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Diarrhoea, acute respiratory infection, and fever among children in the Democratic Republic of Congo (DRC).

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ABSTRACT

Several years of war have created a humanitarian crisis in the Democratic Republic of Congo (DRC) with extensive disruption of civil society, the economy and provision of basic services including health care. These challenges are faced against a background of heavy disease burden, especially of HIV/ AIDS, tuberculosis, diarrhoea, acute respiratory infection, and malaria. Health policy and planning in the DRC are constrained by a lack of reliable and accessible population data. Thus there is currently a need for primary research to guide programme and policy development for reconstruction and to measure attainment of the Millennium Development Goals (MDGs).

This study uses the 2001 Multiple Indicators Cluster Survey to disentangle children's health inequalities by mapping the impact of geographical distribution of childhood morbidity stemming from diarrhoea, acute respiratory infection, and fever. We account for important risk factors and nonlinear effects using a Bayesian geo-additive regression model based on Markov Chain Monte Carlo techniques.

We observe a low prevalence of childhood diarrhoea, acute respiratory infection and fever in the western provinces (Kinshasa, Bas-Congo and Bandundu), and a relatively higher prevalence in the south-eastern provinces (Sud-Kivu and Katanga). However, each disease has a distinct geographical pattern of variation. Among covariate factors, child age had a significant association with disease prevalence. The risk of the three ailments increased in the first 8-10 months after birth, with a gradual improvement thereafter. The effects of socioeconomic factors vary according to the disease. Accounting for the effects of the geographical location, our analysis was able to explain a significant share of the pronounced residual geographical effects. Using large scale household survey data, we have produced for the first time spatial residual maps in the DRC and in so doing we have undertaken a comprehensive analysis of geographical variation at province level of childhood diarrhoea, acute respiratory infection, and fever prevalence. Understanding these complex relationships through disease prevalence maps can facilitate design of targeted intervention programs for reconstruction and achievement of the MDGs.

Keywords: diarrhoea; acute respiratory infection; fever; MDGs; DRC; disease prevalence maps; reconstruction.

INTRODUCTION

Several years of war have created a humanitarian crisis in the Democratic Republic of Congo (DRC) with extensive disruption of civil society, the economy, and provision of basic services with devastating impacts on health systems. The International Rescue Committee (IRC) estimates up to 4.7 million people died as a result of war from 1998 to 2002 (Roberts et al. 2002). At the time of writing the basis for political stabilisation was in place but major efforts will be required nationally and internationally for reconstruction. These challenges are faced against a background of heavy global disease burden, especially of HIV/ AIDS, tuberculosis, diarrhoea, acute respiratory infection, and malaria.

Worldwide, one in 12 children born in 2001 died before their fifth birthday from eminently preventable and treatable conditions, such as pneumonia, diarrhoea and malaria. Acute respiratory infection (ARI) and diarrhoeal diseases are leading causes of the global burden of disease and account for more than 7% (ARI) and 3.7% (diarrhoea) of the global burden of disease and mortality, mostly in developing countries (Lopez et al., 2006; Parashar et al. 2003; Ezzati and Kammen, 2001). Globally as more than 2 billion people continue to rely on biomass (wood, charcoal, agriculture residues, and dung) as the primary source of domestic energy, exposure to indoor air pollution, especially to particulate matter, from the combustion of bio-fuels will continue to be implicated as a causal agent of respiratory diseases in developing countries (Parashar et al. 2003; Ezzati and Kammen, 2001). The reduction of the global burden of disease attributable to these ailments requires targeted intervention.

In the DRC, health policy and planning are constrained by lack of reliable and accessible population data. For example, UNICEF estimates the under-five mortality rate to be 205 per 1000 live births for both 1990 and 2005 and makes estimates of the prevalence of pneumonia (11%), diarrhoea (17%) and malaria (45%) based on available data (UNICEF, 2008). These numbers are likely to be gross under-estimates based on regional trends. We should bear in mind that there are differences between urban and rural areas, and between the regions variably affected by the conflict.

Population level research on the public health aspects of childhood diseases is an important component of programmes for disease prevention and management. Apart from the significant loss of life and injuries in DRC due to conflicts and related diseases, war has become a major element in impoverishment, undermining human security and sustainable development. The impossibility of achieving the United Nations Millennium Development Goals (MDGs4) has been evident over almost a decade in this conflict-affected country. However, there is tremendous need for primary research-based information for programme and policy development during the reconstruction phase.

A diverse set of challenges arise from this context, including: (1) social factors (the large numbers of displaced persons and migrants, high adult HIV prevalence, malaria and co-morbidities); (2) health systems (lack of basic health care facilities, unhygienic conditions and absence of basic medications); (3) political issues (the presence of armed forces and groups). Systematic approaches to child health improvements have been impossible to sustain under these conditions.

National reconstruction requires the building and strengthening of capacity within academic and civil institutions. A primary requirement for effective governance is the availability of high quality evidence-based research, without which policy and planning of services can only be based on conjecture. A stable infrastructure of data collection, analysis, synthesis and dissemination is required to provide a flow of such policy- relevant population data.

The Multiple Indicators Cluster Surveys (MICS2) (UNICEF, 2008a) are a well established source of reliable population level data with a substantial focus on child health. We utilised these data sets to examine, for the first time in DRC, to our knowledge, the geographical distribution of diarrhoea, acute respiratory infection and fever.

BACKGROUND ON HEALTH AND SOCIAL CONDITIONS IN DRC

The DRC is emerging from a period of violent internal conflict characterised by the active engagement of neighbouring countries, mismanagement and corruption. The entire state structure, health sector, social fabric and economy have been left in a state of disarray and degradation. Sparsely populated (estimated population in 2007 was 66 million) in relation to its area (2, 344858 Square Km), the DRC is home to a vast potential of natural resources and mineral wealth. Nevertheless, the DRC is one of the poorest countries in the world, with per capita annual income of about $300 in 2007 (U.S. State Department, 2008).

UNICEF (2008b) highlights a series of multifaceted challenges arising from this context: (1) low vaccination rates for the most common childhood diseases (approximately 65% coverage) ; (2) less than half the population has access to a safe source of clean drinking water and less than one third has access to adequate sanitation facilities. (3) The adult HIV/AIDS prevalence rate was 4.2 per cent in 2005, a significant increase from 2004. The rate is believed to be significantly higher in areas of recent armed conflict, where sexual abuse and violence against women is widespread; (4) there are over 4 million orphaned children in the country; (5) school enrolment rates are declining. More than 4.4 million children (nearly half the school-age population) are not in school. This number includes 2.5 million girls and 400,000 displaced children and (6) Widespread child labour: More than a quarter of children aged 5 to 14 are working (UNICEF, 2008b).

In the 15 year span from 1990 to 2005, the country has experienced stagnating under-five and infant mortality rates. While under-five mortality is estimated at 205 deaths per 1000, infant deaths, which account for a substantial amount of these, are estimated at 129 deaths per 1000 live birth. Under-five deaths are most often due to neonatal causes. Pneumonia causes 23% of under-five deaths, followed by diarrhoea and malaria. Also, 12% of infants have low birth weight and almost 34% of children under the age of 5 years are underweight (UNICEF, 2008b).

The rate of maternal mortality in DRC is also very high at 990 per 100 000 live births. Despite this elevated number, according to the WHO 61% of pregnant women in DRC make antenatal care visits at least once while 47% make 4 visits. Further, 61% of births are attended by skilled birth personnel (WHO, 2008). The Ministry of Planning in DRC has recently completed a Demographic and Health Survey with the technical assistance of MEASURE DHS which will provide information regarding recent demographic, social and health trends in the DRC.

DATA AND METHODS

Data

Data were collected from the 2001 DRC MICS2, a nationally representative sample of women and their children. A total of 12,407 women (response rate of 95%) were interviewed regarding various health issues including the recent health history of the women's siblings (UNICEF, 2008a). In this analysis we report on the recent episodes of diarrhoea, fever and acute respiratory infection of each child under 5 years of age living in the sampled household. The diagnoses for the three illnesses were based on the self-reported recall by mothers of symptoms that had occurred within two weeks prior to the survey date. Illnesses were classified into diarrhoea, fever (define as fever without any other symptoms) and acute respiratory infection (defined as fever with cough or coryza). All information was collected from female interviewees aged 15–49 years. In each survey, the health status of each interviewee's 'young' children (i.e. children aged$\leq$ 59 months) was assessed by asking the interviewee:*"Has your child had diarrhoea in the last 2 weeks"," Has your child had fever in the last 2 weeks", and" Has your child had fever with cough in the last 2 weeks"*. The self-reported sickness status (0/1) of each child for each disease was the outcome of interest. Overall, data on 9454 children were collected in the 2001 survey. In the final regression models, the following predictors were examined: child's gender, child's nutritional status, place of residence, asset index, household size, maternal education, maternal Body Mass Index (BMI), and province of residence. In order to facilitate the comparison with previous studies, variables were categorised as follows. Household size was re-categorised as ‘small’ (if there were fewer than six members), ‘medium’ (if there were six to 10 members) or ‘large’ (if there were at least 11 members). Maternal education was categorised as “no education”, “primary education”, and” secondary or higher education”. As a measure of child’s nutritional status height-for-age (stunting) was re-categorised as a binary variable (yes/no) defined as being two standard deviations or more below the median of the National Center for Health Statistics (NCHS)/Center for Disease Control (CDC) /World Health Organisation (WHO) international reference population. Furthermore, as a proxy measure of current or recent household socioeconomic status (SES) an assets index was generated on the basis of related questions on ownership of items such as television, radio, and bicycle.

The DRC is divided into 11 administrative provinces. Disease prevalence is aggregated and known at a national level. We went a step further and accounted, simultaneously, for location effects on childhood diarrhoea, acute respiratory infection and fever at the disaggregated level of provinces, thereby highlighting relationships that would be overlooked with standard methods. We recognise that the province is still a large unit but disaggregating to this level represents a considerable advance over the use of national averages and our analysis provides province-level information on childhood disease.

One cannot assume that the clusters selected in each district are fully representative of the districts in which they are located, as the surveys only attempted to generate a fully representative sample at the provincial level. Consequently, the spatial analysis will be affected by some random fluctuations. Some of this random variation can be reduced through structured spatial effects as it includes neighbouring observations in the analysis. It should, however, be pointed out that such a spatial analysis should preferably be applied to census data, where the precision of the spatial analysis would be much higher. Unfortunately, most censuses do not collect data on disease (the last census in the DRC was conducted in the 1980’s) and often the full dataset is not available for such analyses. We used geo-additive Bayesian modelling, with dynamic and spatial effects, to assess temporal and geographical variation in diseases. The model used also allows for non-linear effects of covariates on diseases. The modelling approach is described in more detail in the next section.

Examples of issues we raise are: What could explain these provincial differences? Does diarrhoea, fever or acute respiratory infection prevalence vary from province to province because of factors that are not measured by our survey data, which could include severity of conflict and environmental pollution due to displacement? Are these diseases more prevalent in conflict-affected provinces? Or does variation in prevalence from province to province occur because of differences in household socioeconomic status, education, and rural and household infrastructure such as drinking water and sanitation?

Sampling design

The methods, objectives, organisation, sample design, and questionnaires used in the 2001 MICS2 survey for the DRC have been described in detail elsewhere (UNICEF/DR Congo, 2002). In brief, this was a random probability sample of households designed to provide estimates of health, nutrition, water and environmental sanitation, education and children's rights indicators at the national level, for urban and rural areas, and for the 11 provinces. The sample was selected in four stages. A sample of 10,305 households was drawn and 365 SEAs (Standard Enumeration Areas) were selected, with at least one cluster in each province (Congo, 2002). The sample districts were selected following the Expanded Programme on Immunisation (EPI) Cluster Sampling Technique. Within each cluster, the required number of villages was selected through the application of the EPI sampling technique. Within each village the required number of households was selected randomly by spinning a bottle. Full technical details of the sample are included in (UNICEF/DR Congo, 2002). The SEAs are the same as those used in the 1995 DRC MICS1 (Zaire, 1996). The sample is a nationally representative sample of 11 provinces and 28 districts. In addition, out of 143 municipalities ("territories"), 128 were included in the sample.

As for all national surveys and censuses, the questionnaire was in French although interviews were carried out in local languages. Fieldworkers were trained with regard to how to interpret questions in local languages. Details on sampling and fieldwork operations and evaluation of data quality are reported elsewhere (UNICEF/DR Congo, 2002). It is important to mention that use of MICS2 data has limitations. Concerns have been raised about potential bias of relying on the ability of mothers to identify and separate symptoms of fever, pneumonia or diarrhoea (Einterz and Bates, 1997). Nevertheless, there is some evidence from ethnographic studies suggesting that symptoms of various diseases can be consistently distinguished by mothers, especially diagnoses of diarrhoea and pneumonia (Dunyo et al., 1997). Secondly, diagnoses of illnesses depended on mother's report (recall) as is common in retrospective surveys. Accuracy and completeness of mother's recall in 19 national Demographic and Health surveys found that highly educated women were more accurate in reporting and identification of these illnesses (Boerma et al., 1991). To provide a consistent sample, recalls were restricted to 14 days prior to the survey. This has been found to provide reliable results in related studies in other countries (Vaahtera et al., 2000; Kazembe et al., 2007). In addition, the survey results might be influenced by the effects of seasonality in disease prevalence.

Statistical Methods

In the analysis of survey data, the commonly adopted models are probit or logistic, and the standard measure of effect is the odds ratio (Yoannes *et al*., 1992; Woldermicael, 2001). In the present study, however, the MICS2 data contain geographical or spatial information, such as the province or district of individuals in the study and the presence of non-linear effects for some covariates means that strictly linear predictors cannot be assumed. Analysing and modelling geographical patterns for health or survival, in addition to the impact of other covariates, is of obvious interest in many studies. In a novel approach, the geographical patterns of childhood morbidity and the possibly non-linear effects of other factors were therefore explored within a simultaneous, coherent regression framework, using a geo-additive, semi-parametric, mixed model (Fahrmeir and Lang, 2001; Brezger *et al*., 2005; Kandala et al, 2007; Kandala et al. 2008). In brief, the strictly linear predictor:

$$\eta_i = x^{'}\beta + w_i{'}\gamma \qquad (1)$$

is replaced with a logit link function with dynamic and spatial effects, Pr($y_i=1|\eta_\iota$)=e^{η_ι}/(1+ e^{η_ι}) , and a geo-additive semi-parametric predictor μ_i= h(η_ι):

$$\eta_\iota = f_1(x_{i1}) + ... + f_p(x_{ip}) + f_{spat}(s_i) + w'_i \gamma \qquad (2)$$

where *h* is a known response function with a logit link function, *f1, …, fp* are non-linear smoothed effects of the metrical covariates (child's age and maternal BMI), and f_{spat} (s_i) is the effect of the spatial covariate $s_i \in \{1,...,S\}$ labelling the province in DRC. Covariates in w'_i are categorical variables such as gender and urban–rural residence. Regression models with predictors such as those in Equation 2 are sometimes referred to as geo-additive models. P-spline priors were assigned to the functions $f_1,...,f_p$, while a Markov random field prior was used for f_{spat} (s_i) (Fahrmeir and Lang, 2001; Brezger *et al*., 2005; Kandala et al. 2007). Although the estimation process with this model is complex, the estimated posterior odds ratios (OR) that were produced could be interpreted as similar to those of ordinary logistic models.

The analysis was carried out using version 0.9 of the BayesX software package (Brezger *et al*., 2005), which permits Bayesian inference based on Markov chain Monte Carlo (MCMC) simulation techniques. The statistical significances of apparent associations between potential risk factors and the prevalence of recent diarrhoea, acute respiratory infection and fever were explored in chi-square and Mann–Whitney *U*-tests, as appropriate. Multivariate analysis was used to evaluate the significance of the posterior OR determined for the fixed, non-linear effects and spatial effects. A *P*-value of <0.05 was considered indicative of a statistically significant difference.

RESULTS

Analyses were based on valid observations which vary from 9451 for diarrhoea to 9455 for fever. The overall prevalence of diarrhoea (22.4 %), acute respiratory infection (7.1 %) and fever (41.2 %) recorded among the young children in the survey was significantly different from provincial prevalence rates (P<0.001). The aggregated national prevalence rates, however, conceal important geographical variation in the childhood morbidity recorded at provincial level (see Table 1).

[TABLE 1 TO BE INCLUDED HERE]

For acute respiratory infection, for example, the overall prevalence among under-fives was 10.7% but the corresponding provincial-level prevalence varied from 2.7% (in Bas-Congo) to 24.0% (in Sud-Kivu). The results show that children living in Eastern provinces were more affected by acute respiratory infection than those living in the western part of the country. It appears that younger children from Kasai Occidental (29.6%), Kasai-oriental (27.2%) and Equateur (27.0%) were more likely to suffer from diarrhoea than those living in the capital-province of Kinshasa (21.0%). The lowest prevalence of fever was observed in Kinshasa (31.9%), Bandundu (35.6%) and Nord-Kivu (31.3%), while children living in all other provinces appear to be more affected (Table 1).

Table 1 also shows the prevalence of diarrhoea, acute respiratory infection and fever for all fixed categorical factors and the relationship, if any, between each factor and prevalence (not accounting for any spatial effects) in 2001. Several factors appeared to reduce the risk of diarrhoea in young children: a relatively older child's age and a relatively high maternal BMI. Factors associated with a lower risk of childhood acute respiratory infection were: high maternal education, living in Bas-Congo, having a high socio-economic status, living in urban areas, being stunted, a relatively older child's age and a relatively high maternal BMI. The risks of childhood fever appeared to be reduced by living in urban areas, having a high socio-economic status and a high maternal education.

In Figure 1, the left-hand maps show estimated posterior OR of residual spatial provincial effects (i.e. adjusted odds ratios taking into account the auto-correlation structure in the data and other risk factors) for childhood diarrhoea, acute respiratory infection and fever in each province, with the darker colour indicating the maximum posterior OR recorded (1.28 for diarrhoea, 2.85 for acute respiratory infection, and 1.33 for fever) while lighter colour denotes a lower prevalence. A high prevalence of all three diseases was concentrated in the conflict affected provinces (Orientale, Nord-Kivu, Sud-Kivu, Kasai-occidentale and Katanga) in the country. The right-hand maps show the 95% posterior probability maps of childhood diarrhoea, acute respiratory infection and fever. White colour indicates a negative spatial effect (associated with reduced risk of the morbidity) and black colour a positive effect (an increased risk).

[FIGURE 1 ABOUT HERE]

Figure 2 shows for the whole national sample the estimated non-linear (logits) effects of the child's age and maternal BMI on diarrhoea, acute respiratory infection and fever. Shown are the estimated posterior logits of the effects of the child's age and maternal BMI within the 80% and 90% credible interval. There appears to be a clear non-linear association between child's age (left-hand panels) and diarrhoea, acute respiratory infection and fever, the graph for each type of morbidity showing a steep upward curve in the first 6–10 months of life (indicating that child health deteriorates quickly in this period). Maternal BMI (right-hand panels) appears to be almost linearly negatively related to diarrhoea, acute respiratory infection and fever in the young child. As expected, it appears that the lower the maternal BMI, the higher the risks of childhood diarrhoea, acute respiratory infection and fever. This finding is consistent with the observed negative association between maternal BMI and child nutritional status in developing countries. In the graphs relating to maternal BMI, the credible intervals expand rapidly at BMI >30 because of the small sample of obese mothers.

[FIGURE 2 ABOUT HERE]

We accounted for a range of child and household characteristics in Table 2. Table 2 also shows the estimates of dummy variables representing provinces (i.e. without taking into account the spatial autocorrelation in the data). It is important to note that, for all three outcomes, estimates of OR from dummy variables representing provinces (Table 2) are over-estimated compared to estimates of OR from the maps (Figure 1). The later estimates take into account spatial autocorrelation structure. This clearly indicates the importance of accounting for the geographical factors in the estimation.

Children living in families in the second (poor), third (moderate) and fourth (rich) quintile of household economic status had significantly higher risk of diarrhoea than their counterparts in the fifth quintile (richest). The risk of acute respiratory infection was higher for children living in families in the second and fourth quintile of household economic status. Children from mothers with primary and secondary education were associated with an increased risk of childhood fever. The risk of childhood fever appeared to be lower for those living in urban areas.

[TABLE 2 ABOUT HERE]

DISCUSSION

The importance of quantifying the human loss caused by avoidable causes among the vulnerable groups (Children) in a population is widely recognized. Childhood mortality rates are an indication of a country's level of development. In 2000, the United Nations' Millennium Summit identified the improvement of childhood health as one of the eight fundamental goals for furthering human development (The Millennium Development Goals, or the MDGs). As part of the MDGs number 4, the UN established a target of reducing the under-five mortality rates by a factor of two-third between 1990 and 2015 for all national and regional population.

Since ARI and diarrhoeal diseases are leading causes of the global burden of disease and mortality in developing countries, this study examines variations at the provincial-level of diarrhoea, acute respiratory infection and fever prevalence among children under the age of five years in the DRC. Overall, findings highlight significant provincial differences in childhood morbidity in the DRC. The provincial effects are interpreted as surrogates for associations with environmental and unmeasured factors such as armed conflicts. Such differences in childhood morbidity by geographical or administrative provinces of a country are very important for provincial planning and design of further studies. This is particularly important for the DRC, which is pursuing decentralised policies for post-conflict reconstruction.

A low prevalence of childhood morbidity was observed in the western provinces (Kinshasa, Bas-Congo and Bandundu) for all diseases studied, and a relatively higher prevalence of childhood morbidity noted in the south-eastern provinces (Sud-Kivu and Katanga). However, each disease has its distinctive geographical pattern of variation. This leads us to think that beside the socioeconomic difficulties, civil war, cultural values, climate differences and environmental factors are ultimately shaping the spatial distribution of childhood morbidity in the DRC. Although Nord-Kivu, Sud-Kivu and Maniema were engaged in war during the 2001 MICS survey, they each have different patterns of childhood morbidity for the health conditions considered in this paper.

As results of the present study show, socioeconomic, environmental and cultural factors interact in different ways to produce spatial variation in childhood morbidity (Kandala, 2006 and 2007; Bangha, 2007). This suggests that comprehensive modelling including socioeconomic, cultural, environmental and political issues is key to understanding spatial variation of childhood morbidity in sub-Saharan African societies.

The relative "better childhood health" observed in western DRC (Kinshasa, Bas-Congo and Bandundu) could be due to the relative socioeconomic development advantages of these provinces in terms of the presence of health service and education infrastructure. Also, the western provinces were not directly affected by the conflict compared with the rest of the country. The higher risk of morbidity among children observed in the south-eastern provinces may have been fueled by the conflict and associated economic crisis. However, the high prevalence of morbidity in this area is susceptible to bias due to over reporting of cases by women in south-eastern provinces because of the conflict and associated economic crisis.

These findings are consistent with other studies in developing countries. In Cameroon, for instance, Pongou et al. (2006b) showed that the economic crises and large economic adjustment in the 1990s had a long-term impact on child health and survival. Waters et al. (2004) found in Indonesia that, maternal education and economic status—as measured by quintile of adjusted per-capita household expenditures—were very strong predictors of children's nutritional outcomes. In most African countries, under worsening socio-economic conditions, there is a decreased attendance at routine health checks which in turn affects children nutritional status (Prevel et al., 2001).

Findings from this paper also show a positive association between disease prevalence and child's age until around 15 months and a negative effect after this age (Figure 2). In fact, the effect of child's age on diarrhoea, fever and acute respiratory infection has a non-linear curve as pointed out by previous studies (see for example, Kandala, 2006; Kandala et al., 2007; Kandala et al., 2008). This might be because of malnutrition in early feeding practice whilst a child's immune system is not sufficiently developed to protect him or her from contamination by bacteria. Due to poverty, insufficient household sanitary conditions and other related factors, mothers might not be able to feed infants with enough clean breast milk so that mixed low quality foods or contaminated water are used instead (Pongou et al., 2006a, UNICEF, 1998). Furthermore, maternal nutritional status and health contribute to her inability to breast feed. For example, Ahiadeke (2000) found that diarrhoea was prevalent in infants aged 4-6 months from households with poor sanitary conditions unless mothers reverted to exclusive breastfeeding; the deterioration in child health can also be attributed to the fact that most children are weaned early (Woldemicael , 2001). It is likely that as a child's immune system develops, the association with diseases decreased, which is reflected by a gradual decline of the effect of age after 10 months in Figure 2. Another possible explanation may be that maternal immunity may be protective among very young children against infectious agents that may cause each of these symptoms. The decline of maternally derived immunity since birth may account for the increase in effect in early childhood.

Two key questions arise in the light of these findings. Why is the association between disease prevalence and socioeconomic factors (household socioeconomic status and maternal education) nonlinear? Second, does a lack of infrastructure due to economic and political crises standardise the living conditions of all the population regardless of socioeconomic status and education level?

Previous studies have shown a negative linear association between socioeconomic status and prevalence of childhood morbidity, because higher socioeconomic status is associated with healthy living conditions such as drinking water, access to appropriate sanitation and adequate nutrition (Pongou et al., 2006a). Results from the multivariate analyses show no statistical significant association between the household socio-economic status (asset index) and prevalence of fever. However, there is a non-linear association between the asset index and diarrhoea and acute respiratory infection. There is no statistically significant difference in risk of diarrhoea among children from the first (poorest) and the fifth (richest) quintile, but children from the other quintiles (second, third, and fourth) have a statistically significant higher risk of diarrhoea compared to the fifth quintile. Similarly for acute respiratory infection morbidity, children from second and fourth quintiles had an associated higher risk compared with children from the fifth quintile.

Furthermore, living in urban areas seems to have a protective effect on fever and acute respiratory infection in children. The general advantages of urban life on a child's health in sub-Saharan Africa are well documented. As in many Sub-Saharan Africa countries, children from urban areas were found to be twice as likely to be immunised and to have access to basic healthcare services as those from rural areas (UNDP, 2007). In general, such advantages substantially reduce the risk of childhood morbidity.

Previous studies in Sub-Saharan Africa have shown a negative effect of maternal education upon disease prevalence. However, for this study we did not observe an association between disease prevalence and maternal education. As observed in this study, the association between disease prevalence and socio-economics factors (asset index and educational attainment) do not follow a simple linear gradient. The non-linear association for socioeconomic status may reflect a major limitation in the MICS2 surveys (i.e. the socioeconomic status of each study household is based on the answers to questions posed to household member not on an independent assessment of family income, insurance, employment, assets) and therefore subject to misclassification. Another problem with the survey data, at least as far as the present study is concerned, is that the wealthiest (fifth-quintile) households have fewer children, per household than less wealthy households resulting in a relatively small sample of young children from these wealthiest families. Finally, more detailed measures of household poverty are not available.

Despite the limitations discussed above, the present findings give some support to those developing decentralised post-conflict reconstruction health policies for DRC children, allowing interventions to be focused on the worst affected areas and age-groups. Since there are so few modern data-sets on childhood diseases in the DRC, it is hoped that this study will stimulate further investigation of morbidity in children. Identifying and understanding environmental factors that are associated with provincial differences in disease prevalence represents an important investigation to disentangle fully the influences of environment-health links. Both novel and less conventional methodologies including various data sources are required to broaden the view of environment at both child and community level.

CONCLUSION

Using a large-scale household survey data from UNICEF, we have produced for the first time spatial residual maps in the DRC and in so doing we have undertaken a comprehensive analysis of geographical variation at provincial level of diarrhoea, acute respiratory infection, and fever prevalence among children under-five years old in DRC. Disease prevalence maps generated could be a useful tool for policy design for reconstruction and fulfilment of the Millennium Development Goals in DRC. Given the limitations of spatial analysis when the data base is a household survey, an important message emerging from this research is that it would be very worthwhile for census data and other official data sources to undertake such detailed spatial analyses. With such data sources, much more detailed and more precise spatial structures could be uncovered which would be highly relevant for both analytical and policy purposes.

REFERENCES

Ahiadeke, C. (2000). Breast-feeding, diarrhoea and sanitation as components of infant and child health: a study of large scale survey data from Ghana and Nigeria. *Journal of Biosocial Science* 32(1):47-61.

Alam, D S., Marks, G C., Baqui, A H., Yunus, M., & Fuchs, G J. (2000). Association between clinical type of diarrhea and growth of children under 5 years in rural Bangladesh. International Journal of Epidemiology, 29:916-921.

Bangha, M. (2007). Estimating adult mortality in Cameroon from census data on household deaths: 1976-1987, paper presented at the 5th African Population Conference, Arusha 10-14 December, 21 p.

Black, R E. , Brown K H. , Becker, S. (1984). Effects of diarrhoea associated with specific enteropathogens on the growth of children in rural Bangladesh. Pediatrics, 73:799-805.

Boerma, J T. , Black, R E. , Sommerfelt, A E. , Rustein, S O., & Bicego, G T. (1991). Accuracy and completeness of mother's recall of diarrhoea occurrence in pre-school children in demographic and health surveys. International Journal of Epidemiology, 20:1073-1080.

Brezger, A., Kneib, T. , & Lang, S. (2005). BayesX - Software for Bayesian Inference based on Markov Chain Monte Carlo simulation Techniques, Version 1.40.
Available under http://www.stat.uni-muenchen.de/~lang/BayesX.

Dunyo, S K. , Koram, K A. , & Nkrumah, F K. (1997). Fever in Africa and WHO recommendation. Lancet, 350:1549-1550.

Einterz, E M., & Bates, M E. (1997). Fever in Africa: do patients know when they are hot. Lancet, 350:781.

Ezzati, M., & Kammen, M D. (2001). Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure-response study. Lancet, 358:619-624.

Ezzati M., Lopez, A D., Rodgers, A., Vander, H S., & Murray, C J. (2002). The Comparative Risk Assessment Collaborating Group: Selected major risk factors and global and regional burden of disease. Lancet, 360:1347-1360.

Fahrmeir, L., & Lang, S. (2001). Bayesian Inference for Generalized Additive Mixed Models Based on Markov Random Field Priors. Applied Statistics (JRSS C), 50: 201-20.

Gakidou, E., Oza, S., Fuertes, C V., et al., (2007). Improving Child Survival through Environmental and nutritional interventional: The importance of targeting interventions toward the poor. Journal of American Medical Association (JAMA), 298(16):1876-1887.

Guerrant, R L., Schorling, J B., McAuliffe, J F., & de Souza, M A. (1992). Diarrhea as a cause and an effect of malnutrition: diarrhea prevents catch-up growth and malnutrition increases diarrhea frequency and duration. American Journal of Tropical Medicine and Hygiene, 47:28-35.

Källander, K., Nsungwa-Sabiiti, J., & Peterson, S. (2004). Symptoms overlap for malaria and pneumonia–policy implications for home management strategies. Acta Tropica, 90:211-214.

Kandala, N-B., Magadi, M A., & Madise, N J. (2006). An investigation of district spatial variations of childhood diarrhea and fever morbidity in Malawi. Social Science & Medicine, 62: 1138-52.

Kandala, N-B., Ji, C. , Stallard, N., Stranges, S., & Cappuccio, F P. (2008). Morbidity from diarrhoea, cough and fever in children in Nigeria. *Annal of Tropical Medicine and Paratology*, 102(5): 427–445.

Kandala, N-B., Ji, C. , Stallard, N., Stranges, S., & Cappuccio, F P. (2007). Spatial Analysis of Risk Factors for Childhood Morbidity in Nigeria. American Journal of Tropical Medicine and Hygiene: Oct1, 77(4), 770-778.

Kandala, N-B. (2006). Bayesian Geo-additive modelling of Childhood morbidity in Malawi. *Applied Stochastic Models in Business and Industry, 22:139-154.*

Kazembe, L N., Muula, A S., Appleton, C C., & Kleinschmidt, I. (2007). Modelling the effect of malaria endemicity on spatial variations in childhood fever, diarrhoea and pneumonia in Malawi. International Journal of Health Geographics, 6:33.

Lopez, A D., Mathers, C D., Ezzati, M., Jamison, D T., & Murray, C J L. (2006). Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. Lancet, 367, 1747-1757.

Martin-Prével, Y., Traissac, P., Delpeuch, F., & Maire, B. (2001). Decreased attendance at routine health activities mediates d**et**erioration in nutritional status of young African children under worsening socioeconomic conditions. International Journal of Epidemiology, 30:493-500.

Martorell ,R, Yarbrough, C, Lechtig, A, Habicht, JP, & Klein, RE. (1975). Diarrheal diseases and growth retardation in preschool Guatemalan children. American Journal of Physical Anthropology, 43:341-346.

Pongou, R., Ezzati, M., & Salomon, J A. (2006a). Household and Community Socioeconomic and Environmental Determinants of Child Nutritional Status in Cameroon. BMC, Public Heath, 6.98 (1), 19p.

Pongou, R., Salomon, J A., & Ezzati, M. (2006b). Health impact of macroeconomic crises and policies: determinants of variation in child malnutrition trends in Cameroon. International Journal of Epidemiology. 35 (3):648-656.

Parashar, D U., Bresee, S J., & Glass, R I. (2003). The global burden of diarrhoeal disease in children. Bulletin of the World Health Organization, 81 (4).

Roberts, L., Ngoy, P., Mone, C., et. al. (2002). Mortality in the Democratic Republic of Congo: Results from a Nationawide Survey. International Rescue Committee (IRC), New York.

Smith ,K R., Samet, J M., Romieu, I., & Bruce, N. (2000). Indoor air pollution in Developing Countries and acute lower respiratory infections in Children. Thorax , 55:518-532.

Snyder, J D., & Merson, M H. (1982). The magnitude of the global problem of acute diarrhoeal disease: a review of active surveillance data. Bulletin of the World Health Organization, 60:605-13.

US Department of States. (2008). Background notes. The Democratic Republic of Congo. Retrieved 17 June, 2008 from http://www.state.gov/r/pa/ei/bgn/2823.htm

UNDP. (2007). D.R. Congo Human Development Report. New York, NY: United Nations Development Programme.

UNICEF. (2008a). The Multiple Indicators Cluster Survey (MICS2). Retrieved 17 June, 2008 from (http://www.childinfo.org/mics2_datasets.html)

UNICEF. (2008b). Life-saving immunizations planned for a million children in DRC. Retrieved 17 June, 2008, from http://www.unicef.org/infobycountry/drcongo_15387.html

UNICEF. (2008c). Goals for Children and Development in the 1990s. Retrieved 17 June, 2008, from http://www.unicef.org/wsc/

UNICEF. (2008d), The State of the World's children. Retrieved 14 February, 2008, from http://www.unicef.org/infobycountry/drcongo_statistics.html

UNICEF/Ministry of Planning and Reconstruction in DR Congo. (2002). *Enquete Nationale sur la situation des enfants et des femmes, MICS2/2001*, UNICEF, Kinshasa, July 2002, 1, 73; available from http://www.childinfo.org/files/drc.pdf

Vaahtera, M., Kulmala, T., Maleta, K., Cullinan, T., Salin, M., & Ashorn, P. (2000). Epidemiology and predictors of infant morbidity in rural Malawi. Paediatric Perinatal Epidemiology, 14:363-371.

Waters, H., Saadah, F., Surbakti, S., & Heywood, P. (2004). Weight-for-age malnutrition in Indonesian children, 1992–1999. International Journal of Epidemiology, 33:1–7.

WHO. (2008). Partnership for Maternal, Newborn & Child Health. The Democratic Republic of Congo. Retrieved 17 June, 2008, from http://www.who.int/pmnch/countries/drcongo/en/index1.html

Woldermicael, G. (2001). Diarrhoea morbidity among young children in Eritrea: Environmental and socioeconomic determinants. *Journal of Health Population and Nutrition* , 19(2): 83-90.

Yoannes, A G., Streat-eld, K., & Bost, L. (1992). Child morbidity patterns in Ethiopia. *Journal of Biosocial Science* , 24(2): 143-55.

Zaire. (1996). *Enquête nationale sur la situation des enfants et des femmes au Zaïre en 1995. Rapport final*, 166 p.

Table 1: Distribution of factors analysed in childhood morbidity study in the DRC (MICS 2001)

	Diarrhoea N (%)			Acute respir infe. N (%)			Fever N (%)		
	No	Yes	p-value	No	Yes	p-value	No	Yes	p-value
Sex of Child									
Male	3617(76.1)	1135(23.9)	<0.001	4235(89.1)	517(10.9)	0.28	2802(59.0)	1950(41.0)	0.42
Female	3715(79.0)	987(21.0)		4211(89.6)	491(10.4)		2761(58.7)	1940(41.3)	
Stunting									
No	4480(77.0)	1340(23.0)	0.05	5235(89.9)	586(10.1)	0.010	3409(58.6)	2412(41.4)	0.25
Yes	2851(78.5)	781(21.5)		3210(88.4)	422(11.6)		2154(59.3)	1478(40.7)	
Place of residence									
urban	2428(79.3)	634(20.7)	0.003	2811(91.8)	251(8.2)	<0.001	1909(62.3)	1153(37.7)	<0.001
rural	4904(76.7)	1488(23.3)		5635(88.2)	757(11.8)		3655(57.2)	2737(42.8)	
Currently breastfeeding									
No	2414(68.3)	1121(31.7)	0.09	3104(87.8)	431(12.2)	0.11	1998(56.5)	1537(43.5)	0.12
Yes	337(71.4)	135(28.6)		424(89.8)	48(10.2)		281(59.5)	191(40.5)	
Asset Index									
1st quintile	1387(78.9)	372(21.1)	<0.001	1601(91.0)	158(9.0)	<0.001	1085(61.6)	675(38.4)	<0.001
2nd quintile	1434(74.5)	490(25.5)		1660(86.2)	265(13.8)		1039(54.0)	885(46.0)	
3rd quintile	1535(75.4)	501(24.6)		1791(88.0)	245(12.0)		1153(56.6)	883(43.4)	
4th quintile	1485(77.1)	441(22.9)		1691(87.8)	235(12.2)		1132(58.8)	794(41.2)	
5th quintile	1490(82.5)	317(17.5)		1702(94.1)	106(5.6)		1154(63.8)	654(36.2)	
Household size									
Small Household	2105(77.1)	625(22.9)	0.48	2431(89.0)	299(11.0)	0.84	1632(59.8)	1098(40.2)	0.50
Medium Household	3492(78.1)	979(21.9)		3998(89.4)	472(10.6)		2617(58.5)	1853(41.5)	
Large Household	1735(77.0)	518(23.0)		2016(89.5)	237(10.5)		1314(58.3)	939(41.7)	
Mother Education									
None	2025(76.3)	630(23.7)	0.011	2272(85.6)	383(14.4)	<0.001	1543(58.1)	1113(41.9)	0.002
Primary	3061(77.1)	911(22.9)		3551(89.4)	421(10.6)		2275(57.3)	1697(42.7)	
Secondary	2171(79.5)	560(20.5)		2534(92.8)	197(7.2)		1680(61.5)	1051(38.5)	
Province									
Kinshasa	728(79.0)	193(21.0)	<0.001	888(96.4)	33(3.6)	<0.001	627(68.1)	294(31.9)	<0.001
Bas-Congo	529(80.6)	127(19.4)		638(97.3)	18(2.7)		388(59.1)	269(40.9)	
Bandundu	1074(85.4)	183(14.6)		1177(93.6)	80(6.4)		810(64.4)	448(35.6)	
Equateur	165(72.7)	62(27.3)		208(91.6)	19(8.4)		134(59.0)	93(41.0)	
Orientale	984(78.5)	270(21.5)		1094(87.2)	161(12.8)		691(55.1)	564(44.9)	
Nord-Kivu	584(81.2)	135(18.8)		612(85.1)	107(14.9)		494(68.7)	225(31.3)	
Sud-Kivu	532(75.9)	169(24.1)		532(76.0)	168(24.0)		379(54.1)	321(45.9)	
Maniema	205(77.1)	61(22.9)		240(90.2)	26(9.8)		142(53.4)	124(46.6)	
Katanga	1108(75.7)	356(24.3)		1226(83.7)	239(16.3)		781(53.3)	684(46.6)	
Kasai-Orientale	702(72.8)	262(27.2)		880(91.2)	85(8.8)		551(57.1)	414(42.9)	
Kasai-Occidentale	719(70.4)	303(29.6)		949(92.9)	73(7.1)		567(55.5)	455(44.5)	
Total	7330(77.6)	2121(22.4)		8444(89.3)	1009(7.1)		5564(58.8)	3891(41.2)	
	Diarrhoea (Mean and Std. dev.)			Cough (Mean and Std. dev.)			Fever (Mean and Std. dev.)		
	No	Yes	p-value	No	Yes	p-value	No	Yes	p-value
Child's age in months	29.6(17.6)	22.8(14.6)	<0.001	28.3(17.3)	26.1(15.8)	<0.001	28.7(17.7)	27.3(16.5)	<0.001
Maternal BMI	21.3(3.5)	21.0(3.2)	0.005	21.3(3.5)	20.9(3.2)	0.05	21.4(3.6)	21.1(3.3)	0.005

Chi-square test was used for categorical data and Mann-Whitney test for continuous data in the bivariate analysis.

Table 2: Provincial posterior OR estimates of the fixed effect parameters for diarrhoea, acute respiratory infection and fever in DRC (2001 MICS2)

	Diarrhoea			Acute respiratory infection			Fever		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Sex of Child			*						
Male	1			1			1		
Female	0.91	(0.80-1.05)		0.94	(0.78-1.12)		0.99	(0.90-1.11)	
Stunting									
No	1						1		
Yes	1.15	(0.99-1.34)					0.92	(0.82-1.03)	
Place of residence									
Rural	1			1			1		
Urban	1.05	(0.86-1.31)		0.94	(0.72-1.24)	*	0.84	(0.71-0.99)	**
Asset Index									
1st quintile	1.31	(0.95-1.79)		1.16	(0.73-1.73)		1.01	(0.79-1.30)	
2nd quintile	1.65	(1.22-2.22)	**	1.49	(1.01-2.30)	**	1.20	(0.95-1.54)	
3rd quintile	1.51	(1.14-2.06)	**	1.22	(0.83-1.80)	*	1.02	(0.80-1.30)	
4th quintile	1.35	(1.04-1.76)	**	1.48	(1.02-2.16)	**	1.06	(0.86-1.32)	
5^{th} quintile	1			1			1		
Household size									
Small Household	1			1			1		
Medium Household	1.05	(0.90-1.23)		1.06	(0.87-1.31)		1.09	(0.96-1.23)	
Large Household	1.07	(0.89-1.27)		1.05	(0.82-1.32)		1.12	(0.98-1.28)	
Mother Education						*			
None	1			1			1		
Primary	1.06	(0.90-1.25)		1.00	(0.80-1.23)		1.24	(1.09-1.43)	**
Secondary	1.07	(0.87-1.31)		0.89	(0.67-1.20)		1.25	(1.06-1.45)	**
Province†									
Kinshasa	1.54	(0.92-2.58)		1.00	reference		1.00	reference	
Bas-Congo	1.17	(0.68-2.02)		0.90	(0.29-2.77)		1.80	(1.11-2.91)	**
Bandundu	1.00	reference		2.00	(0.81-4.96)		1.07	(0.66-1.72)	
Equateur	1.52	(0.97-2.39)		2.85	(1.21-6.73)	**	1.32	(0.82-2.12)	
Orientale	1.43	(0.90-2.25)		4.06	(1.77-9.29)	**	1.91	(1.20-3.04)	**
Nord-Kivu	1.68	(0.97-2.90)		4.78	(1.91-12.0)	**	1.29	(0.74-2.25)	
Sud-Kivu	1.72	(1.01-2.94)	**	7.00	(2.94-16.7)	**	1.14	(0.66-1.96)	
Maniema	2.08	(1.05-4.11)	**	3.65	(1.19-11.17)	**	1.94	(0.97-3.90)	
Katanga	1.71	(1.07-2.72)	**	4.62	(2.08-10.2)	**	1.56	(0.99-2.45)	
Kasai-Orientale	2.26	(1.42-3.59)	**	2.32	(0.97-5.53)		1.38	(0.87-2.18)	
Kasai-Occidentale	2.29	(1.42-3.68)	**	1.17	(0.42-3.30)		1.09	(0.66-1.79)	

See maps in Figure 1

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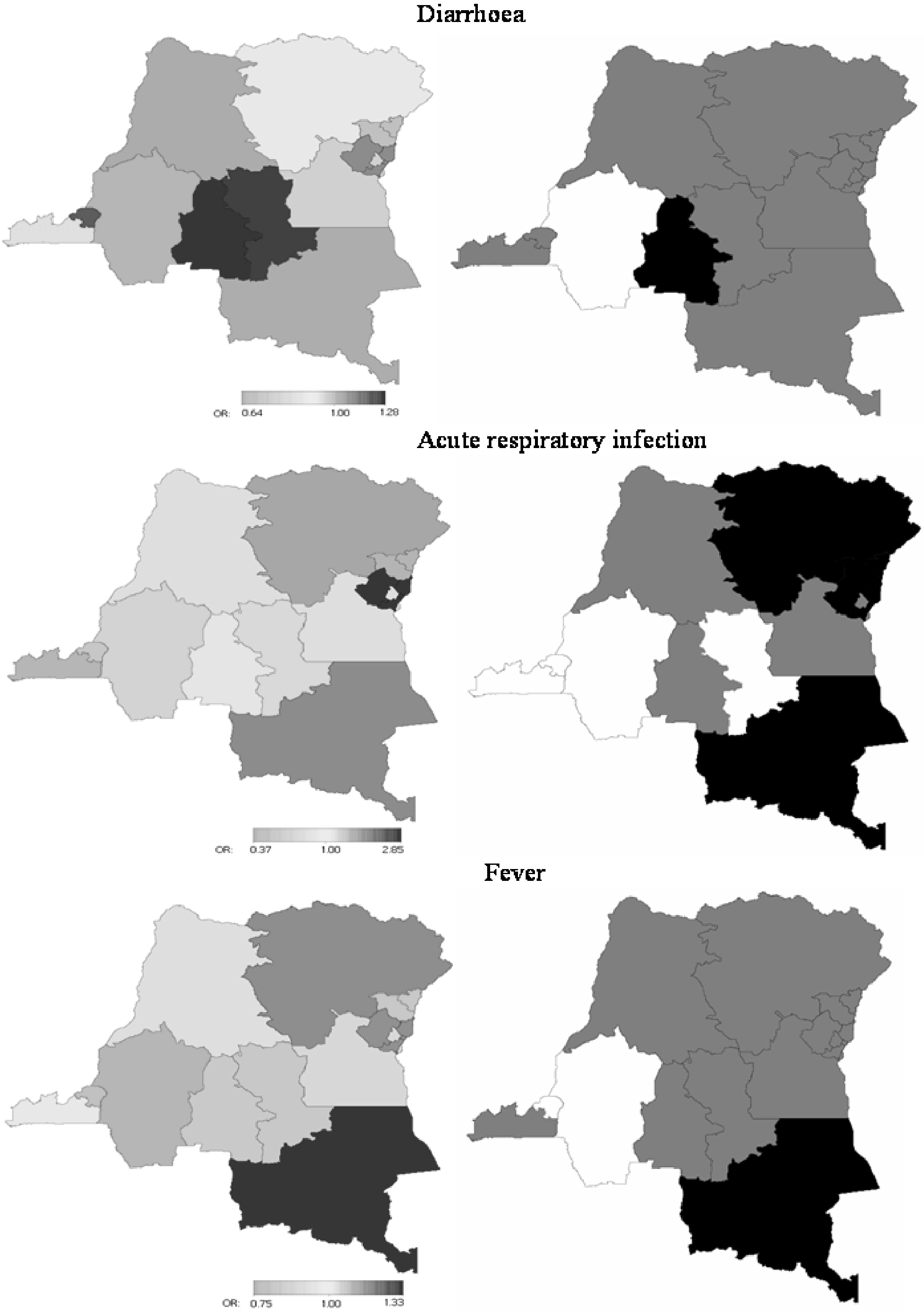
*A significant p-value for the bivariate test (p-value at 0.05 levels)
**A significant p-value for both bivariate and multivariate tests (p-value at 0.05 levels)
† OR are from provinces dummy variables without taken into account the spatial auto-correlation in the data. For provincial spatial effects (accounting for the auto-correlation in the data), see maps in Figure 1.

Figure 1: Estimated Odds ratios of residual spatial provincial effects (left) and 95% posterior probability map (right) of child morbidity (CMICS2, 2001).



Darker areas d – high risk, high morbidity
Lighter coloured – low risk

Black coloured – significant positive spatial effect
White coloured- significant negative spatial effect
Grey coloured – no significant effect

Figure 2: Estimated nonlinear (logits) effects of child's age and maternal BMI on diarrhoea, acute respiratory infection and fever. Shown are the posterior logits within the 95% and 80% credible intervals (CMICS2, 2001).