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Season-Smart: How Knowledge of Disease Seasonality and Climate Variability Can Reduce Childhood Illnesses in Mali

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Introduction

Seasonal variations in temperature and rainfall impact family well-being through its effects on water resources, food production, and disease transmission,[1-4] especially in the Sahel—a stretch of land squeezed between the Sahara desert and the savannah, where a long history of droughts and related famines have been disastrous. The Sahel's weather pattern comprises three seasons: cold and dry, hot and dry, as well as hot and wet. In abnormal years, these seasons are accentuated, detrimentally affecting food production, water availability, and disease transmission. In Mali, malaria, acute respiratory infection (ARI), and diarrhea are seasonal diseases whose incidences are accentuated by climate variability. Therefore, a preventive public health program based on knowledge of seasonality and climate anomalies can reduce childhood illnesses.

Malaria, which is transmitted by the female *Anopheles sp.* mosquito,[1,2] is one of the major protagonists of childhood morbidity and mortality in Africa.[3] Malaria transmission typically starts two months after the beginning of the rainy season and culminates two months after the rainfall peak.[2,4,5] Malaria transmission becomes endemic, i.e. year-round, where mosquito breeding sites and appropriate temperatures persist, e.g. irrigation sites.[6,7] The groups most at risk for malaria are 1) children under 5 years of age who have not yet developed immunity; 2) women in their first pregnancy who are at greater risk due to poor nutritional status; and 3) labor migrants from non-endemic zones.[5,8,9-14]

The suspicion that climate variability modulates transmission of ARI is consistent with factors that affect the transmission of other airborne infectious diseases. Low humidity and dust may damage the mucosal barrier and or inhibit immune defenses, increasing mucosal invasion and infection risk during the dry season. Meningitis, for example, has higher transmission rates in the cold, dry seasons following a period of negative precipitations and or exceptionally strong winter winds, i.e. *harmattan*.[13,14] Indoor overcrowding during cold or dust-storm periods may enhance the spread of airborne infections, including pneumonia and measles.[4,15-17] ARI incidence peaks at the end of the rainy season, as well as during the cold and dry season, probably reflecting the existence of multiple pathogens.[4]

Transmission of different forms of gastro-enteritis peak during the rainy season because of increased contamination of water sources with fecal material.[17-23] Furthermore, the incidence of diarrhea in children and breast-feeding mothers may also be compounded by nutritional deficiencies.[18,25-27,38] Few studies, however, have looked beyond this seasonal pattern to observe the relationship between diarrhea, season, and climate variability.[24-25]

This manuscript documents the seasonality of childhood illnesses for the district of Niono, in Sahelian Mali, and proposes a "season-smart" approach to reduce childhood illnesses: diarrhea, ARI, and malaria.

Methods

The study was conducted in the district of Niono, located in the region of Segou, 330 km northeast of Bamako, Mali. This district has been selected because of the potential for variability in rainfall, temperature, and disease transmission, as well as the opportunity to study the impact of climate variability on health and population interactions in an irrigated zone, namely the 50,000 hectares managed by *Office du Niger* along the *Canal du Sahel*, which is supplied by the Niger River. Six health areas from the northern and southern sections of the district were selected: Nampala, Dogofry, and Sokolo in the Sahel, as well as Boh, Siribala, and Pogo in the savanna. [See **Figure 1** and **Table 1** for the location and characteristics of these health areas.] In 2002, the Niono *Division des Services Socio-Sanitaires* (DSSS) estimated the population of these 6 health zones at 83,151 inhabitants.

Malaria transmission occurs six months of the year in the Sahelian zone of Niono. In the northern Sahelian zone, malaria transmission comprises a 4-month long season with parasite prevalence in the vicinity of 50%. The extreme northern portion of the district, which borders the Saharan zone, belongs to the Sahelian malaria "fringe" where malaria is meso-endemic, with transmission occurring only 2 to 3 months per year, and prevalence staying around 10%; however, climatic variations, e.g. pluviometric increases, could potentially intensify transmission in these areas where malaria prevalence and immunity levels are normally low. In the southern savannah and irrigated regions of Niono parasite prevalence levels are 75% or higher and malaria is endemic.

Studies conducted by the Malaria Research Training Center (MRTC) show that biting and infection rates differed significantly between irrigated and non-irrigated zones.[28,29] Water management practices associated with irrigation further impact mosquito population growth.[30] Finally, irrigated zones influence disease transmission because it drives labor migration, which introduce individuals with differing immunity levels into the local population.[2-3,5,7,9-10] While irrigated zones have higher man-biting rates, levels of vector human blood indices are lower because the population working in irrigated zones have higher immunity and or use bed nets more extensively.[28]

The last three decades have suffered wide fluctuations in rainfall, with positive and negative anomalies occurring in 6 and 10 years, respectively. Zonal rainfall data correlate highly with Atlantic and Indian Oceans sea surface temperature (SST) variations.[31] The rainfall 1995-2004 data—FEWSNet/CPC rainfall monitoring dataset—are based on the Meteosat satellite imagery of cloud density coverage, which was prepared every ten days with a 2 km grid square spatial resolution. [The latitude and longitude of each health area is noted in **Table 1**.] Standard deviation (SD) values for the rainy season—July to September—were computed from a 10-year mean (1995-2004) and displayed in **Figure 2**.

Incidence rates for diarrhea, ARI, and malaria were estimated from monthly consultation records that were kept at 17 community health centers (CSCOMs), for the 1996-2004 period. Although consultations for differing age groups, sex, and disease (>20) were recorded, only data pertaining to diarrhea, ARI, and malaria for children under age 5 (combined male and female) are employed in this analysis. Mean monthly consultation rates for these three diseases are plotted in **Figure 3**.

The "season-smart" approach relies on 1) identification of seasonal patterns and 2) estimation of seasonal disease variability. In other words, once seasonality is established, i.e. the timing of highly infectious periods is known, then a simple linear regression model is employed to estimate the variability of consultation rates. This is expected to improve allocation of resources and intervention strategies in advance, i.e. before disease season. Thus, the first step in developing a "season-smart" intervention strategy is to identify seasonal patterns. This was accomplished with Fourier transforms.[32] While seasonal, i.e. harmonic components, appear as distinct spectral peaks, non-periodic variation is typified by the absence of spectral patterns, i.e. spectral "noisy." Fourier spectral analysis was performed for each disease, using the combined monthly consultation data from the 6 selected CSCOMs. Due to the limited number of consultations, Fourier transforms were performed with the combined data for all ages. Tukey-Hamming spectral window (n=3) was used. Fourier plots show spectral density on the y-axis and period (months) in the x-axis.

Once seasonality is established, estimating disease variability becomes the ultimate goal. Fourier analysis yields information on the magnitude of harmonic components, but it does not explain non-harmonic variability of disease consultation rates. The influence of climatic and geographic factors on disease consultation rates was assessed with linear regression. The choice of linear regression to explain seasonal variation in disease consultation rates stems from the need for a simple approach that can be easily implemented and managed by the local authorities in Niono. The dependent variable is the crude disease incidence, which was calculated as the ratio of disease consultation to the total 2002 population of each health area—detailed age distribution for each health area is unavailable yet the age distribution of these areas are expected to be the same. The models included the following independent variables: latitude of the town where the health center is located, monthly rainfall, monthly temperature, proportion of the population having access to irrigation, and proportion of the population residing within 15 kilometers from the health clinic (to control for access to consultations). The malaria model incorporates a one-month lag because it has been demonstrated that there is a one-month delay between rainfall and malaria transmission.[35]

Results

Rainfall records for these six health areas in Niono show significant climate variability. During the 1995-2004 period, there were negative rainfall anomalies (< -1 SD from a 10 year average) in 1996 and 1997 and positive anomalies (> +1 SD from a 10 year average) in 1999, 2001, and 2003 as shown in **Figure 2.** Negative and positive anomalies varied in level and location. In 1996 all but one health area had a negative anomaly, while in 1997 the exception for 1996 anomalies was the only area with a negative anomaly. In 1999 and 2003 all health areas had positive anomalies while in 2001 only some of the areas displayed positive anomalies.

Figure 3 shows the variation in disease consultation rates for different age brackets and ecological zones, i.e. semi-desert (—) and savannah (---). Malaria consultation rates peak in August-September toward the end of the rainy season. Fourier spectral analysis (**Figure 4**) of monthly consultations reveals a dual harmonic pattern. The 12-month long harmonics is centered on August-September while a much smaller harmonic component (6-month long period) peaks 2-3 month before and after the main consultation peak in August-September, thus effectively "broadening" the transmission season. Diarrhea peaks in July-August during the early rainy season as shown in **Figure 3**. Fourier spectral analysis for diarrhea consultations shows broad harmonic components, with 12 and 6 month long periods respectively (**Figure 4**). ARI incidence peaks twice yearly: in March-May during the hot-dry season and later in August-October during the rainy season. The later peak is more pronounced in the savannah than in the semi-desert. Fourier spectral analysis of ARI consultation time series is consistent with this bimodal pattern; in this case, the 6 and the 12-month long harmonics are "in-phase." Although spectral analysis is based on all age groups, contrarily to mean incidence values graphed in **Figure 3**, spectral similarities between these diseases are remarkable. All three diseases show similar harmonic patterns, i.e. 6 and 12 month long periods, emphasizing the seasonal nature of these diseases. Rainfall Fourier analysis (not shown) displays well-defined 6- and 12-month long harmonic components.

Linear regression results are shown in **Table 2**. The malaria model explains 16% of the variation in malaria consultation rates for children < 1 years of age and 33% of the variation for children 1-4 years of age. For both age groups, malaria consultations are significantly increased with heavy rainfalls, whereas the effects of temperature were statistically significant only for children 1-4 years of age. The impact of irrigation is consistent with expectations, with higher incidence in areas with a larger share of the population having access to irrigation. Children living in the more northern latitudes, e.g. Nampala and Sokolo, have higher malaria incidence than those in the southern section of the zone. Malaria consultation rates for children 1-4 years of age, but not for infants, are inversely correlated with the proportion of the population living within 15 kilometers from the clinic.

The diarrhea model explains 14% and 11% of the variability in consultation rates for infants and children 1-4 years of age respectively. For both age groups, diarrhea consultation rates increase significantly during the months with heavier rainfall. Contrary to expectations, after controlling for the other factors, the effects of temperature on diarrhea consultation rates are not significant although the influence of temperature on diarrhea consultation rates for children 1-4 years of age is nearly significant, $p = 0.101$. Diarrhea consultation rates are significantly higher, for both age groups, in health areas with greater access to irrigation and with a large proportion of the population residing within 15 kilometers of the health center. Infant diarrhea consultation rates are higher in northern latitudes; latitude does not influence diarrhea consultation rates of children 1-4 years of age.

The ARI model explains 13% and 15% of the variability in consultation rates for infants and children 1-4 years of age, respectively. The models differ substantially for infants and older children. Infant ARI consultation rates are significantly higher during hot and dry months. For older children, ARI consultations are not significantly associated with monthly rainfall or temperature, although there is a trend of more ARI during the dry months. ARI consultation rates for both age groups are significantly higher in health areas with a larger share of the population living within 15 kilometers of the health center.

Discussion

These analyses demonstrate the seasonality of childhood infections with diarrhea, ARI, and malaria. Spectral analyses confirm the seasonality of all three diseases with the display of harmonic components for each disease. The spectral harmonic patterns for ARI and malaria are relatively well defined whereas harmonic components for diarrhea are noisy, broad, and poorly defined thus suggesting a strong contribution from non-harmonic components. The malaria season is centered on August-September, ARI seasons occur during the months of March-May and August-October, and diarrhea season peaks on July-August.

Regression analyses confirm the dependence of disease behavior on factors such as rainfall and access to irrigation. High levels of rainfall precipitation increase malaria and diarrhea consultations for both age groups. As others have noted, rainfall creates breeding sites for the malaria vector, *Anopheles sp.*, which increases transmission. The impact of rainfall on diarrhea is more direct; rainfall facilitates the contamination of water sources, objects, surfaces, and aliments with fecal material. ARI rates rise during dry months. This is consistent with increases in atmospheric dust during dry periods, contributing to higher transmission of respiratory illnesses.[37] ARI also rises during rainy periods. The biannual ARI pattern reflects the probable existence of multiple pathogens. As a result, this regression model needs further modifications.

All three diseases are influenced by access to irrigation. Health areas with greater access to irrigation have higher rates of malaria, diarrhea, and ARI. Irrigation creates a network of year-round mosquito breeding sites, enabling vector population growth during the dry months when there would otherwise be no opportunities for mosquitoes to breed. Similarly, the irrigation canals facilitate fecal contamination of water sources and the dissemination of diarrhea transmission throughout the year. However, the influence of irrigation on ARI transmission may be artifactual.

Ecological zone, as measured by latitude, also significantly affects patterns of disease incidence. Malaria and diarrhea are both more prominent in more northern zones, while ARI predominates in southern zones. It is important to note that these effects are noted after access to irrigation is taken into account. The northern health areas have several seasonal lakes, which are carefully maintained by locally constructed dikes to provide villagers with a source of additional water for their animals and vegetable crops. Living near a dam has been shown to increase malaria and other waterborne disease transmission in Ethiopia.[33,34] Furthermore, social and cultural differences could influence not only disease prevention but also response to illness. For example, individuals living in northern zones move back and forth between their home villages and irrigated zones, which have different transmission risks, as has been documented in Mali and other parts of Africa.[10,35] Household surveys that were conducted among families in these health areas show that migrant families are less likely to use bed-nets, particularly when they are moving about as seasonal workers. As a result, they are more likely to become infected, coming home with malaria.[36] Similarly, while migrating, families may not have access to clean water, which would also increase diarrhea transmission. Finally, population dispersion in health areas also affects disease consultation rates for all three diseases. Consultation rates for diarrhea and ARI increase at more accessible health centers; surprisingly, the opposite is observed for malaria.

These models explain less than 30% of variability in disease consultation rates and hence they are inadequate to forecast disease incidence at this stage; however, these results are encouraging because they have identified variables that must be incorporated into (or excluded from) more elaborated versions of these or other models. If a “season-smart” approach were implemented, it could lead to major reductions in consultations and costs to families living in Niono and other zones with seasonal illnesses. For illustrative purposes, if seasonal peaks in malaria, diarrhea, and ARI were removed from the disease consultation time-series, health care costs for families would be significantly lowered. In 2002, there were 3551 infants and 12,427 children 1-4 years of age in these 6 health areas. Smoothing out consultation rates to remove the peaks resulted in an annual reduction of 230-490 consultations for infants and 392-977 for children 1-4 years of age. Savings associated with averted consultations are attributed to: travel costs, fees paid to the health center, purchase of medications, and lost work. All costs were converted to dollars. The total annual cost savings for a family with an infant was $344-$750, while families with children 1-5 years of age would be expected to save $571-$1412. While these are only illustrative calculations, they show the potential gains from tailoring child health interventions according to weather patterns.

Conclusions

Spectral analysis demonstrates marked seasonality for diarrhea, ARI, and malaria incidence in Niono, Mali. While the analysis is limited to the district of Niono, these findings have broad applicability to other Sahelian zones with similar seasonal patterns. Throughout the Sahel, recognition of these seasonal and contextual patterns of influence on disease incidence could open the way for more timely and effective health care interventions. The ultimate goal is to develop algorithms that incorporate harmonic, i.e. seasonal, and non-harmonic components, thereby enabling modeling of seasonal variability in childhood illnesses with forecast capabilities.

Given these seasonal and contextual influences, an effective strategy for reducing childhood illness and related mortality is to become “season-smart” in the implementation of child health programs. Rather than waiting for seasonal illnesses to arrive, as it predictably will, preventive programs should be implemented one or two months prior to the anticipated disease season. For example, the WHO/UNICEF program for the Integrated Management of Childhood Illnesses includes sixteen preventive behaviors, several of which impact the risk of malaria, diarrhea, and ARI. Community and village health workers implementing IMCI could time their instructions and provision of supplies in anticipation of disease season thus reducing shortages and delayed responses.

References

1. National Research Council. *Under the Weather: Climate, Ecosystems, and Infectious Disease*. Washington, DC: National Academy Press; 2001.

2. Molineaux L. The epidemiology of human malaria as an explanation of its distribution, including some implications for its control. In: Wernsdorfer W, McGregor I, eds. *Malaria, Principals and Practice of Malariology*. London: Churchill Livingstone; 1988:913-998.

3. Craig MH, Snow RW, le Sueur D. A Climate-based Distribution Model of Malaria Transmission in Sub-Saharan Africa. *Parasitology Today.* 1999;15(3):109-116.

4. Brewster D, Greenwood B. Seasonal Variation of Pediatric Diseases in the Gambia, West Africa. *Annals of Tropical Paediatrics.* 1993;13(2):133-146.

5. Baird J, Owusu Agyei S, Utz G, et al. Seasonal malaria attack rates in infants and young children in northern Ghana. *American Journal of Tropical Medicine and Hygiene.* March 2002;66(3):280--286.

6. Walsh J, Molyneux D, Birley M. Deforestation: Effects on Vector-Borne Disease. *Parasitology.* 1993;106(Suppl):S55-57.

7. Thomson M, Ericksen P, Ben Mohamed A, Connor S, eds. *Land-Use change and Infectious Disease in West Africa*: American Geophysical Union; 2004. Geophysical Monograph Series 153; No. Ecosystems and Land Use Change.

8. Guyatt H, Snow R. The Epidemiology and burden of Plasmodium falciparum-related anemia among pregnant women in sub-saharan africa. *American Journal of Tropical Medicine and Hygiene.* 2001;64(1,2 S):36-44.

9. Breman J. The Ears of the Hippopotamus: Manifestations, Determinants, and Estimates of the malaria burden. *American Journal of Tropical Medicine and Hygiene.* 2001;64(1,2 S):1-11.

10. Lindsay S, Martens W. Malaria in the African highlands: past, present and future. *Bulletin of the World Health Organization.* 1998;76(1):33-45.

11. Balk D, Pullum T, Storeygard A, Freenwell F, Neuman M. *A Spatial Analysis of Mortalityin West Africa."* Calverton, MD: GIS Series 1, Demographic and Health Surveys, Macro International; 2003.

12. Curtis S, Hossein M. *The Effect of Aridity Zone on Child Nutritional Status: West Africa Spatial Analysis Prototype Exploratory Analysis.* Calverton, Maryland: Macro International; 1998.

13. Connor S. *Mitigating the impact of menigitis epidemics in Africa: assessing the scope for regional forecasting systems.* Liverpool: NOAA-OGP; 2001.

14. Molesworth A, Cuevas L, Morse A, Herman J, Thomson M. Dust clouds and spread of infection. *Lancet.* 2002;359(9300):81-82.
15. Greenwood B. Meningococcal meningitis in Africa. *Transactions of the Royal Society of Tropical Medicine and Hygiene.* 1999;93(4):341-353.
16. Greenwood B, Greenwood A, Bradley A, et al. Factors influencing susceptibility to meningococcal disease during an epidemic in the Gambia, West Africa. *J of Infection.* 1987;14:167-184.
17. Vaahtera M, Kulmala T, Maleta K, Cullinan T, Salin M, Ashorn P. Epidemiology and predictors of infant morbidity in rural Malawi. *Paediatric Perinatal Epidemiology.* October 2000;14(4):363-371.
18. Drasar B, Tomkins A, Feachem R. Diarrhoeal Diseases. In: Chambers R, Longhurst R, Pacey A, eds. *Sesonal Dimensions to Rural Poverty*. London, Great Britain: Frances Pinter (Publishers) Ltd.; 1981:102-112.
19. Tomkins A. Seasonal Health Problems in the Zaria Region. In: Chambers R, Longhurst R, Pacey A, eds. *Seasonal Dimensions to Rural Poverty*. London, Great Britain: Frances Pinter (Publishers) Ltd.; 1981.
20. Sallon S, el Showw R, elMasri M, Khalil M, Blundell N, Hart C. Cryptoporidiosis in children in Gaza. *Annals of Tropical Paediatrics.* 1991 1991;11(3):277-281.
21. Callejas D, Estevez J, Porto-Espinoza L, Monsalve F, Costa-Leon L, al e. Effect of climatic factors on the epidemiology of rotavirus infection in children under 5 years of age in the city of Maracaibo, Venezuela. *Investigacion Clinica.* June 1999 1999;40(2):81-94.
22. Singh R, Hales S, deWet N, Raj R, Hearnden M, Weinstein P. The influence of climate variation and change on diarrheal disease in the Pacific Islands. *Environmental Health Perspectives.* Feb 2001 2001;109(2):155-159.
23. Musa H, Shears P, Kafi S, Elsabag S. Water quality and public health in northern Sudan: A study of rural and peri-urban communities. *Journal of Applied Microbiology.* November 1999;87(5):676-682.
24. Lipp E, Huq A, Colwell R. Effects of global climate on infectious disease: the cholera model. *Clinical Microbiology Reviews.* Oct 2002 2002;15(4):757-770.
25. Lawoyin T, Ogunbodede N, Olumide E, Onadeko M. Outbreak of cholera in Ibadan, Nigeria. *European Journal of Epidemiology.* 1999;15(4):367-370.
26. Nishio O, Matsui K, Lan D, al e. Rotavirus infection among infants with diarrhea in Vietnam. *Pediatrics International.* 2000;42(4):422-424.
27. Maneekarn N, Ushijima H. Epidemiology of rotavirus infection in Thailand. *Pediatrics International.* 2000;42(4):415-421.
28. Toure Y, Bagayoko M, al e. Malaria transmission in irrigated and non-irrigated rice cultivation zones in Niono, Mali. Paper presented at: Malaria International Meetings, 1999; South Africa.
29. Dolo G, Briet O, al e. Rice cultivation and malaria transmission in the irrigated Sahel of Mali, West Africa. *Tropical Medicine & International Health.* 2001.
30. Ijumba JN, Lindsay SW. Impact of irrigation on malaria in Africa: paddies paradox. *Med Vet Entomol.* 2001;15(1):1-11.
31. Ndiaye O. Current Seasonal Forecasting Methods and Downscaling. Paper presented at: Climate Prediction and Agriculture in West Africa (CLIMAG) Demonstration Project; April 23-25, 2001, 2001.
32. Chatfield C. *The analysis of time series - an introduction*. 5th edition ed. London, UK.: Chapman and Hall; 1996.
33. Ghebreyesus T, Haile M, Witten K, Getachew A, Yohannes A, al e. Incidence of malaria among children living near dams in northern Ethiopia: community based incidence survey. *BMJ.* Sep 11, 1999 1999;319(7211):663-666.
34. Alemayehu T, Ye-ebiyo Y, Ghebreyesus T, Witten K, Bosman A, Teklehaimanot A. Malaria, schistosomiasis, and intestinal helminths in relation to microdams in Tigray, northern Ethiopia. *Parassitologia.* September 1998 1998;40(3):259-267.
35. Bagayoko M, Sogoba N, Niambele MB, Toure AA, D M. Monitoring and predicting malaria epidemics in a Sahelian zone. Paper presented at: Climate Prediction and Diseases/Health in Africa, 1999; Bamako, Mali.
36. Findley S, Sogoba N, Balk D, et al. Tracking the sensitivity of early childhood diseases to climate variability in Niono District, Mali. Paper presented at: Population Association of America, 2002; Atlanta, Georgia.
37. Molesworth A, Cuevas L, Thomson M. *Forecasting Meningitis epidemics in Africa.* LIverpool: LSTM; 2002.
38. Adams A. Seasonal variations in nutritional risk among children in central Mali. *Ecology of Food and Nutrition.* 1994;33:93-106.

Table 1: Description of Niono study zones.

	Health zone	Latitude	July-Sept Average rainfall (mm)	Villages	Households	Population	Children <5 years
Sahel	**Nampala**	15.3	264.9	25	1222	7485	1460
	Dogofry	14.8	302.3	21	3340	22696	4426
	Sokolo	14.7	298.9	16	2284	13776	2686
	Subtotal		288.7	62	6846	43957	8572
Savannah	**Boh**	14.1	388.3	9	1026	6671	1301
	Sirbala	14	343.7	24	3541	21356	4271
	Pogo	13.9	405.3	19	1118	11167	2178
	Subtotal		379.1	52	4659	22591	4405
Total				**114**	**12581**	**83151**	**16322**

Sources: *Carte Sanitaire de Niono*, DSSS-Niono, 2002; and FEWS.

Table 2: Regression analysis of factors influencing variability of disease consultations.

	< 1 yr.			1 – 4 years		
Malaria	**Beta**	**t**	**Signif**	**Beta**	**t**	**Signif**
Rainfall (lag 1 mo)	.172	4.06	.000	.319	4.17	.000
Temperature	-.031	-.733	.464	-.219	-5.80	.000
Latitude	.147	3.06	.002	.179	4.17	.000
% Irrigated	.370	6.79	.000	.213	4,36	.000
%Pop <15km	-.062	-1.23	.218	-.293	-6.54	.000
R^2	.16	(df =5,474)		.33	(df = 5,474)	
Diarrhea	**Beta**	**t**	**Signif**	**Beta**	**t**	**Signif**
Rainfall	.112	2.59	.010	.196	4.49	.000
Temperature	.014	.320	.749	.072	1.64	.101
Latitude	.144	2.93	.004	.064	1.28	.200
% Irrigated	.372	7.49	.000	.251	4.97	.000
%Pop <15km	.209	4.76	.000	.156	3.52	.000
R^2	.14	(df =5,474)		.11	(df =5,474	
ARI	**Beta**	**t**	**Signif**	**Beta**	**t**	**Signif**
Rainfall	-.110	-2.53	.012	-.065	-1.52	.130
Temperature	.114	2.65	.008	.003	.061	.952
Latitude	-.138	-2.81	.005	-.295	-6.06	.000
% Irrigated	.224	-4.57	.000	.130	2.68	.008
%Pop <15km	.139	3.22	.001	.088	2.05	.041
R^2	.13	(df =5,474)		.15	(df =5,474)	

Figure 1: Location of the Niono Study Areas
(Left and right maps represent Mali and Niono, respectively)

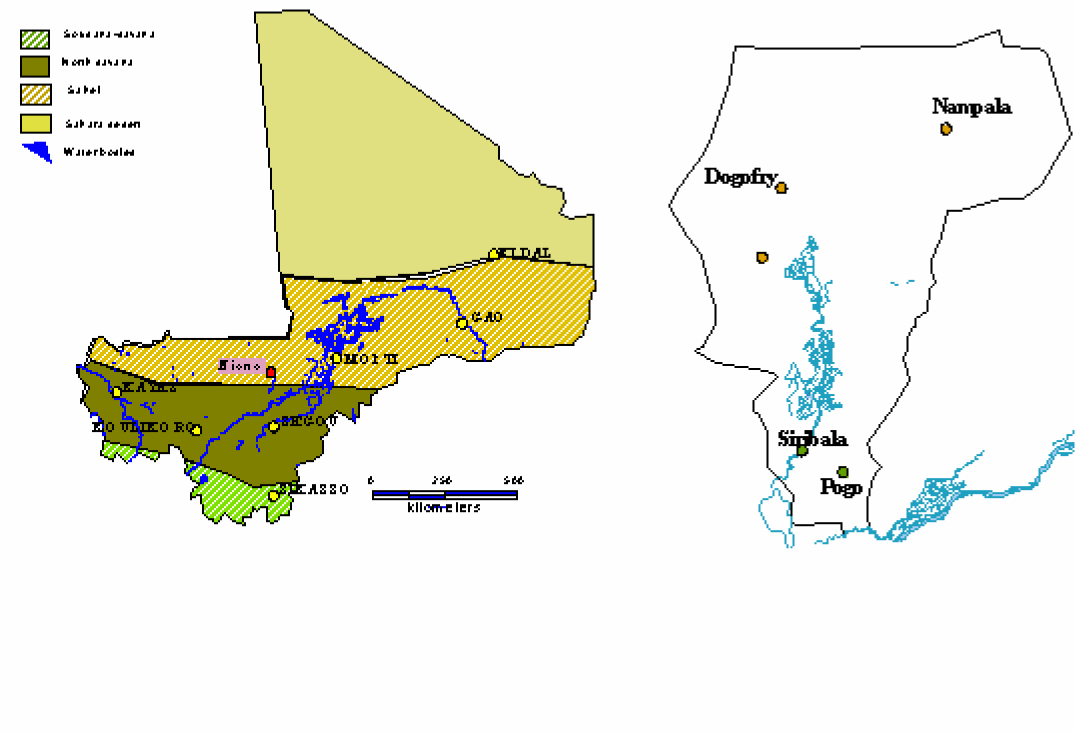


Figure 2: Rainfall standard deviations for the July-September period, Niono 1995-2004.

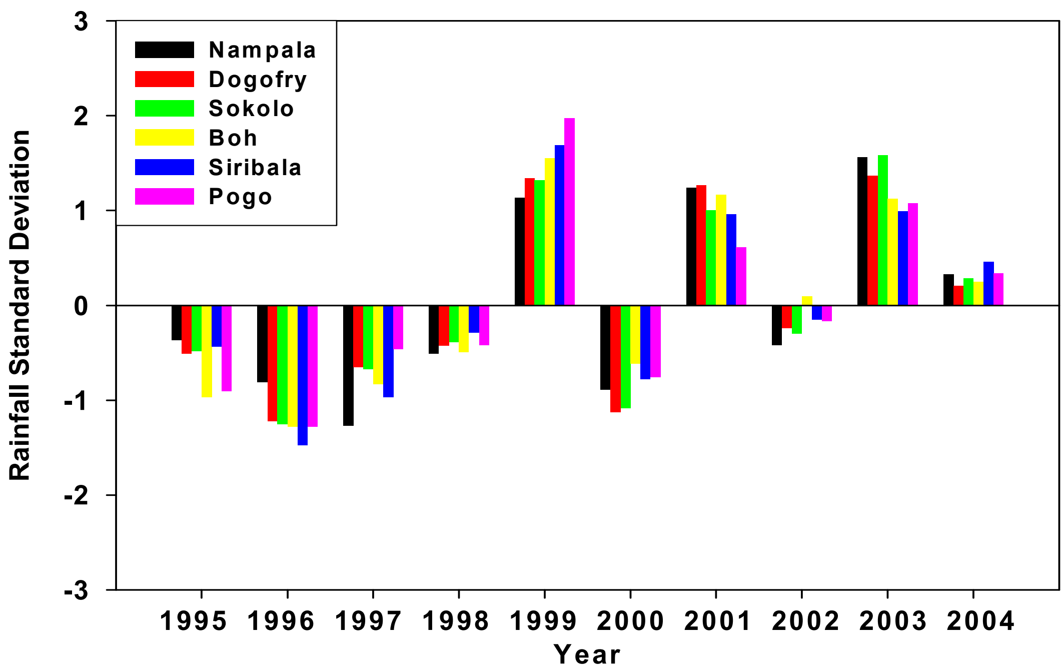
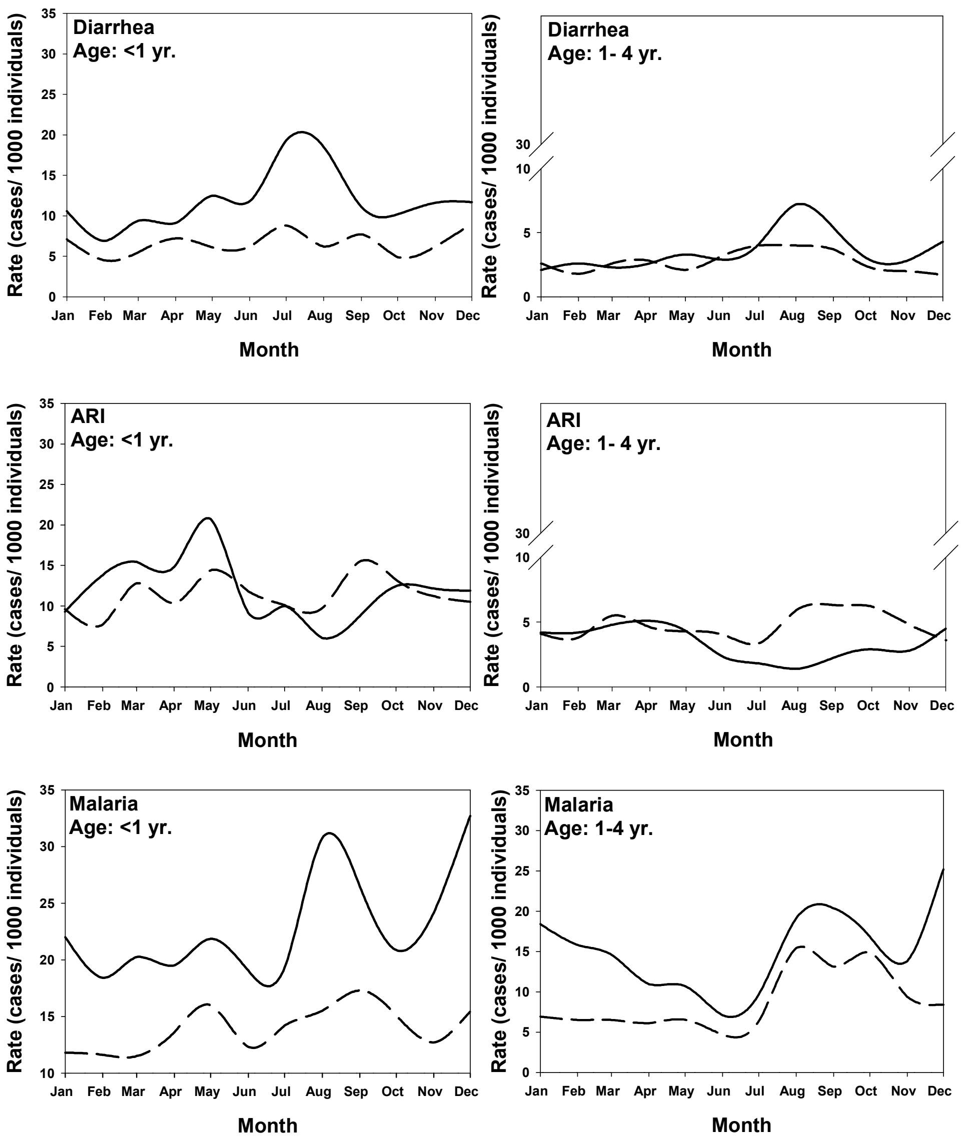


Figure 3: Mean monthly disease consultation rates by ecological zones



— semi-desert
--- savannah

Figure 4: Fourier analysis of disease consultation time series, 1996-2004.