The Influence of Rainfall Variations on Child Survival in Rural Burkina Faso

Stéphanie Dos Santos[♦] & Sabine Henry[*]

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[?] Département de démographie. Université de Montréal. CP 6128, succ. Centre-Ville. Montréal (QC). H3C 3J7. CANADA. tel : 001.514.343.6111 ext. 1963. fax : 001.514.343.2309. s.dos.santos@umontreal.ca

[*] Département de démographie. Université de Montréal. CP 6128, succ. Centre-Ville. Montréal (QC). H3C 3J7. CANADA. tel : 001.514.343.6111 ext. 1959. fax : 001.514.343.2309. sabine.henry@umontreal.ca

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Introduction

In sub-Saharan Africa, health conditions continue to be the worst of all developing regions and child mortality rates are running at an average rate of 174 deaths per thousand births, compared with 121 per thousand in low income regions as a whole (World Bank, 2004). Beyond the effects of the classical determinants of child survival (mothers' and fathers' education, birth interval, economic status of the household, etc.), ecological factors (such as drought or land degradation) can have a strong influence on child survival in rural subsistence societies, particularly through their impact on malnutrition and on income reduction. More precisely, ecological factors affect the quantity and variety of food crops produced and the quantity and quality of water. They can also influence the availability of income-generating work and the time mothers can spend at home in child care.

In the early 1970s, in sub-Saharan Africa, 70 million people were affected by chronic food shortages, and this number attained 100 million by 1985 (Kiros and Hogan, 2000). Famine induced by drought has almost certainly contributed to continued high African mortality levels (Caldwell and Caldwell, 1992). Persistence of unfavourable climatic conditions could lead not only to a sharp reduction of the food production but also to the disorganisation of food distribution. The consequence for the population is a deterioration of alimentation (Palloni, 1988). In addition, the availability of a basic minimum food supply of sufficient variety is critical to ensure adequate amounts of all nutrients. The most vulnerable groups to excess famine deaths are the young and the old (Kiros and Hogan, 2000). In Niakhar (Senegal), 60% of deaths among children aged 1 to 60 months have been attributed to malnutrition (Garenne *et al.*, 2000). Infant mortality is expected to increase because malnutrition, by reducing birth weight, influences the neo-natal and post-neonatal mortality (Palloni, 1988). Maternal diet and nutrition during pregnancy also affect birth weight and, during lactation, influence the quantity and nutrient quality of breast milk (Mosley and Chen, 1984). In the case of breastfeeding, babies are less vulnerable to strong food reduction than expected, except if breastfeeding is not exclusive or if malnutrition also concerns the mothers. In addition, the survival of children aged 1 to 5 is very sensitive to food shortage because of young children's needs for solid food and because their immune system is not completely developed (Palloni, 1988). Moreover, famines help the rapid spread of disease through the weakening of immune systems, through resulting migrations, through the breakdown of sanitary services, and through the readiness of famine victims to eat whatever they can get (Kiros and Hogan, 2000). Using a coarse classification of aridity in West-Africa, Curtis and Hossain (1998) have shown that the effect of aridity zone on the risk of a child being wasted is highly significant. Another study, using DHS data for ten West-African countries, has found a positive effect of rainfall on child mortality but only for ages 1-5 (Balk *et al.*, 2004). However, in this last study, Burkina Faso is represented by only two values of rainfall, as the country experiences mean annual rainfall varying from 370mm to 1140mm.

During the rainy season, energy expenditure related to heavy agricultural tasks is at a maximum and intake is at a minimum after the exhaustion of the previous year's food supplies and before the current year's harvest (Jaffar *et al.*, 2000). Using the demographic surveillance systems (DSS) established in the Nouna district (in North-western Burkina Faso), Kynast-Wolf et al. (2002) reported a highly significant monthly effect on mortality, with the highest mortality observed in February (the dry season) and the lowest in July and August. However, in the Gambia, no marked difference in the rate of death between Gambian children born in the harvest season (defined as the period from January to June) and those born in the hungry season (defined as the period from July to December) was found (Jaffar *et al.*, 2000).

In addition to malnutrition, ecological factors may influence child survival by reducing income. In periods of drought, rural families experience many difficulties such as the reduction of food production, abnormal increases in food grain prices and the non-availability of jobs (Paul, 1998). In poor societies in particular, families may spend 80 percent or more of their disposable income on food; thus variations in income or food prices may directly translate into rising rates of malnutrition mortality. In rural subsistence economies, even seasonal variability in income and/or food availability may lead to seasonal swings in mortality.

Finally, rainfall seasonality may also have effects on pathogens by increasing the development of water-related vectors, the development of water-related diseases (such as cholera and diarrhoea). Dry conditions seem to protect population from diseases transmitted by vectors such as malaria for a while, by limiting their development. This benefit is only temporary however as the increase in deaths comes with the return of the rains (Dyson, 1991).

Objective

Even if the importance of the ecological factors has already been emphasized in the well-known article written by Mosley and Chen (1984) on the determinants of child survival, there is little empirical evidence on this topic. The few studies on this topic used very simple data (coarse classifications of rainfall or an indicator determining the season). Based on accurate rainfall data, this study aims to ***examine the influence of rainfall variations on child survival in rural Burkina Faso***. More precisely, it is one of the first times that three dimensions of climate have been analysed in all regions in Burkina Faso (West Africa): aridity, drought, and seasonality of rainfall.

Background

General Background

According to international statistics, Burkina Faso is one of the poorest countries in the world: ranked 175th of 177 countries in the Human Development Index (UNPD, 2004). Largely a rural country with more than 80% of its population living in settlements of less than 10,000 inhabitants, agriculture (mainly subsistence farming and cattle-raising) is the main source of income: 90% of the population is engaged in these activities (INSD, 2000). The country's economy itself depends heavily on this economic sector: subsistence farming and cattle-raising together account for one-third of the country's GDP. Moreover, its productivity is especially determined by environmental factors (Niemeijer and Mazzucato, 2002). As a consequence, the agro-climatic conditions are critical to rural households, for which agriculture represents the main source of livelihood.

Child mortality

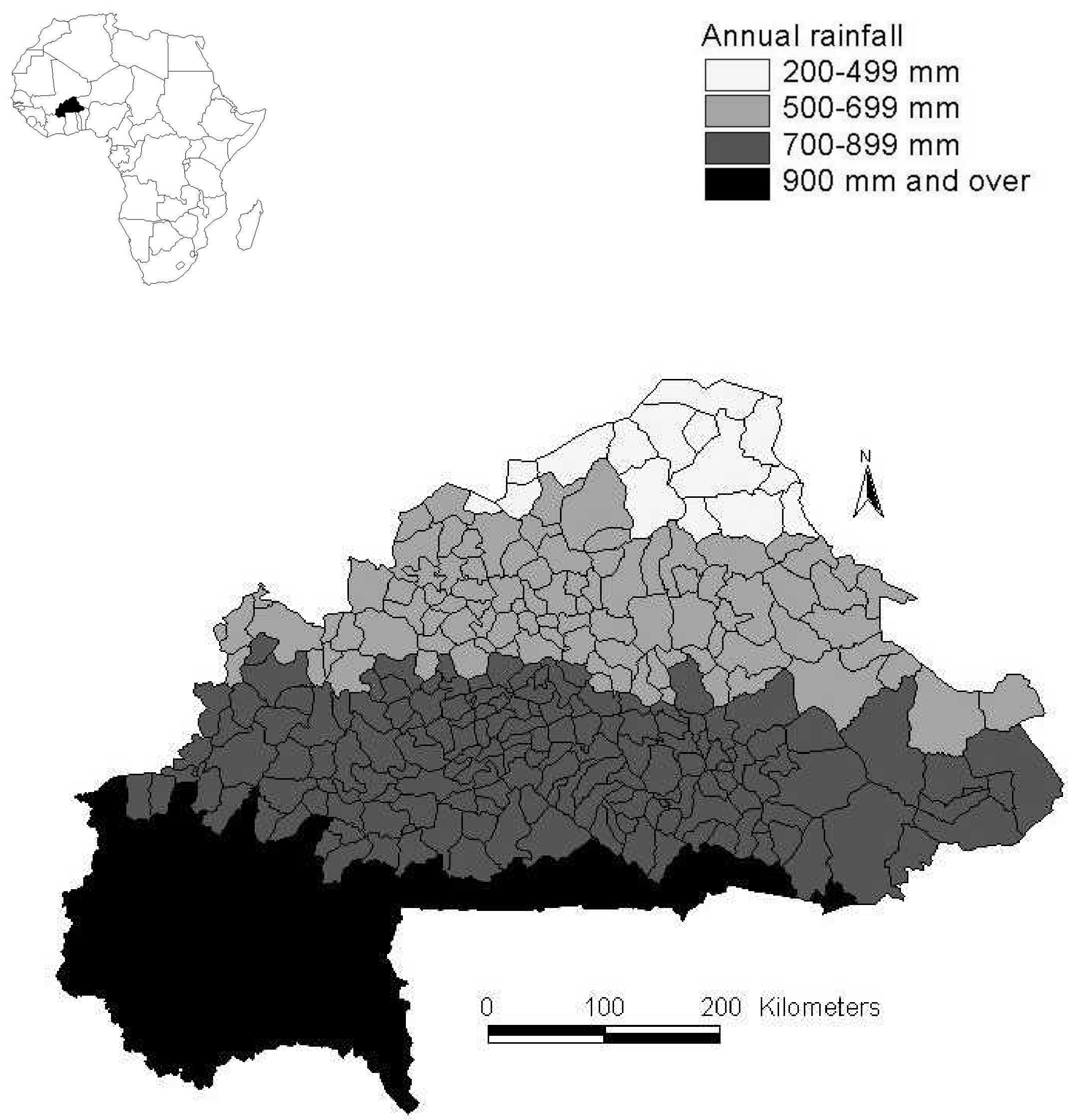
This country experiences high levels of child mortality compared to the rest of western Africa (WHO, 2004), with large geographic disparities within the country. The child mortality rate is 116 per thousand in the Western region while it is more than 180 per thousand in the Sahel, the East and the Central regions (Schoumaker, 2002).

Environmental Conditions in Burkina Faso

Burkina Faso is bordered by Mali on the north and west, by Niger on the east and by Benin, Togo, Ghana, and the Côte d'Ivoire on the south. It has a tropical climate with two very distinct seasons: the rainy season with between 600 and 900 mm of rainfall, and the dry season during which the Harmattan, a hot dry wind from the Sahara, blows. The rainy season lasts approximately 4 months, May/June to September, and is shorter in the northern part of the country.

Four large agro-climatic regions can be defined, characterised by a strong south–north decreasing gradient of average annual rainfall (Figure 1). The Sahel in the north receives less than 500 mm rainfall a year and high temperatures. These very constraining agro-climatic conditions led to extensive pastoralism and rain-fed agriculture of pearl millet and sorghum (Hampshire and Randall, 1999). In the south, favourable environmental conditions, and especially average rainfall above 900 mm, allow for cash crops like maize and cotton apart from millet and sorghum (Ingram *et al.*, 2002).

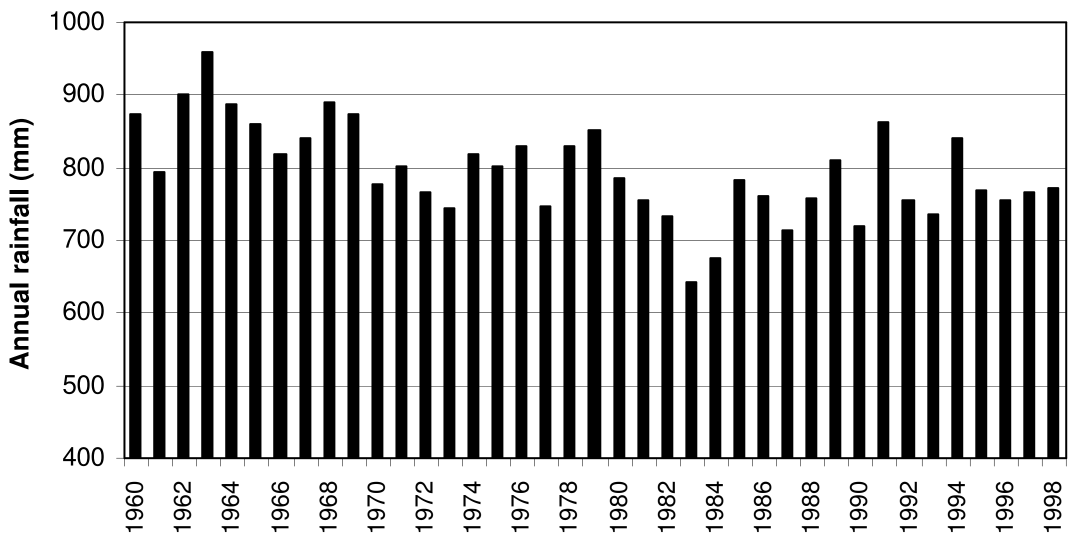
Figure 1. Map of Burkina Faso showing mean annual rainfall at the department level, 1960-98



Source: New, Hulme and Jones, 2000.

In addition, large year-to-year variations in total precipitation (Figure 2) and in the timing of rainfall lead to extremely variable crop outcome and uncertainty at the household level (Reardon *et al.*, 1988; Roncoli *et al.*, 2001). Since the late 1960s, Burkina Faso has experienced several droughts, especially in the early 1970s and most recently, in the mid-1980s (Hampshire and Randall, 1999; Nicholson, 2001; Roncoli *et* *al.*, 2001). This situation follows the general pattern over the last 50 years in Sahelian West Africa, characterized by a long-term downward trend of rainfall (Nicholson, 2001; Niemeijer and Mazzucato, 2002).

Figure 2. Annual Rainfall in Burkina Faso, 1960-1998



Source: New, Hulme and Jones, 2000.

Data

An original aspect of this work is the use of exceptionally reliable multi-source data for the study of how rainfall variations influence child survival in Burkina Faso.

1. Individual and household data are provided by a nationally-representative detailed retrospective (life-history type) survey, conducted in 2000 by the UERD of the University of Ouagadougou, the Demography Department of the University of Montreal and the CERPOD (Poirier *et al.*, 2001). In all, 9,612 life histories were collected from 3,570 households in the sample. The household questionnaire included questions on the individual characteristics of the different members and on their housing conditions. The detailed biographical questionnaire covered family origins, migration, employment, matrimonial and fertility histories. In this last unit, 3,751 women were surveyed, with 17,544 births and 3,268 deaths among these children.

2. Covering the 1960-1998 period, **rainfall data** were obtained from the global monthly precipitation data set produced by the Climatic Research Unit at the University of East Anglia (New *et al.*, 2000). These data were interpolated from a network of stations at a spatial resolution of 0.5 degree latitude and longitude. Monthly rainfall data were extracted from this database and three rainfall variables were constructed at the department level using geographical information systems (GIS).

Methods

In this study, we focus on child death between 1970 and 1998. Each child, born in rural areas[1], is followed from his or her first month[2] to the age of 5 until his or her death or until the time of censoring. Child biographies are censored by the survey (in 2000), the age of 5, the fostering of the child[3], or a departure to abroad or a city. The data are organised as a child-period data file in which each line represents a one-month period. The dependant variable indicates if a death occurs during each month interval. Overall, the sample consists of 8,230 children and a total of approximately 370,000 child-periods.

Event-history methods are used to estimate the impact of various characteristics of rainfall on child survival, controlling for relevant variables related to the child and his or her mother. The event history approach allows us to take into account time-varying explanatory variables. Binary logistic regression methods are used to estimate discrete-time event history models (Allison, 1995). The statistical model is specified as follows:

$$\log\left(\frac{p_{ti}}{1-p_{ti}}\right) = \alpha_t + \beta'.\mathbf{X}_{\mathbf{ti}} \qquad (1)$$

where p_{ti} is the conditional probability that child *i* experiences the event (death) at age *t*, given that the event has not already occurred. α_t represents the baseline hazard function, and $\boldsymbol{X_{ti}}$ is a vector of child, mother and rainfall covariates. Both time-constant and time-varying covariates are included in the models. Censored cases (no death) are treated as the reference category. In the model, the standard errors of the regression

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[1] Defined as <10,000 inhabitants at the day of birth (Beauchemin *et al.*, 2002).
[2] The first month is excluded from the analysis because birth deaths are more often linked to endogenous factors, such as congenital malformations or hereditary diseases.
[3] In this case, it is not possible to analyse the effect of mother characteristics on child death.

coefficients are adjusted for maternal clustering accordingly using Huber-White standard errors (Hox, 2002).

Explicative variables

Table 1 shows the categorization of the variables used in the models.

Variables related to the child and to his or her mother

A number of biodemographic variables have consistently been shown to affect the probability of child death. They include the child's sex, birth order and multiple births. We included these variables and the period of history (generation) to control for any effects they might have on child mortality. The age of child forms the baseline hazard of child death.

In addition, we included variables that might determine mother's health knowledge and behaviour such as cultural (ethnic group) and socio-economic (education and age of mother) factors.

All of these variables are time-constant covariates. Mother's education is not a time-varying covariate, but the level attained at the time of the survey. We assume that if a mother goes to primary school at least one year (generally before 10 years old), she does so before her first delivery.

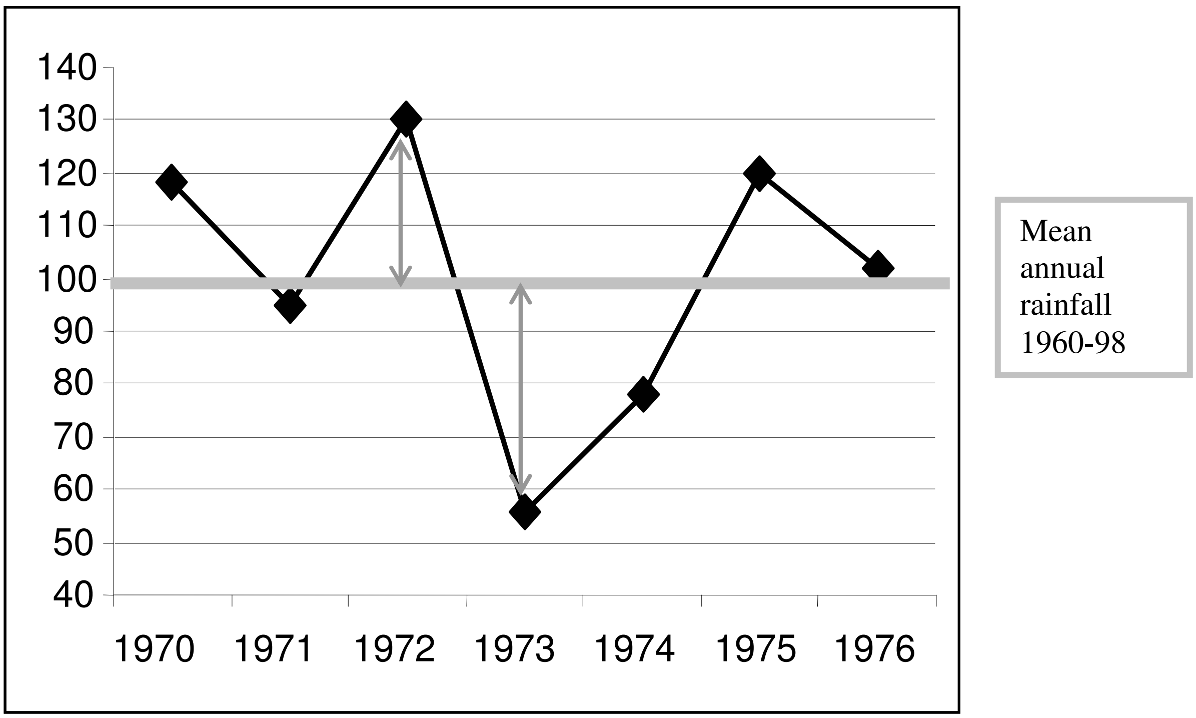
Rainfall variables

Three variables measured at the department level are used to capture three dimensions of the potential impacts of rainfall on child death: the mean annual precipitation over the 1960-1998 period (aridity), the percent of normal precipitation over the year (drought) and the percent of normal precipitation over the month (seasonality). All of these rainfall variables are time-varying covariates.

The first variable, the annual mean of precipitation is considered a good indicator of agricultural productivity and of vulnerability to drought. Four categories are compared: less than 500 mm per year, 500 to 699 mm per year, 700 to 899 mm per year, and more than 900 mm per year (Figure 1). These categories correspond to areas where crops with similar yield responses to water are cultivated (Doorenbos and Kassam, 1987).

The second variable indicates the extent to which rainfall in the department over the year differed from the long-term rainfall conditions in the department. The measure is the ratio of the mean rainfall over the year of child observation to the mean annual rainfall over the 1960–1998 period (Figure 3), and three categories are compared in the models (less than 85%, 85 – 94%, and 95% and over).

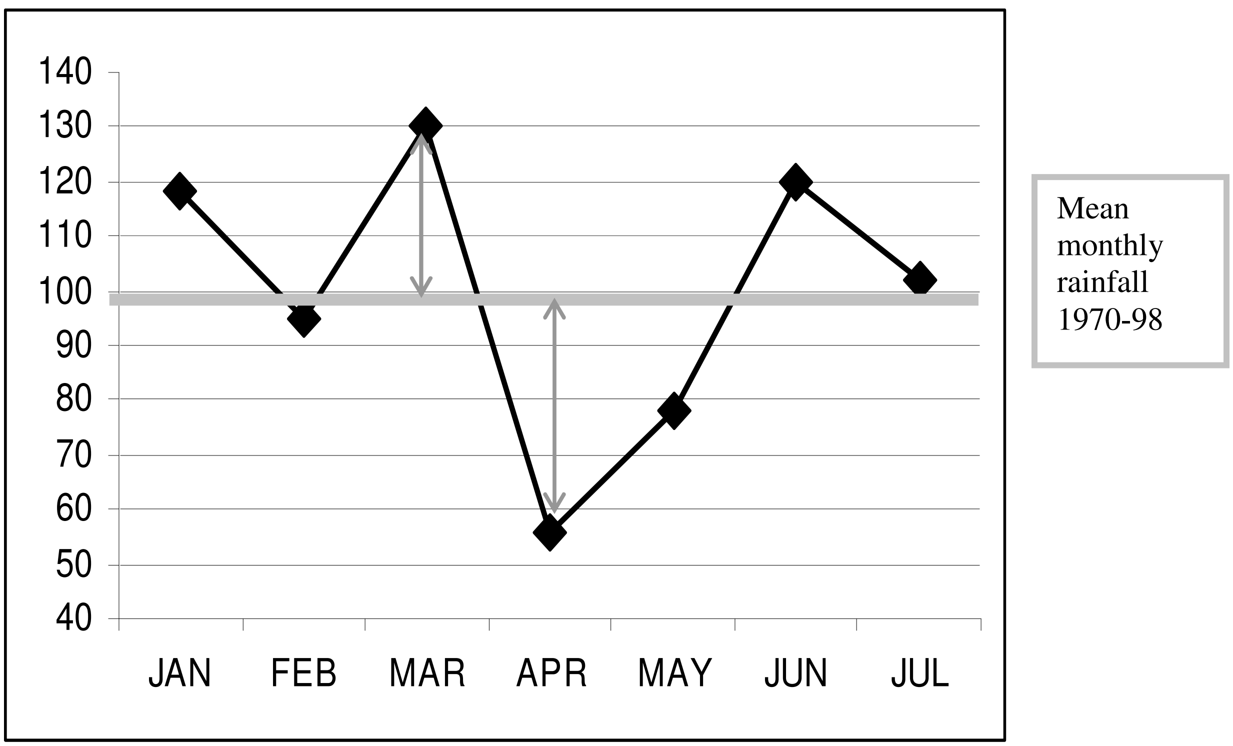
Figure 3. Percent of normal precipitation over the year



Overall, it is expected that the risk of child death will increase if the year is unfavourable for rainfall conditions (drought effect). More accurately, the influence of drought on the risk of death is expected to be higher in drier agro-climatic regions than in wetter regions. By consequence, an interaction variable of these two variables is introduced in the model.

The third variable indicates the extent to which rainfall in the department differed over the month of child observation from the long-term rainfall conditions in the department for the same month. The measure is the ratio of the rainfall over the month of child observation to the mean monthly rainfall over the 1970–1998 period (Figure 4), and five categories are compared in the models (less than 85%, 85 – 94%, 95-105%, 105-114%, and 115% and over). Because rainfall may be very low in the dry season (1mm or less), the indicator is calculated only for months with at least 20mm of rainfall. AGRHYMET[4] defines the begin of the rainfall season when 20mm of water falls in 1 or 2 days without a dry period occurring during the next 30 days (AGRHYMET, 1992). For the very dry months, the value of the indicator is fixed to the reference category (normal conditions). It is expected that the risk of child death will increase if rainfall for the month is far off normal conditions (higher or lower).

Figure 4. Percent of normal precipitation over the month



Finally, in the literature, season at birth is often used as a proxy for climatic influence (Blacker, 1991). This variable is introduced as a control variable. Two seasons are compared: the harvest season, defined as the period from January to June and the hungry season, defined as the period from July to December (Jaffar *et al.*, 2000). The risk of death is expected to be higher during the hungry season.

[4] Regional centre of agronomy, hydrology and meteorology, working on Burkina Faso, Cap-Vert, Gambia, Guinée-Bissau, Mali, Mauritania, Niger, Senegal, and Chad.

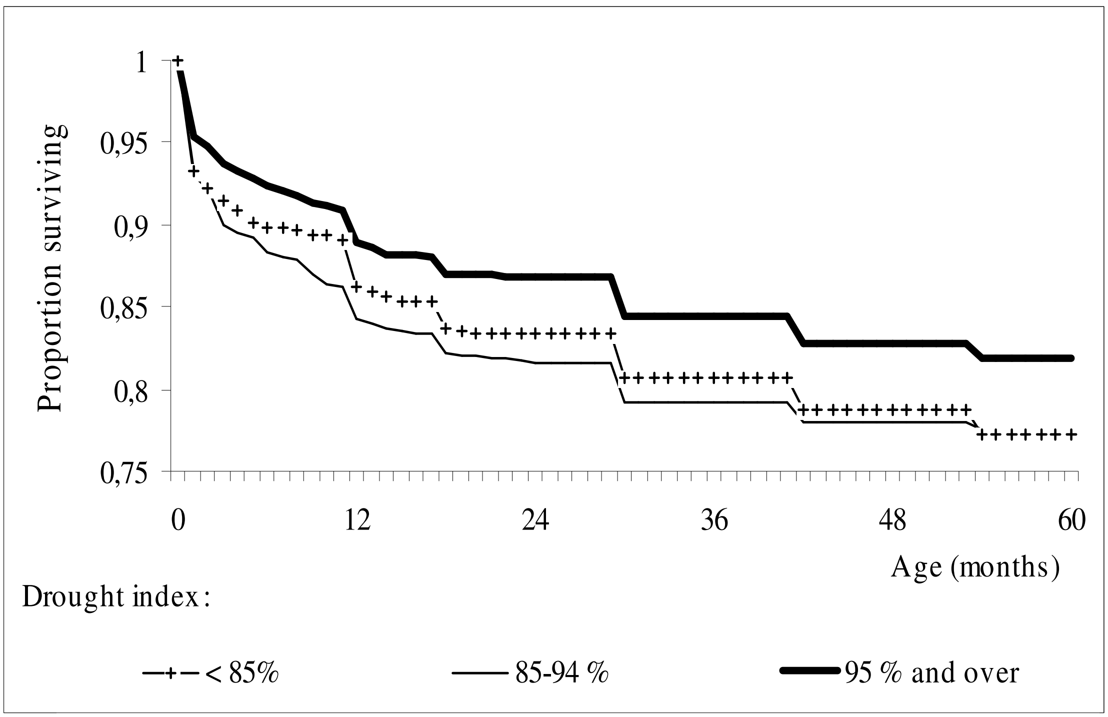
Table 1. Descriptive Statistics of Sample at the Time of Death or Censoring

	% of sample
Child variables	
Age	
<12 months	12.78
12-23 months	8.39
24 months and over	18.83
Sex	
Boy	50.98
Girl	49.02
Birth order	
1	18.17
2-5	56.88
6 and over	24.95
Generation	
1970-79	21.29
1980-89	36.33
1990-98	42.38
Twins	
1 child	97.78
twins	2.22
Mother variables	
Age	
< 20	4.89
20-29	43.80
30 and over	51.31
Education	
No education	96.44
Primary and over	3.56
Ethnic group	
Mossi	45.41
Bobo, Dagara, Mandingue, Senoufo, Lobi	21.10
Fulani	9.05
Other	24.44
Rainfall variables	
Mean annual rainfall(aridity)	
<500mm	4.51
500-699mm	29.24
700-899mm	44.00
900mm and over	22.26
Drought index	
<85%	7.96
85-94%	26.44
85% and over	65.61
Monthly rainfall(seasonality)	
<85%	9.96
85-94%	4.89
95-104%	67.12
105-114%	7.15
115% and over	10.88
Season of birth	
Harvest season	52.06
Hungry season	47.94
Sample size	8,230

Descriptive results

Of the 8,230 children[5] in the database, 1,153 died between the first and the 60th month of life. Figure 5 displays Kaplan-Meier survivor functions for children according to the drought index. Although the risk of dying before 60 months is relatively rare, the effect of drought is fairly clear. Children who had lived in regions with normal recent rainfall conditions had higher survival rates than did those living in regions with a rainfall deficit. The differences between the survival curves of children who had lived in the rainiest regions and the two other with less rainfall are significant[6].

Figure 5. Survival of Children by Drought Index, 1970-1998 (Kaplan Meier plot)



Even if the positive effect of living in a region with normal recent rainfall conditions appears to be clear, it was seen only after infancy and especially during later childhood (after 18 months).

[5] The database counts 8,735 children at birth and 8,230 children from the first month of live.

[6] Differences observed are significant with the Cox test: p=0.006 between the curve "85 – 94%" and the curve "more than 95%" and p=0.028 between the curve "less than 85%" and the curve "more than 95%".

Multivariate Results

Table 2 presents the multivariate results including child, mother, and rainfall characteristics. The net effect of each variable and an interaction effect on child mortality are estimated in the logistic model.

Table 2. Event-History Model of Child, Mother and Rainfall Effects on the Risk of Death

	Odds ratio
Child variables	
Age	0.96***
Sex	
Boy (R)	1.00
Girl	1.10
Birth order	
1 (R)	1.00
2-5	0.89
6 and over	1.24
Generation	
1970-79 (R)	1.00
1980-89	0.80*
1990-98	0.84^{+}
Twins	
1 child (R)	1.00
twins	1.86***
Mother variables	
Age	
< 20 (R)	1.00
20-29	0.74*
30 and over	0.61***
Education	
No education (R)	1.00
Primary and over	0.58*
Ethnic group	
Mossi (R)	1.00
Bobo, Dagara, Mandingue, Senoufo, Lobi	0.92
Fulani	0.99
Other	1.08
Rainfall variables	
Mean annual rainfall and drought index	
<500mm * <85%	0.88
<500mm * 85-94%	1.50
<500mm * 95% and over	1.04
500-699mm * <85% (R)	1.00
500-699mm * 85-94%	0.62**
500-699mm * 95% and over	0.79*
700-899mm * <85%	0.51*
700-899mm * 85-94%	2.26**
700-899mm * 95% and over	2.09
900mm and over * <85%	0.53*
900mm and over * 85-94%	2.78***
900mm and over * 95% and over	1.56

Monthly rainfall	1.17
<85%	0.71*
85-94%	1.00
95-104% (R)	1.26*
105-114%	0.95
115% and over	
Season of birth	
Harvest season (R)	1.00
Hungry season	0.99
***: p<0.01; **: p<0.05 ; *: p<0.10; +: p<0.20 (two-tailed tests)	

As shown in various studies on this topic, the mother's education reduces child mortality and twins experienced an increased mortality risk. The effect of the mother's age is negatively related to the risk of child mortality. In contrast to the idea that young girls have a higher risk of death than boys, the effect of sex is not significant much like the effect of birth order.

The first rainfall variable introduced in the model is an interaction term, composed by the drought index[7] as the focal independent variable and the agro-climatic regions[8] as the moderator variable. Table 3 reports the odds ratio of different categories created by combining the drought index with the agro-climatic region. Odds ratios are expressed to allow the direct comparison of the agro-climatic regions within the drought regions (Table 3A) and the comparison of the drought regions within the agro-climatic regions (Table 3B).

Table 3. Results for the Interaction Variable.

Table 3A. Comparison of Agro-Climatic Regions by Drought Regions

	<500m	500-699mm	700-899mm	900mm and over
<85%	0.88	1	0.51 *	0.53 *
85-94%	1.32 +	1	1.15	1.46 *
95% and over	0.92	1	1.06	0.82

Table 3B. Comparison of Drought Regions by Agro-Climatic Regions

	<85%	85-94%	95% and over
<500mm	1	0.94	0.82
500-699mm	1	0.62 **	0.79
700-899mm	1	1.41	1.64 +
900mm and over	1	1.73 +	1.23

[7] Defined as the ratio of the mean rainfall over the year of child observation to the mean annual rainfall over the 1960–1998 period (Figure 3).

Table 3A shows that the 500-699mm region is distinguished from the other agro-climatic regions. More interesting are results from Table 3B. In the 500-699 mm region, the risk of child mortality is reduced when more than 85% of the normal amount of rain falls during the year. The pattern is the same in the driest region, but the result is not significant. By contrast, the risk of child mortality is increased in the wettest rainfall regions (more than 700mm) when recent rainfall conditions are more favourable. This opposite pattern may be explained by two different causes of child deaths in Burkina Faso, according to the agro-climatic regions. In the two driest regions, the impact of drought influences child death through malnutrition and the reduction of income while in wetter regions, a rainfall deficit limits the development of vectors and so protects children from malaria.

Concerning rainfall conditions during the month, it is expected that the risk of child death will increase if rainfall for the month is far off normal conditions (higher or lower). This variable - measured by a time-varying variable indicating the extent to which rainfall in the department over the month of child death differed from the long-term rainfall conditions in the department for the same month - showed that the risk of child death is reduced during the months with 85 – 94% of normal rainfall and increased during the months with 105-115% of rainfall conditions. This result may be explained by an increase of pathogens during the wettest months and a reduction of pathogens during the driest months, as suggested by Dyson (1991). It brings up the fact that the first causes of child death in Burkina Faso are the development of water-related vectors (malaria), the development of water-borne diseases (such as diarrhoea) or the development of water-washed diseases before the effect of malnutrition or income reduction.

As observed in The Gambia (Jaffar *et al.*, 2000), a non-significant effect of the birth season on child death has been found. This result contrasts with the highly significant seasonal effect identified in the Nouna district in Burkina Faso (Kynast-Wolf *et al.*, 2002).

[8] Defined as the mean annual precipitation over the 1960-1998 period (figure 1).

Discussion and Conclusions

High child mortality continues to be a disturbing feature of public health in many developing countries. Information on mortality patterns is needed for the evaluation of health politics, identification of health hazards, planning of public health activities, and for many other issues. The objective of this study was to analyse the influence of rainfall conditions on child survival in rural Burkina Faso. Although many researchers are convinced of the benefits of multi-disciplinary studies, practical issues have often limited their number. In terms of ecological factors, population scientists must settle for available data (often coarse classifications of rainfall or environmental vulnerability). In this study, rainfall variables are measured with accuracy at fine spatial and temporal resolutions. To provide an in-depth understanding of the effect of rainfall on child death, three dimensions of climate have been analysed. In addition, the event-history approach allows us to take into account the conditions of the child's environment during his or her first five years and not only at the time of the survey, as has generally been done by previous studies. The likelihood of child survival could be different if for example a child moved during his first five years from a village with unfavourable climatic conditions to a village with favourable climatic conditions. Our approach takes this residential change into account, by using the mother's migratory history collected by the survey.

As reported in the results, child survival in Burkina Faso depends on rainfall conditions. A rainfall deficit increases child mortality in the more vulnerable region (500-699mm), where crops are not adapted to the environmental conditions, by malnutrition and the reduction of income. In the driest region (<500mm), the principal activity is cattle-raising, an activity adapted to the local environmental conditions.

By contrast, a rainfall deficit reduces child mortality in wetter regions by limiting the development of pathogens. Results from monthly rainfall variability support this interpretation. The risk of child death is reduced during the months with 85 – 94% of normal rainfall and increased during the months with 105-115% of rainfall conditions. Finally, season of birth has not been found as significant, as in The Gambia (Jaffar *et al.*, 2000).

The results of this paper should not be considered as definitive, as several improvements may be introduced. Separate analysis for each period of childhood (infancy, toddlerhood, later childhood) should be considered. As found in Balk et al. (2003), the unweaned infants are expected to be less vulnerable to climatic variations than children aged 1-5, thanks to the protection of breastfeeding (Palloni, 1988). Wealth status, based on housing variables, and the urban-abroad experience of the mother before the child's birth (Muhidin and Ledent, 2005) should also be controlled. Finally, the introduction of community variables (such as the presence of a health centre) will be reported in forthcoming publications.

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