UNIVERSITY OF CAPE COAST

A MULTILEVEL AND SURVIVAL ANALYSIS OF THE ECOLOGICAL FACTORS ASSOCIATED WITH UNDER-FIVE MORTALITY IN GHANA.

VINCENT BIO BEDIAKO

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A MULTILEVEL AND SURVIVAL ANALYSIS OF THE ECOLOGICAL FACTORS ASSOCIATED WITH UNDER-FIVE MORTALITY IN GHANA

BY

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A thesis submitted to the Department of Population and Health of the Faculty of Social Sciences, College of Humanities and Legal Studies, University of Cape Coast, in partial fulfilment for the award of Master of Philosophy in Population and Health

SEPTEMBER 2022

DECLARATION

Candidate's Declaration

I officially declare that this report is the result of my original research. No portion of it has been submitted to another university or institution for consideration for another degree.

Signature of Candidate: ………………………... Date: ………………….

Name: Vincent Bio Bediako

Supervisor's Declaration

I now certify that the preparatory work and presentation of the thesis were carefully monitored by the University of Cape Coast's guidelines.

Signature of the Principal Supervisor: ……………… Date: ……………

Name: Prof. Fiifi Amoako Johnson

ABSTRACT

Under-five mortality continues to be a major public health challenge in many sub-Saharan African countries. To assist Ghana in achieving the Sustainable Development Goal three target two of eliminating preventable infant and under-five mortality, a thorough understanding of the risk factors for death in children under five is critical for guiding targeted interventions. This study examines the ecological factors (environmental and social) associated with under-five mortality in Ghana. The study adopted the positivist research philosophy using quantitative methods to model data from four rounds of Ghana Demographic and Health Survey, Demographic and Health Survey Geospatial Covariates and Land Cover Climate Change Initiative datasets. Cox proportional hazard and multilevel logistic regression techniques were used to quantify the associations between the ecological factors and under-five mortality in Ghana, accounting for important confounders. The analysis covered 12460 (1998 GDHS= 3298 2003 GDHS = 3611, 2008 GDHS = 2742, and 2014 GDHS = 2809) children aged 0 to 59 months for whom information on survival status and complete data on other selected variables were available. The results show that the probability of dying was significantly lower for children sampled from 1998, 2003, and 2008 GDHS when compared to those surveyed in the 2014 GDHS. The results suggested that temperature, annual rainfall, and malaria incidence were significantly associated with under-five mortality regarding the ecological factors.

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DEDICATION

This work is dedicated to my father, who has been an unwavering supporter of my education.

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CHAPTER ONE

INTRODUCTION

1.0 Chapter Introduction

The chapter summarises the thesis subject and reveals a research gap in the study of under-five mortality. The study highlighted several thematic issues surrounding under-five mortality. The study emphasised focusing on under-five mortality by introducing ecological factors.

1.1 Background to the study

Under-five mortality is a significant and critical health outcome; it has been adopted as an indicator of development for developing and developed countries (Kiross, Chojenta, Barker, Tiruye, Loxton, 2019). Research evidence shows that many associated factors of under-five deaths, including mother's age at birth, birth interval, and living standard (Gupta, Ladusingh & Borkotoky, 2016), are preventable through social interventions and governmental policies. Nonetheless, World Health Organisation (2018) reported that 5.4 million deaths were recorded in 2018 among children under five years. Given the worrying under-five figures reported, further analysis shows wide regional differentials in under-five mortality, with low- and middle-income countries bearing a disproportionate share of the death toll compared to high-income countries. For example, in the 1990s, there was a 20-fold difference (180 versus 9 deaths per 1000 live births) in under five deaths between sub-Saharan African and high-income countries (Sartorius, Sartorius, Chirwa & Fonn, 2011). Furthermore, patterns are observed in under-five between countries with low and high incomes, with estimates of 76 deaths and 7 deaths per 1000 live births in low-income and high-income countries, respectively, by 2000 (Ogbo et al., 2019). Recent years have seen a substantial difference in the number of under-five deaths in different parts of the world, even though a lot of work has been done by world bodies to stop these deaths. In 2019, the global mortality rate stood at 38 per 1000 live births compared to the African region, with 74 per 1000 live births (WHO, 2021).

There has been a substantial reduction in mortality rates in the past four decades, particularly among those under five years worldwide. This significant development has led to increased child survival in many countries. Estimates from research indicate a reduction in worldwide death rates from 69 in 2000 to 38 deaths per 1000 live births in 2016 – a reduced rate of 45% (Collaborators, 2017). The reduction in under-five mortality could be associated with economic growth across all levels, be it country, regional or global. Reduced parity and strengthened public health programs globally and across countries are some of the efforts that have ensured that children born anywhere in the world have a higher probability of living to the age of five. In addition, the Millennium Development Goal (MDG) agenda and the improved support can be indicated as significant contributors to this outstanding achievement so far. (Ogbo et al., 2019).

Aside from the wide regional differentials, a research report that within-country variations are even broader (Robinson, Meier, Trinitapoli & Svec, 2014). Despite the decline, under-five mortality is still considered a major financial and public health challenge worldwide (Al-thani, Toumi, et al., 2017). This is partly because the significant decline in under-five mortality has not occurred in all regions at the same rate. With regards to Ghana, the recent Demographic and Health Survey reported substantial regional variability in under-five mortality rates (Ghana Statistical Service (GSS), Ghana Health Service (GHS) & ICF International, 2015). The varied under-five mortality rate was reported across the then ten (10) administrative regions of Ghana in the 2014 demographic and health survey. It was reported that Greater Accra recorded the least under-five mortality rate, with an estimated 47 per 1000 live births. This estimate is below the national average of 60 per 1000 live births. The northern region recorded the highest under-five mortality rate, with 111 per 1000 live births. This estimate is close to twice the national average. Apparent differences and clustering in under-five mortality exist within Ghana. Therefore, it is safe to say that a more profound look into the district and subdistrict levels will provide higher estimates than what has been observed at the regional levels.

Overall, Ghana has observed some massive improvement in under-five mortality since the demographic and health survey in 1988. Progressively, under-five mortality rates have reduced from 155 deaths per 1000 live births to 60 deaths per 1000. This incredible achievement can be attributed to the global agenda to reduce death among the younger generations. The progressive decline since the 1988 GDHS can be attributable to various efforts made by the country. These efforts include policies institutional and physical measures targeted at reducing Under-five mortalities. Kolekang (2019) notes that efforts in Ghana to reduce the under-five morality are both preventive and curative. Physical measures or efforts to reduce under-five mortality in Ghana focus on access to healthcare. For instance, Awoonor-Williams et al. (2013) found that community interventions such as providing primary health care at the CHPS programme reduced Under Five mortality. In addition, Ghana Essential Health

Intervention Project, an intervention to reduce mortality, resulted in a drastic reduction in malaria cases and malaria among under-fives. This had a positive reductive effect on deaths among under-five children.

Another critical effort Ghana put in place which contributed to the decline in Under-five mortality is Ghana's Policy on Under Five's Child Health Policy which has an implementation period of 2007 to 2015. The primary focus of the policy was to reduce child mortality to 40 deaths per 1,000 live births by the year 2015. Moreover, this objective of the policy was to be achieved through various measures. Provision of antenatal care, delivery care and postnatal care services at various public care facilities are some of the implementing strategies of the policy. Meeting the nutritional needs of the children, treating childhood illnesses, and preventing malaria through nationally strategic programmes are also some of the implementing measures of the procedure (Ministry of Health, Ghana, 2015; Agbadi et al., 2021). This policy was a critical mitigating effort by Ghana to deal with Under-five mortality

Measures such as immunising children against major diseases are essential efforts the country used to reduce Under-five mortality. Immunising the children helped mitigate preventable deaths among children under five years because of diphtheria, measles, pertussis, poliomyelitis, tetanus, and tuberculosis (Adokiya, Baguune & Ndago, 2017). Apart from the immunisation effort, the government of Ghana also introduced a free maternal health care policy. This policy provided free health care to mothers in Ghana and contributed to reducing maternal and under-five mortality in Ghana (Azaare, Akweongo, Aryeetey & Dwomoh, 2020). It is also critical to note that the national health insurance policy and community health planning services also had a mitigating effect on under-five mortality (Agbadi, P. et al., 2021)

However, the rate of decline in under-five mortality has stagnated in recent times. The Ghana Health Service (2017) reported that the country's under-five mortality rates have reduced but have stagnated in recent times. This statement has been reemphasised by Iddrisu, Alhassan and Amidu (2019). They indicated categorically that Ghana has failed to record any substantial improvement in under-five mortality rates despite declines in the global rate. The stagnation in infant and under-five mortality may be attributed to varied circumstances surrounding under-five children's health. One plausible reason which can help explain this stagnation can be the much attention paid only to the intermediate determinants (Socioeconomic and demographic) of child survival. Whilst ignoring the critical dimension of ecological factors and how geographic space influences health (Ladusingh, Gupta & Yadav, 2016). Traditional demographic and epidemiological studies' emphasis on investigating the proximate determinants of child survival has made it difficult for some countries to meet the MDG-IV target of reducing infant mortality rate (Singh, Pathak, Chauhan & Pan, 2011).

Currently, some countries are facing difficulties in achieving the Sustainable Development Goal three (3) target two (2). To address this gap in the literature and reduce under-five mortality, we need to shift our focus from the immediate surroundings of children under five years. We, therefore, must focus on the external context and factors as determinants of under-five mortality. This is necessary and cost-effective because public health interventions target communities, not individuals. Consequently, if the direct and indirect ecological factors determining under-five mortality rates are identified, it would be more accessible and within means, for the determinants to be targeted at the aggregate level to help improve children's survival under five years.

Despite the worldwide decline in mortality estimates, under-five deaths continue to be high in the region. Nonetheless, the disparities are wider at the local authority level, where intervention programmes are implemented and monitored more comprehensive, yet much is not known about the levels and differences. Furthermore, research evidence shows that national and regional level statistics often mask within-country geographical variations that contribute to the high under-five mortality rates.

1.2 Statement of the Problem

Most research on under-five mortality has analysed their studies based on Mosley and Chen's (1984) analytical framework for child survival. In most of these studies, the factors associated with under-five mortality essentially included individual, maternal and household characteristics. For instance, in their research on under-five mortality, Gebretsadik and Gabreyohannes (2016) analysed covariates at the individual and maternal levels. Their study did not consider household and community-level variables. Arku and colleagues (2016) accounted for only cooking fuel and sanitation facilities as the only environmental factors in their research. The study failed to account for the significant role of environmental factors on under-five mortality.

Other studies have considered environmental factors as significant correlates that influence under-five mortality. However, for most of these studies, the environmental variables included were restricted to the household level, namely water source (Tigabu E, Petros & Endeshaw, 2010); latrine ownership, waste disposal, source of water and water treatment (Godana and Mengiste, 2013); type of root materials, type of floor material, animal live with family in one house, several rooms, availability of latrine and availability of handwashing facility (Workie, Akalu, & Baraki, 2019).

Mosley and Chen (1984) conceptualised environmental factors associated with under-five mortality (water quality, disease vector, household air quality etc.). Nonetheless, the elements were conceptualised only at the household level, without considering these children's communities. Mosley and his colleague (1984) posited that these environmental contaminations affect children differently since they operate at the household level. The authors justified the immediate surrounding of the child as the primary environmental determinant of the child's survival. Despite accounting for the roles of environmental contaminations as having a significant associative effect on child survival, the authors failed to account for the ecological factors by analysing the household-level factors that equally play an important role in influencing children's survival in most developing countries. Dues to this shortfall, further studies that adopted the framework do not account for the ecological (environmental and social) factors

This study used data from four rounds of the Ghana Demographic and Health Survey and extracted ecological data from Demographic and Health Survey Geospatial Covariates and Land Cover Climate Change Initiative datasets to investigate ecological factors associated with under-five deaths in Ghana.

To examine the association of ecological factors with under-five mortality. Multilevel logistic regression and survival analysis were used to explore the associative effect of ecological factors on under-mortality. The Ghana Demographic and Health Survey has a hierarchical structure where the child is at the first level. This child belongs to a mother who lives in a household. The household is in a community, part of a district, and the district is also part of a region. A multilevel logistic regression can model the dataset's hierarchical structure.

On the other hand, under-five mortality has been analysed using the dichotomous variables dead versus alive. However, the survival time in the dataset allows for the modelling of survival analysis. Furthermore, this modelling allows the researcher to account for the time of exposure inherent in the dataset. Therefore, the study modelled both methods to determine which environmental factors are associated with under-five mortality.

1.3 Research Objectives

The overarching objective of the study is to examine the ecological factors associated with under-five mortality in Ghana. Specifically, the study aims to examine:

1. trends in under-five mortality in Ghana.
2. the ecological factors (environmental and social factors) associated with under-five mortality; and,
3. How much of the variability in under-five mortality at the community and district level is explained by the ecological factors (environmental and social).

1.3.1 Research Questions

The study asked the following research questions based on the objectives and the stated research hypothesis.

1. Are there significant temporal changes in under-five mortality in Ghana?
2. Which ecological factors are associated with under-five mortality in Ghana?
3. How much of the variability in under-five mortality at the community and district levels is explained by the ecological factors?

1.3.2 Research Hypothesis

Global and national statistics on mortality report a decreasing trend, although current statistics of deaths indicate a lower reduction in Ghana. According to Acheampong and Avorgbedor (2017), the decline in under-five mortality has stalled, and the effect is more pronounced at distinct levels. With no identified ecological factors associated with under-five mortality, research must be carried out to examine the impact of ecological factors on under-five mortality. Based on the literature, the study hypothesised that

1. There was a statistically significant change in under-five mortality across time.
2. Ecological factors are significantly associated with under-five mortality
3. There are variations in under-five mortality at the community and district levels, and the ecological factors (environmental and social) account for some of these variations.

1.4 Significance of the Study

The significance of this study allowed the researcher to model the two analytical approaches general used in analysing data on under-five mortality. The findings from the study provided the researcher with enough statistical evidence to select the best analytical model to study under-five mortality. Another significance of the this study was the expected contribution to better understand how ecological factors are associated with under-five mortality in Ghana. Furthermore, the study's findings are beneficial to the research community as it accounted for ecological factors that have not been considered in most demographic and epidemiological research on under-five mortality. As a result, this study serves as reference material for students and other researchers interested in the association between under-five mortality and the associated ecological factors. In addition, the conclusions from the research aid in tracking countries' progress toward achieving the three targets for under-five mortality set out in the Sustainable Development Goals (3).

CHAPTER TWO

REVIEW OF RELATED LITERATURE, THEORIES AND CONCEPTUAL FRAMEWORK

2.0 Introduction

The interaction between maternal, environmental and proximate factors on under-five mortality has been studied for many years. Demographers have investigated some correlates of under-five mortality more closely than others. The following review is intended to provide critical and exhaustive literature on the key thematic areas of under-five mortality that guide the choice of variables for analysis. Further, this study section introduced the theoretical philosophy that underpinned the study. Finally, a conceptual framework of the theories and critical thematic issues was developed.

2.1 Under-five mortality trends in Sub-Saharan Africa and Ghana

Worldwide, under-five mortality is considered a significant index of health and wellbeing of children and doubles as a critical developmental index of countries (Gebretsadik & Gabreyohannes, 2016). Evidence shows a substantial decline in the global prevalence of mortality among children under five years, from 5.9 million deaths in 2015 to 5.3 million in 2018 (Worku, Teshale & Tesema, 2021). Analogously, the United Nations, World Health Organisation (WHO) and World Bank report in 2019 revealed that the under-five mortality rate declined worldwide by 59 percent, from 93 deaths per 1000 live births in the 1990s to 39 deaths per 1000 live births (Agbadi, Agbaglo, Tetteh, Adu, Ameyaw & Nutor, 2021; UNICEF, UN, WHO & World Bank, 2019).

Since there has been this decline in the world's burden of under-five mortality, it remains a significant public health concern, especially for countries in SSA (Worku, Teshale & Tesema, 2021). For example, evidence shows that Africa contributes as much as 14 percent to the global burden of under-five mortality, while in SSA, it constitutes nearly 50 percent of child mortality (Worku, Teshale & Tesema, 2021). Furthermore, Worku, Teshale and Tesema (2021) opine that, in 2018, SSA recorded the highest burden of under-five mortality as 1 in every 13 live births died before age 5; this is reported to be 15 times higher than under-five mortalities registered in high-income countries. This implies that the under-five mortality rate for SSA stood at 78 deaths per 1000 live births in 2018 (Agbadi et al., 2021). As such, it is essential to engineering efforts that will accelerate the substantial decline in under-five mortality in SSA.

Although sub-Saharan Africa is responsible for a disproportionately high number of deaths among children under the age of five, there seems to have been some reduction in child mortality rates within the sub-region throughout the course of recent history. The mortality rate for children under the age of five in West and Central Africa sub region decline from the year 196.66 deaths per 1000 live births in 1990 to 187.09 deaths per 1000 live births in 1995(Unicef, WHO, UN & World Bank, 2021a). The sub region witnessed a further decline from 167.92 deaths per 1000 live births 2000 to 142.01 deaths per 1000 live births in 2005 (Unicef, WHO, UN & World Bank, 2021a). The sub region witnessed further decline from 120.16 deaths per 1000 live births in 2010 to 107.92 deaths per 1000 live births in 2014 (Unicef, WHO, UN & World Bank, 2021a).

Furthermore, the mortality rate for children under the age of five in Eastern and Southern Africa also witnessed a decline from 163.04 deaths per 1000 live births in 1990 to 153.81 deaths per 1000 live births in 1995 (Unicef, WHO, UN & World Bank, 2021b). There was a further decline from 134.14 deaths per 1000 live births in 2000 to 105.91 deaths per 1000 live births in 2005 (Unicef, WHO, UN & World Bank, 2021b). A subsequent decline was observed from 81.31 deaths per 1000 live births in 2010 to 66.79 deaths per 1000 live births in 2014 (Unicef, WHO, UN & World Bank, 2021b).

Ghana's situation is not too different from other SSA countries. In Ghana, successive governments have heavily invested in developing and implementing health programmes, policies and actions necessary to act as a catalyst for eliminating under-five mortality (Aheto, 2019). Notable among these policies and programmes are the Community-Based Health Planning and Services (CHPS) policy, Child Health Policy 2007–2015, and National Health Insurance, in which the free treatment of children aged below 18 years are embedded (Aheto, 2019; Bosomprah, Ragno, Gros & Banskota, 2015; Browne, Kayode, Arhinful, Fidder, Grobbee & Klipstein-Grobusch, 2016). These collective initiatives facilitated the decline in Ghana's under-five mortality rate from 110 deaths per 1000 live births in 1993 to 70 deaths per 1000 live births in 2014 (GSS, GHS & ICF, 2015). Nonetheless, Ghana failed to achieve the targets of the Child Health Policy 2007–2015, which envisioned reducing the under-five mortality rate to 40 deaths per 1000 live births (Agbadi et al., 2021). Figure 1 shows the trend in the under-five mortality rate in Ghana.

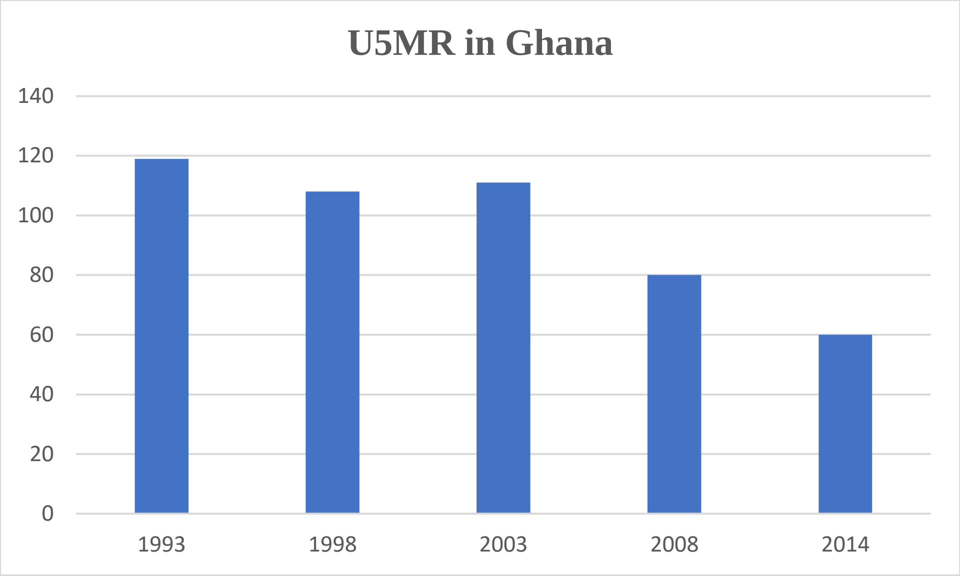

Figure 1: Trends in under-five mortality in Ghana
Source: Ghana Statistical Service (GSS), Ghana Health Service (GHS) & ICF International (2015)

As shown in Figure 1, the trend of under-five mortality indicates that Ghana has been declining from 1993 to 2014, except for between 1993 and 2003, where there was a slight increase in the rate from 108 deaths per 1000 live births to 111 deaths per 1000 live births. Nevertheless, it can be inferred that overall, the figures portray a declining trend in the rate of under-five mortality in Ghana. However, the rate of change has been slow, and that is where more efforts and strategies would be needed to accelerate the country's prospects in attaining its set targets as well as achieving the Sustainable Development Goal (SDG) target 3.2, which envisions to reduce under-five mortality rate to at least as low as 25 deaths per 1000 live births (Acheampong, Ejiofor, Salinas-Miranda, Wall & Yu, 2019; WHO, 2015).

Within the Ghana context, there is regional variation in decline of under-five mortality over the years. Upper West Region witnessed a decline from 193.45 deaths per 1000 live births in 1990 to 71.87 deaths per 1000 live births in 2014 (Unicef, WHO, UN & World Bank, 2021c). Also, Upper East

Region witnessed a decline from 136.43 deaths per 1000 live births in 1990 to 51.48 deaths per 1000 live births in 2014. Northern Region also witnessed a decline from 191.25 deaths per 1000 live births in 1990 to 81.12 deaths per 1000 live births in 2014 (Unicef, WHO, UN & World Bank, 2021c).

Moreover, Brong Ahafo Region saw a decline in under five mortality from 103.94 deaths per 1000 live births in 1990 to 49.34 deaths per 1000 live births in 2014 (Unicef, WHO, UN & World Bank, 2021c).. Furthermore, volta saw a decline from 104.9 deaths per 1000 live births in 1990 to 49.11 deaths per 1000 live births in 2014. Ashanti Region also observed a decline from 101.73 deaths per 1000 lives to 59.32 deaths per 1000 live births in 2014. Futhermore, a decline was observed in Eastern Region from 110.22 deaths per 1000 live births in 1990 to 51.2 deaths per 1000 live births in 2014 (Unicef, WHO, UN & World Bank, 2021c).

There was a decline is western region from 119.02 deaths per 1000 live births in 1990 to 46.98 deaths per 1000 live births in 2014 (Unicef, WHO, UN & World Bank, 2021c). Also, central region saw a decline from 123.15 deaths per 1000 live births in 1990 to 55.77 deaths per 1000 live births in 2014. Finally, Greater Accra Region also saw a decline from 84.64 deaths per 1000 live births to 38.72 deaths per 1000 live births (Unicef, WHO, UN & World Bank, 2021c).

2.2 Policies on Under Five Morality in Ghana

Over the years, police interventions have been put in place to address the issue of under-five mortalities in Ghana. The Ghana Child Health Policy (CHP) and the Child Health Strategy (CHS) are two of the measures that have been implemented (Ministry of Health, 2007). The primary goals of these initiatives are to expand people's access to medical care, ensure the highest possible standard of medical treatment, and stimulate more demand for necessary services (Ministry of Health, 2007). The primary focus is on illnesses that are prevalent, such as cholera and diarrhoea, which mostly impact young children. The management of diarrhoea is improved with the use of low-osmolarity oral rehydration salts and zinc, as well as the introduction of new vaccinations against measles, pneumococcal illness, and rotavirus. There are several vaccination programs available in Ghana; thus, the country's overall immunization rate for measles has increased from 68.8 percent in the year 1998 to 79.9 percent in the year 2008 and 87.7 percent in the year 2010. (Ministry of Health, 2007).

Community-Based Health Planning and Services (CHPS) (Nyonator et al., 2005), User Fees Exemption for Delivery (UFED) (Ministry of Health, 2004), Focused Antenatal Care (FANC) (Kayode et al., 2016), and National Health Insurance Scheme (NHIS) were among the additional intervention programs and policies that were put into place (Government of Ghana, 2003). While the UFED (Ministry of Health, 2004) and NHIS programs aim to lessen the financial burden of healthcare service and eliminate inequity in healthcare uptake, the CHPS program seeks to bring healthcare closer to the people by providing primary health care service. The goal of the FANC is to increase the rate of maternal and infant survival through the provision of individualized antenatal care. This type of care involves conducting an in-depth evaluation of a pregnant woman's sociocultural beliefs, lifestyle, and medical characteristics in order to facilitate the earlier diagnosis and treatment of illness and pregnancy-related complications.

Additional to these national efforts and policies, a number of regions have implemented their own distinctive intervention strategies. . One such program is the Kybele program, which is being carried out in the Greater Accra region (Srofenyoh et al., 2012). Accelerated Child Survival and Development (ACSD) (Kayode et al., 2016) was a program that was sponsored by the United Nations Children and Education Fund (UNICEF) in the Northern, Upper East, and Upper West regions, and Kangaroo Mother Care (KMC) (Kayode et al., 2016) was a program that started in 2007 in six different regions.

2.3 Environmental factors associated with under-five mortality

Under-five mortality correlates strongly with several factors. Therefore, this review section explores various environmental factors and their association with under-five mortality. This section reviewed ecological factors which are mainly environmental factors. These included the mean temperature, maximum temperature, aridity, drought episodes, annual precipitation, rainfall, enhanced vegetation index, dry land surface temperature, night land surface temperature, land surface temperature, and wet days.

In a study by Bandyopadhyaya, Kanji and Wang (2012), it was found that in 14 SSA n countries, a one-degree Celsius increase in the average maximum temperature resulted in one per cent increased diarrhoea prevalence. Interestingly, the authors found that an increase in monthly average maximum temperature significantly increased the prevalence of diarrhoea. However, there was a substantial reduction in most diarrhoea about the rise in monthly minimum temperature. Given the significant association between childhood diarrhoea and under-five mortality (Alebel, Tesema, Temesgen, Gebrie, Petrucka & Kibret, 2018), it can be inferred from Bandyopadhyaya et al.'s (2012) study that maximum temperature exacerbates the odds of under-five mortality.

2.3.1 Aridity

Another crucial ecological determinant is the aridity of the community in which the child finds him or herself. Aridity, which denotes the prolonged absence of rain or moisture, is an incredibly significant determinant as geospatial areas with elevated levels of aridity are likely to suffer more infant and under-five mortality (Balk, Pullum, Storeygard, Greenwell & Neuman, 2004). In communities with high aridity, it is expected that they will have challenges with access to potable drinking water and a struggle with sanitation. In highly arid areas, precipitation that would have otherwise worsened their situation becomes a conduit to increasing children's chances of surviving by water, providing agricultural production materials, and enhancing general sanitation levels (Balk et al., 2004). In very arid ecologies, its consequences on agriculture can be bizarre, affecting the child's nutritional status and leading to mortality (Stanke, Kerac, Prudhomme, Medlock & Murray, 2013).

In very arid communities or ecologies, the increased temperature may increase pathogen proliferation in food and water sources (D'Souza, Becker, Hall & Moodie, 2004). This situation makes it easy for the child to get infected and die because of the pathogenic reaction. For instance, Okunlola and Oyeyemi (2019) revealed in their study that there is a statistically significant relationship between aridity and the incidence of malaria in

Nigeria, hence, exacerbating the risk of under-five mortality since malaria infection at that early age is often lethal. Similarly, Bandyopadhyaya, Kanji and Wang (2012) also found that during periods of aridity, the prevalence of diarrhoea increases among children, increasing the odds of dying before age five. In Somalia, Kinyoki et al. (2016) observed that “a unit increase in annual rainfall lowered the probability of children experiencing stunting by 12%”. Given that stunting is directly associated with under-five mortality. It is safe to infer that annual rainfall is related to children’s survival before their fifth birthday. Therefore, it is not surprising that children living in arid and semiarid zones have the lowest infant and child survivorship; they have a 15 percent and 12 percent higher risk of death than children in the optimal range (Balk et al., 2004).

2.3.2 Drought episodes

Drought episodes indirectly affect child mortality as it operates through some mediators. A study in Uganda revealed that extended periods of drought were significantly associated with child malnutrition (Amegbor, Zhang, Dalgaard & Sabel, 2020). Drought directly affects agricultural productivity, contributing to food insecurity and high malnutrition among children (Grace, Davenport, Funk & Lerner, 2012). This childhood malnutrition, in turn, exacerbates the risk of under-five mortality.

2.3.3 Annual Precipitation

Annual precipitation has also been identified as another crucial ecological factor influencing the likelihood and rate of under-five mortality among a given population. However, precipitation does not directly influence under-five mortality like many ecological factors. Instead, it operates by exposing children to undernourishment and stunting as well as other diseases such as diarrhoea which exacerbates their odds of dying before age 5 (Bandyopadhyaya, Kanji & Wang, 2012; Horn, et al., 2018). For example, in their study, Findley, Balk, Barlow and Sogoba (2002) show that malaria incidence surged one or two months after peak rainfall. Given that children under five are at substantial risk of dying from malaria, then it can be inferred that precipitation is significantly associated with under-five mortality.

2.3.4 Annual Rainfall

Other studies have also shown that under-five mortality because of diarrhoea can be attributed to below-average rainfall (Bandyopadhyay, Kanji & Wang, 2012), heavy rain (Tornheim, Manya, Oyando, Kabaka, O'reilly, Breiman & Feikin, 2010) and rainfall shocks (Rabassa, Skoufias, & Jacoby, 2014). Likewise, Alexander, Carzolio, Goodin and Vince (2013) reported a strong positive association between precipitation and mortality from diarrhoea in Botswana. This means that the higher level of rainfall is associated with a higher likelihood of childhood diarrhoea, translating to the child's death. Similarly, Horn and colleagues (2018) also assert a significant association between diarrhoea and precipitation. Here again, children under five are more vulnerable to dying from diarrhoea, reinforcing the argument that precipitation determines under-five mortality.

2.2.5 Enhanced vegetation index

The enhanced vegetation index measures the density of green leaves within a particular geographic region; it usually ranges between 0-100 (Dwomoh, 2021). This index is associated with child health outcomes. For example, in the study by Tottrup et al. (2009), the authors observed that "districts with dense vegetation, high rainfall, and low elevation experienced the lowest reductions in child mortality". This means that the higher the vegetation index, the lower the risk of under-five mortality and vice versa. The vegetation index of an area indicates the likelihood of crop survival and the abundance of yields to be met to meet the nutritional needs of children.

2.4 Socio-ecological factors associated with under-five mortality

Aside from the environmental factors of the ecology associated with under-five mortality, a social component also plays a significant role in influencing under-five mortality. The social-ecological factors relate to a specific geographical area's socio-economic and socio-political conditions. This section of the review details major works that have researched the association of these factors with under-five mortality.

2.4.1 Malaria incidence and ITN coverage

Malaria is endemic in SSA, including Ghana. It is also anecdotal knowledge that children under five are at risk of severe malaria, resulting in disability. The worst-case scenario is the child's death in the worst-case scenario. The evidence available shows that each year, 900,000 cases of malaria happen among children under five (Afoakwah, Nunoo & Andoh, 2015). Various strategies have been adopted to combat malaria in the general population, especially children under five. One of such strategies is using insecticide-treated mosquito nets (ITNs) (Munos et al., 2016). Since introducing ITNs, researchers have assessed their relationship with under-five mortality. In a multi-country study, Lim et al. (2011) found that the scale-up of ITN coverage was accompanied by a substantial decline in the incidence and risk of under-five mortality. Similarly, a study in SSA also revealed that ITN was associated with a more significant reduction in malaria among children and subsequently translated into a substantial decline in under-five mortality (Fullman, Burstein, Lim, Medlin & Gakidou, 2013). Using the Mbita Health and Demographic Surveillance System database, Analogous findings from Kenya indicated that under-five mortality was significantly lower in areas where ITN coverage was high than in regions with more inadequate ITN coverage (Komazawa, Kaneko, K'Opiyo, Kiche, Wanyua, Shimada & Karama, 2012).

Balk and colleagues (2004) in their study found that even though under-five mortality is highly recorded in rural areas than in urban areas, within the rustic ecological setup, there remains a density continuum that indicates that children residing in the most sparsely populated regions (less than 25 inhabitants per square km) suffer the lowest probability of survival. Similarly, in the case of the urban ecology, infants enjoy survival possibilities; however, for those who reside in densely populated areas, that is, with more than 1000 persons per square kilometre, their likelihood of survival is compromised (Balk et al., 2004). A plausible explanation for this compromised survival may be that the population may be living in a slum or a shanty dwelling where maternal health services are unavailable or inadequate (Wood, 2003). Likewise, Garenne (2010) also posits that high population density is strongly associated with under-five mortality. Nevertheless, another study in China (Hu, Wang, Li, Ren & Zhu, 2011) also revealed that the built population is associated with under-five mortality; however, the authors contend that the association is weak.

This review indicates that malaria is among the leading causes of death among children under-fives. Globally, the WHO (2016) posits that children under five are at the most significant risk of malaria and that malaria accounts for 70 percent of under-five mortality. Moreover, evidence shows that the risk of under-five mortality is equally high in areas where malaria is high. Conversely, in areas where the prevalence of malaria is low, it translates into a lower burden of under-five mortality. For example, a study in rural Tanzania revealed that, as most malaria declined in Tanzania, it led to a decline in the under-five mortality rate by 54.3%, from 33.3 to 15.2 per 1,000 person-years (Kanté et al., 2014). A study that sought to investigate malaria-anaemia prevalence as a measure of malaria-related mortalities in SSA found that West African countries had the highest malaria prevalence (Papaioannou, Utzinger & Vounatsou, 2019). This high malaria prevalence in West African countries was significantly correlated with higher prevalence and risk of under-five mortality as Burkina Faso, Guinea, and Cameroon had the highest burden of under-five mortality.

2.3.2 Nightlight composition

The nightlight composite indicates the number of human activities at night (Tewara, Mbah-Fongkimeh, Dayimu, Kang & Xue, 2018). The higher the nightlight composite, the more likely children are exposed to precursors like malaria and other diseases, leading to a child's death before their fifth birthday. Tewara et al. (2018) revealed in their study that highly dense populations are exposed to more excellent nightlight composite. Such situations expose children to the bites of mosquitoes and subsequently lead to higher risks of under-five mortality.

2.4.3 Global human footprint

The global human footprint is an index that measures the proportion of productive land appropriated on average by each entity in a specific geographic location for waste management, housing/accommodation, food and water, transport, and other uses (Dwomoh, 2021). Some studies have shown that a global human footprint is associated with child health outcomes. For instance, Dwomoh (2021) found a strong association between global human footprint and neonatal mortality.

2.3.4 Distance to the nearest waterbody

This indicator is a straight-line distance to the nearest major water body (Dwomoh, 2021). Within the framework of the SDGs, target 6.1 calls for universal and equitable access to safe and affordable drinking water (Mulligan, van Soesbergen, Hole, Brooks, Burke & Hutton, 2020). For that reason, households must have "access to an improved water source that is located on-premises, available when needed, and free from faecal and priority chemical contamination" (Bain, Johnston & Slaymaker, 2020). Literature also shows that in LMICs like Ghana, women and children are the leading water carriers (Pickering & Davis, 2012). As such, the time spent accessing the nearest water point is crucial to the health and wellbeing of children. According to the findings of Pickering and Davis (2012), a 15-min reduction in the duration to water source corresponds to a 41 percent average relative reduction in diarrhoea prevalence, improvement in child nutritional status, and an 11 percent relative decline in under-five deaths.

2.5 Immediate factors of under-five mortality

The immediate factors in the study have been conceptualised as those considered the child's characteristics.

2.5.1 Sex of child

Additionally, some studies assert that mortality risk in children under five varies significantly by sex. Males are disproportionately disadvantaged in the literature regarding child survival. Female children are less likely than male children to die before their fifth birthday (Ahinkorah et al., 2020; Yaya, Bishwajit, Okonofua & Uthman, 2018). For example, in a study of SSA countries, Boco (2014) found that male children were more likely to die before age five than female children. Similarly, in Bangladesh, Khan and Awan (2017) also reported the odds of under-five mortality being higher among male children than female children. This association is due to the influence of biological factors. Ahinkorah et al. (2020) show that male children are biologically predisposed to neonatal infections and are frequently born prematurely. Male children are more likely to die before their fifth birthday because of these conditions than female children.

2.5.2 Birth Interval

Birth interval is a critical predictor of many maternal and child health outcomes. The WHO recommends that women leave at least 24 months of the birth interval between their current birth and subsequent pregnancy to minimise the risk of maternal, perinatal and child health outcomes (Belaid et al., 2021). There is mounting evidence that a strong correlation exists between birth interval and under-five mortality. (Budu et al., 2021; Kozuki & Walker, 2013). Short birth intervals, intentional or unintended, can have deleterious consequences on the child, with the worst-case scenario leading to the death of children before age 5 (Budu et al., 2021). For example, a study conducted in Ethiopia revealed that shorter birth interval was associated with a significantly substantial risk of under-five mortality (Bereka, Habtewold & Nebi, 2017). Similarly, in Ghana, a study by Budu et al. (2021) reported that children born to mothers with less or equal 2 years had significantly lower odds of dying before age five. Houle et al. (2013) showed a statistically significant association between shorter birth intervals and under-five mortality in South Africa. Specifically, Houle et al.' (2013) revealed that children under 24 months of age whose subsequent sibling was born within 11 months were 2.5 times more likely to die before age five than those whose next sibling was born after 11 months.

2.5.3 Immunization Status

Immunization has been noted as a significant factor in predicting mortality in children under the age of five. This is because it protects against illnesses that can cause both morbidity and mortality in children under five. For instance, deaths from measles, one of the top five diseases that account for half of all deaths to children under age 5 worldwide, fell by 74 percent between 2000 and 2007, largely due to increased vaccinations (Zuehlke, 2015). (Zuehlke, 2015). Haroun & Mahfouz (2007) showed vaccination to be statistically substantially linked with under-five mortality.

2.5.4 Weight of the Child

Weight has also been identified as a determinant of under-five mortality. Several studies have looked at weight and under-five mortality (Watkins, Kotecha & Kotecha, 2016; Tesema, Teshale & Tessema, 2021).

Watkins, Kotecha and Kotecha (2016) found child's weight to be associated with under-five mortality in England. Moreover, Tesema, Teshale and Tessame (2021) found child's weight to be statistically significantly associated with under-five mortality in east Africa.

2.5.5 Birth Order

Although the direction of the impact is unknown a priori, birth order may also have a role in the chance of newborn and child death. The direction of the effect is equivocal. According to the findings of a number of research, the baby and child mortality rate is very high for the first born, but it is much lower for the second and third order births (Chandrasekhar, 2010). In point of fact, a number of research suggest to a U-shaped influence of birth order, with the chance of infant mortality decreasing after the birth of the first child and then rising again for children born in birth orders four and above (Titaley et al., 2008; Uddin & Hossain, 2008).

According to the hypothesis of intrahousehold resource competition, first born children have a better chance of securing necessary resources inside the household, such as food and care, which in turn lowers the likelihood that they will pass away (Vos et al., 2004). On the other side, research has shown that first-born children have a greater chance of passing away than children who come after them in the birth order. This is because first-born children are more likely to be born to moms who started having children at a younger age.

Firstborn children seem to have worse health later in life. Siblings who were born later have a greater mortality risk when they mature and enter the workforce (Barclay & Kolk, 2015). There is little information on how birth order affects a child's health later in life. According to Argys et al. (2006), siblings who were born later had a higher likelihood of engaging in hazardous behaviors including smoking, drinking alcohol, and using marijuana. According to some data, children who were born later and who grow up in big households are more likely to have accidents (Bijur, Golding & Kurzon, 1988).

2.6 Intermediate factors of under-five mortality

The intermediate factors have been conceptualised in this study to capture the mother's characteristics. These factors are mediating factors that can significantly influence the health and survival probabilities of the child.

2.6.1 Mother's age at birth

Maternal age also plays a critical role in determining the risk and prevalence of under-five mortality. In a multi-country study of the determinants of under-five mortality among SSA countries, it was found that younger maternal age was significantly associated with higher odds of a child dying on their fifth birthday (Yaya, Bishwajit, Okonofua & Uthman, 2018). Similarly, in India, Singh and Tripathi (2013) found that increasing maternal age is a protective factor in under-five survival. Another study from Delhi, India, revealed that younger maternal age significantly exacerbates the risks of under-five mortality (Sinha, Aggarwal, Osmond, Fall, Bhargava & Sachdev, 2016). In Ghana, Sarkodie (2021) also found that increasing maternal age was a protective factor for under-five mortality; however, younger maternal age and births after age 40 exacerbated the risk of under-five mortality. This finding by Sarkodie (2021) confirms the results of a study by Acheampong and Avorgbedor (2017) that children born to mothers aged between 15 and 24 were at the most significant risk of under-five mortality.

Correspondingly, Finlay, Özaltin and Canning (2011), in their study of 55 LMICs, concluded that children born to teen mothers were at greater risk of dying before their fifth birthday than other age groups within the reproductive age. This consistency in literature about how younger maternal age increases the likelihood of under-five mortality could be explained from the perspective that younger mothers (less than 24 years) often lack the experience of childbirth and childcare. As such, they cannot meet the nutritional requirements of their children. This may lead to adverse child health outcomes such as stunting, undernourishment, and diarrhoeal infections, which may increase the odds of a child born to such mothers dying before age five.

2.6.2 Parity of the mother

Another crucial factor that determines the prevalence of the under-five mortality rate and predicts the odds of a child dying before age five is parity. Parity in terms of pregnancy refers to “the number of times that a woman had given birth to a foetus with a gestational age of 24 weeks or more, regardless of whether the child was born alive or was stillborn” (Gaillard et al., 2014, p.267). The literature suggests a significant association between parity and under-five mortality, with children born to multiparous mothers being the most disadvantaged. In Eastern Ethiopia, for example, Bereka, Habtewold, and Nebi (2017) revealed that children born to multiparous mothers were 4.751 more likely to die before their fifth birthday than children born to uniparous mothersDesta (2011) reported a similar finding, who found that multiple parties were associated with disproportionately higher risks of dying before age five. A related study that used demographic and health survey data from 47 low-and-middle-income countries (LMICs) revealed that, even after controlling for available confounders, the association between parity and under-five mortality remained statistically significant with higher equality predicting greater risk of under-five mortality (Kozuki, Sonneveldt & Walker, 2013). Likewise, a recent study by Worku, Teshale, and Tesema (2021) confirms that multiple parties were significantly associated with higher odds of under-five mortality. A plausible explanation for the significant association between higher equivalence and higher risks of under-five mortality could be that such mothers often become over-confident about their capacity to cater for the health needs and wellbeing of the child since they already have prior experience with childbirth and childcare (Worku, Teshale & Tesema, 2021). Besides the lower resistance to infection and higher risk of premature birth among male children, difficult labour related to a larger average body size and head circumference of the male child has also been linked to the higher risk of under-five mortality among males as compared to female children (Drevenstedt, Crimmins, Vasunilashorn & Finch, 2008; Van Malderen et al., 2019).

2.6.3 Religion of the mother

Religion also plays a significant role in predicting under-five mortality among a given population. For example, a study from India has revealed a significant association between the religious affiliation of mothers and under-five mortality, with children born to Christian mothers having lower odds of under-five mortality and a greater likelihood of survivorship (Singh & Tripathi, 2013). This is congruent with Bhalotra, Valente and Van Soest (2010), who found that children born to Hindu women were more likely to die before age five than any other religious group.

In Mozambique, Cau, Sevoyan and Agadjanian (2013) revealed that mothers' affiliation to any religious body significantly positively affected child survival compared with those without religious affiliation. Specifically, the authors showed that collaboration with three denominations (i.e., Catholic, Protestant and Apostolic churches) resulted in lower odds of under-five mortality while increasing child survival. A recent study in Ethiopia (Gebremichael & Fenta, 2020) also indicates that under-five mortality was 1.2 times more likely for children born to Muslim mothers than mothers of orthodox religious beliefs.

2.6.4 Mother's educational level

There is a replete of evidence showing that maternal educational level significantly correlates with the odds of under-five mortality. Most studies contend that higher levels of education translate to lower odds of child mortality, whereas low levels of education are linked with higher likelihoods of under-five mortality. This is exemplified in a study from Nigeria (Kayode, Adekanmbi & Uthman, 2012) that found that children born to mothers with no formal education had a greater likelihood of dying before their fifth birthday as compared to those with formal education; and, within the formal education bracket, children born to mothers with secondary or higher education were less likely to under prematurely as compared to those whose mothers had only primary education. In accordance with Kayode, Adekanmbi and Uthman (2012), Ahinkorah et al. (2020) found that in Chad, the likelihood of under-five deaths was 1.72 times higher among children whose mothers had no formal education as compared to children whose mothers had formal education.

There is a plethora of evidence from Bangladesh (Khan & Awan), Nigeria (Ezeh et al., 2015) and sub-Saharan Africa (Van Malderen, Amouzou, Barros, Masquelier, Van Oyen & Speybroeck, 2019) that substantiate the assertion that formal education provides has both direct and indirect association with reducing the risk of under-five mortality. This is likely because formal education predisposes mothers to health information and messages. Hence, they are more likely to adopt timely health-seeking behaviours (Ahinkorah et al., 2020). For that reason, they often have a higher tendency to seek prompt health care for the slightest ill-health of their child. Another perspective is that women with higher levels of education are usually empowered economically to afford necessities, including food supplements which are quintessential to the health and wellbeing of children while reducing the odds of under-five mortality (Aheto, Taylor, Keegan & Diggle, 2017). This is further substantiated by evidence from sub-Saharan Africa, which indicates that the overall decline in under-five mortality within the region is partly attributable to national policies that facilitate women's education (Bado & Sathiya Susuman, 2016). Moreover, such approaches increase maternal awareness about child health and hygiene, reducing the risk of under-five mortality.

2.6.5 Occupation of the mother

Employment is quintessential to under-five mortality. However, it is essential to note that the different occupational levels suggest significant variations in the risk and prevalence of under-five mortality. For example, Singh and Tripathi (2013) show that mothers working in agriculture are a considerable risk factor for under-five mortality compared to non-agricultural sectors. This may not be a direct effect of the occupational but shrouded by the impact of the residence. Usually, agriculture resides in rural areas where the availability and accessibility of health care facilities and services is often a challenge. This could explain why under-five mortality tends to be high among children born to mothers who work in the agriculture sector.

2.6.6 Marital Status

According to Clark and Hamplová (2011), the marital status of the mother can have a significant impact on the health and wellbeing of her children. This is because the mother's marital status is a reflection of the family environment, which includes the number of adults who are directly involved in the children's day-to-day care and the resources that are available to the family. Many children, especially in eastern and southern Africa, are brought up in families that do not include both of their biological parents as a consequence of the high rates of birth outside of marriage as well as the unstable nature of marriages. Premarital births are extremely prevalent. According to the findings of one research that looked at nine nations in eastern and southern Africa, the percentage of first births that occurred outside of marriage varied from 13 percent in Malawi to 56 percent in Namibia (Harwood-Lejeune, 2001).

In several of these countries, there is also a high incidence of divorce and separation. In Ethiopia, Togo, and Malawi, around half of all first marriages do not last and result in divorce (Locoh & Thiriat, 1995; Tilson & Larsen, 2000; Bracher, Santow & Watkins, 2003). In sub-Saharan Africa, young mothers who already have children have an increased chance of becoming a widow, and this risk is especially high in the nations that have been most struck by the AIDS pandemic (Luginaah, Elkins, Maticka-Tyndale, Landry & Mathui, 2005).

In industrialized nations, notably in North America, a great number of research have investigated the connections between a woman's marital status and the health and happiness of her children (Amato, 2000). According to the findings of these research, children who are raised by a single mother have a greater tendency to have negative results in terms of their cognitive development, behavioral adjustment, and health outcomes (Gennetian, 2005; Magnuson & Berger, 2009; Angel & Worobey, 1998; Dawson, 1991). Studies have shown that children who are brought up in families with stepfathers often have a worse quality of life than children who live in households with their biological fathers. This is true even if the mother remarries after having been a single parent at some point in their lives (McLanahan & Sandefur, 1994).

2.6.7 Race

Despite the fact that a sizable population identifies as Hispanic black and Hispanic white, the majority of the research on newborn health inequalities in the U.S. has defined Hispanic ethnicity, black, and white race as mutually incompatible categories (Humes et al., 2011). Few studies have examined child health outcomes among black mothers who identify as Hispanic or among Hispanic women of different racial backgrounds. In one research, Henry-Sanchez and Geronimus (2013) revealed that adjusted analyses utilizing data from 1995–1999 showed that black Hispanic mothers had considerably greater risks of infant death than Hispanic white women. According to more recent research, Hispanic black women had better birth weight outcomes than NHBs and are less likely to have preterm or small-for-gestational-age births (Green, 2014). (Bediako et al., 2015).

The Centers for Disease Control and Prevention (CDC) reported that approximately one-third (36 percent) of infant deaths were due to preterm related causes in 2013. Additionally, the CDC found that infants who were considered "late preterm" had a higher risk of infant mortality than those who were born full term. There is an ongoing trend of a greater incidence of premature birth among black women compared to white women. In 2016, it was projected that the rate of premature deliveries among black women was fourteen percent, whereas the incidence of premature births among white women was a significant amount lower at nine percent (CDC, 2017). According to the Centers for Disease Control and Prevention and the National Center for Health Statistics, seventy-three percent of black baby fatalities were the result of problems related with premature delivery (2017).

2.6.7 Ethnicity

Collins (2004) highlighted the importance of the ethnicity-based categorization schema by demonstrating the connection between ethnicity and illness risk or health outcomes via genetic or non-genetic (social, cultural, education, and economic) surrogate links or a union of the two, as well. Culley (2006), on the other hand, argued that "ethnicity is contextual." As a result, health outcomes are influenced by the circumstances in which they are found. Further, Culley (2006) stated that the connection between ethnicity and health outcomes or illness risk is influenced by characteristics such as age and gender. The relevance of the aforementioned criteria is influenced by context, he said. Ethnicity is crucial for health outcomes, but it shouldn't be taken in isolation.

Ethnicity has been linked to child survival in several studies (Antai et al., 2010; Omariba & Boyle, 2007; Fayeun & Omololu, 2011). In Kenya, for example, Omariba, Beaujot, and Rajulton (2007) showed that the Luo tribe had the greatest infant mortality, whereas the Kikuyus had the lowest. Child mortality was twice as high as newborn mortality among the Luo and Kikuyu ethnic groups, despite the fact that both groups had the highest and lowest rates of child death. In addition, the research found that the differences between ethnic groups in child mortality were greater than the differences in neonatal mortality across ethnic groups.

Fayeun and Omololu (2011) discovered that the death rate for children under the age of five in Nigeria varies considerably by ethnicity. Antai and Moradi (2010) also found that other variables like as maternal education and age may alter the connection between ethnicity and under-five mortality. Health-seeking behavior, such as hospital delivery and child vaccination, may be affected by factors such as maternal education and other socioeconomic features (Antai 2010; Aremu et al. 2011). As a result, racial differences in educational achievement and attitudes toward health care might be seen.

2.7 Proximal factors

Proximal factors cover those considered distal to the child and affect the child through the mother's characteristics.

2.7.1 Father's educational level

Besides the maternal factors strongly associated with the risk of under-five mortality, there is a growing interest in paternal factors such as fathers' educational level in predicting the risk of under-five mortality. In a study conducted in India, Singh and Tripathi (2013) demonstrated the essential role of fathers' educational level on under-five mortality. The authors found that a higher paternal level of education was associated with more excellent child survivorship. Thus, children whose fathers had secondary education were more likely to survive than those whose fathers had no formal education or only primary education. This is consistent with a previous study by Boone and Zhan (2006) that showed that children whose fathers had no formal education or lower education levels are at greater risk of dying before their fifth birthday.

2.7.2 Wealth status of the household

Like many maternal and child health outcomes, there is evidence to show that household wealth status is significantly associated with under-five mortality. For example, Van Malderen et al. (2019) found that in several African countries (i.e., Angola, Benin, Burundi, Burkina Faso, DR Congo, Guinea, Mali, Namibia, Nigeria, Rwanda, and Zimbabwe), the likelihood of under-five mortality is significantly lower among children who are born to mothers of the wealthiest wealth index. A similar finding was reported in a recent study by Sarkodie (2021) that found that the children born to women in the poorest wealth index in Ghana were more likely to experience the death of their child before the fifth birthday. This could be because they have greater access to financial resources and can afford quality and timely health care for their children, especially in places with no health insurance. Also, mothers within the richest wealth index can afford adequate food and supplements for their children, making them more likely to meet the nutritional needs of their children. This reduces the risk of nutritional deficient diseases and promotes child survivorship.

2.7.3 Number of under-five children in the household

Evidence suggests that the number of children under-five significantly predicts the prevalence and risk of under-five mortalities. For example, in a study in Ethiopia, Bedada (2017) reported that the number of children under five years of age in a household strongly affected under-five mortality. Thus, the higher the number of children under-five, the greater the odds of under-five mortality and vice versa. In Bedada's (2017) study, it was reported that children born to mothers who had two or more children under age five were 2.4 times more likely to die before their fifth birthday than households with only one child under age five.

Gebretsadik and Gabreyohannes (2016) also assert that household or family size was a significant socioeconomic determinant of under-five mortality, with households with higher membership recording higher under-five mortality rates. However, other scholars have a varied perspective on the size of the home and its effect on under-five mortality. Conversely to the assertions of Gebretsadik and Gabreyohannes (2016), Desta (2011) in the publication, Infant and child mortality in Ethiopia: the role of socioeconomic, demographic and biological factors in the previous five years period between 2000 and 2005 suggests that there is an inverse relationship between household size and under-five mortality. Thus, the smaller the household size, the higher the under-five mortality rate and vice versa. This inconsistency in the household size between the two reviewed studies may be explained by the time gaps between these two studies. For example, in Ghana, Afoaka et al. (2015) found that household size had a statistically significant negative effect on under-five mortality.

2.7.4 Place of residence

Several studies contend a significant association between place of residence and the likelihood of a child dying before their fifth birthday. For example, in Ghana, Acheampong and Avorgbedor (2017) showed that under-five mortality among children born to mothers in rural areas far exceeded that of children born to urban-dwelling mothers. In another study, Sarkodie (2021) revealed that the odds of child survival beyond age 5 were significantly higher among children born to urban-dwelling mothers.

Interestingly, a study of some SSA countries indicates that, even though the effect of place of residence on under-five mortality is narrowing due to the surge of informal settlements like slums in urban areas, a child's odds of dying before the fifth birthday remains consistently higher among those born to rural dwelling mothers (Van Malderen et al., 2019). This is supported by a preponderance of evidence from sub-Saharan Africa (Yaya et al., 2019), Ghana (Agbadi et al., 2021; Aheto, 2019) and Chad (Ahinkorah et al., 2020). This consistency in the relationship between place of residence and under-five mortality could be justified from the perspective that, most often, mothers in rural areas lack access to quality health care for their children, with the nearest health care facility being miles away from such rural communities (Ahinkorah et al., 2020). Thus, exacerbating the risk of death among children under five in rural areas compared to urban residents.

2.8 Nutritional factors

Malnutrition is one of the factors that has been consistently associated with the death of children in hospitals across the world, including both Africa and other regions (Caulfield, de Onis, Blossne & Black, 2004). According to the findings of Caulfield, de Onis, Blosne, and Black (2004), moderate and severe underweight were linked to an increased risk of death from pneumonia. Kilifi, Kenya was the location of a study that came to the conclusion that severe underweight was a risk factor for post-discharge mortality (Moisi, 2011). There is a correlation between being undernourished and having an increased risk of dying from diarrheal diseases (Gupta, Sarker, Rout, Mondal & Pal, 2015). As a result, malnutrition is one of the identifiable risk factors for paediatric hospital mortality that ought to be taken into consideration when determining the likelihood of passing away upon admission.

Malnutrition is accountable for 30 percent of all fatalities in children under the age of five in the world (Black et al., 2008). Around 50% of the population in developing nations falls into this category (World Health Organisation, 2005). An estimated 40 percent of all infant fatalities in Ghana are caused by malnutrition (Unicef-Ghana, 2008). One-third of mortality in children under the age of five were related to malnutrition, which included stunting, severe wasting, vitamin A and zinc deficits, and inadequate breastfeeding (De Onis, Brown, Blossner & Borghi, 2012). Over the course of a lifetime, 165 million children under the age of 5 suffer from stunting; 101 million are underweight, and 52 million are wasted (United Nations Children's Fund, World Health Organization & The World Bank.) The majority of these children live in 36 countries, with Southeast Asia and sub-Saharan Africa bearing the greatest burden of childhood infections (2012).

2.9 Theoretical Framework

Theories are an essential aspect of research. They are a set of logical propositions that aid the understanding and explaining a given phenomenon. In the discourse of under-five mortality, the analytical framework for child survival by Mosley and Chen (1984) has been widely used in this regard. This study will adopt the Mosley and Chen (1984) analytical framework to drive home ecological and social factors that have an associative effect on under-five mortality in children in Ghana as such specific aspects of both theories were adapted to suit the conceptualisation of this work.

This study is based on the Moseley and Chen (1984) framework for the analysis of child survival, including infant and under-five mortality in developing countries (Mgwada, 2019; Kibria, Burrowes, Choudhury, Sharmeen, Ghosh, Mahmud & Angela, 2018; Khadka et al., 2015; Moseley & Chen, 1984). According to Bakari Mgwada (2019), this framework seeks to explore the relationship between child mortality on the one hand and socioeconomic and proximate determinants on the other hand, with the overall goal of establishing the ecological determinants of under-five mortality.

The originators of this framework posit that all factors that influence the risk of and the outcome of those diseases affecting individuals constitute the proximate determinants (Mgwada, 2019; Moseley & Chen, 1984). Moseley and Chen (1984) posit that these proximate determinants may be biological or medical and thus classify them into five major categories: maternal factors, environmental contamination, nutrient deficiency, injury and illness (Van

Malderen et al., 2019; Mosely & Chen, 1984). Mgwada (2019) also assert that child mortality and morbidity have a relationship with the proximate determinants put forward by Moseley and Chen (1984).

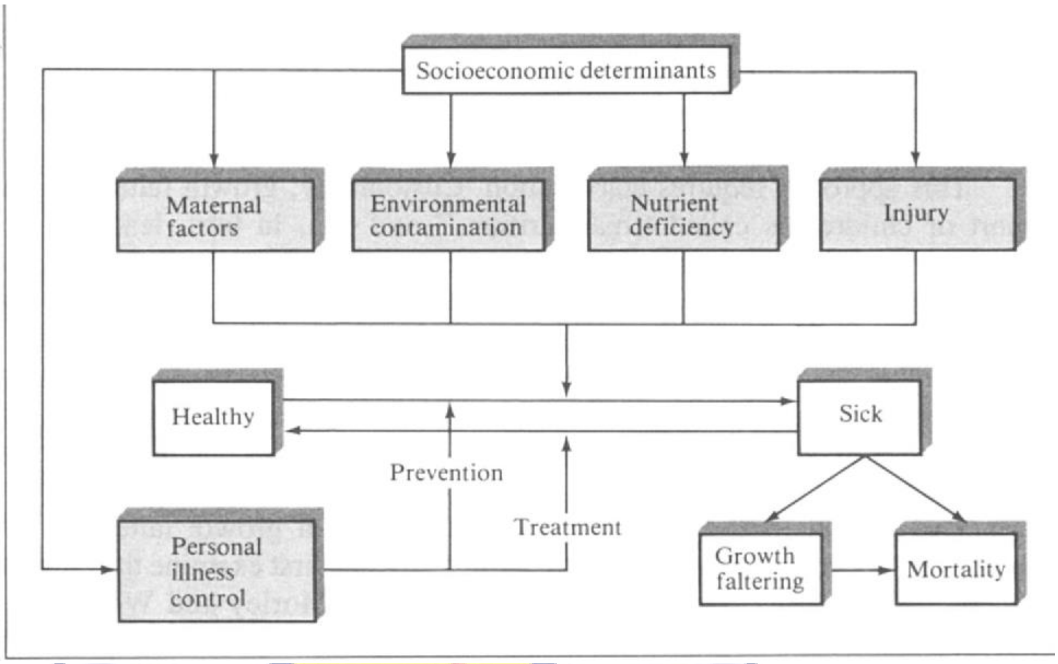

Figure 2: Analytical framework for child survival by Mosley and Chen (1984)
Source: Mosley and Chen (1984)

This implies that proximate determinants or intermediate variables which encapsulate the mother's characteristics (mother's age at birth, parity of the mother, mother's educational level, religion, mother's occupation), ecological pollution (water and air pollution, insect vector, food, skin, soil, inanimate objects), nutrient deficiency (vitamins, mineral, protein, calories and micronutrients), injury (injuries which are related to disabilities, accidents) and personal illness control (personal preventive measures and medical treatment) have a profound influence over child survival and ultimately, infant and under-five mortality (Mgwada, 2019; Khadka et al., 2015). However, its impact on child survival is not always direct (Van Malderen et al., 2019); sometimes, it is affected by the dynamics of socioeconomic determinants.

Thus, Moseley and Chen (1984) further suggest that the relationship between child mortality transcends to have a link with other determinants, including national policies and health programmes, hygiene and the provision of safe drinking water, maternal education, hazard management and control, improvement of infrastructure, access to adequate food and output from agriculture and other production sectors (Mgwada, 2019; Kibria et al., 2018). This implies that socioeconomic variables ought to operate within the proximate determinants to influence child survival and infant and under-five mortality (Mgwada, 2019; Khan et al., 2018; Mugo et al., 2018). For instance, Khan and colleagues (2018) argue that theoretically, socioeconomic determinants of child mortality must operate under the proximate determinants. Such socioeconomic determinants can be categorised into three segments: the individual, household and community variables (Khan et al., 2018; Moseley, 1984).

This framework is thus a classic conceptual framework for understanding under-five mortality, particularly in developing countries like Ghana. Scholars have widely used it to explore infant and under-five mortality (Mgwada, 2019; Van Malderen et al., 2019; Kibria et al., 2018; Mugo et al., 2018; Khadka et al., 2015; Moseley, 1985). As a result of its prolific use has informed some contemporary conceptual frameworks, including the World Health Organization's social determinants of health inequalities framework developed by Solar and Irwin (2010). Given this, the researcher adopts the Moseley and Chen (1984) framework to study child survival in developing countries and operationalises it to fit in the context of an ecological determinism considering the Chronosystem within which these children find themselves.

2.7 Operational conceptual framework

Figure 3 indicates the modified Moseley and Chen (1984) framework for studying child survival in developing countries. The ecological fact comprises the built environment', drought/aridity; annual rainfall/precipitation; and annual mean, minimum and maximum temperature. In the conceptual framework of this study, the primary variables were ecological factors. The intermediate variables/proximate determinants of children under-five characteristics, maternal characteristics, paternal and household characteristics were reconceptualised to be immediate factors for the child level factors, intermediate for the maternal level and proximal factors for the paternal and household factors. The interaction of all these factors influences the outcome variable: child mortality.

From figure 3, it can be observed that the ecological factors have several pathways on the outcome variable. The first pathway indicates that the ecological and social factors in the model directly influence under-five child survival. For instance, studies show that children under five who live in ecological areas with an average of fewer than 2 ml of rainfall daily have an 86.9 percent probability of survival after 59 months, while infants who live in a density radius of more than 1000 persons per square kilometre having a less likelihood of survival (Balk et al., 2004). Again, children living in arid and semiarid zones have the lowest infant and child survivorship, 15 and 12 percent, respectively (Balk et al., 2004). This is a clear indication of the direct influence of ecological factors on under-five mortality.

However, taking the established systems in the community into account, other mediating factors play out in the presence of the primary variables to influence the study's outcome. The intermediate variables are a combination of the social aspects and proximate determinants, which includes social factors (malaria incidence, global human footprint, built environment, travel times, population density), maternal characteristics (age at birth, birth interval, parity); nutrient deficiency (vitamins, mineral, protein, calories and micronutrients); injury and illness (Van Malderen et al., 2019), and socioeconomic determinants (Mugo et al., 2018; Khadka et al., 2018; Balk et al., 2004). These intermediate variables will exacerbate the effects of the ecological factors on child survival. This implies that where the intermediate variables are positive, it will nullify the impact of the inequality caused by one's ecology and subsequently serve as a protective factor against under-five mortality. However, if the intermediate variables are negative, it will exacerbate the effects of the ecological factors and increase the risk of infant and under-five mortality. For instance, the availability of drinkable water is an ecological factor; however, its influence on infant and under-five mortality is exacerbated by household characteristics (intermediate variable).

Literature shows that households with a low wealth index tend to be exposed to drinking from unclean water sources, putting their infants and children under five at risk of morbidity and mortality (Nattey, Masanja & Klipstein-Grobusch, 2013). In a study by Mugo and colleagues (2018), the results showed that 34 percent of the households in the study had no access to treated bed nets. If these people live in an ecology where the proportion of the land is mash land, coupled with this inaccessibility to treated bed nets, infant and under-five morbidity and mortality because of malaria will surge. Thus, intermediate variables may sometimes exacerbate the ecological factors influencing infant and under-five mortality. Therefore, the role of ecological factors in determining health and health outcomes, including infant and under-five mortality, is imperative.

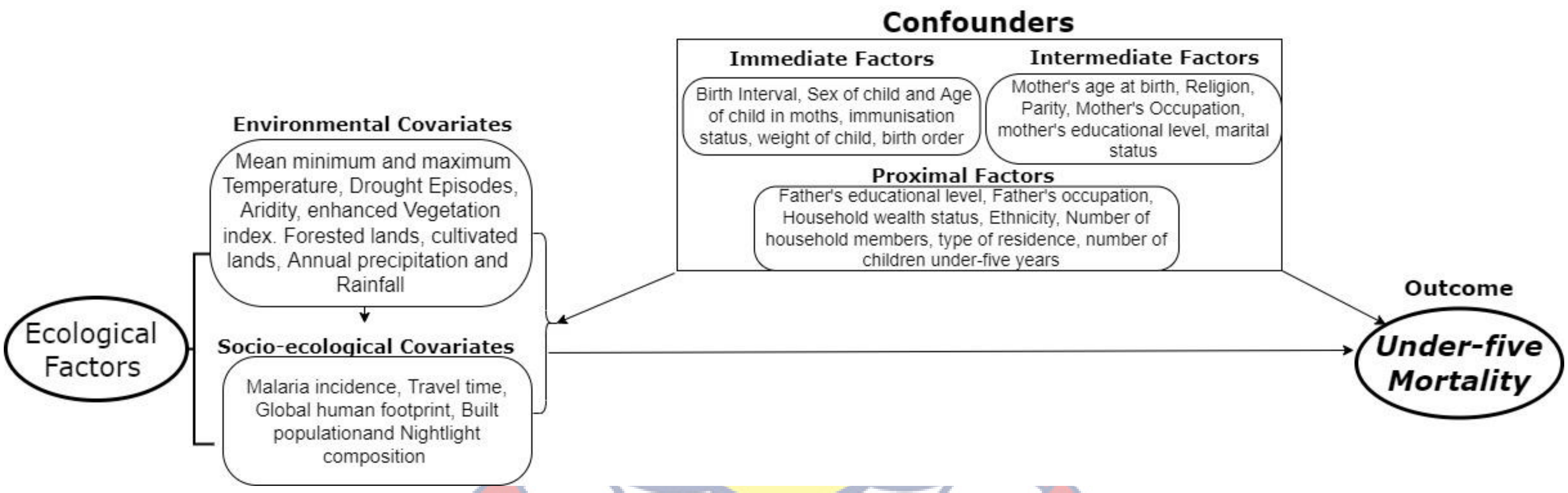

Figure 3: Conceptual framework adapted from Mosley and Chen's (1984) Analytical Framework of Child Survival in Developing countries.

Source: Author's construct (2021) Adapted from Mosley and Chen (1984)

CHAPTER THREE

DATA AND STUDY METHODS

3.0 Introduction

This chapter presents the methods used to examine the association between under-five mortality and ecological factors. Issues covered include research paradigm and design, study area, data description, study variables, and analysis methods. In addition to this, ethical considerations are discussed.

3.1 Research paradigm

The positivist research philosophy was used in this study. Positivists believe reality is stable, observable, and objectively described (Parsons, 2017), which allows them to investigate phenomena without interfering with the subjective meanings ascribed to them. The study, guided by this paradigm, tested and predicted the survival probabilities of under-five children after accounting for ecological factors (environmental and socio-ecological) that may negatively impact their health.

3.2 Research design

The study used cross-sectional data and quantitative methods to investigate the relationship between ecological factors (environmental and socio-ecological) and under-five mortality. The study was quantified by estimating the associative effects of ecological factors and confounders; thus, the philosophy used for this study was to quantify and generalise the results.

3.3 Study Area

The study area is Ghana; the country has a land area of 238 537 square kilometres and is situated within the Sub – Saharan African Region. Ghana is bordered by three French-speaking countries: Burkina Faso on the North, Côte d'Ivoire on the East, and Togo on the West. In the South lies the Gulf of Guinea. Currently, the country has 16 and 275 administrative regions and districts, respectively. Figure 4 below shows the map of Ghana indicating these 16 regions.

The 2021 Population and Housing Census reported a total population of 30,792,608 in Ghana, with an annual growth rate of 2.1% (GSS, 2021). The corresponding population density is 103 persons/km^2. Out of the total population, 14.8% are children under five, and the sex ratio is pegged at 97 males per 100 females (GSS, 2013). Over the years, the government of Ghana has engaged in several policy implementations to improve child health because at least 1 out of every ten Ghanaian is a child under the age of five years. Most interventions have been geared toward immunisation, nutrition, and health care (Asuming & Kanmiki, 2020).

In Ghana, the climate is tropical, with a dry season in winter and a rainy season in summer due to the African monsoon. The rainy season lasts from May to September in the north, from April to October in the centre, and from April to November in the south. On the contrary, along the east coast, the rainy season is shorter and goes from April to June, with a break in July and August, and a slight recovery in September and October.

The rainiest area is the south, where precipitation is above 1,500 millimetres (60 inches) per year, and even more so the small west coast area, where it reaches 2,000 mm (80 in) per year. The driest areas are the north, where the rainfall amounts to around 1,000 mm (40 in) per year, and the eastern coast, which includes Accra, where it drops below 800 mm (31.5 in). Anyway, as we have said, in the north, there's only one rainy season, which reaches its peak in the summer months, while on the coast, the rainy season is divided into two.

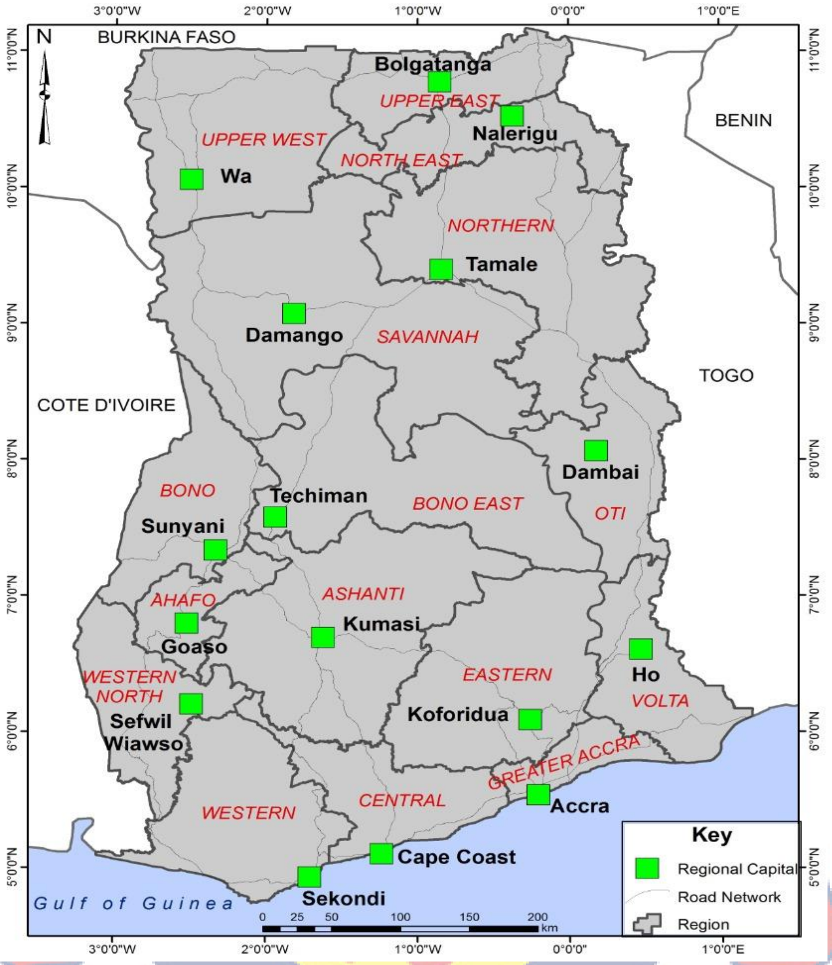

Figure 4: Map of Ghana

Source: GIS: Department of Geography and Regional Planning, University of Cape Coast (2020)

3.4 Data Description and Preparation

This study used three different datasets to examine the relationship between the ecologic factors influencing under-five mortality. The datasets used were the Ghana Demographic and Health Survey dataset (GSS & MI, 1999; GSS, GHS, & ICF 2004; 2008; 2015), Demographic and Health Survey Geospatial Covariates (Mayala, Fish, Eitelberg, & Dontamsetti, 2018) and the Land Cover Climate Change Initiative dataset (ESA Land Cover CCI project team; Defourny, 2019).

The outcome variable of interest (under-five mortality) was derived from the Ghana Demographic and Health Surveys (GDHS), whilst covariates were derived from all three data sources.

3.4.1 GDHS

The data for the study comes from four rounds of the Ghana Demographic and Health Survey (1998, 2003, 2008 and 2014) (https://dhsprogram.com/Data/). The GDHS is a cross-sectional, nationally representative study that collects demographic and health information on women, men, and household members. Six rounds (1988, 1993, 1998, 2003, 2008 and 2014) of GDHS have been conducted in Ghana, led by the Ghana Statistical Service to collaborate with allied institutions and stakeholders. However, the data for the study is limited to the last four rounds (1998, 2003, 2008 and 2014) of GDHS conducted in the country because the most significant variables were available in the geospatial covariate dataset from 2000 onwards.

The GDHS adopted a two-stage stratified sampling design. The country was stratified into regional (10) domains as at the time of the data collection. The sampling frame for the 1998 GDHS was the 1984 Ghana Population and Housing Census (GPHC) that for the 2003 and 2008 GDHS was 2000 GPHC, and the 2014 GDHS was the 2010 GPHC. At the first stage of sampling, Primary Sampling Units (PSU), also referred to as clusters (Census Enumeration areas), were selected from the Ghana Population and Housing Census (GPHC). The 1998 GDHS sampled 400 clusters, the 2003 and 2008 GDHS sampled 412 clusters, whilst the 2014 GDHS sampled 427 clusters. In the second stage, households were sampled using a systematic random sampling approach from each cluster. The number of households sampled for the 1998, 2003, 2008 and 2014 GDHS were 6,375, 6,251, 12,323 and 12,831, respectively (GSS & MI, 1999; GSS, GHS, & ICF 2004; 2008; 2015). All the selected surveys' sampling weights were applied to account for unequal sampling probabilities.

The dataset on under-five mortality and some socioeconomic/demographic variables used in this study were derived from the Ghana Demographic and Health Surveys (GDHS) 1998-2014. The survey adopted a cross-sectional design in amassing demographic and health information among selected Ghana households; it covers under-five mortality and associated socio-demographic/economic correlations. The methods of sampling for the GDHS were designed to be representative. Advanced quantitative methods are employed in analysing the data, and as such, the results from this study will embody the qualities of objectivity, inference, and generalisability.

3.4.2 Demographic and Health Survey Geospatial Covariates

The geographical position of the centre of each cluster is taken at two stages, either during the fieldwork or the listing stage of the survey. First, the positions recorded are verified and processed to ensure that they fall within their respective administrative areas. To ensure study participants are protected, their locations are displaced – sometimes called 'geo-masked' or 'geo-scrambled.' The displacement for the actual location within each cluster is geo-masked to protect respondents who answered the survey questions. Efforts are made to ensure that the removal of locations is not moved into other administrative units.

3.4.3 Land cover and land use dataset

To extract the variables; cultivated lands, natural and semi-natural forested lands, regularly flooded areas and areas covered by water bodies, a landcover dataset (global landcover) was downloaded in a raster file format from the UCL-Geomatics (Belgium) website (http://maps.elie.ucl.ac.be/CCI/viewer/ download.php). The file was imported into ArcGIS Pro version 2.6.2. The study projected the shapefile of Ghana to the same geographic coordinate system (GCS WGS 1984) as the global land cover dataset to enable compatible use. After the projection, the Ghana shapefile was clipped onto the global landcover; this function specifically gives the landcover for Ghana from the global land cover dataset.

After clipping, reclassification of the land cover of Ghana was done using the FAO classification system as a guide. According to the FAO classification system, land cover can broadly be categorised into eight (8) different classifications. The FAO classification was modified to suit the context of the study. The variables generated from land cover included cultivated lands, natural and semi-natural forested lands, regularly flooded areas and areas covered by water bodies

The following function converted Ghana's landcover from a raster file format into a vector file format using the raster to polygon function in the ArcGIS Pro. This function was carried out because the specific analyses cannot be carried out with raster files, so the conversion to a vector file format is needed.

A spatial join function was conducted to transfer the spatial information in the Ghana Demographic and Health Survey GPS dataset to the Shapefile of

Ghana. The output of this function shows the corresponding districts of all the GDHS clusters. Then, another spatial join was conducted between the land cover of Ghana and the shapefile of Ghana. Finally, the dissolution function was performed on the product of the spatially joined feature by the district name and the label of the land cover data.

3.5 Limitations of Dataset

A major limitation of synthesizing three different dataset was that the timeline for the collection of the data were different. For the GDHS dataset, the study design used for the data collection wasn't appropriate to correctly capture outcome of the study. Also, there were missing data in geospatial covariates which likely resulted underestimation of the true effect of the geospatial covariates.

3.6 Sample size and study population

The study population is children aged 0 to 59 months. The study focused on this group because they are considered variable, and the under-five mortality rate is a measure of development. Data from the children recode files for the four successive surveys (1998, 2003, 2008 and 2014) were used for the analyses. The file contains information on survival status and other factors associated with children's health under five years. The independent factors include the child's age, maternal and house characteristics and demographics for the children and other members of their households.

3.7 Variable

3.7.1 Dependent variable

The dependent variable, under-five mortality, was based on the *survival status* of each child in the study. The dependent variable is coded 1 (dead) if a child dies before age five and 0 otherwise.

3.7.2 Independent variables

The independent variables consist of the primary factors and confounders. The primary factors constitute the ecological (environmental and socio-ecological) factors extracted at the community level. The confounders were categorised into immediate, intermediate and proximal level factors-based conceptualisation from the literature.

Table 1: Variable definition of ecological predictors

Variable	Definition
Built population	An index ranges from 0 to 1, where 0 represents extremely rural and 1 illustrates highly urban.
Day land surface temperature	Mean annual daytime land surface temperature.
Enhanced vegetation index	Density and condition of the greenness of an area.
Global human footprint	An index ranges between 0 (low) to 100 (high), covering human population pressure (population density), human land use and infrastructure (built-up areas, nighttime lights, land use/land cover), and human access (coastlines, roads, railroads, navigable rivers).
Irrigation	The average proportion of the area equipped for irrigation at the time.
ITN coverage	The proportion of people who slept under an insecticide-treated net the night before was surveyed.
Land surface temperature	The average annual land surface temperature.
Malaria prevalence	The average parasite rate of plasmodium falciparum (PfPR) in children between 2 and 10 years old.

Nightlight composite	The average nighttime luminosity of the area shows the differentiation of regions based on the density of population and the degree of electrification of dwellings, commercial and industrial premises, and infrastructure. The indicator is a proxy measure of urbanisation and development, with higher intensity of nightlight reflecting a higher degree of urbanisation and development.
Night land surface temperature	The average nighttime land surface temperature.
Proximity to national borders	The geodesic distance to the nearest international borders.
Proximity to protected areas	The geodesic distance to the nearest protected area (e.g., national parks, national forests, and national seashores) is defined by the United Nations Environment World Conservation Monitoring Centre.
Proximity to water	The geodesic distance to either a lake or the coastline.
Rainfall	The average annual rainfall.
Slope	Roughness the terrain.
Travel times	The average time (minutes) required to reach a settlement of 50,000 or more people.
Population density	The number of persons per square kilometre.
Forested lands	The proportion of land area covered by forest was a proxy variable adopted in the study to measure the disease situation associated with a particular area
Land area covered by water	This variable has a strong association with flooding and drowning, which is likely to cause death to people living loser to these areas

Sources: (Mayala, Fish, Eitelberg, & Dontamsetti, 2018); (ESA Land Cover CCI project team; Defourny, 2019)

Confounding variables

Besides the environmental and social variables, different studies have reported other significant predictors of under-five mortality (Dey et al., 2013; Goswmai & Das, 2014; Qian-Qian et al., 2017; Moschovis et al., 2018; Ewusie et al., 2014; Nikoi & Anthamatten, 2013; Parbey et al., 2019; Ronald et al., 2006; GSS, GHS & ICF 2015). Given data availability from the DHS, selected confounders included sex, child's age, birth interval, mother's age, education, religion, parity, wealth, father's education, and place of residence.

These were broadly categorised into immediate, intermediate as well proximal factors.

Table 2: Variables used for the study

Variable	Codes	Variable type
Survival Status		Categorical
Dead	Dead = 1	
Alive	Alive= 0	
Environmental Factors		
Drought episodes		Continuous
Cultivated Lands		Continuous
Mean Temperature		Continuous
Forested Lands		Continuous
Aridity		Continuous
Land area covered by water bodies		Continuous
Enhanced Vegetation Index		Continuous
Social Predictors		
Global Human Footprint		Continuous
Travel times		Continuous
Built Population		Continuous
Malaria Incidence		Continuous
Nightlight's Composite		Continuous
Confounding variables		
Immediate Factors		
Sex of child		Categorical
Male	Male = 1	
Female	Female = 2	
Birth Interval		Categorical
< 24 months	< 24 months = 1	
24-35 months	24-35 months = 2	
36-47 months	36-47 months = 3	
48+ months	48+ months = 4	
Age in months		Categorical
<6 months	<6 months = 1	
6-11 months	6-11 months = 2	
12-23 months	12-23 months = 3	
24-35 months	24-35 months = 4	
36-57 months	36-47 months = 5	
48-59 months	48-59 months = 6	

Intermediate Factors		
Mother's education		Categorical
No education		
Primary Education		
Secondary Education +		
Maternal age at birth		Categorical
<20	< 20 years = 1	
20-24	20-24 years = 2	
25-29	25-29 years = 3	
30-34	30-34 years = 4	
35+	35 + years = 5	
Parity		Categorical
1-2	1-2 = 1	
3-4	3-4 = 2	
5-6	5-6 = 3	
7+	7+ = 4	
Mother's Occupation		Categorical
Not working	Not working = 1	
Professional/Service	Professional/Service = 2	
Sales/Manual	Sales/manual =3	
Agricultural	Agricultural = 4	
Proximal factors		
Wealth		Categorical
Poorest	Poorest = 1	
Poorer	Poorer = 2	
Middle	Middle = 3	
Richer	Richer = 4	
Richest	Richest = 5	
Father's education		Categorical
No education	No education = 0	
Primary	Primary = 1	
Secondary	Secondary = 2	
Higher	Higher = 3	
Residence		Categorical
Urban	Urban = 1	
Rural	Rural = 2	
Number of household members		Categorical
1-3	1-3 = 1	
4-5	4-5 = 2	
6-7	6-7 = 3	
8+	8+ = 4	
Time to get water		Categorical
On-premise	On premise = 0	
Within 5minutes	Within 5 minutes = 1	
6-14 minutes	6-14 minutes = 2	
15-25 minutes	15-25 minutes	
26-40 minutes	26-40 minutes	
40+ minutes	40+ minutes	

Source: GDHS 1998, 2003, 2008 & 2014

3.8 Statistical analysis

Bivariate and multivariate analyses were performed to explore the associative effects of under-five mortality and the primary and confounding factors. For the continuous covariates, the researcher investigated if the underlying relationships were non-linear by including the quadratic and cubic terms (polynomial). Analysis of Variance (ANOVA) was used to determine the mean differences in children's mortality status for the continuous ecological factors. Cross-tabulation was performed to determine the percentage of children who died before age five and the categorical covariates. A chi-square test conducted was to ascertain whether the observed differences were statistically significant ($p < 0.05$). Results were presented as weighted percentages with 95% confidence intervals.

A survival and multilevel regression analyses were conducted on the pooled data (1998, 2003, 2008 and 2014 GDHS), examined the ecological (environmental and socio-ecological) factors associated with under-five mortality, accounting for the year of survey, the confounders and the extent of nesting of observations at the community and district levels. In addition, data were pooled to capture the effects of time on the risk of death across the four successive surveys.

A multilevel logistic regression approach was adopted to avoid underestimation or overestimation of standard errors of the estimated coefficients due to the stratified nature of the GDHSs (Dickinson & Basu, 2005; Snidjers & Bosker, 2012). Since children are nested in communities and communities in districts, the analysis was performed at three levels with the child at level 1(n = 12460), communities at level 2 (n = 1632) and districts at level 3 (n=178). The log odds of dying for child i in community j and district k follow the function of the form:

$$logit(\pi) = \beta_0 + \beta_{d1}X_{(d1)ijk} \dots + \beta_{ds}X_{(ds)ijk} + \beta_{p1}X_{(p1)ijk} + \beta_{ps}X_{ps(ijk)} + v_k + u_{jk} + \varepsilon_{ijk}$$

Where B0 is the intercept; $\beta_{d1} \dots \beta_{ds}$ are the regression coefficients for the primary factors and $\beta_{p1} \dots \beta_{ps}$ are the regression coefficients for the confounders $X_{d1} \dots X_{ds}$ are the primary factors, $X_{p1} \dots X_{ps}$ are the confounding factors. The level two and three random effects are denoted by $u_{jk} \sim N(0, \sigma^2{}_u)$ and $v_k \sim N(0, \sigma^2{}_v)$, respectively. The significance of the random effects at the community and district levels indicates significant differences in under-five mortality at those levels.

The intraclass correlation coefficient (ICC) was used to estimate the proportion of variance in childhood under-five mortality attributable to differences at the community and district levels (Lorah, 2018). The ICC for level 2 (1) and level 3 (2) is calculated.

$$ICC = \frac{\sigma^2{}_u}{\sigma^2{}_u + \sigma^2{}_v + \sigma^2{}_e} \quad \dots\dots\dots \quad (1)$$

$$ICC = \frac{\sigma^2{}_v}{\sigma^2{}_u + \sigma^2{}_v + \sigma^2{}_e} \quad \dots\dots\dots \quad (2)$$

The survival approach was used to examine the exposure time to death. This is relevant because traditional logistic regression, which has been used extensively to study under-five mortality, only measures the status as dead and alive by accounting for the time the children might have contributed before dying and how their exposure to certain ecological and socio-ecological factors might be better understood when studying in this perspective. For instance, a child who died at 48 months and a child who died at 12 months are remarkably different in terms of their exposure time in their environment. In the GDHS, births in the last five years before the survey provide some retrospective duration of children born, which hypothetically represents the commencement of the study, with other variables like the date of the interview describing the end of the study. During interviews, mothers provide some helpful information (variables) that were used to extend the survival time of the child. Among these variables is the child's date of birth, the child's current age at the time of the study (months), whether the child is dead or alive, and the child's age at death. Children who experience the event (died) are uncensored, and those who did not share the event at the end of the study become censured at the researcher cannot tell what happened to those children.

3.7.1 Test for multicollinearity

A test for multicollinearity between the explanatory variables was performed using the Interval-by-Interval Pearson's R for the continuous variable and Ordinal by Ordinal Spearman correlation for the categorical variables and the Pearson Moment Correlation Coefficient for the continuous variables. The results showed a low correlation among variables and, in effect, low potential for multicollinearity.

3.8.2 Approach to Modelling

A sequential approach to model building was adopted for survival and multilevel analysis in examining the association between under-five mortality and ecological factors. A null model (Model 0) was first fitted to provide the base information on the variation in childhood mortality attributable to the differences observed. In Model 1, the year of survey and residence were added to assess time and geographical effects, respectively. While accounting for the year of survey and place of residence, Model 2 examined the effects of the environmental factors on under-five mortality. Model 2 provided substantial information on whether environmental factors influence under-five mortality. In model 3, previous fitted models were conditioned whilst social variables were included. Subsequent models accounted for confounders at the various levels

Confounders were retained if only they were significant at $p < 0.05$ (Snidjers & Bosker, 2012) in at least one of the models. Model 4 assessed the effects of immediate factors (child level) on children under-five survival status, while in Model 5, intermediate factors (maternal) were accounted for. Model 6 included proximal factors (father and household factors) in determining whether they are important predictors of the mortality status of children under-five.

A forward selection approach was used on the polynomials to fit the variables in increasing order. The significance of the regression coefficient was tested at each step of model fitting. Variables were kept in the models in increasing order until the t-test for the highest order term was nonsignificant. Then, the insignificant order was taken out, but their quadratic or quartic term that tends to be significant were retained. However, insignificant variables that were significant after accounting for their second- or third-degree order, but their quadratic and quartic terms became insignificant, were not included in the model.

Conclusion

This chapter discusses the study design and methods of analysis. The four most recent GDHSs were pooled and synthesised with data from

Demographic and Health Survey Geospatial Covariates and the Land Cover Climate Change Initiative dataset to examine the associative effect of ecological factors on under-five mortality. Both bivariate and multivariate analyses were explored to assess this associative effectiveness. Other issues covered include research design, study area, sampling techniques, limitations, and ethical considerations.

CHAPTER FOUR

STUDY FINDINGS AND RESULTS

4.0 Introduction

This chapter presents and discusses the bivariate and multivariate analysis results to examine the ecological factors associated with under-five mortality and the extent of nesting in under-five mortality at the community and district levels.

4.1 Frequency distribution of confounders

Table 2 shows the weighted percentage distribution of the sampled children by their background characteristics and survey year. In addition, the table shows the percentage of children who died before attaining five years of age (Appendix 1, Table 2). From the table, it can be observed that the percentage of children who died before their fifth birthday constituted 8.3 percent.

The majority of the children selected were aged 12-23 months, 21.5 percent, 19.9 percent, 20.3 percent and 19.8 percent from the 1998 GDHS, 2003 GDHS, 2008 GDHS and 2014 GDHS, respectively. The results revealed that more than half of the sampled children were males except for the 1998 GDHS (49.2%). Regarding the birth interval, a higher percentage of the children were the first child of their mothers for the 1998 GDHS. For all survey points, the lowest category were children with birth intervals of less than 24 months. Except for the 1998 GDHS, children with birth intervals of more than 48 months had the highest proportion compared to the other categories over the same survey periods (Table 2).

As expected of the intermediate factors, younger women in all the four selected surveys were likelier to have children below five years (Table 2). The results further showed that the maternal educational attainment for more than half of children in each of the surveys was secondary or higher, 51.6%, 56.7% and 61.2%, from the 2003 GDHS, 2008 GDHS and 2014 GDHS, respectively. Table 2 shows that women of Christian affiliation were dominant (over 70%) in all the surveys. With regards to parity, the proportions decreased with increasing parity. Through various survey points, children whose mothers indicated working in the professional/service sector were least presented in all survey points. However, more than half of the mothers in all four surveys were engaged in agriculture.

Regarding the proximal factors, the majority of the fathers of the sampled children were secondary school graduates. Like the mother's occupation, most fathers were engaged in the agricultural sector for all the survey points (Appendix 1, Table 2). The proportion of children in rural-urban residences conforms to the country's population distribution, with the majority of the sampled children resident in rural areas (Table 2). Except for the 1998 GDHS, the majority of the respondents belonged to the poorest households. Also, most of the sampled households had two of their children under-five years compared to the other households. The time taken to get water has been reported in the table and it shows that in the 1998 GDHS, few households were able to get water in their house. Within the same survey point, most households had to walk more than 15 minutes to get potable water for domestic use. In the 2014 GDHS, more households could access portable water in their homes. For the variable number of household members, all survey points in the study indicated that most of the households included had 4-5 household members compared with the other categories.

Table 3: Weighted percentage distributions of sampled children by background characteristics and year of survey

SELECTED VARIABLES	1998 GDHS n =3298		2003 GDHS n= 3611		2008 GDHS n= 2742		2014 GDHS n= 2809	
	%	n	%	n	%	n	%	n
DEPENDENT VARIABLE								
Survival Status								
Alive	92.3	3026	91.5	3302	93.5	2545	90.3	2548
Dead	7.7	272	8.7	309	6.5	197	9.7	261
CONFOUNDING VARIABLES								
Immediate Factors								
Age in months								
<6 months	13.4	455	14.3	516	15.1	434	17.3	474
6-11 months	11.1	368	11.3	415	11.4	321	10.5	293
12-23 months	21.5	695	20.3	739	19.9	547	19.8	562
24-35 months	17.7	572	18.9	669	17.3	478	18.3	530
36-47 months	18.4	624	19.0	699	17.1	449	17.4	478
48-59 months	17.8	584	16.2	573	19.17	513	16.7	472
Sex of child								
Male	49.2	1622	51.0	1849	52.0	1399	53.5	1481
Female	50.8	1676	49.0	1762	48.0	1343	46.5	1328

Cont'd **Table 3: Weighted percentage distributions of sampled children by background characteristics and year of survey**

SELECTED VARIABLES	1998 GDHS n =3298		2003 GDHS n= 3611		2008 GDHS n= 2742		2014 GDHS n= 2809	
	%	n	%	n	%	n	%	n
Birth interval								
<24 months	33.9	1090	30.6	1087	31.1	830	29.5	876
24-35 months	23.2	782	24.7	901	22.0	628	23.3	647
36-47 months	20.3	689	18.7	720	19.5	545	16.9	519
48+ months	22.6	737	26.0	903	27.5	739	30.3	857
Intermediate Factors								
Mother's age at birth								
<20 years	12.7	398	9.4	346	7.2	250	5.3	190
20-24 years	27.2	878	23.8	851	23.2	684	20.2	623
25-29 years	24.2	791	26.2	938	28.0	711	27.5	736
30-34 years	17.8	593	19.8	722	21.4	572	24.4	653
35+ years	18.1	638	20.8	754	20.2	525	22.6	607
Mother's education								
No education	38.5	1542	41.7	1760	34.3	1086	31.1	1080
Primary	20.3	598	23.0	764	24.7	655	19.8	581
Secondary or higher	41.2	1158	35.4	1087	41.0	1001	49.0	1148
Religion								
Christianity	70.3	2098	45.3	1696	69.4	943	73.7	966
Islam	11.5	466	4.3	215	19.2	556	18.7	626
Other	18.2	734	50.6	1700	11.5	1243	7.5	1217

Cont'd **Table 3: Weighted percentage distributions of sampled children by background characteristics and year of survey**

SELECTED VARIABLES	1998 GDHS n =3298		2003 GDHS n= 3611		2008 GDHS n= 2742		2014 GDHS n= 2809	
	%	n	%	n	%	n	%	n
Parity								
1-2	37.4	1178	33.7	1176	34.2	913	33.4	888
3-4	29.7	994	30.1	1078	35.4	946	34.4	965
5-6	18.4	640	21.1	789	18.3	523	21.5	622
7+	14.4	486	15.1	568	12.1	360	10.7	334
Mother's occupation								
Not working	14.0	481	10.6	359	9.6	260	15.9	443
Professional/Service	5.7	162	6.3	198	9.6	241	5.7	144
Sales/Manual	45.1	1427	38.3	1271	43.6	1102	48.9	1238
Agricultural	35.1	1228	44.7	1783	37.2	1139	29.5	984
Proximal Factors								
Father's education								
No education	30.0	1279	38.4	1627	27.2	1006	23.6	918
Primary	8.9	283	8.3	311	12.7	245	12.2	326
Secondary	55.5	1562	47.8	1501	52.1	1294	54.4	1316
Higher	5.6	174	5.5	172	8.0	197	9.9	249
Father's occupation								
Professional/Service	19.4	567	11.5	377	22.1	548	14.6	388
Sales/Manual	26.4	764	28.9	858	28.6	662	29.8	671
Agricultural	54.2	1967	59.5	2376	49.3	1532	55.6	1750

Cont'd Table 3: Weighted percentage distributions of sampled children by background characteristics and year of survey

SELECTED VARIABLES	1998 GDHS n =3298		2003 GDHS n= 3611		2008 GDHS n= 2742		2014 GDHS n= 2809	
	%	n	%	n	%	n	%	n
Number of children under-five years in Household								
0-1	44.1	1418	41.4	1427	40.2	1094	41.4	1161
2	39.9	1298	42.0	1530	42.0	1155	43.3	1176
3+	16.0	582	16.7	654	17.8	493	15.2	472
Number of household members								
1-3	21.8	668	13.6	467	17.2	435	18.1	467
4-5	34.6	1088	37.7	1273	38.6	994	38.8	1055
6-7	25.1	845	26.5	959	25.1	723	26.8	756
8+	18.5	697	22.2	912	19.2	590	16.3	531
Time to get water								
On Premise	12.7	377	15.4	479	16.2	378	26.3	599
Within 5 minutes	18.0	555	16.4	583	5.5	522	8.9	244
6-14 minutes	19.1	616	24.1	906	16.0	639	22.2	580
15-25 minutes	20.3	698	22.7	851	4.1	530	22.2	703
26-40 minutes	17.0	595	13.4	499	49.8	374	12.5	400
40+ minutes	13.0	457	8.0	293	8.4	299	8.0	283
Wealth Status								
Poorest	12.3	669	26.3	1224	26.4	921	23.8	945
Poorer	18.4	655	22.6	818	21.6	591	20.2	589
Middle	22.6	649	19.8	637	18.1	437	18.9	500
Richer	23.8	665	16.3	488	19.1	457	18.8	425
Richest	23.0	660	15.0	444	14.8	336	18.3	350
Residence								
Urban	24.2	711	32.4	961	37.5	907	45.2	1118
Rural	75.8	2587	67.6	2650	62.5	1835	54.8	1691

4.2 A univariate analysis of the ecological variables

Table 3 of the result section presents the univariate analysis of the ecological variables selected for the study. From the table, it can be observed across all the four surveys that the mean value for precipitation continually increased until the 2014 GDHS, where precipitation reached its minimum mean value compared to values from the other surveys. For the aridity variable, the lowest value was reported in the 2014 GDHS and the highest value was in 2008. The trend has been increasing since the 1998 GDHS (Table 3). The land surface temperature has gradually increased from the 1998 GDHS with its highest value in 2014; its median value shows that the variable was normally distributed for the 2008 and 2014 datasets. For malaria incidence, the highest mean value was observed in the 1998 GDHS. Across the four survey points, a decreasing trend in malaria incidence could be observed, with the lowest value obtained in the most recent GDHS. Among the social variables, the mean for the coverage of intermittent treat nets increases with the most recent survey point. Again, the median indicated that the variable was normally distributed across all survey points. As shown in Table 3, travel times had a decreasing trend with its highest mean value recorded in the 1998 GDHS; however, the value reduced sharply in the 2014 GDHS.

Table 4: Distribution sampled under-five children by ecological factors and survey year

Ecological Variables	**1998 GDHS n= 400**		**2003 GDHS n=412**		**2008 GDHS n=412**		**2014 GDHS n=427**	
	Mean (*95% CI*)	Median	Mean (*95% CI*)	Median	Mean (*95% CI*)	Median	Mean (*95% CI*)	Median
Annual precipitation	84.1 (*83.1, 85.0*)	85.2	92.7 (*92.0, 93.5*)	94.2	108.1 (*106.6, 109.6*)	109.7	82 (*81.3, 82.8*)	82
Aridity	24.7 (*24.3, 25.2*)	25.2	28.2 (*27.7, 28.7*)	29.3	32.4 (*31.8, 33.1*)	33.3	23.7 (*23.3, 24.2*)	24.3
Drought episodes	1.14 (*0.9, 1.3*)	0	1.12 (*0.94, 1.31*)	0	1.33 (*1.12, 1.53*)	0	1.44 (*1.23, 1.64*)	0
Enhanced vegetation index	3361.9 (*3261, 3462.7*)	3646.6	3496.3 (*3394.1, 3598.4*)	3720.9	3471.4 (*3366.6, 3576.1*)	3462.4	3501.2 (*3400.8, 3601.7*)	3564
Land surface temperature	25.2 (*25.0, 25.4*)	24.5	25.2 (*25.0, 25.4*)	24.8	25.8 (*25.6, 26.0*)	25.7	26.1 (*25.9, 26.3*)	26.2
Maximum temperature	32.1 (*31.9, 32.2*)	31.6	32.0 (*31.9, 32.1*)	31.5	32.5 (*32.4, 32.6*)	32.0	32.5 (*32.4, 32.6*)	32.0
Mean temperature	27.26 (*27.20, 27.33*)	27.2	27.6 (*27.5, 27.7*)	27.4	27.96 (*27.90, 28.0*)	27.8	27.8 (*27.7, 27.9*)	27.6
Minimum temperature	22.53 (*22.45, 22.61*)	22.3	23.3 (*23.2, 23.3*)	23.1	23.5 (*23.4, 23.6*)	23.0	23.1 (*23.0, 23.2*)	22.9
Proximity to water	58945.8 (*52444, 65447.6*)	34715.7	57648.6 (*51305.5, 63991.8*)	31009.1	63647 (*56916.6, 70377.4*)	35485.5	66071.3 (*59160.6, 72982.0*)	33885.4
Rainfall	1049.2 (*1026, 1072.4*)	1102	1135.3 (*1111.7, 1158.9*)	1157.1	1339.0 (*1314.4, 1363.6*)	1368	967.0 (*914.2, 1019.7*)	987.4
Wet days	11.9 (*11.8, 12.1*)	12.3	12.6 (*12.4, 12.8*)	12.6	14.1 (*13.8, 14.4*)	14.3	12.0 (11.8, 12.2)	12.2
Malaria Incidence	0.54 (0.53, 0.55)	0.56	0.45 (0.44, 0.47)	0.50	0.42 (0.40, 0.51)	0.52	0.30 (0.29, 0.31)	0.31
ITN Coverage	0.11 (0.11, 0.12)	0.12	0.12 (0.11, 0.13)	0.12	0.18 (0.17, 0.19)	0.17	0.59 (0.58, 0.61)	0.61
Travel Times	169.0 (156.1, 182.4)	151.4	168.3 (154.7, 181.9)	160.0	55.1 (53.0, 57.2)	47.0	48.0 (41.8, 54.1)	39.0
Built Population	0.1 (0.0, 0.1)	0.0	0.12 (0.9, 0.15)	0	0.18 (0.14, 0.22)	0	0.19 (0.15, 0.23)	0
Night Light Composition	1.0 (0.6, 1.3)	0.6	1.9 (1.3, 2.4)	0.06	2.5 (1.8, 3.2)	0.1	2.6 (2.0, 3.1)	0.1
Global human footprint	33.6 (32.0, 35.1)	30.4	35.5 (33.7, 37.3)	30.7	38.3 (35.9, 40.8)	32.2	39.0 (36.7, 41.0)	32

4.2 Bivariate analysis of under-five mortality and Ecological factors

4.2.1 Primary Factors (Environmental and Socio-ecological factors).

Table 4 demonstrates the bivariate result between the primary factors selected for the study and under-five survival status. Across all the four surveys, there were some inconsistent findings between the environmental, socio-ecological factors and under-five mortality. From table 4, it can be observed that only in the 2008 GDHS was a significant difference in the mean of annual precipitation for children who died (mean=103.81, 95% CI=101.81, 105.79) and those who survived (mean= 106.44, 95% CI= 105.84, 107.04) within the same time. The other survey points did not show any statistical difference. In the 2008 GDHS, areas with low annual precipitations had higher under-five deaths than areas with higher precipitation. Similarly, for drought episodes, a significant difference in the mean of drought episodes for children who died before their fifth birthday (mean= 2.21, 95% CI=1.93,2.50) compared to their counterparts who survived (mean= 1.63, 95% CI = 1.55, 1.71). There was no difference in the mean rainfall values for children who died throughout all the survey periods compared to those who survived (Table 4).

There was a statistically significant difference for maximum temperature only for the 1998 and 2008 GDHS. The mean difference of maximum temperature for children who died in 1998 GDHS (mean= 32.68, 95% CI= 32.50, 32.85) compared to those who survived (mean=32.41, 95% CI= 32.36, 32.46). For the 2008 GDHS, the mean maximum temperature for those who died was 33.06 (95% CI= 32.86, 33.25); for those who survived, their mean maximum temperature was 32.84 (95% CI= 32.79, 32.90). Children's mortality was more prominent in areas with high maximum temperatures than those with low maximum temperatures. Their means were statistically large enough for the remaining environmental factors to depict any difference between children who survived and those who died. For Aridity and land surface temperature, Table 4 demonstrates a significant difference in the 2008 GDHS.

Also, Table 4 demonstrates results on some socio-ecological variables included in the study. For all the surveys, intermittent treated net was not statistically significantly different for under-five children who died and those who survived. For the other socio-ecological variables, only malaria incidence, global human footprint and travel time were statistically significant at two survey points, 1998 and 2008 for malaria incidence and 1998 and 2003 for travel times and global human footprint. For malaria incidence, the mean malaria incidence ratio in the 1998 GDHS for children who died before their fifth birthday was 0.54 (95% CI = 0.53, 0.55) compared to those who survived with a mean of 0.51(95% CI= 0.52). The difference indicated that children from areas with high malaria incidence had a higher chance of dying than those sampled from areas with low malaria incidence. In the 2008 GDHS, the mean malaria incidence ratio for children who died was 0.49 (95% CI = 0.46, 0.51) compared to those who survived 0.45 (95% CI= 0.43, 0.46) For the global human footprint, the mean for children who died in 1998 GDHS was 33.55 (95% CI = 32.00, 35.11) for those who survived their mean global human footprint was 37.88 (95% CI= 37.27, 38.50). The two categories show that under-five children sampled from areas of low global human footprint had higher chances of dying than children sampled from areas of high global human footprint. A similar pattern was observed for the 2003 GDHS. Also, under-five children sampled from areas with low built population (mean = 0.06, 95% CI = 0.04, 0.08) and low nightlight composition (mean=0.98, 95% CI =0.63, 1.333) had higher proportion of under-five deaths when compared to those from highly built population (mean = 0.12, 95% CI= 0.11, 0.13) and areas with high nightlight composition (mean= 37.88, 95% CI=37.27, 38.50). The difference between these two variables was only statistically significant in the 1998 GDHS.

Table 5: Bivariate analysis of under-five mortality by ecological factors and survey year

Variables	GDHS 1998 Mean (95% CI)		GDHS 2003 Mean (95% CI)		GDHS 2008 Mean (95% CI)		GDHS 2014 Mean (95% CI)	
	Survival Status		Survival Status		Survival Status		Survival Status	
	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead
Annual precipitation	84.97 (84.64, 85.30)	86.04 (85.02, 87.06)	91.71 (91.45, 91.97)	92.59 (91.26, 93.16)	106.44 (105.84, 107.04)	103.81 (101.81, 105.79) *	81.97 (81.97, 82.27)	81.32 (80.54, 82.10)
Aridity	24.36 (24.19, 24.53)	24.16 (23.63, 24.69)	27.11 (26.93, 27.28)	27.32 (26.73, 27.91)	31.44 (31.16, 31.72)	30.08 (29.09, 31.07) **	23.27 (23.10, 23.44)	22.86 (22.35, 23.38)
Drought episodes	1.63 (1.55, 1.71)	2.21 (1.93, 2.50) **	1.89 (1.82, 1.97)	1.95 (1.70, 2.20)	2.12 (2.02, 2.21)	2.20 (1.89, 2.50)	1.94 (1.85, 2.04)	1.96 (1.67, 2.24)
Land surface temperature	25.40 (25.32, 25.48)	25.62 (25.36, 25.88)	25.49 (25.42, 25.57)	25.53 (25.20, 25.64	25.94 (25.87, 26.02)	26.22 (25.96, 26.48) *	26.40 (26.32, 26.49)	26.57 (26.31, 26.83)
Maximum temperature	32.41 (32.36, 32.46)	32.68 (32.50, 32.85) **	32.52 (32.47, 32.57)	32. 49 (32.32, 32.65)	32.84 (32.79, 32.90)	33.06 (32.86, 33.25) *	32.79 (32.74, 32.85)	32.92 (32.74, 33.10)
Mean temperature	27.40 (27.38, 27.42)	27.54 (27.45, 27.62) **	27.81 (27.78, 27.83)	27.77 (27.68, 27.85)	28.06 (28.04, 28.09)	28.13 (28.04, 28.21)	27.88 (27.85, 27.92)	27.91 (27.81, 28.00)
Rainfall	1058.0 (1050, 1066)	1071.0 (1048, 1094)	1119.0 (1106, 1159)	1133.0(1111, 1126)	1336.0 (1326, 1344)	1314.0 (1282, 1346)	997.0 (991.0, 1002.9)	989.5 (974.72, 1004.22)
Malaria Incidence	0.51 (0.51, 0.52)	0.54 (0.53, 0.55) **	0.44 (0.44, 0.45)	0.45 (0.44, 0.47)	0.45 (0.45, 0.46)	0.49 (0.46, 0.51) **	0.30 (0.30, 0.31)	0.30 (0.29, 0.31)
ITN Coverage	0.12 (0.11, 0.12)	0.11 (0.11, 0.12)	0.12 (0.11, 0.12)	0.12 (0.11, 0.13)	0.17 (0.17, 0.18)	0.18 (0.17, 0.19)	0.60 (0.59, 0.60)	0.59 (0.58, 0.61)
Travel Times	153.06 (149.08, 157.03)	169.16 (156.12, 182.42) *	153.62 (149.58, 157.65)	168.34 (154.73, 181.95) *	55.12 (53.04, 57.20)	54.24 (47.37, 61.11)	49.63 (47.62, 51.65)	47.98 (41.84, 54.12)

Cont'd **Table 5: Bivariate analysis of under-five mortality by ecological factors and survey year**

Variables	GDHS 1998 Mean (95% CI)		GDHS 2003 Mean (95% CI)		GDHS 2008 Mean (95% CI)		GDHS 2014 Mean (95% CI)	
	Survival Status		Survival Status		Survival Status		Survival Status	
	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead
Built Population	0.12 (0.11, 0.13)	0.06 (0.04, 0.08) **	0.14 (0.13, 0.15)	0.12 (0.09, 0.15)	0.21 (0.20, 0.22)	0.18 (0.14, 0.22)	0.20 (0.19, 0.21	0.19 (0.15, 0.23)
Night Light Composition	2.33 (2.13, 2.52)	0.98 (0.63, 1.33) **	2.06 (1.90, 2.23)	1.87 (1.32, 2.43)	2.76 (2.55, 2.98)	2.47 (1.77, 3.17)	2.53 (2.34, 2.71)	2.55 (1.96, 3.14)
Global human footprint	37.88 (37.27, 38.50)	33.55 (32.00, 35.11) **	37.47 (36.90, 38.05)	35.52 (33.73, 37.32) *	40.0 (39.28, 40.73)	38.89 (35.92, 40.87)	39.71 (39.03, 40.38)	38.83 (36.67, 41.00)
Forested lands	0.19 (0.18, 0.19)	0. 24 (0.22, 0.26) **	0.21 (0.20, 0.22)	0.24 (0.22, 0.26) *	0.20 (0.19, 0.21)	0.21 (0.19, 0.23)	0.27 (0.27, 0.28)	0.25 (0.23, 0.28)

4.2.1 Confounders: Immediate Factors

Concerning the immediate factors, the results revealed that across all the four surveys (Table 5) in the 1998 GDHS, the cross-tabulation indicates a significant difference between child's age in months and under-five mortality. From table 5, the majority of the children who died in the 1998 GDHS were aged less than 6 months, with a percentage of 31.2 percent (95% CI= 26.8%, 35.6%). For those aged 48+ month in the 1998 GDHS, only 0.2 percent (95% CI= 0.0, 0.52) of them died. This pattern was consistent across all the other survey points 2003, 2008 and 2014 GDHS. Regarding birth interval, mortality was significantly different across all categories. For instance, percentage who died with birth interval of less than 24 months in the 2014 GDHS was 22.9 percent (95% CI= 17.4%, 29.6%) compared to those with 48+ month 5.3 percent (95% CI= 3.7%, 6.9%). The observed difference was significant. A higher percentage of children who died had a birth interval of less than 24 months. There was no statistical difference between mortality and sex of the child

4.2.2 Intermediate factors

The 1998 and 2003 GDHS surveys showed significant differences in the proportion of children who died to their mother's educational attainment regarding the intermediate factors. The percentage of deaths among children whose mothers had secondary or higher education was lower (mean=5.9%, 95% CI= 4.7, 7.2) compared to those whose mothers had no and primary education (mean = 9.4%, 95% CI=7.8, 11.1) across all four surveys (Table 4). There were also significant differences except for the 1998 GDHS between mother's parity and under-five mortality status. More deaths were observed among children whose mothers had high parity. There was high mortality among those whose mother's hand parity of 7 or more in the 2014 GDHS (mean=18.1%, 95% CI = 13.6%, 22.6%) (Table 4). For the mother's age at birth, a significant difference was only observed in the 1998 GDHS. However, across all the survey points, the proportion of children dead was higher for those whose mothers' age at birth was below 20 years (mean=11.6%, 95% CI = 7.9%, 14.8%). Higher percentage of deaths were reported among children whose mothers were Muslims (mean= 8.7%, 95% CI= 5.7%, 11.4%) and those whose mothers belonged to other religions (mean= 9.8%, 95% CI= 7.3, 12.2%) compared the Christian religious group (mean= 7.0%, 95% CI= 6.0%, 8.1%). Except for the 2014 GDHS, the mother's occupation significantly differed across the various categories. In 2014 GHDS, children whose mothers indicated to be working in the professional/service sector had higher percentage of under-five deaths (mean= 16.3%, 95% CI= 10.6%, 22.4%0 compared to the those whose mother's indicated not working (mean= 8.8%, 95% CI = 6.2%, 11.6%).

4.2.3 Proximal factors

The analysis revealed a statistically significant difference in under-five mortality for children and fathers' educational attainment. Fathers with no educational attainment had a high proportion of their children dying in the study compared to those with formal education. The significant differences between father's educational attainment and under-five mortality were only observed for the 1998 and 2008 GDHS. In the 1998 GDHS, children whose fathers had no education had a higher percentage of under-five mortality (mean=10.5%, 95% CI = 8.3, 12.6) compared to those whose fathers had higher educational attainment (mean=4.1, 95% CI = 1.1%, 7.1%). For household wealth status, only the 1998 showed some statistical difference across the various statuses with poorest households having higher proportions of under-five mortality (mean= 11.0%, 95% CI= 7.9%, 14.1%) compared to the richest household (mean=5.0%, 95% CI = 3.4%, .6.6%). Some inconsistencies were observed across all four surveys; the results show that the percentage of under-five deaths was not always lower for wealthier households (Table 4). Table 4 also showed that apart from the 1998 GDHS, rural settings have a disproportionately higher percentage of under-five deaths. For the 2014 GDHS, the proportion of under-five mortality from rural places of residence was 10.2 percent (95% CI = 8.7%, 11.8%) when compared to urban areas with 9.0 percent (95% CI = 7.4%, 10.6%); however, the difference was not larger enough to be statistically significant. Both variables indicated significant differences across all the categories for the number of children under-five years in the household and the number of household members. However, the results were counterfactual in reasoning. For both variables, a higher percentage of under-five deaths were among households with low under-five children and members (Table 5).

Table 6: Mean percentage distribution of background of under-five mortality by background characteristics and survey year

Background Characteristics	1998 GDHS % [95% CI]	n	2003 GDHS % [95% CI]	n	2008 GDHS % [95% CI]	n	2014 GDHS % [95% CI]	n
Overall								
CONFOUNDERS								
Immediate Factors								
Sex of child	*p-value = 0.802*		*p-value = 0.705*		*p-value = 0.337*		*p-value = 0.484*	
Male	7.8 [*6.5, 9.2*]	1622	8.8 [*7.4, 10.2*]	1876	7 [*5.7, 8.4*]	1398	10 [*8.5, 11.6*]	1487
Female	7.6 [*6.3, 8.9*]	1676	8.5 [*7.2, 9.8*]	1805	6 [*4.7, 7.4*]	1341	9.2 [*7.6, 10.8*]	1335
Age in months	*p-value = 0.000*		*p-value = 0.000*		*p-value = 0.000*		*p-value = 0.000*	
<6 months	31.2 [*26.8, 35.6*]	455	40.4 [*36.1, 44.9*]	523	28.2 [*23.8, 32.6*]	431	42 [*37.4, 46.4*]	493
6-11 months	11.5 [*8.2, 14.8*]	368	7.0 [*4.5, 9.6*]	425	7.6 [*4.7, 10.8*]	321	8.8 [*5.6, 12.3*]	298
12-23 months	6.1 [*4.4, 8*]	695	4.8 [*3.2, 6.4*]	765	4.4 [*2.6, 6.2*]	547	2.6 [*1.2, 3.9*]	558
24-35 months	3.2 [*1.7, 4.5*]	572	3.6 [*2.1, 5.0*]	682	1.7 [*0.05, 2.8*]	478	2.0 [*0.08, 3.3*]	529
36-47 months	1.7 [*0.71, 2.9*]	624	1.7 [*0.07, 2.7*]	706	0.09 [*0, 1.7*]	449	2.6 [*1.1, 4*]	474
48-59 months	0.2 [*-0.17, 0.52*]	584	0.05 [*0, 1.2*]	580	0.04 [*-0.01, 0.1*]	513	0.9 [0, 1.7]	470
Birth Interval	p-value =0 .000		p-value=0.000		p-value=0.041		p-value=0.000	
First child	10.8 [8.6, 13.0]	349	9.1 [6.9, 11.3]	709	7.7 [5.4, 9.9]	532	8.9 [6.5, 11.4]	513
<24 months	13.2 [9.6, 16.8]	782	15.5 [11.7, 19.1]	378	10.3 [6.8, 13.8]	298	14.0 [9.9, 18.2]	273
24-35 months	8.6 [6.6, 10.55]	689	7.6 [5.9, 9.5]	901	5.7 [3.7, 7.5]	628	11.2 [8.7, 13.6]	647
36-47 months	5.8 [4.1, 7.6]	737	5.8 [4.0, 7.6]	720	6.8 [4.6, 9.0]	545	8.6 [6.1, 11.3]	519
48+ months	5.3 [3.7, 6.9]	741	8.5 [6.6, 10.3]	903	5.3 [3.7, 6.9]	739	5.1 [3.6, 6.6]	857

Cont'd **Table 6: Mean percentage distribution of background of under-five mortality by background characteristics and survey year**

Background Characteristics	1998 GDHS % [*95% CI*]	n	2003 GDHS % [*95% CI*]	n	2008 GDHS % [*95% CI*]	n	2014 GDHS % [*95% CI*]	n
Intermediate Factors								
Mother's age at birth	*p-value = 0.010*		*p-value = 0.256*		*p-value = 0.266*		*p-value = 0.404*	
<20 years	11.6 [*7.9, 14.8*]	317	11.0 [7.6, *14.5*]	319	7.4 [*3.7, 11.2*]	192	11.2 [*6.1, 16.7*]	162
20-24 years	7.6 [6.4, *10.1*]	877	7.7 [5.8, *9.5*]	806	6.5 [*4.5, 8.4*]	597	8.1 [5.8, *10.3*]	597
25-29 years	5.7 [*4.3, 7.7*]	787	8.4 [6.5, *10.2*]	889	5.4 [*3.8, 7*]	698	10.1 [*8, 12.3*]	736
30-34 years	8.3 [*5.3, 9.5*]	627	7.7 [5.7, *9.8*]	672	6 [*4.1, 8*]	536	10.9 [*8.6, 13.3*]	662
35+ years	7.3 [5.5, *9.6*]	690	9.9[*7.7, 12.2*]	707	8.4 [*6.1, 10.9*]	522	8.7 [*6.5, 11*]	665
Mother's education	*p-vale = 0.004*		*p-value = 0.040*		*p-value = 0.073*		*p-value = 0.356*	
No education	9.4 [*7.8, 11.1*]	1542	8.9 [*7.4, 10.4*]	1766	6.8 [*5.2, 8.5*]	1085	10.5 [*8.4, 12.5*]	1081
Primary	8 [*5.9, 10.1*]	598	10.4 [*8.3, 12.6*]	787	8.1 [*6, 10.2*]	654	10.5 [*7.9, 13.1*]	580
Secondary or higher	5.9 [*4.7, 7.2*]	1158	7.2 [6.4, *9.3*]	1128	5.3 [*4, 6.7*]	1000	8.8 [*7.3, 10.3*]	1161
Religion	*p-value = 0.064*		*p-value = 0.341*		*p-value = 0.004*		*p-value = 0.944*	
Christianity	7.0 [*6, 8.1*]	2098	9.4 [8.0, *10.9*]	2408	5.5 [*4.5, 6.6*]	1794	9.6[*8.3, 10.9*]	1949
Islam	8.7 [*5.7, 11.4*]	466	8.2 [3.7.1, *12.7*]	765	7.9 [*5.6, 10.3*]	556	10.1 [*7.4, 12.6*]	626
Other	9.8 [*7.3, 12.2*]	734	8.0 [6.7, *9.3*]	508	10.2 [*6.9, 13.8*]	389	9.3 [*5.1, 13.1*]	247
Parity	*p-value = 0.403*		*p-value = 0.003*		*p-value = 0.000*		*p-value = 0.000*	
1-2	6.9 [*5.4, 8.3*]	1178	7.1 [5.6, *8.6*]	1242	4.3 [*3, 5.7*]	910	7.9 [*6.1, 9.6*]	903
3-4	7.6 [*5.9, 9.3*]	994	8.1 [6.5, *9.8*]	1080	6.6 [*5.1, 8.2*]	946	9.1 [*7.2, 10.9*]	964
5-6	8.7 [*6.4, 11*]	640	9.1 [*7, 11.2*]	791	7 [*4.7, 9.2*]	523	9.1 [*6.8, 11.6*]	623
7+	8.9 [*6.2, 11.4*]	486	12.5 [*9.7, 15.5*]	568	11.9 [*8.4, 15.5*]	360	18.1 [*13.6, 22.6*]	332
Mother's occupation	*p-value = 0.190*		*p-value = 0.940*		*p-value = 0.145*		*p-value = 0.034*	
Not working	9.4 [*6.6, 12*]	481	8.6 [5.7, *11.5*]	388	9.5 [*5.8, 13.1*]	259	8.8 [*6.2, 11.6*]	444
Professional/Service	8.7 [*4.5, 12.7*]	162	7.9 [4.1, *11.3*]	204	4.7 [*2.1, 7.3*]	241	16.3 [*10.6, 22.4*]	146
Sales/Manual	6.7 [*5.4, 7.9*]	1427	8.5 [7.0, *10.1*]	1299	6.1 [*4.7, 7.5*]	1100	9.1 [*7.5, 10.6*]	1240

Cont'd **Table 5: Mean percentage distribution of background of under-five mortality by background characteristics and survey year**

Background Characteristics	1998 GDHS % [95% CI]	n	2003 GDHS % [95% CI]	n	2008 GDHS % [95% CI]	n	2014 GDHS % [95% CI]	n
Agricultural	8.3 [6.7, 9.9]	1228	9.0 [7.5, 10.4]	1790	6.8 [5.2, 8.4]	1139	9.7 [7.7, 11.8]	992
Proximal Factors								
Father's education	*p-value = 0.001*		*p-value = 0.301*		*p-value = 0.001*		*p-value = 0.133*	
No education	10.5 [8.3, 12.6]	1111	9.5 [6.8, 10.2]	1304	9.2 [7, 11.2]	898	10.2 [7.9, 12.6]	882
Primary	8.7 [6.2, 11.2]	481	9.9 [8.1, 13.2]	282	8.3 [5.4, 11.4]	350	12.5 [8.8, 15.9]	376
Secondary	6.5 [5.4, 7.7]	1539	7.7 [6.3, 8.9]	1621	5.1 [3.9, 6.2]	1294	8.6 [7.1, 10]	1313
Higher	4.1 [1.1, 7.1]	167	9.1 [4.9, 13.2]	186	4.3 [1.6, 7.2]	197	10.9 [7.3, 14.8]	251
Father's occupation	*p-value = 0.000*		*p-value = 0.053*		*p-value = 0.014*		*p-value = 0.023*	
Professional/Service	3.7 [2.2, 5.2]	564	10.7 [7.8, 13.9]	391	4.3 [2.6, 5.8]	548	12.2 [9, 15.5]	397
Sales/Manual	6.5 [4.8, 8.1]	752	7.0 [5.4, 8.6]	982	6.2 [4.4, 7.9]	673	8 [6.6, 9.6]	1066
Agricultural	9.7 [9.7, 11.1]	1982	9.1 [7.8, 10.3]	2020	7.8 [6.8, 9.3]	1518	10.5 [8.7, 12.4]	1359
Number of children under-five years in Household	*p-value = 0.000*		*p-value = 0.000*		*p-value = 0.000*		*p-value = 0.000*	
0-1	11.8 [10.1, 13.5]	668	15.4 [13.5, 17.3]	1404	11.5 [9.3, 13.1]	1069	13.4 [13.2, 17.4]	1161
2	5.2 [4.0, 6.4]	1088	3.4 [2.7, 4.6]	1424	3.2 [2.2, 4.3]	1113	5.1 [3.8, 6.4]	1176
3+	2.5 [1.2, 4.0]	845	4.6[2.9, 6.4]	565	3.8 [2.1, 5.5]	472	6.6 [4.2, 9.1]	472
Number of household members	*p-value = 0.000*		*p-value = 0.000*		*p-value = 0.000*		*p-value = 0.000*	
1-3	13.5 [10.9, 16]	668	16.5 [13.1, 19.8]	461	12.1 [9.1, 15.1]	435	15.3 [12.2, 18.6]	469
4-5	6.2 [4.7, 7.6]	1088	7.7 [6.2, 9.1]	1281	4.7 [3.4, 6]	993	8.5 [6.8, 10.2]	1057
6-7	5.7 [4.2, 7.4]	845	7.2 [6.2, 9.1]	898	5.7 [4, 7.6]	722	6.8 [4.9, 8.6]	760
8+	6.4 [4.5, 8.5]	697	7.3 [5.4, 9.2]	754	6.3 [4.2, 8.4]	589	10.9 [8, 13.9]	536

Cont'd **Table 6: Mean percentage distribution of background of under-five mortality by background characteristics and survey year**

Background Characteristics	1998 GDHS % [95% CI]	n	2003 GDHS % [95% CI]	n	2008 GDHS % [95% CI]	n	2014 GDHS % [95% CI]	n
Time to get water	*p-value = 0.001*		*p-value = 0.144*		*p-value = 0.013*		*p-value = 0.211*	
On Premise	3.7 [2, 5.7]	388	9.2 [6.6, 11.6]	523	5.6 [3.4, 7.7]	378	9.6 [7.4, 11.7]	599
Within 5 minutes	10.6 [8, 13]	553	6.6 [4.5, 8.7]	557	4.8 [1.5, 8.6]	126	5.4 [2.4, 8.1]	244
6-14 minutes	8.9 [6.6, 11.1]	615	8.4 [6.3, 10.1]	818	8.3 [5.7, 11]	394	9.7 [7.2, 12]	584
15-25 minutes	5.7 [4, 7.6]	696	10.7 [8.5, 12.9]	769	13.9 [7.3, 20.5]	121	10.5 [8, 12.9]	706
26-40 minutes	8.1 [5.9, 10.6]	590	7.3 [4.9, 9.6]	455	5.8 [4.5, 7]	1421	10.4 [7, 13.6]	403
40+ minutes	8.2 [5.6, 10.9]	456	9.2 [5.9, 12.8]	272	7.2 [3.7, 10.5]	299	12.1 [7.6, 16.3]	286
Wealth Status	*p-value = 0.008*		*p-value = 0.949*		*p-value = 0.263*		*p-value = 0.847*	
Poorest	11.0 [7.9, 14.1]	669	8.5 [6.6, 10.3]	893	7.1 [5.3, 9.1]	921	9.8 [7.5, 12.1]	956
Poorer	8.5 [6.3, 10.9]	655	8.9 [6.8, 10.7]	768	5.3 [3.4, 7]	590	10.8 [8.1, 13.3]	597
Middle	7.8 [5.9, 9.8]	649	9.2 [6.9, 11.2]	671	8.4 [5.9, 10.9]	436	9.4 [6.9, 12]	501
Richer	7.8 [5.9, 9.7]	665	8.0 [5.5, 9.9]	553	6.1 [4.1, 8.3]	456	9.4 [6.9, 12]	424
Richest	5 [3.4, 6.6]	660	8.5 [5.9, 10.6]	508	5.6 [3.3, 7.8]	336	8.7 [6.2, 11.2]	348
Residence	*p-value = 0.004*		*p-value = 0.417*		*p-value = 0.631*		*p-value = 0.297*	
Urban	5.3 [3.7, 6.8]	711	8.1 [6.2, 9.4]	1099	6.2 [4.8, 7.8]	905	9.0 [7.4, 10.6]	1118
Rural	8.5 [7.4, 9.6]	2587	8.9 [7.6, 9.9]	2294	6.7 [5.5, 7.9]	1834	10.2 [8.7, 11.8]	1704

Source: GDHS 1998; 2003; 2008; 2014

Table 7: Multicollinearity of continuous ecological variables

Variable	1	2	3	4	5	6	7	8	9
1. Precipitation									
2. Aridity	.904**								
3. EVI	.366**	.592**							
4. Cultivated lands	.032**	.031**	.406**						
5. DLST	-.493**	-.761**	-.791**	-.124**					
6. Drought	-.157**	-.427**	-.381**	-.036**	.542**				
7. Natural lands	.033**	-.068**	-.024**	-.459**	.042**	.397**			
8. NLST	-.194**	-.433**	-.805**	-.397**	.717**	.336**	.078**		
9. Rainfall	.807**	.793**	.571**	.181**	-.633**	-.162**	.087**	-.461**	
10. Temperature	-.282**	-.607**	-.533**	.049**	.769**	.753**	.291**	.492**	-.275**

**. p<0.01 (2-tailed) *p<0.05. N = 12460

The multicollinear of interval-by-interval Pearson's R shows the corelation between the continuous ecological variables used in the study. from the table it can be observed that there is a significant relationship between the variables. The table shows that the corelation between precipitation and aridity was positive strong (r=0.904, p< 0.01). The direction of the relationship was not even across all the variables. Day land surface temperature had a weak negative association with precipitation (r= -0.493, p< 0.01). However, there was a moderately strong negative relationship between day land surface temperature and aridity (r= -0.761, p< 0.01)

4.3 Multivariate Analysis (Multilevel logistic analysis)

Objective 1: Examine the trends in under-five mortality in Ghana

Figure 4 shows that the proportions of under-five children who died across the four survey points have not been uniform. From figure 4, we can observe the highest proportion of death recorded in the 2014 survey, and the lowest proportion was recorded in the 2008 survey. The findings from the analysis showed that there had not been any significant change in under-five mortality across time (all the four survey points). However, the results in Figure 4 show that a significant increase in under-five mortality was observed between the 2008 and 2014 GDHS. The chi-squared test of the trend analysis indicated a statistical difference in the proportion of under-five deaths between the two survey periods (X^2= 8.38, p-value=0.039).

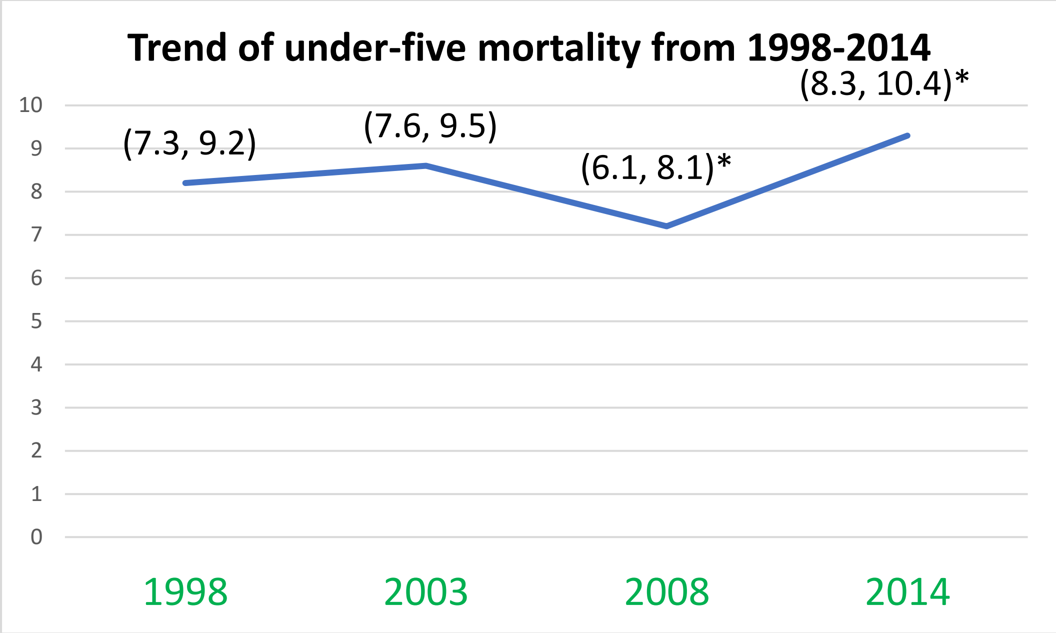

Figure 5: Under-five mortality trends in Ghana 1998-2014

Source: Author's construct (2021)

Objective 2: Examine How much of the variability in under-five mortality at the community and district level is explained by ecological factors

Table 7 shows the estimated odds ratios, 95% confidence intervals, and the multilevel logistic regression analysis model summary statistics. The null model (Model 0) shows significant ($p<0.05$) random effects variances at the community and district level, indicating that without accounting for any predictors, there exit significant variations between communities and between districts in the proportion of under-five mortality. The Intraclass Correlation Coefficient (ICC) from the null model shows that 71.6 percent of the variation in under-five mortality is attributable to differences at the community level and 28.4 percent at the district level.

When the year of survey and place of residence were included in the model (Model 1), the community and district level variances declined by 2.0 percent and 3.3 percent, respectively. However, all the random effect variances remained significant at p<0.05. At the community and district levels, the decline in variances shows that the survey year explained 2.0 percent and 3.3 percent of the differences in under-five mortality variance at the district and community levels, respectively.

Including the environmental factors in the model (Model 2), drought accounted for 22.4 percent of the observed differences in under-five mortality at the district level and 4.1 percent of the remaining under-five mortality at the community level. The variability at the district level became statistically insignificant after including the environmental factors, whilst the under-five variance at the community level remained statistically significant (Table 6, Model 2).

Model 3 accounted for the socio-ecological predictors. The inclusion of malaria incidence increased the community level variance by 3.4 percent. The increase in the community level variance suggests malaria incidence increases the variability in under-five survival status between communities. The district-level variance remained statistically insignificant.

In Model 4, immediate factors of under-five mortality were included in the model. The results show that the immediate factors accounted for 22.1 percent of the remaining variation in under-five mortality at the community level. Including the immediate predictors did not account for the observed variation in under-five mortality at the district levels. There was no statistically significant variability at the community and district levels with survey year, environmental, socio-ecological and immediate factors accounted for.

The intermediate predictors, maternal age at birth, parity, and mother's occupation, were added in Model 5. Model 5 showed that the intermediate factors accounted for 15 percent of the differences at the district level and 12.4 percent at the community level. The variances at the community and district levels remained statistically insignificant in Model 5.

Regarding the proximal factors, only the father's educational attainment remained statistically significantly associated with under-five mortality ($P<0.05$). Father's educational attainment explained 17.6 percent and 8.1 percent of the remaining variability at the community and district levels. However, the remaining variability at the community and district levels was not statistically significant.

Table 8: Distribution of percentage of variance explained at the district and community level

Levels	Null Model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
District (% explained)	28.4 (26.1, 30.2)	2.0 (0.8, 2.3)	22.4 (20.1, 24.0)				
Community (% explained)	71.6 (62.1, 76.3)	3.3 (2.1, 3.7)	4.1 (3.1, 5.6)	3.4 (2.5, 4.7)	22.1(22.1, 25.6)		
District	0.060 (0.028) *	0.058 (0.028) *	0.037 (0.024)	0.032 (0.023)	0.031 (0.023)	0.026 (0.022)	0.024 (0.022)
Community	0.151 (0.062) **	0.148 (0.062) *	0.150 (0.061) *	0.140 (0.060) *	0.121 (0.059) *	0.085 (0.057)	0.080 (0.056)

Objective 3: Examine the ecological factors (environmental and social) associated with under-five mortality.

Interpretation of the model coefficients is based on the final model (Table 7, Model 6), which accounted for the primary factors and the significant confounders. However, the interpretations were only focused on the ecological factors (environmental and social) after accounting for all confounders in the study. The primary predictor significantly associated with under-five mortality was malaria incidence. The confounders identified to be statistically significantly associated with under-five mortality status were the year of survey, birth interval, parity of the mother, maternal age, mother's occupation, and father's educational attainment (Table 7, Model 6).

Regarding the primary factors, the results show that a degree Celsius change in the mean temperature of a district corresponds to a 2% reduction in the odds of under-five mortality in the district (OR= 0.98, 95% CI= 0.82, 1.23). Regarding malaria incidence, with each increase in the mean malaria incidence of a district, the odds of an under-five child dying increases by 14 percent among study participants who resided in districts of high malaria incidence (OR= 1.14, 95% CI= 1.25, 2.63).

Table 9: Multilevel Regression on Under-five mortality and ecological factors

Variables	Model 1 OR (*95% CI*)	Model 2 OR (*95% CI*)	Model 3 OR (*95% CI*)	Model 4 OR (*95% CI*)	Model 5 OR (*95% CI*)	Model 6 OR (*95% CI*)
Year						
1998 GDHS	0.90 (*0.91, 1.07*)	0.98 (0.78, 1.18)	0.75 (0.50, 1.00)	0.72 (0.47, 0.97) **	0.75 (0.50, 1.00) **	0.71 (0.41, 0.95) **
2003 GDHS	0.91 (*0.72, 1.10*)	0.93 (0.74, 1.12)	0.81 (0.60, 1.01)	0.80 (0.59, 1.00) *	0.83 (0.63, 1.03) *	0.79 (0.59, 0.99)
2008 GDHS	0.76 (0.56, *0.96*) *	0.77 (0.52, 1.03) *	0.68 (0.42, 0.94) *	0.66 (0.40, 1.33) **	0.69 (0.43, 0.95) **	0.64 (0.41, 0.87) **
2014 GDHS	1.00	1.00	1.00	1.00	1.00	1.00
Environmental Factors						
Annual Rainfall		1.04 (0.94, 1.14)	0.98 (0.87, 1.09)	0.97 (0.86, 1.07)	0.96 (0.85, 1.07)	
Annual Rainfall ^2		0.93 (0.87, 0.99) *	0.94 (0.88, 1.00)	0.94 (0.88, 1.00) *	0.94 (0.88, 1.0) *	
Mean Temperature		1.08 (0.98, 1.18)	1.01 (0.91, 1. 11)	1.02 (0.92, 1.12)	1.02 (0.92, 1.12)	0.98 (0.82, 1.23) **
Mean Temperature ^2		0.92 (0.86, 0.97) **	0.91(0.86, 0.97) **	0.92 (0.86, 0.98) **	0.95 (0.89, 3.43) *	0.93 (0.87, 1.63) **
Social Factors						
Malaria Incidence			1.19 (1.09, 1.29) **	1.20 (1.10, 130) **	1.17 (1.07, 1.27) **	1.14 (1.05, 1.23) **
Immediate Factors						
Birth Interval						
<24 months				1.00	1.00	1.00
24-35 months				0.72 (0.55, 0.89)	0.50 (0.31, 0.69)	0.50 (0.31, 0.69)
36-47 months				0.58 (0.39, 0.77) **	0.41 (0.20, 0.62)	0.41 (0.20, 0.62) *
48+ months				0.57 (0.40, 0.74) **	0.41 (0.22, 0.60) **	0.41 (0.22, 0.60) **

Cont'd Table 9: **Multilevel Regression on Under-five mortality by ecological factors**

Variables	Model 1 OR (*95% CI*)	Model 2 OR (*95% CI*)	Model 3 OR (*95% CI*)	Model 4 OR (*95% CI*)	Model 5 OR (*95% CI*)	Model 6 OR (*95% CI*)
Intermediate Factors						
Parity						
1-2					1.00	1.00
3-4					1.83 (1.64, 2.02)	1.78 (1.59, 1.97) **
5-6					2.25 (2.04, 2.46) **	2.13 (1.93, 2.34) **
7+					2.90 (2.68, 3.12) **	2.76 (2.54, 2.98) **
Mother's Occupation						
Not Working					1.00	1.00
Profession/Service					1.08 (0.76, 1.40)	1.17 (0.84, 1.50)
Sales/Manual					0.86 (0.65, 1.07)	0.88 (0.67, 1.09)
Agricultural					0.80 (0.59, 1.01) **	0.79 (0.58, 1.00) **
Father's Educational Level						
No education						1.00
Primary						0.88 (0.87, 1.61)
Secondary						0.76 (0.75, 1.37) *
Higher						0.66 (0.33, 0.99) **

** *p*-value < 0.01 * *p*-value < 0.05

4.3 Survival analysis of the ecological factors associated with under-five mortality

Table 6 shows the estimated hazard ratios, corresponding 95% confidence intervals and model summary statistics for the effects of the ecological (environmental and social) factors and confounders on under-five mortality.

Including the environmental factors in the model (Model 2), drought episodes, annual rainfall and mean temperature were identified to be statistically significantly ($p<0.05$) associated with under-five mortality. However, enhanced vegetation index, forested land area, land surface temperature, wet days and aridity were not significantly associated with under-five mortality. This observation will explain the high collinearity between most of the environmental variables. Accounting for the environmental factors, the year of the survey remained significant at $p<0.05$. (Table 8, Model 2).

Model 3 accounted for the socio-ecological predictors. The significant predictors were malaria incidence, global human footprint ($p<0.01$) and ITN coverage ($p<0.05$). After accounting for the socio-ecological, drought episodes in Model 2 became statistically insignificant, whilst annual rainfall, mean temperature, and survey year remained statistically significant. Also, accounting for the socio-ecological predictors, all the categories of the survey years became statistically significant ($p<0.01$). Regarding the environmental covariates, after accounting for the socio-ecological, there was a 1 percent increase in the risk of dying for a millimetre change in the annual rainfall. However, there were no changes in the risk of surviving for mean temperature after controlling for other variables.

4.4.1 Interpretation of model co-efficient for Cox proportional hazard.

Interpretation of the model coefficients is based on the final model (Model 6), which accounted for the significant primary factors and confounders. The final model's environmental and socio-ecological predictors associated with under-five mortality were malaria incidence, annual rainfall, and mean temperature. The confounders identified to be statistically significantly associated with under-five mortality were the year of survey, the birth interval of the child, mother's age, parity, mother's occupation and father's educational attainment (Table 8, Model 6).

With regards to the primary factors conceptualised as environmental and socio-ecological covariates, the results show that a degree Celsius change in mean temperature and a millimetre change in annual rainfall increase the hazard of dying by 6 and 5 percent on average, respectively. Further on the socio-ecological, the results show that for each number of people per year, a change in malaria incidence increases the hazard of dying by 12 percent, on average, for children under five.

Table 10: Cox Proportional Hazard Regression on Under-five mortality and ecological factors

Variables	Model 1 HR [95% CI]	Model 2 HR [95% CI]	Model 3 HR [95% CI]	Model 4 HR [95% CI]	Model 5 HR [95% CI]	Model 6 HR [95% CI]
Year						
1998 GDHS	0.87 [0.74, 1.04]	0.94 [0.78, 1.12]	0.61 [0.45, 0.84] **	0.60 [0.44, 0.82] **	0.62 [0.46, 0.85] *	0.72 [0.58, 0.89] **
2003 GDHS	0.91 [0.77, 1.08]	0.93 [0.78, 1.10]	0.66 [0.49, 0.88] **	0.66 [0.49, 0.88] **	0.69 [0.52, 0,92]	0.80 [0.67, 0.96] *
2008 GDHS	0.77 [0.64, 0.93] **	0.76 [0.61, 0.95] *	0.60 [0.45, 0.80] **	0.60 [0.45, 0.81] **	0.63 [0.47, 0.84] **	0.66 [0.53, 0.81] **
2014 GDHS	1.00	1.00	1.00	1.00	1.00	1.00
Environmental Factors						
Annual Rainfall		1.04 [0.95, 1.13]	0.98 [0.89, 1.08]	0.96 [0.88, 1.06]	0.95 [0.86, 1.04]	0.95 [0.87, 1.05]
Annual Rainfall ^2		0.93 [0.88, 0.98] **	0.94 [0.90, 1.0] *	0.94 [0.89, 0.99] *	0.94 [0.90, 1.00] *	0.95 [0.89, 1.00] *
Mean Temperature		1.03 [0.94, 1.114]	1.01 [0.92, 1.11]	1.04 [0.95, 1.13]	1.04 [0.94, 1.12]	0.99 [0.92, 1.08]
Mean Temperature ^2		0.92 [0.87, 0.97] **	0.91 [0.87, 0.97] **	0.92 [0.88, 0.97] **	0.93 [0.88, 0.98] **	0.94 [0.89, 0.99] *
Drought Episodes		1.10 [1.00, 1.21] *				
Social Factors						
Malaria Incidence			1.12 [1.02, 1.23] **	1.14 [1.04, 1.25] **	1.13 [1.04, 1.24] **	1.12 [1.0, 1.21] **
Global Human Footprint			0.90 [0.83, 0.97] **	0.89 [0.83, 0.96] **	0.92 [0.85, 1.0] *	
ITN Coverage			0.88 [0.79, 0.98] *	0.88 [0.79, 0.99] *		
Immediate Factors						
Birth Interval						
<24 months				1 .00	1.00	1.00
24-35 months				0.74 [0.63, 0.86] **	0.57 [0.48, 0.68] **	0.56 [0.47, 0.67] **
36-47 months				0.59 [0.49, 0.71] **	0.47 [0.39, 0.57] **	0.47 [0.39, 0.57] **
48+ months				0.60 [0.51, 0.71] **	0.49 [0.41, 0.59] **	0.49 [0.41, 0.69] **

Annual Rainfall ^2 = Annual rainfall squared

Cont'd Table 10: Cox Proportional Hazard Regression on Under-five mortality by ecological factors

Variables	Model 1 HR [95% CI]	Model 2 HR [95% CI]	Model 3 HR [95% CI]	Model 4 HR [95% CI]	Model 5 HR [95% CI]	Model 6 HR [95% CI]
Intermediate Factors						
Mother's age at birth						
< 20 years					1.00	1.00
20-24 years					0.73 [0.58, 0.91] **	0,73 [0.58, 0.92] **
25-29 years					0.69 [0.54, 0.89] **	0.70 [0.54, 0.90] **
30-34 years					0.65 [0.49, 0.86] **	0,66 [0.50, 0.87] **
35+ years					0.59 [0.44, 0.80] **	0.59 [0.44, 0.80] **
Parity						
1-2					1.00	1.00
3-4					1.82 [1.50, 2.20] **	1.79 [1.47, 2.17] **
5-6					2.39 [2.37, 3.01] **	2.30 [1.82, 2.90] **
7+					3.18 [2.43, 4.16] **	3.10 [2.37, 4.06] **
Mother's Occupation						
Not Working					1.00	1.00
Profession/Service					1.11 [0.82, 1.51]	1.17 [0.86, 1.59] **
Sales/Manual					0.85 [0.70, 1.04]	0.87 [0.71, 1.05]
Agricultural					0.77 [0.63, 0.93] **	0.77 [0.63, 0.93]
Proximal Factors						
Father's Educational Level						
No education						1.00
Primary						0.88 [0.71, 1.10]
Secondary						0.75 [0.64, 0.88] **
Higher						0.72 [0.52, 0.98] *
-2 log likelihood	19220.85	19195.48	19175.18	19115.82	19011.04	19006.08

4.6. Hazard curves and the log-rank test for categorical variables

The study plotted the hazard function to show the survival probabilities across the age in months of children under five years for the nominal variables. As a statistical requirement, a log-rank test was also performed to ascertain if the observed hazard function between the nominal variables is statistically difference from other categories of a variable.

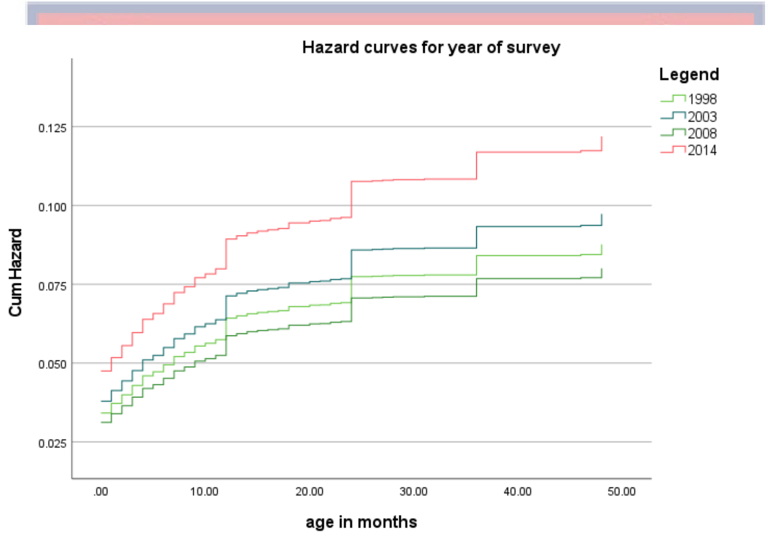

Figure 6: Hazard curves for the year of survey

Source: Author's construct (2021)

Table 11: A log-rank test for the year of survey

Variable	Mean estimate (*95% CI*)	Log Rank (Mantel-Cox)
Survey Year		8.13 *
1998	54.14 (*53.59, 54.69*)	
2003	53.95 (*53.41, 54.49*)	
2008	54.72 (*54.15, 55.30*)	
2014	53.50 (*52.87, 54.14*)	

Figure 6 shows the hazard curve (function) for the survey year; it can be observed that children sampled in 1998 had the lowest risk of dying among the four survey points. At the early stages of life, the survival probabilities of the children sampled in 1998 are not different from those sampled in 2003 and 2008. However, as the child's age progresses, the difference in the cumulative survival probabilities becomes obvious across the four survey points. Surprisingly, the risk of dying was highest in the 2014 GDHS. Further, the log rank test indicated that the survival probabilities between the survey year were statistically significant (X^2 =8.13, p-value= 0.04).

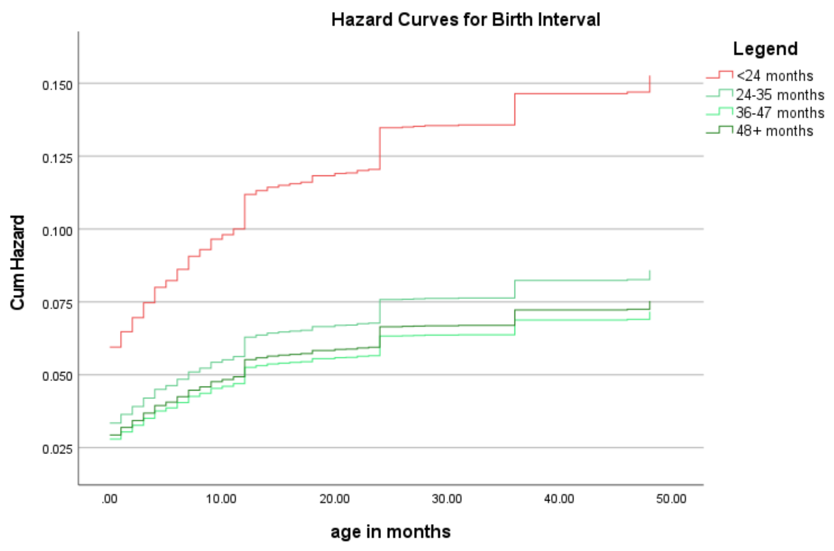

Figure 7: Hazard curves for the birth interval (immediate)

Source: Author's construct (2021)

Table 12: A log-rank test for birth interval

Variable	Mean estimate (*95% CI*)	Log Rank (Mantel-Cox)
Birth interval		52.38 **
<24 months	52.61 (*52.03, 53.19*)	
24-35 months	54.03 (*53.44, 54.62*)	
36-47 months	55.02 (*54.43, 55.60*)	
48+ months	55.01 (*54.59, 55.61*)	

*** p-value < 0.01*

Figure 7 demonstrates the hazard function for the birth interval of sampled children from 1998 to 2014 across various ages. From the figure, they risk of dying under-five years was low among under-five children whose birth interval was above 24 months (figure 5). The category with the highest survival time was children with birth intervals between 36-47 months and those whose birth interval was above 48 months. The mean estimate showed children whose birth interval was less than 24 months were likely to die by age 52 months, this narrative was different for the children whose birth interval was higher than 24 months. The difference in survival probabilities was statistically significant (X^2 =52.38, p-value= 0.01)

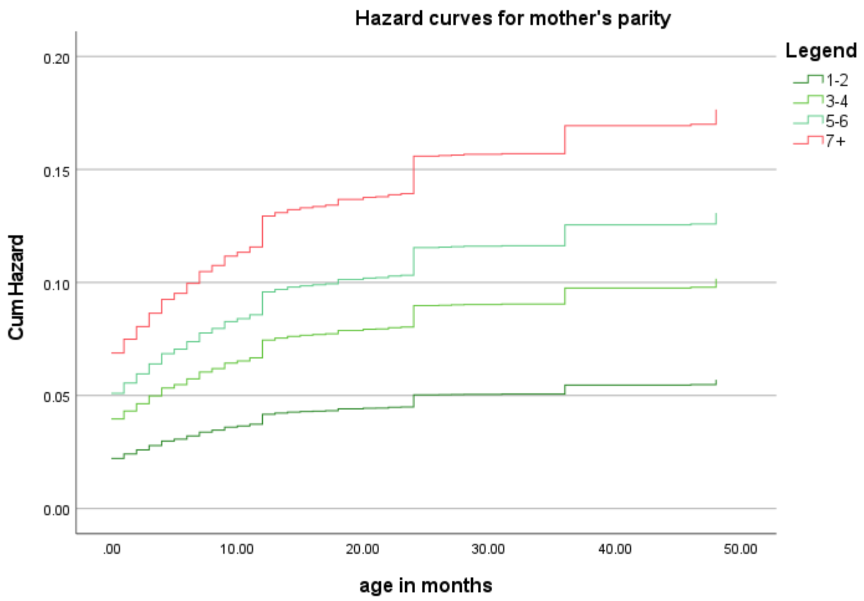

Figure 8: Hazard curves for parity of the mother

Source: Author's Construct (2021)

Table 13: A log-rank test for mother's parity

Variable	Mean estimate (*95% CI*)	Log Rank (Mantel-Cox)
Parity		46.48 **
1-2	54.93 (*54.47, 55.39*)	
3-4	54.46 (*53.97, 54.95*)	
5-6	53.58 (*52.92, 54.23*)	
7+	51.95 (*51.06, 52.84*)	

*** p-value < 0.01*

Figure 8 displays the survival probabilities of mother's parity across the four survey points. Survival probabilities were high among under-five children whose mothers have 1-2 children. Their survival time was higher (Mean=54.93, 95%CI (*54.47, 55.39*) compared to the other groups after conditioning for all contributors in the study. However, as the mother's parity increases, under-five children's survival probabilities decrease in response. Children whose mothers had a parity of more than 7 had the lowest survival probabilities (Mean= 51.95, 95% CI (*51.06, 52.84*) compared to others. The log-rank test indicated there was a significant difference between the various categories of mother's parity (X^2 = 46.48, p-value > 0.01)

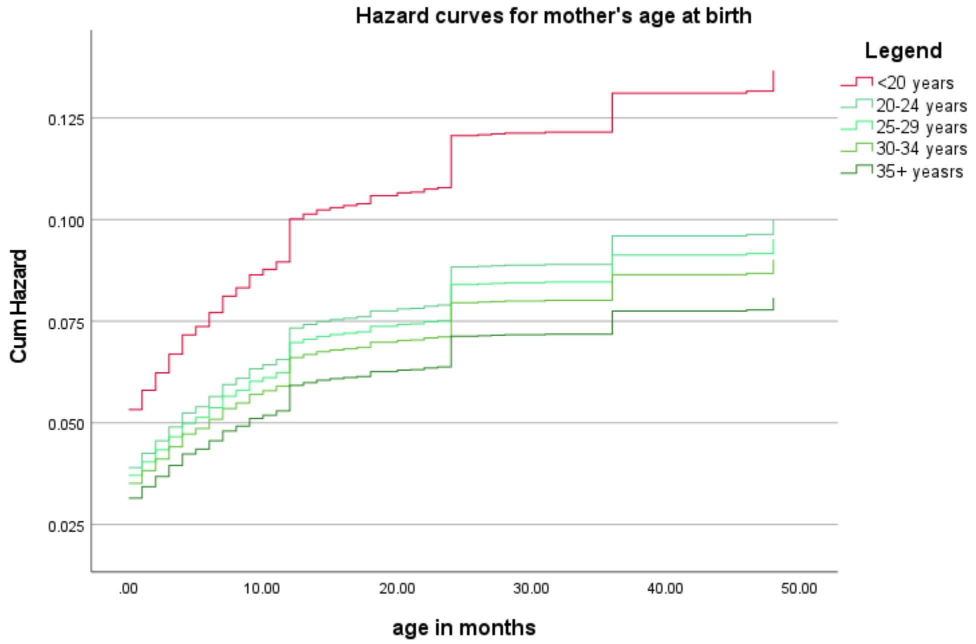

Figure 9: Hazard curves for mother's age at birth
Source: Author's Construct (2021)

Table 14: A log-rank test for mother's age at birth

Variable	Mean estimate (*95% CI*)	Log Rank (Mantel-Cox)
Parity		14.47 **
<20 years	52.75 (*51.72, 53.77*)	
20-24 years	54.60 (*54.05, 55.15*)	
25-29 yeas	54.46 (*53.91, 55.04*)	
30-34 years	53.96 (*53.32, 54.60*)	
35+ years	53.69 *(53.03, 54.35)*	

** *p-value < 0.01*

Figure 9 above shows that the hazard function was high for under-five children whose mothers were less than 20 years at birth compared to the other categories after accounting for all the variables. Children who belong to mother's whose age were less than 20 years had a shorter survival time (Mean = 52.75, 95% CI (*51.72, 53.77*). A child's risk of dying reduces with mother's age, for mothers who were aged 20-24 years (Mean = 54.60, 95% CI (*54.05, 55.15*) and 25-29 years (Mean = 54.46, 95% CI (*53.91, 55.04*). For mothers who were 30-34 years (Mean = 53.96, 95% CI (*53.32, 54.60*) and 35+ years (Mean = 53.69, 95% CI (*53.03, 54.35*), the survival time for their children were shorter compared to those whose mother were aged 20-24 years (Mean = 54.60, 95% CI (*54.05, 55.15*) and 25-29 years (Mean = 54.46, 95% CI (*53.91, 55.04*). The log-rank test indicated a statistically significant difference in the categories of mother's age at birth with regards to survival probabilities.

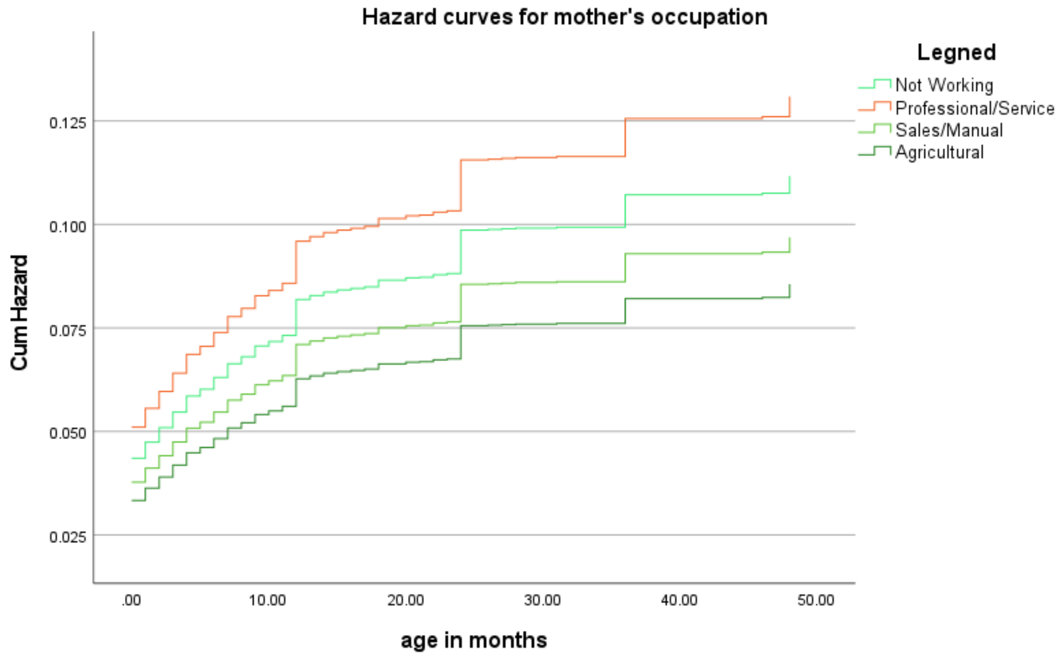

Figure 10: Hazard curves for mother's occupation

Source: Author's Construct (2021)

Table 15: A log-rank test for mother's occupation

Variable	Mean estimate (*95% CI*)	Log Rank (Mantel-Cox)
Parity		7.76 *
Not working	53.24 (*52.35, 54.14*)	
Profession/Service	53.95 (*52.76, 55.14*)	
Sales/Manual	54.48 (*54.05, 54.92*)	
Agricultural	53.92 (*53.47, 54.37*)	

* *p-value = 0.05*

Figure 10 shows that the hazard function was high for under-five children whose mothers' occupation was professional/service compared to the other occupational categories after accounting for all the variables. Hover from the log-rank test, Children who belong to mother's who were not working had a shorter survival time (Mean = 53.24, 95% CI (*52.35, 54.14*) compared children who belonged mothers in the professional/service (Mean =

53.95, 95% CI (52.76, 55.14). A child's survival time increases when mothers are engaged in some occupation rather than not working. Children belonging to mothers worked as a sale/manual worker had the highest survival time (Mean = 54.48, 95% CI (*54.05*, *54.92*) compared with the other occupational categories. Comparatively children with the lowest survival probabilities belonged mothers who worked in the agricultural sector. The log-rank test indicated a marginal statistical difference between the occupational categories of the mother (X^2 =7.76, p-value = 0.05).

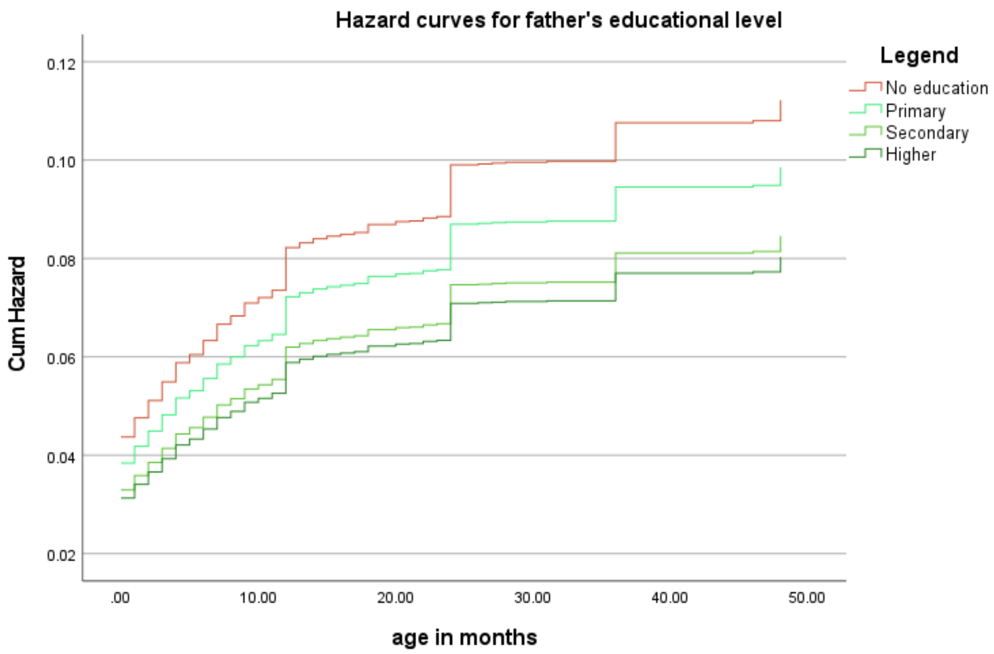

Figure 11: Hazard curves for father's educational level
Source: Author's Construct (2021)

Table 16: A log-rank test for father's educational level

Variable	Mean estimate (*95% CI*)	Log Rank (Mantel-Cox)
Parity		30.97 *8
No education	53.11 (*52.61*, *53.61*)	
Primary	53.84 (*52.88*, *54.80*)	
Secondary	54.81 (*54.41*, *55.20*)	
Higher	55.13 (*54.11*, *56.14*)	

* *p-value < 0.01*

Figure 11 demonstrates the cumulative survival distribution for fathers' educational level of sampled children from 1998 to 2014 across the various ages. From the figure, hazard was low among under-five children whose fathers had higher education compared to the other educational levels (figure 7). Children whose fathers had no education had a greater risk of dying compared to children whose fathers have received formal education. The log-rank test in Table 11 shows that the mean survival time was shorter for children whose fathers had no education (Mean = 53.11, 95% CI (*52.61, 53.6*) compared to those whose fathers had higher formal education (Mean= 55.13, 95% CI (*54.11, 56.14*). There was a statistical significance between the survival distribution of under-five children and their fathers' level of formal education.

CHAPTER FIVE

DISCUSSION OF FINDINGS

5.0 Introduction

This study examined the trends and ecological predictors of under-five mortality in Ghana, accounting for essential confounders and nesting at the community and district levels. The section discusses the study's findings concerning the existing literature on the predictors of under-five mortality. The findings show that mean temperature, malaria incidence, birth interval, maternal age, parity, maternal occupation, and father's educational attainment are significant y predictors of under-five mortality in Ghana.

5.1 Ecological Factors

Mean Temperature

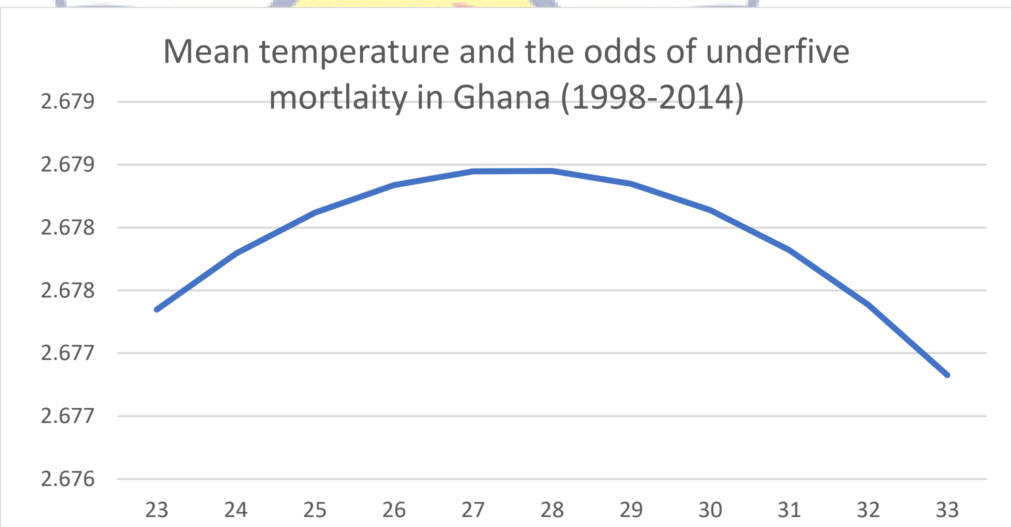

Figure 12: A line graph showing the distribution of mean temperature and odds of under-five mortality

Source: Author's construct (2021)

From figure 12 above, it can be observed that at lower mean temperatures, the odds of under-five mortality are low. However, as mean temperature increases, the odds of under-five mortality increase at lower rates.

The increase odds of under-five mortality reach a maximum when the mean temperature is between 27-28°C. Beyond these Temperature values, the odds of under-five mortality begin to fall. At a mean temperature of 33°C, the odds of under-five mortality reach its lowest level.

The mean temperature significantly predicted children dying before their fifth birthday. The significant relationship between mean temperature and under-five mortality in Ghana corroborates a study from Kenya (Sewe, Rocklöv, Williamson, Hamel, Nyaguara, Odhiambo & Laserson, 2015) that found a significant association between mean temperature and under-five mortality. This is due to the role of temperature in raising the outbreak of diseases such as malaria, acute respiratory infections and diarrhoeal infections (Kurane, 2010). For instance, "the mosquito vector *a gambiae* has been shown to increase at temperature extremes and a linear increase in vector abundance with increasing rainfall in the hot climatic area of Malindi, Kenya" (Sewe et al., 2015, p. 1991). Thus, a higher mean temperature increases the risk of exposure to certain diseases like Cerebrospinal Meningitis or disease vectors, thereby increasing their likelihood of dying before age five.

Annual Rainfall

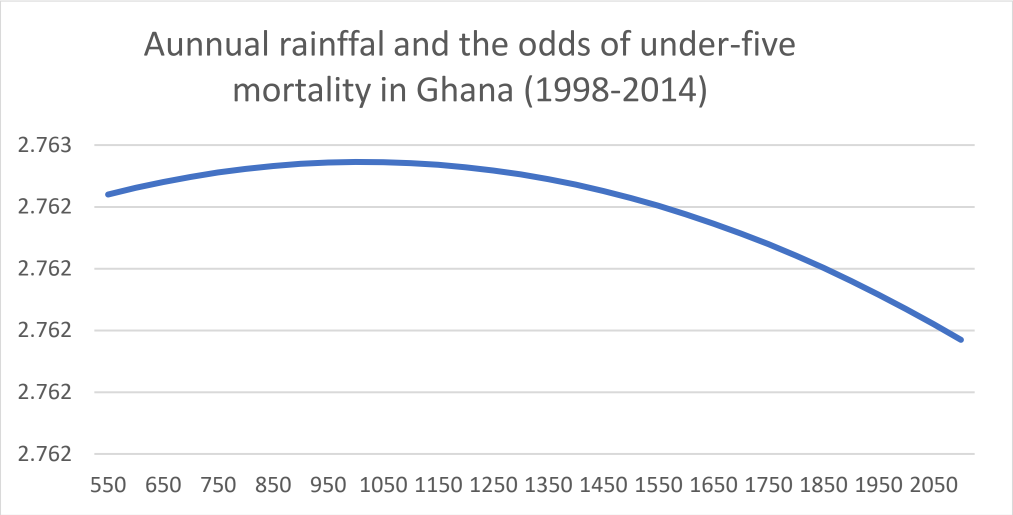

Figure 13: A line graph showing the distribution of annual rainfall and odds of under-five mortality

Source: Author's construct (2021)

Figure 13 above shows the annual rainfall values and their corresponding odds of under-five mortality. From the figure, it can be observed that the odds of under-five mortality are high when annual rainfall values are low. The odds of under-five mortality reach an optimal level when annual rainfall values are between 950mm -1050mm. An increase in rainfall values corresponds to a reduction in the odds of under-five mortality.

Annual rainfall was significantly associated with under-five mortality—the impact of rainfall on children's health and, consequently, under-five mortality work in various ways. Reduced rainfall is linked to low crop yield in many developing countries (Kyei-Mensah, Kyerematen, & Adu-Acheampong, 2019). This reduction in crop yields directly influences children's nutritional status, identified as a proximate determinant of under-five mortality. Reduced rainfall is also significantly associated with disease infections, particularly in areas where they rely on unimproved water sources for their domestic activities (Anyamba et al., 2019). Reduced rainfall means water scarcity, and households are more likely to depend on unclean water for drinking and cooking. This unhygienic water contains disease-causing organisms which are likely to infect children. Research findings from Mukabutera et al. (2016) in Rwanda concur with the findings of this study.

The findings of ecological factors give an indication of the impact of the external environment which these children lives. The finding fits with the conceptual framework as a higher-level variable that impact on other factors to indirectly influence under-five mortality. A direct relationship is established as ecological factors influences under-five mortality.

5.2 Socio-ecological Factors

The results from the analysis show that malaria incidence, global human footprint and ITN coverage significantly predicted under-five mortality in Models 3 and 4; however, in the final Model, only malaria incidence was significant in predicting under-five mortality. This finding corroborates a study conducted in the rural Gambia that revealed that malaria incidence and diarrhoeal disease were responsible for about 58 percent of under-five mortality (Jasseh, Howie, Gomez, Scott, Roca, Cham & D'alessandro, 2014). The insignificance of ITN coverage and global human footprint in the final Model was because of the high collinearity between ecological variables included in the study. The findings imply that under-five mortality attributable to malaria is because of the low coverage of the insecticide-treated nets. As such, there is the need for Ghana to invest in the scale-up of malaria vaccination and control programmes (e.g., indoor residual spraying) to expedite the process towards attaining the target of the Sustainable

Development Goals (i.e., reducing under-5 mortality to 25 per 1000 live births by 2030) (You et al., 2015).

5.3 Method comparison (Multilevel logistic regression and Survival analysis)

The two statistical models used for the study had different results concerning the primary and confounding factors. However, the pattern of the associative effect was in the same direction for both models. The effect size generated from the two statistical models was slightly different for the two models. The multilevel logistic regression assumed a hierarchical structure in the dataset. The multilevel logistic regression was used to identify the nesting of under-five mortality across the various hierarchical structures inherent in the dataset. The survival analysis examined the time it took for children born around the same period to die. The survival analysis considers the death of under-five children as an event stretching through time. Exposure before death must be considered when dealing with mortality.

The primary variables significantly associated with under-five mortality differed among the two statistical models. For the multilevel logistic regression, only mean temperature (environmental) and malaria incidence (socio-ecological) were significantly associated with under-five mortality. However, for the survival analysis, the significant variables associated with under-five mortality differed from the multilevel logistic regression. In the survival analysis, annual rainfall, mean temperature (environmental) and malaria incidence (socio-ecological) were the significant variables associated with under-five mortality.

For the confounding variables, the variables identified to be significant for the two models were slightly different. In the multilevel logistic regression, the statistically significant variables that were associated with under-five mortality included birth interval (immediate), parity, mother's occupation (intermediate) and father's educational level (proximate). For the survival analysis, all the variables that were significant for the multilevel logistic regression were the same except for the mother's age at birth which was the additional significant variable to the survival analysis.

Cox proportional hazard and binary logistic regression have extensive been used and compared in the areas of their parametric estimates. There is much difference when Cox proportional hazard and binary logistic regression are used to identify risk factors (George, Seals, & Aban 2014). However, the findings from the study do not conform to what was said by (Wang, Brown, An, Yang & Ligmann-Zielinska, 2013) as the factors identified were slightly different with different parametric estimates.

Based on the findings from the study, the researcher selected the cox proportional hazard regression as a better statistical model when used to study under-five mortality. This is because the Cox proportional hazard regression offers more information about under-five mortality than whether or not the mortality occurred, as in the case of the multilevel logistic regression (George, Seals, & Aban 2014). Another imperative reason a survival analysis outperforms a multilevel logistic regression is that the survival analysis has a greater statistical power to detect a significant exposure effect than methods of a binary outcome (Staley, Jones, Kaptoge, Butterworth, Sweeting, Wood & Howson, 2017). Furthermore, through the literature, survival analysis has been opined to outperform logistic regression (Wang, Brown, An, Yang & Ligmann-Zielinska, 2013).

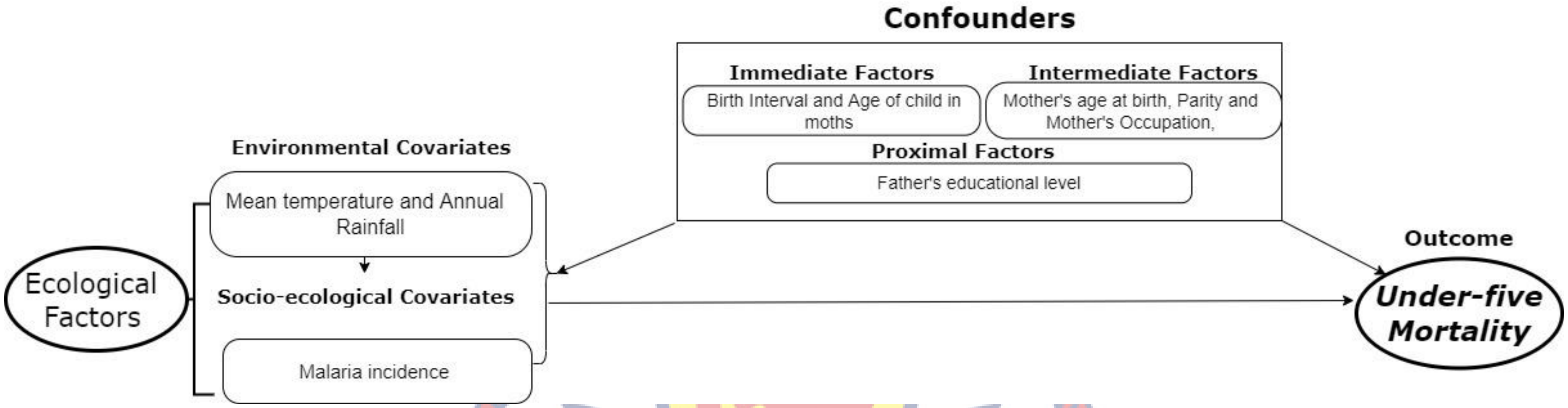

Figure 14: Conceptualisation of study findings

Source: Author's construct (2021)

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

The present study investigated the ecological factors associated with under-five in Ghana, accounting for essential confounders and nesting at the community and district levels. Specifically, this study aimed to examine (a) trends in under-five mortality, (b) the ecological factors (environmental and socio-ecological factors) associated with under-five mortality; and (c) how much of the variability in under-five mortality at the community and district levels is explained by the ecological factors (environmental and social).

The data used in the study were derived from the Ghana Demographic and Health Survey dataset (1998-2014), Demographic and Health Survey Geospatial Covariates (1998-2014) and the Land Cover Climate Change Initiative dataset (1992-2015). Regarding the analyses, a multilevel and cox hazard proportional regression was used. The corresponding 95% confidence intervals were used to determine the significance of both ecological and confounders in the study. Highlights of the key findings, conclusions and recommendations are presented in this chapter.

6.1 Summary of Key Findings

It was found that children sampled from 1998, 2003, and 2008 had a significantly lower likelihood of dying before age five than those sampled in the 2014 GDHS.

6.1.1 Ecological factors associated with under-five mortality

The result suggests that environmental and social factors predict under-five mortality in Ghana. For both analysis methods (multilevel logistic regression and survival analysis), mean temperature and malaria incidence were observed as the statistically significant ecological factors associated with under-five mortality in Ghana.

Results from the multilevel logistic regression indicated that mean temperature and malaria incidence were significantly associated with under-five mortality. The results from the survival analysis indicated that annual rainfall, mean temperature and malaria incidence were significant ecological factors that explained the variability in the likelihood of children dying. The result showed that higher mean temperature and malaria incidence were associated with a significantly higher likelihood of death of a child before their fifth birthday. Variability in annual rainfall also significantly explained the disparities in under-five mortality.

This study also showed that under-five mortality in Ghana was predicted by environmental and socio-ecological factors and confounded by other controlled factors. The ecological factors (temperature, rainfall and malaria incidence) had a significant association with under-five mortality after accounting for immediate (birth interval), intermediate (mother's age at birth, parity and mother's occupation) and proximal factors (father's education) in the model. The study confirmed previous studies that showed that birth interval strongly predicted the risk of under-five mortality in Ghana. A shorter birth interval emerged as a critical immediate factor that predicted under-five mortality. The present study also corroborated extant studies that found mothers with lower age at birth, higher parity, maternal occupation, and low educational attainment of the father significantly associated with the odds of under-five mortality in Ghana.

6.1.2 Variability explained at the community and district level

The analysis showed significant differences in under-five mortality at the community and district levels without accounting for any covariates. This indicates whist some communities and districts have low under-five mortality; others have substantially high levels of under-five mortality. The Intraclass Correlation Coefficient (ICC) from the null model indicated that 71.6 and 28.4 percent of the variation in under-five mortality was attributable to the differences at the district and community levels, respectively.

Nesting of under-five mortality at the district level became statistically insignificant after accounting for the environmental factors in the model. The environmental factor (mean temperature and malaria incidence) explained 22.4 percent of the variability at the district level. This indicates that differences in ecological factors among districts contribute to some differences in under-five mortality at the district level.

Regarding nesting of under-five mortality at the community level, the immediate factors explained 22.1 percent of the variability in under-five mortality. This means that the nesting of under-five mortality at the community level could be explained by the immediate factors of children in these communities

6.2 Conclusion

In the survival analysis, the ecological (environmental and social) predictors statistically significantly associated with under-five mortality after accounting for trend and significant confounders were malaria incidence, annual rainfall and mean temperature. However, only the mean temperature and malaria incidence were significantly associated with under-five mortality after accounting for trends and confounders for the multilevel logistic regression.

Inferring from the study's findings, environmental and social factors are principal factors in predicting under-five mortality. The study underscores the importance of always considering the environmental and social factors in understanding the predictors of under-mortality in Ghana. Furthermore, the findings can potentially inform local and country-scale interventions to attenuate temperature-related under-five mortality. Besides the environmental and social factors, the study concludes that under-five mortality in Ghana is confounded by birth interval, maternal age, parity, maternal occupation, and educational attainment of the father. Thus, environmental, social, immediate, intermediate and proximal factors should be considered in determining the best predictors of under-five mortality in Ghana.

The study contributions to the Mosley and Chen (1984) analytical framework by indicating that association between rainfall, mean temperature, malaria incidence and under-five mortality. The findings from the study revealed that the external factors are significant associated with under-five mortality. this evidence serves as an addition to the theory.

6.3 Recommendations

Based on the findings of this study, the following recommendations are suggested for policy, practice and research:

1. The ministry of Health and the Ghana Health Service strengthen it campaign of insecticide treated nets should reduce under-five mortality.

2. Ghana Health service through health education programmes should educate mothers on insecticide-treated nets to increase usages.
3. Ghana Health service and the Ministry of Health should strengthen health programmes communities and districts with mean temperature with values of 27-28^{o}C.
4. Health programmes should target communities and district with annual rainfall values between 950mm-1050mm. This recommendation will be carried out by the Ministry of Health and Ghana Health Service.
5. The study recommends the Ministry of Health and Ghana Health Service that health intervention programmes target under-five mortality, given the viability of cases between communities and districts. Communities and districts with a high under-five mortality should be targeted

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