie de l’enfant*” (Child survival days) vaccination, coverage for measles vaccine also increased in 1999 and the following years. This increase was also the result of the renewal of routine vaccination activities through the EPI, as revealed by the large rise in DTP3 vaccine coverage during the 2000s (figure 4).

Anti-tetanus vaccination of pregnant women greatly increased in the 1980s and 1990s, with the proportion of those having received at least one anti-tetanus injection during their pregnancy increasing from 31% for those giving birth during the period 1981-86, and then to 71%, 84% and 90% respectively for those who delivered in 1987-1992, 1992-1997 and 2000-2005. The vaccines received during a pregnancy ensure protection over several years, and the children arising from later pregnancies are also protected, even if the mother has not been revaccinated. Consequently, the immunity to neo-natal tetanus resulting from the anti-tetanus vaccinations of pregnant women progressed even more than the figures indicate.

#### **- malaria control programmes**

Malaria is endemic in Senegal and one of the major causes of child mortality. Antimalaria programmes have for long been based on prevention using chloroquine-based chemoprophylaxis (called ‘chloroquinization’), and treatment, also based on chloroquine, which was the cheapest antimalarial drug. This policy was brought into question following the emergence of chloroquine-resistant strains of the parasite at the end of the 1980s and their rapid transmission across the country in the years after (Trape et al., 1998 ; Trape et al., 2002). It was not until the end of 2003 that a new treatment combining amodiaquine + sulfadoxine/pyrimetamine (AQ+SP) was introduced as a replacement for chloroquine for the first-line treatment of malaria in all health facilities in Senegal. In 2006, this treatment was replaced by another one combining artesunate + amodiaquine, known as ACT (Artemisinin-based Combination Therapy). Rapid diagnostic tests of malaria were also introduced in 2007 in all health facilities to ensure rapid and effective treatment. A program of mass distribution of insecticide-treated nets (ITN) was also launched in 2008 throughout Senegal (Programme National de Lutte contre le Paludisme, 2010 ; Trape et al., 2011). The distribution of ITN has been coupled with distribution of mebendazole - to treat infestations by worms - and vitamin A supplement to all children less than five years old, as during the “*Journées locales de supplémentation en vitamine A couplées au déparasitage (JLS)*” in 2009.

Trends in the proportion of children benefiting from these new malaria control methods can be tracked using the national surveys conducted since 2005. According to the declarations made by the persons interviewed, the proportion of households with at least one mosquito net increased from 38% to 72% from 2005 to 2010-2011, and the proportion of those who had at least one insecticide-treated net (ITN), from 27% to 63% (Ndiaye et Ayad 2006 ; Ndiaye et Ayad 2007 ; Ndiaye et Ayad 2009 ; ANSD 2011). The proportion of children under age 5 who slept under an ITN during the night preceding the survey increased from 10% in 2005 to 35% in 2010-2011.

The treatments received by the children under age 5 also changed. Among those who had a fever during the two weeks preceding the survey (30% in 2005, 23% in 2010-2011), 12% took antimalarial drugs rapidly, the same day or the next day in 2005, versus 6% in 2010-2011. The proportion was lower in 2010-2011 possibly because some of the children

with fever had a rapid malaria test, which in general turned out to be negative, ruling out malaria as a cause of the fever<sup>1</sup>; this test could not be done in 2005, since it was not yet available in health facilities. The use of chloroquine was still frequent in 2005 (two-thirds of the treatments the same day or next day) although since 2003 the official recommendation has been to no longer use it. In 2010-2011, it is much less frequently used, in less than one-sixth of cases, half of the children who had antimalarial drugs rapidly receiving ACT.

### **c. The impact of the changes in health infrastructure and health programmes on child mortality**

Child mortality, as we have seen above, declined continuously in Senegal between World War II and the late 1980s. In 45 years, from 1945 to 1990, the probability of dying before the age of 5 was reduced by two-thirds, from approximately 400 per 1,000 to 140 per 1,000. The decline accelerated in the late 1970s and early 1980s, when a new health policy oriented towards primary health care was initiated. The ensuing development of health infrastructures in the various regions, and the implementation of the Expanded Programme for Immunization (EPI) probably contributed significantly to the accelerated decline (Pison et al., 1995).

The stagnation of child mortality in the late 1980s and early 1990s coincided with a stagnation of improvements to the health infrastructures and programmes. In particular, the EPI, which had greatly advanced during the 1980s, then marked time, with a decrease in vaccination coverage during the 1990s. This decrease is probably one factor explaining why the decline in child mortality ceased thereafter in the 1990s. And the renewal of vaccination efforts at the end of the 1990s and the beginning of the 2000s is one of the reasons for the renewed mortality decline thereafter.

The stagnation of child mortality in the 1990s also corresponds to the spread of chloroquine resistance in Senegal, which probably resulted in an increase in malaria deaths among children. However, the new malaria control policy developed in the 2000s has progressively changed behaviours and treatments and this has probably contributed to the renewed decline in child mortality, along with the resumption of vaccination efforts.

For a better understanding of the mortality trends of children in Senegal, we shall now examine the changes that have occurred in the causes of death. Unfortunately, reliable information is not available for causes of death on a national scale, but the observations made in the three rural demographic surveillance sites in Senegal will give an idea of the changes that have taken place in this country.

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<sup>1</sup> Malaria transmission is seasonal in Senegal with a peak of transmission from August to November (this period in an average, the transmission period is in general shorter in the north of the country, and longer in the south, and varies also locally depending on the presence or not of stagnant water) (Trape et al., in press). The 2005 DHS survey took place between February and June, a period during which malaria transmission was low, and the majority of fever episodes among children were not related to malaria. The 2010-2011 DHS survey occurred between October 2010 and May 2011, a period during which malaria transmission was also in general at relatively low levels, with the exception of the regions which were the first to be surveyed, in October and November.

## **B. CHANGES IN CHILD MORTALITY AND CAUSES OF DEATH RECORDED IN THE THREE RURAL DEMOGRAPHIC SURVEILLANCE SITES OF SENEGAL**

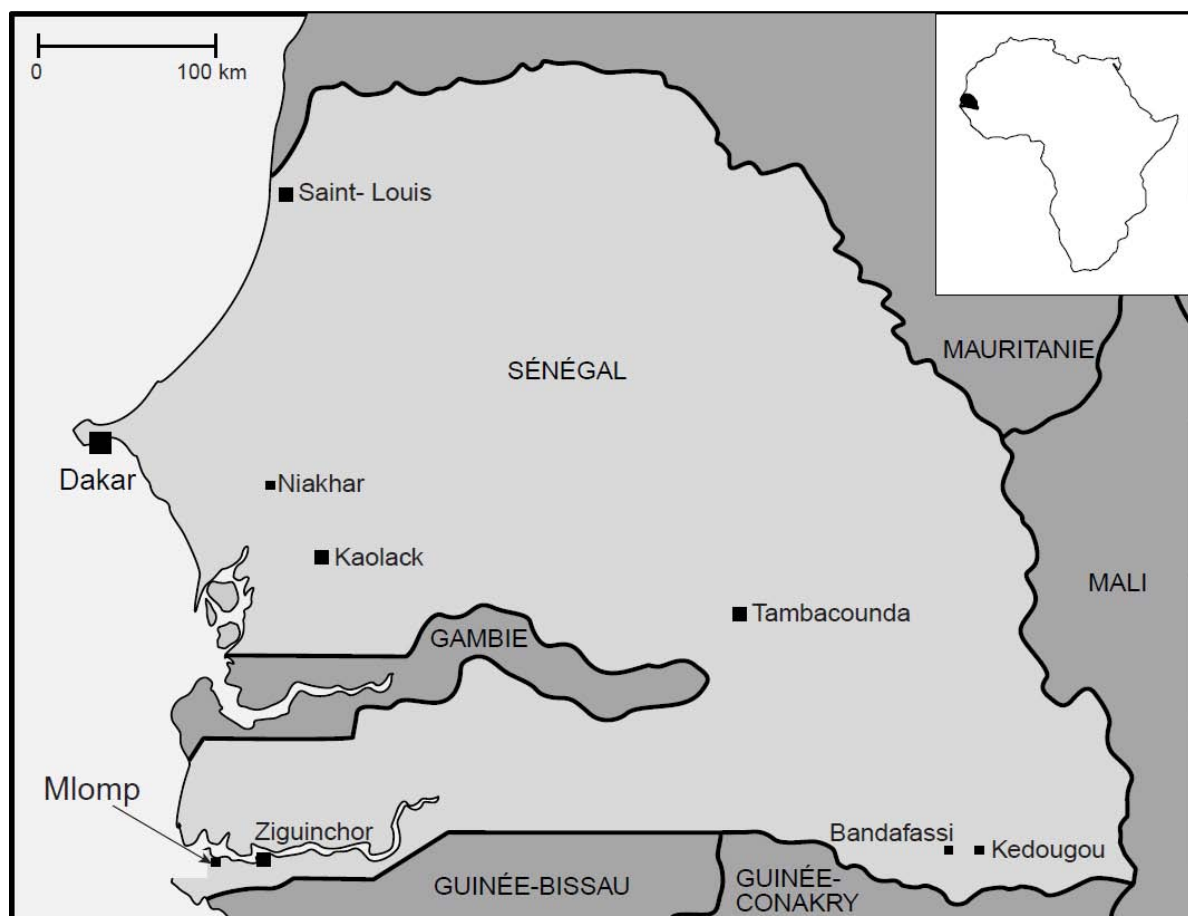
The populations of three Senegalese rural areas, Bandafassi, Mlomp and Niakhar, have been monitored for more than twenty-five years (Pison et al, 1993 ; Pison et al., 1997, Delaunay et al., 2001). Changes in child mortality and causes of child death in these populations have been documented precisely. As these demographic surveillance sites are located in areas of the country that are very diverse, the mortality differences between them give an idea of the overall geographic variations within the country.

### ***1. The Bandafassi, Mlomp and Niakhar surveillance sites***

#### **a -Locations and characteristics**

The Bandafassi population site is situated in south-east Senegal and, at a distance of 750 km, is the site farthest from Dakar, the capital city (figure 5). The Niakhar site, situated in the west and most populated area of the country, is the closest (150 km from Dakar). Mlomp, located in the south-west, like Bandafassi, is at a distance of 500 km .

Figure 5. Location of Bandafassi, Mlomp and Niakhar sites in Senegal



In 2010, the three sites had populations of about 13,000 inhabitants (Bandafassi), 43,000 (Niakhar), and 8,000 (Mlomp). Population density differed greatly from one site to the other, being highest in Niakhar (177 inhabitants per square km), lowest in Bandafassi (19) and intermediate in Mlomp (63). The ethnic composition also varies. In Niakhar, it is homogenous, with 96% of the population belonging to the Serer ethnic group, and in Mlomp likewise, one ethnic group, the Diolas, is dominant. The population of Bandafassi is more diverse, however, and divided into three ethnic groups: the Fula (57% of the population), the Bedik (28%) and the Mandinka (16%)<sup>2</sup>. Detailed descriptions of these three sites are given elsewhere (Pison et al, 1993; Pison et al., 1997; Delaunay et al., 2001).

The populations of the three sites have access to health centres operated by nurses: one in Bandafassi, one in Mlomp, and three in Niakhar. Their level of activity varies. The Mlomp dispensary, operated by a nurse who is also a Catholic nun, is the busiest. In addition to an outpatient clinic it has 12 hospital beds and a small laboratory. All pregnant women in Mlomp attend prenatal visits and deliver in a maternity clinic, most frequently the one located close to the health centre, which has 10 beds. Pregnant women at risk are systematically taken to Ziguinchor hospital (at a distance of 50 km) some time before delivery. Deliveries in the Mlomp maternity clinic are assisted by two matrons supervised by the nurse from the health centre.

The health centres of the other two sites are less active, and the proportion of women delivering in a maternity clinic is low: 15% in Niakhar during the 1988-1997 period, and 3% in Bandafassi. Throughout Senegal, about one woman in two delivered in a maternity clinic during the 1988-1997 period, the proportion increasing to 62% during the 2000-2004 period and 73% in 2006-2010 (Ndiaye et Ayad 2006 ; ANSD 2011). The proportion is higher in towns than in rural areas: respectively 80% and 30% during the 1988-1997 period, 88% and 47% in 2000-2004, and 93% and 60% in 2006-2010 (Ndiaye et al., 1994 ; Ndiaye et al., 1997). The proportions observed in Niakhar and Bandafassi are therefore well below the average for rural areas of the country. The exceptional situation in Mlomp, where the level is very high and well above the urban average, results from the efforts of health personnel in the area, and the delivery traditions of the Jola ethnic group, who do not favour delivery at home (Enel et al., 1993).

Mlomp also preceded the other sites with vaccinations. At the outset, in 1971, the vaccination programme only involved a few of the children, but by the late 1970s it had gradually increased in influence until practically all children were fully vaccinated. The vaccination coverage has subsequently been maintained at this very high level up to the present day. In Bandafassi, apart from vaccinations received during national campaigns, practically no child was vaccinated until 1987. It was only then, following the acceleration of the EPI organised at the beginning of that year, that child vaccination began on a regular basis, resulting that year in a sudden increase in vaccination coverage. From a level approaching 0% it rose to 48% of children aged 12 to 35 months in February 1987 (Desgrées du Loû and Pison, 1996). Over the following years, efforts waned and vaccination coverage

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<sup>2</sup> Fertility is high in all three sites, but with appreciable differences between them. In 1990, it was highest in Niakhar, where the total fertility rate was, on average, 7.7 children per woman, lowest in Mlomp (5.0) and intermediate in Bandafassi (6.3).

tended to decrease, but the revival of the EPI in 1995 brought it once more to a peak, this time even higher than in 1987, with 80% of the children fully vaccinated. Unfortunately efforts waned once more in subsequent years and coverage rapidly fell to below 50% in 1999 (Guyavarch, 2003).

## **b. Population surveillance**

The population of each site has been monitored for several years by means of multi-round survey techniques (Pison et al, 1993; Pison et al., 1997; Delaunay et al., 2001; Guyavarch, 2003; Duthé, 2006; Kante, 2009). Following an initial census, villages are repeatedly visited on a regular basis. The list of those present on the previous occasion is checked during each visit, and information is collected concerning the births, marriages, migrations and deaths (including cause of death) that have taken place in the meantime. Surveillance did not start in the same year in the various sites, and the frequency of visits is different. In Bandafassi and Mlomp, where surveillance started in 1970 and 1985, respectively, visits are carried out on an annual basis, whereas in Niakhar, where surveillance started in 1984, the frequency of visits has changed. It was annual from 1984 to 1986, weekly from 1987 to 1997, three-monthly from 1997 to 2005, and subsequently four-monthly.

As in many rural African areas, most deaths occur without the presence of a doctor to certify the event or diagnose the cause. The cause of death is determined by the ‘verbal autopsy’ method, which involves collecting information on the circumstances of the death and the symptoms of the disease that preceded it from the family of the deceased person. The same questionnaire is employed for these interviews at the three sites (Garenne and Fontaine, 1988 ; Desgrées du Loû et al., 1996b).

Information collected directly from the family is collated with clinical information from the health centre or hospital registers for those patients who died or had a clinical examination there before their death. In the case of Mlomp, most people who died had visited the health centre during their final illness, and information is consequently available from the register kept by the nurses since the beginning of the survey. The completed verbal autopsy questionnaire is submitted to two doctors who each make an independent diagnosis. If they disagree, a third doctor rereads it and acts as an arbiter.

The accuracy and reliability of diagnoses based on this method is variable, depending on the cause of death (Snow et al., 1992). Neonatal tetanus, for example, is quite easily identified by this means, as is measles. There is a specific word for measles in every language, and everyone can identify it when an epidemic breaks out. When a mother who has lost her child is asked whether the cause of death was ‘measles’ (using the name employed in her own language), she is seldom mistaken, and her personal diagnosis can generally be considered reliable<sup>3</sup>. For many other diseases, diagnosis made through the verbal autopsy method is not very reliable. Malaria, for example, is easily mistaken for other diseases that also involve fever (Snow et al., 1992 ; Desgrées du Loû et al., 1996 ; Duthé, 2008 ; Duthé et al., 2010) (see also discussion below).

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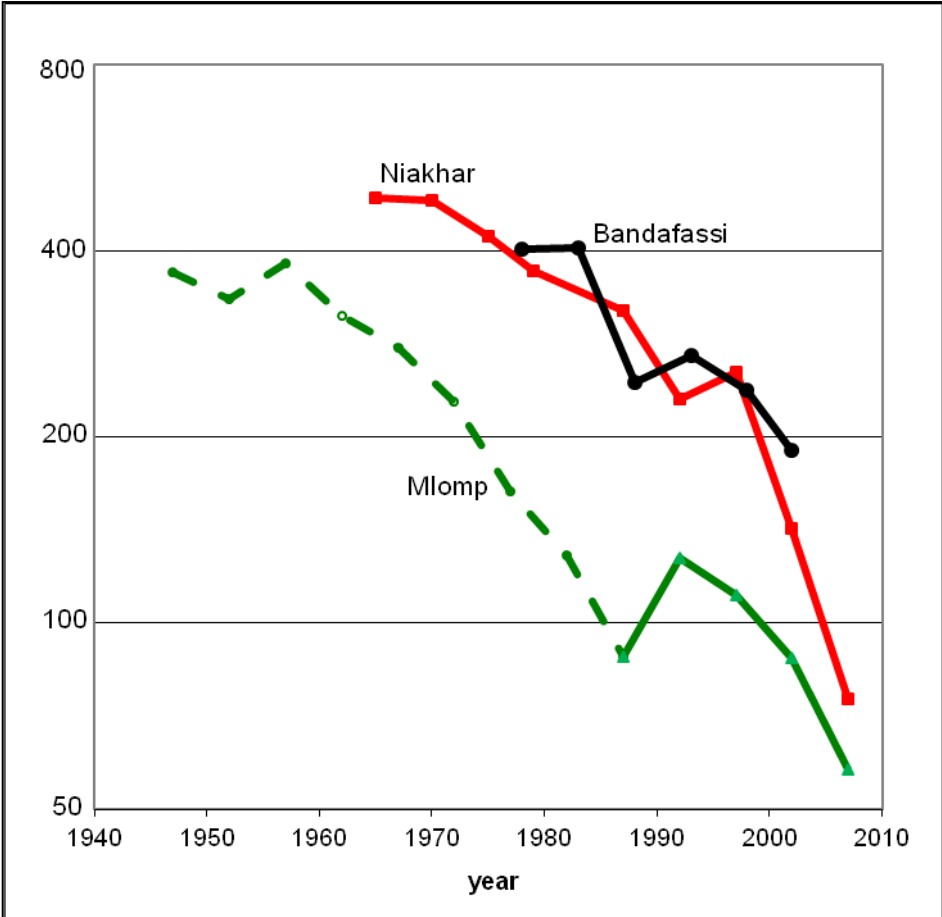
<sup>3</sup> Due to the spread of immunization since the 1980s and the resulting decline in epidemics, however, self-diagnosis of measles is not as reliable as in the past.

Information gathered by the population surveillance systems at the three sites is of high quality for African rural populations. In particular, coverage of events is practically exhaustive and their dating is precise. This ensures good reliability of the resulting demographic measures, in particular those relating to mortality level and trends.

**2. Child mortality trends in the three demographic surveillance sites of Senegal**

The mortality trends of children under five (5q0) in the three demographic surveillance sites of Senegal are shown in figure 6.

Figure 6. Child mortality (5q0, per 1,000) by period of five years in the three rural sites of Senegal: Bandafassi, Mlomp and Niakhar (5q0: probability for a new-born child of dying before age 5) (to be completed later for Bandafassi)



Sources : Bandafassi, Mlomp and Niakhar demographic surveillance sites

Note: for the Mlomp site, estimates for the period 1945-1984 are derived from maternity histories collected retrospectively in 1985, and for subsequent years, from the surveillance data.



Similar patterns are found in the three areas studied: a first period with a plateau and a second period with a fall. The fall was interrupted in a similar fashion in the late 1980s in the three sites, and child mortality subsequently remained at about the same level or even rose slightly during the 1990s. Mortality then started to decline again rapidly. The simultaneous stagnation observed on the three sites is concomitant with the trend observed at national level based on national survey estimates; this shows that this stagnation was real and is not an artefact related to measurement problems.

The differences between the mortality trends in the three sites concern timing and levels. In Bandafassi, the site farthest from Dakar, child mortality commenced its rapid decline the latest (after 1986), and this decline coincides with the acceleration of the Expanded Programme of Vaccination in 1987 (Desgrées du Loû and Pison, 1996a). As mentioned above, the proportion of vaccinated children was very low until that year. The vaccine coverage then increased sharply in the area as a result of the vaccination campaign of 1987, with nearly half of the children fully vaccinated just afterwards. Child mortality (5q0) then decreased rapidly: it was 40% lower during the six years after the acceleration of the EPI than during the six years before (Desgrées du Loû and Pison, 1996a).

In Niakhar, 150 km from Dakar, the fall began earlier, starting in the early 1970s. This was mainly attributed to a drop in rainfall causing a reduction in malaria (Cantrelle et al., 1986), but the fall continued at the same rate after the dry years had passed. The immunization campaign against measles from 1978 to 1982, the introduction of EPI in the early-mid 1980s, more progressively than in Bandafassi, and campaigns for promoting malaria chemoprophylaxis and presumptive treatment of fever with chloroquine, are probably the main reasons for the initial mortality decrease observed from the mid 1970s up to the early 1990s (Delaunay et al., 2001 ; Trape et al., in press).

The Mlomp zone was clearly different from the other two in that the fall started earlier (from the mid-1960s), and reached a much lower level – the risk of death before 5 years declined four-fold in 20 years. As mentioned above, this rural zone, very distant from Dakar, has been equipped since 1961 with a dispensary and a private maternity clinic providing quality health services to a large majority of the population in the area (Pison et al., 1993).

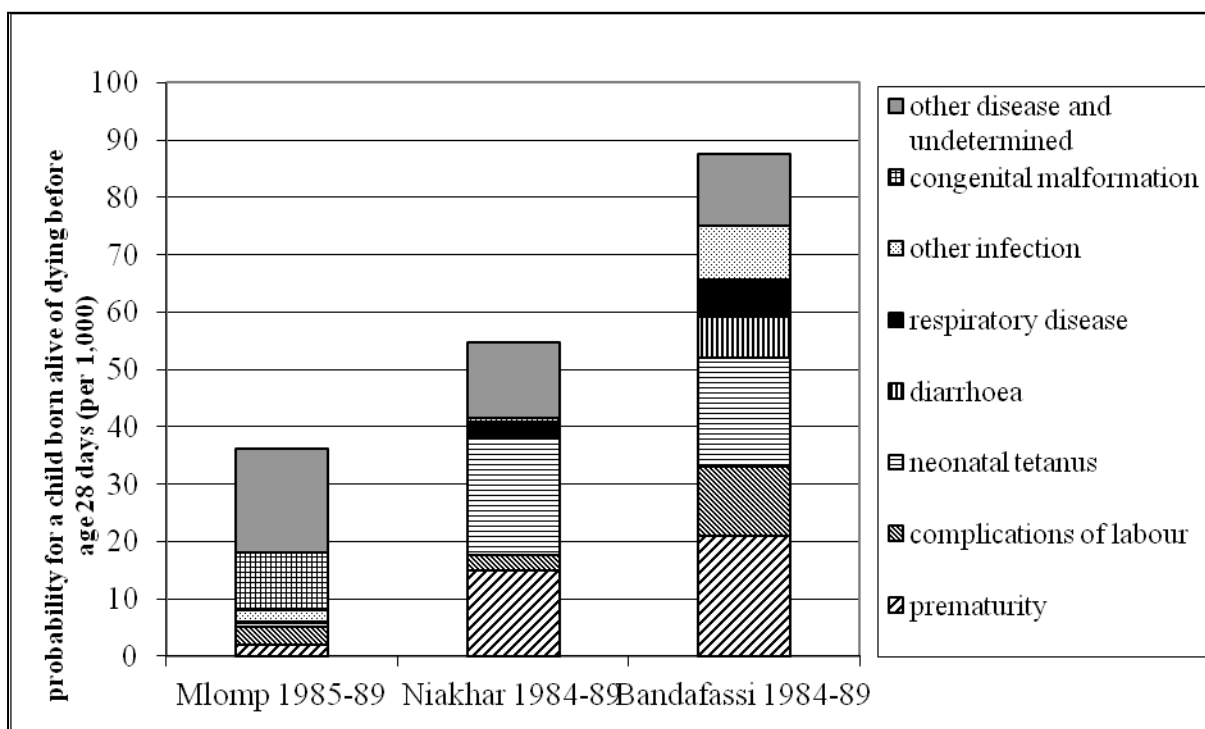
There is a correlation between mortality decline and the availability of health services in these three rural zones before the stagnation of the 1990s. The educational level of women and household incomes at the time were low in all these areas. The rapid fall in child mortality in rural areas of Senegal during the late 1970s could therefore have been closely linked to the decentralization of infrastructures, and to the new public health policy which provided new services to populations with no previous access to health care.

The study of causes of death provides insights on the mechanisms of mortality decline.

### 3. Distribution of the causes of death during the 1980s

Figures 7 and 8 compare child mortality and its causes in Bandafassi, Mlomp and Niakhar during the second half of the 1980s (1984-1989 period in Bandafassi and Niakhar, and 1985-1989 in Mlomp), distinguishing neonatal mortality (figure 7) from mortality between one month and five years (figure 8).

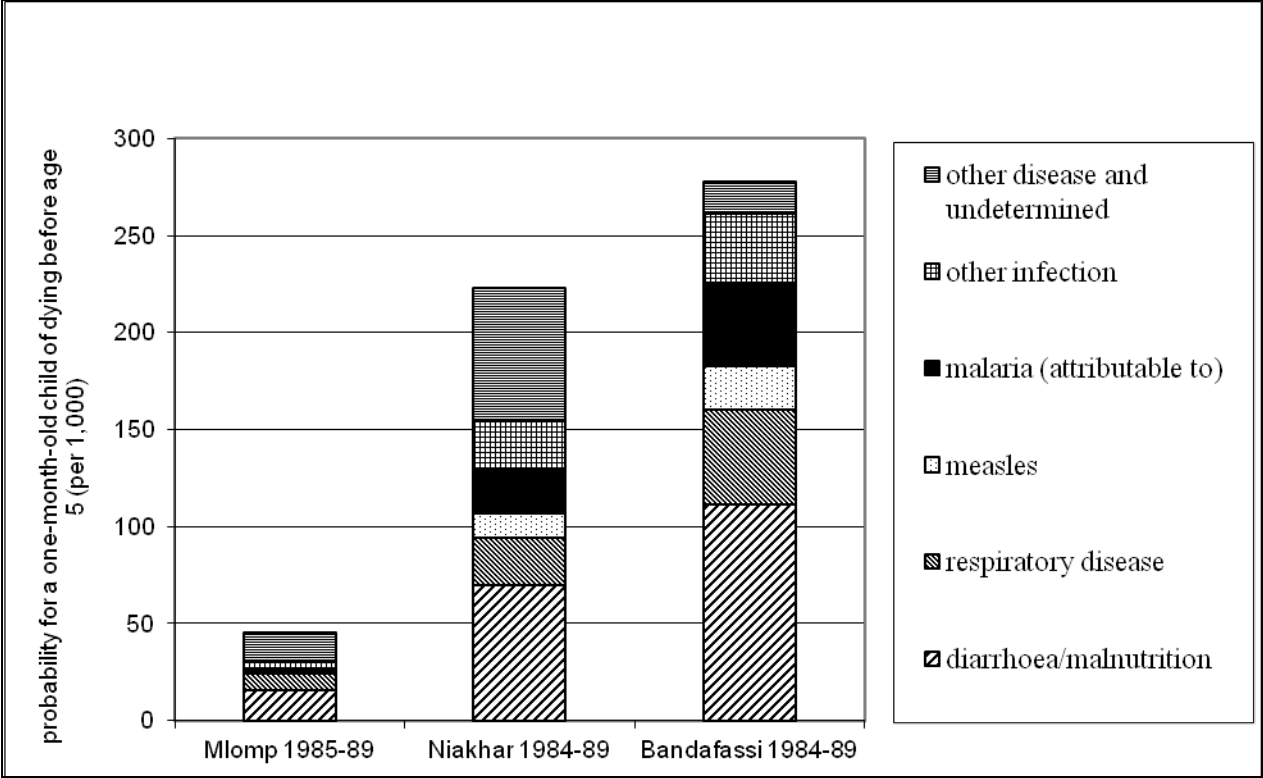
Figure 7 - Neonatal mortality by cause of death in the three demographic surveillance sites of Senegal (period 1984-1989)



Neonatal mortality was lowest in Mlomp (36 per thousand) and highest, more than double, in Bandafassi (87 per thousand), with an intermediate level of 55 per thousand in Niakhar. The overall difference was due to differences in mortality for all the major causes of death. Neonatal tetanus, responsible at that time for one third of the neonatal deaths in Niakhar and one quarter in Bandafassi, and accounting on the two sites for the deaths of about 20 newborns per thousand, was only 1 per thousand in Mlomp. There were almost the same contrasts for deaths due to premature delivery and low birth weight (2 per thousand in Mlomp as against 15 and 21 per thousand in Niakhar and Bandafassi respectively). Beyond the neonatal period and up to 5 years (figure 8), the overall difference in mortality level was even greater (45, 223 and 277 per thousand in Mlomp, Niakhar and Bandafassi, respectively), and it was again linked to the differences in mortality for each of the major causes of death –

diarrhoea and malnutrition, pneumonia, malaria etc. Measles, a major cause of death in Bandafassi and Niakhar at that time, was absent in Mlomp.

Figure 8 - Mortality of children from age 28 days to age 5 years by cause of death in the three demographic surveillance sites of Senegal (period 1984-1989)



Unfortunately, we have no information on the causes of child mortality in Mlomp before the 1970s when it was still high there, but it is probable that the same causes as those present in Bandafassi and Niakhar in the recent period were dominant at the time. If we assume that the causes of death in Bandafassi and Niakhar in the second half of the 1980s reflected those prevalent in Mlomp, twenty years previously – at a time when death from all causes reached the same levels there – it is likely that there was a fall in each of the major causes of death.

Let us examine now in more detail the evolution of two important causes of child death, a first one, measles, which regressed substantially in the 1970s and 1980s thanks to vaccinations, and a second one, malaria, which increased in the 1990s before declining rapidly in the 2000s.

**4. Measles, a fast regressing cause of death**

As just noted, there are large differences between the three sites in deaths from measles. This cause of death disappeared earlier in Mlomp than in the two other sites: it accounted for only two deaths in Mlomp during the twenty five years from 1985 to 2010, among a total of

some 430 deaths of children under 5 years, but it was still a major cause of death in Bandafassi and Niakhar during the second half of the 1980s.

As mentioned above, measles was a disease that villagers could easily identify until recent decades. Information is consequently available on cases of measles-related deaths occurring in Bandafassi since the start of demographic surveillance in 1970, well before the introduction of verbal autopsy questionnaires in 1984. This makes it possible to trace the evolution of measles-related mortality since 1970 in this site. A change occurred after the introduction of immunization in 1987. Before then, measles was responsible for a high proportion of deaths. Among children from 1 to 20 months old it accounted for about 1 in 7 deaths (14% in 1970-1986), and of 1 in 3 (33%) among children aged 21 to 59 months, thus making it the primary cause of death. From 1987, however, measles was responsible for only 3% and 5% of deaths at these ages during the six year-period 1987-1993 (Desgrées du Loû and Pison, 1996).

Figure 9 - Annual fluctuations of measles mortality among children under five years old at Bandafassi and Niakhar  
(to be completed later for years 2002 to 2010)

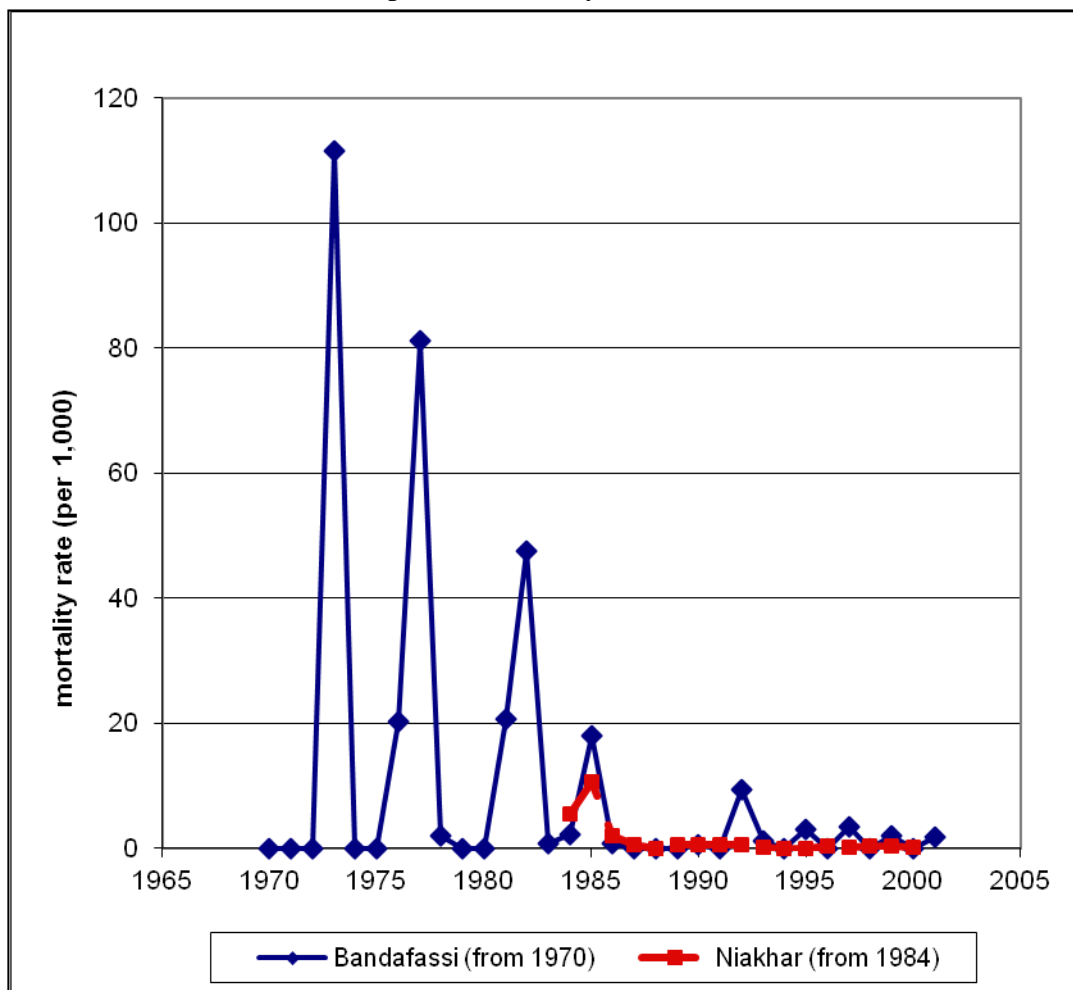


Figure 9 retraces the annual variations in measles mortality rates in Bandafassi among all children under 5 years old over the whole period, from 1970 to 2002. The annual variations in Niakhar are also shown from 1984. The figure shows that before 1987 measles occurred in the Bandafassi area only in epidemics with comparatively long intervals between them. More than a decade often elapsed between two successive epidemics in the same village. Because of the long intervals, whenever a village was affected by an epidemic, it was massively hit – within only a few weeks, many children fell ill (practically all those who were born since the previous epidemic), with very high mortality rates. At least 15% of all children below five years old died in the 1976-77 and the 1981-1982 epidemics (Pison et Langaney, 1985).

The epidemiology of measles in Bandafassi changed after the introduction of the EPI in 1987. Apart from an epidemic which occurred in 1992 and led to relatively fewer deaths than previously, deaths from measles were observed more frequently (every two years) but the numbers in each epidemic were ten to fifty times lower than in the 1970s and the first half of the 1980s. Measles became increasingly endemic, and much less lethal.

A similar change occurred in Niakhar, although observations shown in figure 9 start only in 1984. The last big measles epidemic, which was national and also affected Bandafassi, was in 1985 in Niakhar. Since then, measles has become a much less frequent cause of death.

Deaths from measles in both Bandafassi and Niakhar declined greatly in the 1980s, and this marked regression of one of the main causes of child mortality was the most spectacular consequence of introducing vaccinations in these two populations. The lessening of vaccination coverage in the 1990s led to a slight rise in deaths from measles in Bandafassi, but this was well below the extremely high pre-vaccination levels. In Niakhar, it remained at a relatively low level in the 1990s and the 2000s.

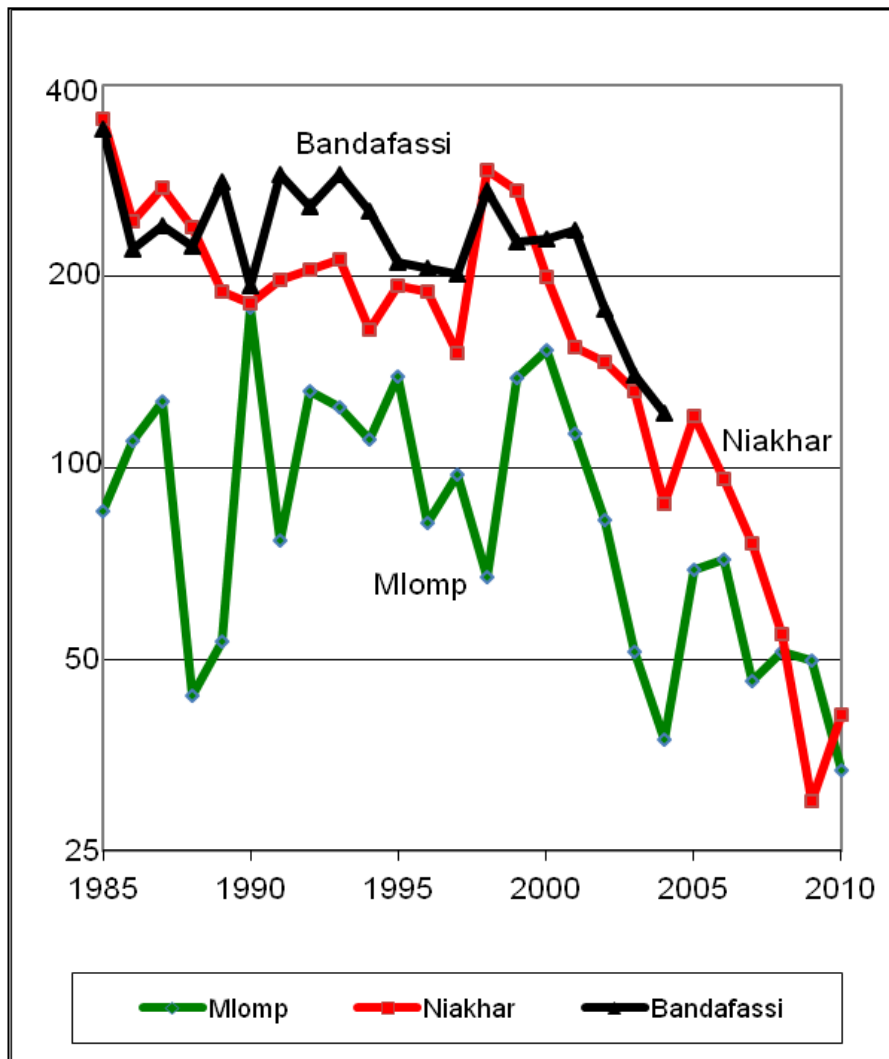
### ***5. Temporary rise in deaths from malaria in the 1990s and rapid fall afterwards***

The rapid decrease in overall child mortality over the 1970s and 1980s contrasts with the setback observed during the 1990s. Let us examine the evolution on the three sites year by year since 1985 (figure 10). In Mlomp, under-five mortality varied considerably from one year to the next between 1985 and 2000, tending to increase slightly over this period. It stagnated during the 1990s in Bandafassi and decreased slightly in Niakhar with the exception of the years 1998, 1999 and 2000 during which child mortality increased due to a meningitis outbreak (Trape et al., forthcoming).

In the following years, under-five mortality fell rapidly on the three sites, decreasing nearly four-fold in nine years in Mlomp and Niakhar (if we compare the estimate for the most recent year, 2010, with that for 2001).

Figure 10 - Annual fluctuations of child mortality (5q0) since 1985 in the three sites of Senegal.

(to be completed later for Bandafassi)



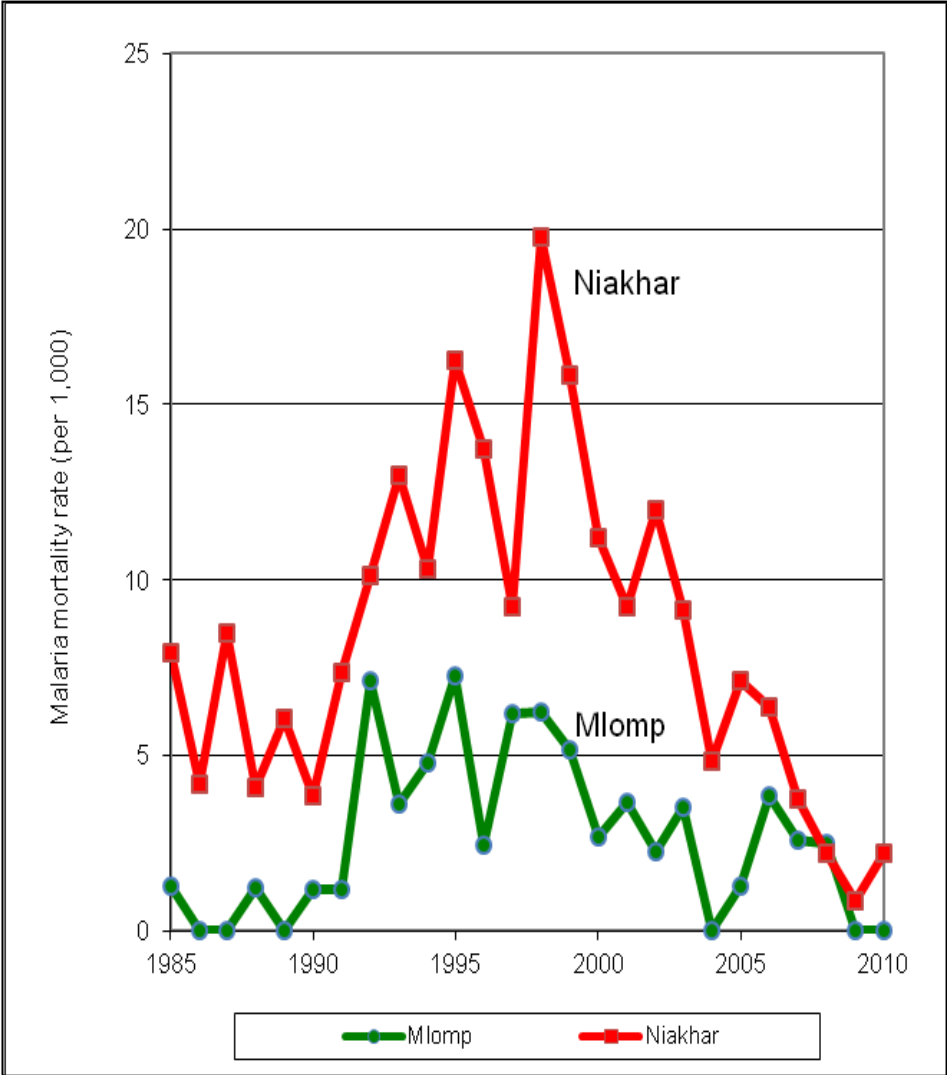
Let us examine now the trends in mortality attributable to malaria in the three sites since 1985 (figure 11). Deaths from malaria are more difficult to diagnose than those from measles. This disease, as mentioned above, cannot be identified with any certainty through the verbal autopsy method, because of the difficulty in distinguishing it from other diseases that also cause fever. So here, “malaria” is a broad category that includes “true malaria” but also “unspecified fever”. In Mlomp, however, malaria-related mortality could be retraced with some accuracy, because many of the children who died following bouts of fever had sought advice from the local health centre, where biological tests (using thick blood films) were made to verify the malaria diagnosis.

Figure 11 shows the evolution of malaria-related mortality in the three areas since 1985. In Mlomp, it was relatively low until 1991 (five times lower than Bandafassi and eight times

lower than Niakhar); a sign that the fight against malaria organized by the health centre in the 1970s and 1980s was successful. Malaria-related mortality rose sharply between 1991 and 1993, and has subsequently remained at higher levels. During the periods 1985-1991 and 1993-2000, malaria increased 7-fold in Mlomp, 2.5-fold in Bandafassi and 2-fold in Niakhar. This rise was largely attributable to the appearance and spread of malaria strains in the late 1980s and early 1990s that were resistant to chloroquine, the anti-malarial widely used in Senegal both preventively and curatively up to the present day (Trape et al., 1998), and which dramatically reduced malaria-related mortality in Mlomp from 1975 onwards. This unfavourable trend in malaria deaths is one of the reasons why overall child mortality stagnated in Bandafassi and Niakhar in the 1990s and rose again in Mlomp.

Figure 11 - Annual fluctuations of mortality attributable to malaria (5q0) since 1985 in the three sites of Senegal.

(to be completed later for Bandafassi)

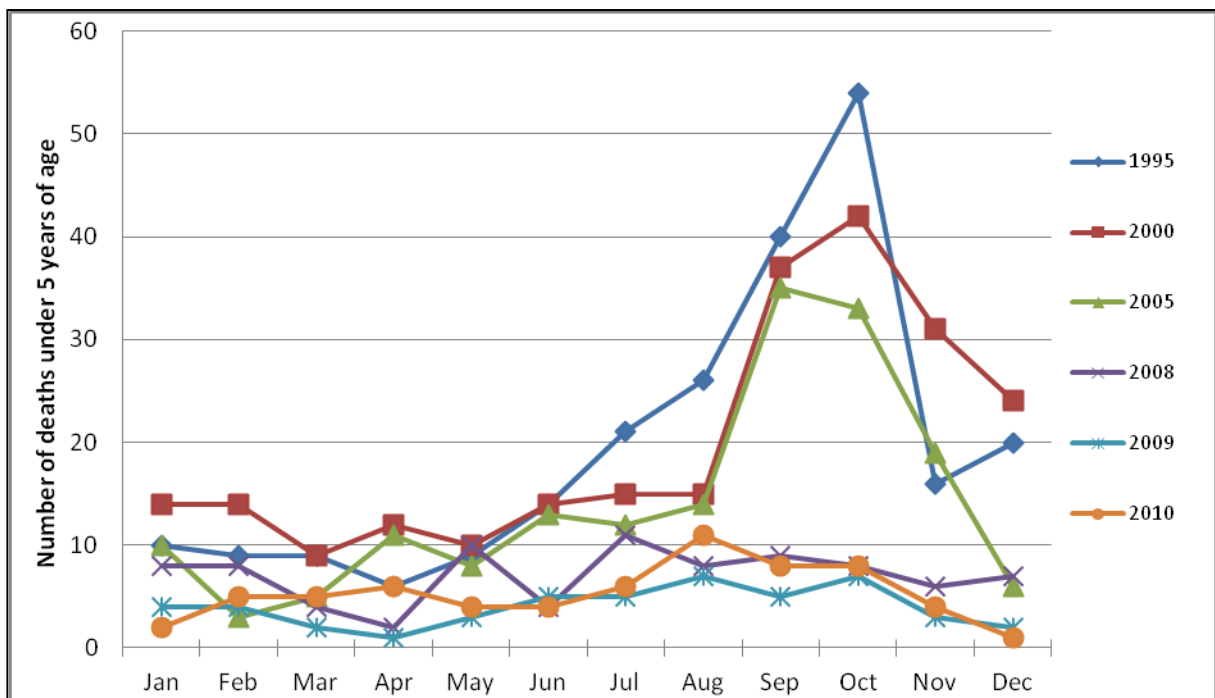


Malaria mortality has decreased markedly in Niakhar and Mlomp from 2000 onwards. In Niakhar, it was 10.5, 7.6, 6.6 and 2.0 per thousand per year in under 5 year old children during the periods 2000-2003, 2004-2005, 2006-2007 and 2008-2010 respectively (Trape et al., in press).

The question remains whether these trends are real or artefacts ?

As mentioned above, both the sensitivity and the specificity of verbal autopsy technique vary considerably according to causes of deaths and epidemiological context (Snow et al., 1992). Although malaria has some symptoms in common with other diseases, such as fever and impairment of consciousness, we believe that correct estimates of deaths attributable to this disease were obtained in Niakhar using this method (Trape et al., in press). In the Sahel and sub-Sahel, rains occur only during a short period of the year, and the seasonal peak of children deaths with a picture of high fever, seizure and/or coma occurring a few weeks after the malaria vectors increase massively in numbers allows a diagnosis of malaria to be made with a much better sensitivity and specificity than in areas where rains occur year round.

Figure 12 - Seasonal pattern of deaths among children under 5 years of age in 1995, 2000, 2005 and each year since 2008 in Niakhar.



Source : Trape et al., in press

Figure 12, which concerns only the Niakhar site, shows that overall child mortality used to vary a lot according to the season until recently, with a peak during the second part of the rainy season. This peak was related partly to the peak of malaria transmission (Trape et al., in



press). The seasonal peak of mortality has been reduced a lot in Niakhar in the recent years (2008-2010), and this correlates well with the drop in mortality attributable to malaria ; an indication that our estimates of mortality attributable to this disease are probably plausible for this area.

In Mlomp, malaria-related mortality could be retraced also with some accuracy, because many of the children who died following bouts of fever had sought advice from the local health centre, where biological tests (using thick blood films) were made in order to ascertain whether the malaria diagnosis should be confirmed.

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The decline in child mortality in the 1970s and 1980s in the three Senegalese sites was allied to the reduction in deaths from infectious diseases, thanks largely to vaccinations. Death from measles, previously one of the primary causes of child mortality, regressed considerably after the introduction of vaccinations. But in the 1990s, as in the whole country, vaccination ceased to increase in Bandafassi and Niakhar. Deaths from malaria increased sharply following the spread of chloroquine resistance across the country. Stagnation of the vaccination effort and the resurgence of malaria mortality allied to chloroquine resistance explain the halt in the infant mortality decline in Bandafassi and Niakhar. In Mlomp, where nearly all the children had been vaccinated for at least 20 years, it was the rise in malaria mortality that explained the resurgence of child mortality in the 1990s. The change in malaria control policy and the revival of health programs targeting children through for example the “*Journées de la survie de l’enfant*” are probably the main reasons of the new rapid decline of child mortality in the 2000s.

### **C. DISCUSSION: LESSONS FROM SENEGAL**

Mortality has declined in Sub-Saharan Africa over the last 60 years but the decrease has not been regular. It has accelerated over some periods, as during the last decade, and slowed down during others. This is not solely attributable to AIDS. In order to determine other diseases or factors that also played a part, our study focuses on Senegal – a country with very low AIDS prevalence but where trends in child mortality have closely resembled those of the whole region. In addition, Senegal has the advantage of possessing relatively numerous information sources available for tracing child mortality trends on a national scale, as well as three demographic surveillance sites in rural areas where child mortality could be followed and the causes of deaths studied in detail over almost 25 years.

Senegal experienced an appreciable and steady fall in child mortality from the end of World War II until the late 1980s. In 45 years, from 1945 to 1990, the risk of a newborn child dying before the age of 5 years was divided by three, dropping from about 400 per thousand to 140 per thousand. The fall accelerated towards the end of the 1970s and early 1980s, at a time when a new public health policy oriented towards primary health care was introduced. This led, in particular, to an increase in primary health care infrastructures in the regions (they had previously been highly concentrated in Dakar), and to the introduction of the Expanded Programme for Immunization (EPI).

In the three Senegalese demographic surveillance sites, child mortality has declined over the last 30 to 50 years, decreasing seven-fold in Mlomp and ten-fold in Niakhar. In all of them, the fall was interrupted in a similar fashion in the late 1980s, as it did in the country as a whole, and child mortality then remained at about the same level during the 1990s at Bandafassi and Niakhar, and even rose slightly in Mlomp. Mortality declined again afterwards, at an even more rapid pace than before the pause.

On the three sites, the decline in child mortality in the 1970s and 1980s was allied to the reduction in deaths from infectious diseases, thanks largely to vaccinations. Death from measles, previously one of the primary causes of child mortality, regressed drastically after the introduction of vaccinations. But in the 1990s, just as in the whole country, vaccination coverage ceased to increase in Bandafassi and Niakhar, and deaths from measles, while not returning to the previously very high levels, stopped their downward trend. Deaths from malaria, on the other hand, increased sharply following the spread of chloroquine resistance across the country. Stagnation of the vaccination effort and revival of malaria mortality allied to chloroquine resistance explain the halt in the decline of infant mortality in Bandafassi and Niakhar. In Mlomp, where nearly all the children had been vaccinated for at least 20 years, it was the rise in malaria mortality that explained the resurgence of child mortality in the 1990s.

These observations are probably valid for the whole country, and deaths from malaria must have appreciably increased. The pause in the vaccination drive must also have impeded the struggle against death by infection. These two phenomena were the main reasons for the fifteen year cessation of the decline in under-5 mortality in Senegal, a country that, despite having so far escaped a severe AIDS epidemic and its consequences on mortality, has still experienced a health crisis leading to a halt in the decline of child mortality. This crisis was due to the conjunction of several factors, in particular: a new epidemiological situation created by resistance to chloroquine; an inefficient healthcare system; an inability to ensure basic health services (such as vaccinations); and an unfavourable economic situation.

Mortality decline resumed rapidly in the 2000s due also to a combination of factors, among which the renewal of vaccination efforts and investments in anti-malaria programs played an important role. The decrease in mortality observed in the three sites during the 2000s is due to decreases in all the main causes of childhood deaths, including diarrhoeal diseases and acute respiratory infections. Both programs probably had a much larger impact than would be expected from a mere reduction or eradication of deaths from malaria or vaccine-preventable infections, and they might have had synergic effects.

When measles vaccine was introduced in Africa in the late 1970s and early 1980s, several studies showed that it coincided with a major reduction in child mortality (Aaby et al., 1995). Since this was not explained by measles prevention, the concept that vaccines have non-specific effects emerged, suggesting that health interventions affect general immunity and these non-specific effects are broader than specific preventive effects. Live vaccines like BCG and measles and polio vaccines are beneficial, but inactivated vaccines like DTP and hepatitis B vaccine have negative effects, particularly for girls (Kristensen et al., 2000 ; Garly et al., 2004). Vitamin-A supplementation is usually considered the most cost-effective intervention to reduce child mortality, the assumption being that it saves lives by preventing

vitamin A deficiency. Its effect is more probably due to an amplification of the beneficial and negative effects of vaccines by vitamin-A supplementation (Benn et al., 2009).

Hence, vaccination and vitamin-A supplementation programmes and campaigns have affected child mortality much more than usually assumed. The so-called vaccine-preventable infections including measles, TB, whooping cough, diphtheria, tetanus, and polio have probably not accounted for more than 10-25% of the childhood deaths in Africa – malaria, diarrhoea, sepsis and respiratory infection being far more important (Benn et al., 2009).

Concerning the programs to control malaria, studies have pointed out that some reduced overall child mortality more than would be expected from a mere reduction or even an eradication of malaria deaths. In the 1980s, control of malaria with either seasonal chemoprophylaxis or insecticide-treated nets in The Gambia reduced overall mortality in children by nearly 50%, a much larger reduction than was anticipated, and reduced deaths attributed to pneumonia and diarrhoea as well as those attributed to malaria (Alonso et al., 1991). More recently, a malaria control programme on the island of Bioko, which employed both insecticide-treated nets and indoor residual spraying, reduced under-5 child mortality from 152 per 1000 to 55 per 1000 over a 4 year period (Kleinschmidt et al., 2009). How a reduction in the incidence of malaria could have such a marked effect on overall mortality is uncertain, but there is evidence that malaria impairs the immune response, increasing susceptibility to other infections (Mackenzie et al., 2010), and that continuous exposure to malaria impairs weight gain during the malaria transmission season (Shiff et al., 1996).

The changes in health conditions and programmes observed in Senegal are common to many countries in Sub-Saharan Africa and explain why many of them experienced the health crisis in the 1990s and the renewal of progress in the 2000s, irrespective of whether or not they were hit by the AIDS epidemic.

Child mortality will continue to decline rapidly in coming years if efforts to control infectious diseases are increased and if diseases and conditions responsible for early deaths, in particular those in the neonatal period, which represent a growing percentage of child deaths, receive more attention.

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