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Rainfall Variation and Food Security in Malawi

A Panel Data Study with Valuable Insights from the Field

Abstract

This study addresses the question of how climate variability, in terms of seasonal rainfall variation, might affect food security in Malawi. It hypothesizes that seasonal rainfall variation could cause food insecurity and that the consequences of weather hazards possibly differ within the country. An additional aim of this study is therefore to map local resilience in Malawi to estimate the adaptation ability by analyzing two subsamples. The hypothesis is tested by using a two-way fixed effect regression analysis and panel data for 28 districts in Malawi covering the years 2000, 2004, 2010 and 2015. This study finds no statistically significant effect of seasonal rainfall variation on children's health for the examined years.

Keywords: Food Security, Consumption Smoothing, Adaptation, Resilience, Climate Change

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List of Abbreviations

FAO Food and Agriculture Organization of the United Nations

DCCMS The Department of Climate Change and Meteorological Services

DHS Demographic and Health Surveys

IPCC Intergovernmental Panel on Climate Change

ITCZ Intertropical Convergence Zone

NAP National Adaptation Program

MDHS Malawi Demographic and Health Surveys

MET Meteorological station

MFS Minor Field Study

MVAC Malawi Vulnerability Assessment Committee

SIDA Swedish International Development Cooperation Agency

UNDP United Nations Development Program

USAID United States Agency for International Development

WFP World Food Program

WHO World Health Organization of the United Nations

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1. Introduction

Food security in Malawi is an outstanding policy issue, widely visible and recognized. The Malawian government reports on increased vulnerability for households due to insufficient resilience to socioeconomic and climate related shocks (Sahley et al. 2005). In year 2010, 71.4 % of the population lived below the international poverty line[1] and did not manage to buy or harvest enough food for their family (World Bank, 2018).

Climate change and food security are major global issues affecting people worldwide, in particular those living in the countryside of low-income countries like Malawi where 83.55 % of the population lives in rural areas (World Bank, 2018). There is a vibrant debate on how to enable the vision of a food secure planet and supply the world population with nutrients and food enough to avoid famine and starvation. There is also an explicit need to understand and combat the severe issues of climate change and its consequences (IPCC, 2018). A deeper understanding of global adaptation ability to climate change, which varies widely across the world but also within countries, is crucial to find sustainable solutions and make improved political and economic decisions. How people respond to income variation caused by exogenous shocks, like climate related events, is an attractive insight from an economic perspective. Malawi is very often used as an example of a vulnerable country in need of increased capacity building. During COP21 in Paris 2015, the Malawian government shared experiences from climate change adaptation and contributed to the discussion on adaptation financing in low-income countries. Tawonga Mbale, Acting Director of the Department of Environmental Affairs in Malawi, highlighted the challenges with the current weakness in adaptation monitoring (UNDP, 2015).

This study estimates the effect of irregular precipitation on health status for children below age five in Malawi. The primary purpose is to analyze how vulnerable the population in Malawi is to climatic variability, in terms of rainfall variation. Furthermore, the study searches answers to if resilience differ within the country and how climate change might affect food security.

[1] In terms of 2011 purchasing power parity, which equalizes its purchasing power across all currencies and countries, the current international poverty line is valued at $1.90 (World Bank, 2018).

The main question of interest for this study is: *How does seasonal rainfall variation affect health status for children below the age of five in Malawi?*

The additional objective is: *How does seasonal rainfall variation affect health status for children below the age of five to mothers who are 1) low educated 2) underweight?*

To estimate the effect of seasonal rainfall variation on health status for children below age five in Malawi this study uses longitudinal data for the 28 districts in Malawi covering the years 2000, 2004, 2010 and 2015. The time period is limited due to accessibility of the Demographic and Health Surveys conducted periodically in Malawi. The regression analysis includes district fixed effects and time fixed effects to evaluate the question of interest. Furthermore, the additional objective is analyzed through two subsamples with the same 28 districts as entities and the same four years using district fixed effects and time fixed effects for the regression analysis. The subsamples are defined through two restrictions. The first one is the education level of the mother and the second one is the weight of the mother.

This study is aiming to contribute with deeper understanding of the empirical relation between climate variability and food security in Malawi. The results are partially in line with previous research, especially on precipitation in Malawi where significant results from analyzing seasonal rainfall variation are unusual (Ngongondo et. al, 2014). This study concludes that more research on how rainfall variation and weather hazards can affect vulnerability and capacity building in Malawi needs to be prioritized. It is of importance not only to reduce extreme poverty and sustain food security but also for the economic and political development of the country as well as an example in the worldwide debate on climate change and adaptation.

This study contains six main sections and begins with an introduction to the background and the foundation of the theoretical framework which leads to the examined hypotheses. The method is presented in section three followed by the data description and the econometric approach. Section four presents the results along with the interpretation and the results are further discussed and analyzed in section five. Section six concludes the findings of this study.

2. Theoretical Framework

This section begins with a brief introduction to Malawi as a country but also its unique situation which explains why it is an interesting example for this study in particular. Furthermore, it places the hypothesis of this study into a defined context. It continues with a selection of studies on vulnerability, risk mitigation and consumption patterns in low-income countries like Malawi. The theories presented in this section define the baseline of the framework for this study and the continued analysis.

2.1 Background

Malawi is a peaceful country in south-eastern Africa with borders to Tanzania, Zambia and Mozambique. The country has no shoreline but the third largest lake in Africa, Lake Malawi, and an approximate population of 18 million people (World Bank, 2018). The normal growing season is meteorologically defined as November to April (Ngongondo et al. 2014). This places Malawi in a vulnerable position being a densely populated low-income country in sub-Saharan Africa dependent on only one rainy season and therefore only one major harvest per year. The geographical situation for Malawi is further characterized by limited farmable land. Malawi is unique due to this single period of precipitation compared to other countries with similar fundamental conditions in terms of demography and land area. This illustrates that Malawi is an interesting country for this study in particular. Most equatorial countries in east Africa experience a bimodal seasonal distribution of rainfall (S. E. Nicholson, et. al, 2014). Despite the lack of agricultural area, the majority of Malawians still operate as small-scale farmers and more than 80 % of the population still lives in the rural parts of Malawi, working within the agricultural sector (FAO, 2014).

The agricultural sector in Malawi is widespread and mainly rain-fed. Out of all land area in Malawi, 61.41 % is agriculture land (Trading Economics, 2018). The agriculture land in Malawi is measured to 5 580 000 hectare and the irrigated area to 29 000 hectares. This shows how very reliant Malawi is on dependable rainfall when only roughly 0.5 % of the agriculture land area is irrigated. The main weather hazards that affect rain-fed agriculture negatively are late onset of rains, erratic rainfall, long-lasting dry spells and floods (Ngongondo et al. 2014). Malawi has during recent years experienced all of them in different ways (Vincent et al. 2014).

The primary aim of this study is to analyze the complex relation between food security and climate change. Recent studies of Malawi show that the number of vulnerable households, in terms of food security, has increased (MVAC, 2017). Strong political and economic incentives affecting this topic came to light during COP21 in Paris 2015 where an urgent need of mapping local resilience to enable good decisions and implementation of climate change adaptation and investments was drafted. Due to the general perception that climate change causes severe consequences in Malawi there is a need to understand underlying facts and data to capture and evaluate the actual impact climatic variation has for the country and its population, especially among the most vulnerable.

In Malawi, the seasonal rainfall depends primarily on two factors whereby the first one is the position of the Intertropical Convergence Zone, ITCZ, and the second one is the Indian Ocean Sea Surface Temperatures (UNDP, 2006). There are two main rain-bearing systems, the ITCZ itself and the Northwest Monsoon which consist of tropical Atlantic air that through the Congo Basin reaches Malawi (Ngongondo et al. 2011). All mentioned systems vary in timing and intensity from year to year. Previous findings from studies with longer time spectrum are also able to take these systems into account show that rainfall onset and cessation tend to delay seasonally over Malawi (Ngongondo et al. 2014) but the growing season period seems to be left without significant changes. The annual average of rainfall varies from 725 to 2500 millimeters across the country (Ngongondo et al. 2014). The geographical conditions of Malawi are dominated by the Great Rift Valley and Lake Malawi which results in a highly variable topography (UNDP, 2006). These fundamental geographical factors create varying conditions for capacity building and adaptation within the country. Since the majority of the population in Malawi sustain from small-scale fields it is of great importance that farmers can access more drought resistant crops through means but also new skills and knowledge. Investing time and money in diversifying the crops is a way for the small-scale farmers to reduce the idiosyncratic risk they are facing when the climate is changing.

2.2 Rainfall Variation and Climate Variability

The concept of climate change is often separated into the two branches, mitigation and adaptation. This study will mainly focus on the fraction of adaptation measures and vulnerability to climate change. According to IPCC (2012) there are three main factors evaluated when estimating vulnerability to climate change and disrupted weather patterns. The first one is exposure to hazards, the second one is sensitivity to those hazards and the third one is capacity to adapt to those hazards. Putting this into the Malawian context it is clear that the rainfall variation is fulfilling the first criteria of exposure to hazards. Secondly, Malawi has an economy dominated and dependent by mainly rain-fed agriculture whereby sensitivity to the hazard is obvious. When evaluating the capacity to adapt to hazards multiple other factors are measured and included. The concept of capacity building has followed the research on responses to climate change and how vulnerability can be reduced (NASA, 2018). The focus of this study is in line with the theory on the ability of households to smooth consumption between two time periods to avoid a state of being liquidity constraint. One example that clearly shows the importance of rain for Malawi is the dependence on maize as staple food (Minot, 2010). The variation in precipitation influences the harvest which in turn determines how food secure that year will be for the households. This relation underlies the purpose and design of this study and is described in Figure 1. Food security is defined by vulnerability which is measured by several indicators for health status of children below the age of five. Within the framework of this study, the box of harvest in Figure 1 could also be replaced with another intermediate factor since reduced form estimates are being used.

Figure 1 - simplified illustration of the relation between climate variability and vulnerability including the intermediate variable which can vary with location and other prerequisites.

This study relies upon the IPCC definition of extreme weather events. Extreme weather events can, by this definition, vary depend on location but are mainly characterized by being an exception for the time of the year and the location of interest. The event is named rare, but that definition may also vary though it is mostly in line with, above or below the 90th or 10th percentile of a probability density function that is estimated from actual observations (IPCC, 2005). If the pattern with rare events continue over a longer period of time, for example a season, the definition *extreme climate event* could be applied. The definition of adaptation demarcate how we adjust our way of living with regards to the contemporary or anticipated future climate (NASA, 2018). NASA’s definition points out that reducing severe consequences of climate change, like extreme weather and food insecurity, is the goal with adaptation. It also emphasizes that maximization of the opportunities from climate change that might be advantageous is important to succeed with the adaptation process.

2.3 Vulnerability and Risk Mitigation in Malawi

Imagine Malawi as a well-functioning economy with effective market structures. That perfect picture could potentially tell the story of no households vulnerable to transitory income shocks. In this case, idiosyncratic risk would be diversified away leaving no impact on consumption levels. Poor households would be able to borrow against future income to smooth consumption. This is a basic assumption presented by Jonathan Morduch in his study of poverty and vulnerability (Morduch 1994) which still today applies to the situation in Malawi. Morduch continues by describing how decreased health status and food security in relation to idiosyncratic and covariate shocks may be considered as part of an expanded concept of poverty. In addition to that the availability of mechanisms that households use to smooth consumption is of importance to mention. One main argument Morduch emphasizes is that the lack of insurance in many cases could intensify the poverty problem. Since it is challenging to forecast idiosyncratic risk, the solution to reduce it will mainly be through diversifying. In Malawi this is not always possible due to the geographical prerequisites where one major season of rain is determining whether the harvest will be successful in terms of food supply, or if it will be insufficient and therefore lead to a large deficit.

In low-income countries, like Malawi, the conceivable demand for insurances and credits is probably high (Morduch 1995). Due to the dependency of agriculture the incomes in Malawi are on average low and usually volatile. Disrupted weather patterns could therefore easily conduce into income shocks, primarily faced by farm households but also experienced nationwide since food prices also alter rapidly. When households loses the opportunity to borrow or insure against the interlinked income fluctuations there is high chance that body size will become suffering (Morduch 1995). Another consequence these exogenous events might lead to is that children drop out of school which leads to low human capital (Morduch 1995) and in the longer perspective affect the socioeconomic situation for households.

According to Binswanger & Rosenzweig (1993) the vulnerable households will potentially shift production to more traditional, but less profitable, activities when the environment becomes riskier. Since the rainfall timing is so important for these households it can be strategic to postpone projected investments until more information about the expected weather conditions is available (Binswanger & Rosenzweig, 1993). This cautious way of acting could improve the income smoothing of the household but can also increase the economic burden in terms of reduced yields due to delaying the onset of production. A common method of reducing the impact of weather shocks is among the most vulnerable households to diversify plots. This is something many progressive farmers in Malawi are investigating. Maize is still the traditionally staple food but more drought resistant crops like cassava and sweet potato are in high demand.

One significant challenge with the theoretical framework of income and consumption smoothing is that they are both complicated to distinguish. In a scenario where insurance or credit mechanisms are completely absent, all income will equal consumption and the tradeoff between risk aversion and maximization of the anticipated profit will translate into the choice of production (Morduch, 1995).

This study is focusing on food security in terms of the internationally recognized definition from USAID in 1995 saying that food security consists of three elements which are food availability, access to food and utilization of food (Sahley et al. 2005). These elements clearly illustrate the issue Malawi is facing in terms of food deficit and the definition is therefore applicable for the objectives of this study.

2.4 Previous Research

The literature review for this study has focused primarily on studies of rainfall variation in Malawi that tangent the theories presented in 2.2 Rainfall Variation and Climate Variability. This is because understanding of the weather variability together with the theoretical framework is key to the further analysis but also to defining of the model itself and computing the variable for rainfall. The general consensus from evaluating meteorological and geographical studies is that the total amount of seasonal precipitation is constant but the intensity over the days is changing (Ngongondo et al. 2011). Findings from several studies with longer time spectrum show that rainfall onset and cessation tend to delay seasonally over Malawi (Ngongondo et al. 2014) but the growing season period seems to be left without significant changes. The growing season of Mimosa station[2] in Mulanje district lasted 204 days while stations in the Lower Shire areas experienced the shortest growing seasons with 85 days on average. Bolero station in the north reported the shortest growing season of all northern stations with an average of 88 days. The same study by Ngongondo is highlighting that average total precipitation on regional level is reported to have decreased over Malawi, nevertheless with no significant results in general which makes it difficult to draw conclusions with economic significance but there is still an implication of relevance which will be further discussed in this study.

Kumbuyo et al. (2015) carried out a study on inter-annual rainfall fluctuation in Malawi where they found that geographical location and topography are both key factors in the distribution of precipitation and they also concluded that rainfall is seasonal to a large extent. Many similar studies have been conducted all around the world and significant variations of precipitation in

[2] For all 73 Meteorological stations and their locations see appendix 2.

Southern Africa, especially during recent decades, have been found (Fauchereau et al. 2003). Fauchereau et al. presents a study where they find that inter-annual rainfall variation has been increasing since the end of 1960 and the trend is moving more rapidly during recent years. The major consequences from this climatic variability that Fachereau et al. finds are expansive and intensified droughts.

There is an outspoken lack of well updated and straightforward studies on the relation between climate change and food security in Malawi and previous research demand new methodology to be used and new perspectives to be applied **(**Ngongondo et al. 2011**)**. This study is trying to initiate bridging of that gap and emphasize further research exploring new methodologies for deeper understanding by examining the topic from an economic perspective using longitudinal data for the regression analysis. Ngongondo et al. emphasizes further in their study 2014 that there is a need of establishing how the changes in onset and cessation in Malawi might correlate with climate change policy implementation on all levels to enable addressing of this question properly. This is also closely related to capacity building within the adaptation process of the country. Hence, this study also estimates the effect of delayed onset and cessation on the dependent variables of interest for the research objectives. Kumbuyo et al. (2015) concludes their study by stating that due to the dependency on regular precipitation for the rain-fed agriculture in Malawi, the strong seasonality in rainfall presented in their study should be highly considered when the water resources management system is structured and monitored.

3. Method

This section describes the way this study has been carried out together with necessary delimitations followed by a presentation of the data used for the analysis and descriptive statistics. Furthermore, the econometric approach is defined together with the regression model.

The foundation for this study was set during eight weeks of field work in Malawi in April and May 2018, enabled by a Minor Field Study grant from the Swedish International Development Cooperation Agency. It is an empirical study where regression analysis is used to analyze potential underlying causal effects. The study evaluates the hypothesis that climate variability leads to food insecurity in Malawi. Climate variability is measured by seasonal rainfall variation and food insecurity by three health indicators for children below the age of five. The hypothesis is tested by using a two-way fixed effect regression analysis and panel data for 28 districts in Malawi covering the years 2000, 2004, 2010 and 2015. Furthermore, the study investigates if there exist differences in climate change adaptation within the country with the aim to map local resilience in Malawi to better understand vulnerability and food security. To do so, the study focuses on two subsamples. The first one restricted to children with low-educated mothers and the second one to children with mothers who are underweight.

The aim and objectives of this study, within the theoretical framework and context introduced, results in the hypotheses presented below. The hypotheses will be tested with panel data regression in the estimated regression model. The findings from this study will determine if it is possible to reject $\beta_1 = 0$ and thereby confirm the possible causality between seasonal rainfall variation and children's health status in Malawi for the examined years.

$\beta_1 = 0 \rightarrow$ *does not support the theory that seasonal rainfall variation affects children's health status and could therefore cause food insecurity in Malawi.*

$\beta_1 \neq 0 \rightarrow$ *supports the theory that seasonal rainfall variation affects children's health status and could therefore cause food insecurity in Malawi.*

3.1 Data

The rainfall data for this study was kindly provided by the Malawi Department of Climate Change and Meteorological Services. The health data for children and women was downloaded from the online DHS data bank provided by the United States Agency for International Development. The study uses four different Malawi DHS datasets covering year 2000, 2004, 2010 and 2015.

This study uses reduced form estimates to analyze the effect of rain on children's health. It conceptualizes a model consisting of the independent variable rainfall variation for which we have data, the unknown variable which is affected by variation in rainfall and the dependent variable measuring children’s health in Malawi. This relation is simplified and illustrated in Figure 1. The principal aim is to find whether there is an effect or not within this framework. Since the data for the intermediate variable is unknown this study will focus primarily on the regression model with rainfall as independent variable and then narrow it down into subsamples to establish if large effects can be excluded and furthermore if moderate effects can be found when focusing on smaller groups.

The subsamples are derived from the concept of vulnerability since this study focuses on mapping local resilience and ability to adaptation within Malawi. Hence, there are two main subsamples this study examines. Firstly, the regression model is restricted to children from mothers with low education and secondly the regression model is restricted to children from mothers who are underweight. There is an evident pattern showing that children to mothers with low or none education face a higher risk of suffering from malnutrition. This is stated in all MDHS reports for the years evaluated in this study. Secondly, the mother’s weight is used to restrict the subsample since food insecurity might also affect adults and women in particular.

Three main dependent variables are used to estimate food security and vulnerability, all frequently used by well known organizations within global health and designed to report worldwide nutrition status of children according to international standards (Onis and Blössner, 1997). The three variables height-for-age, weight-for-height and weight-for-age are presented in Table 1. Height-for-age is used to measure stunting which is a sign of long-term chronic malnutrition. Weight-for-age indicates wasting which is defined as acute malnutrition. Weight-for-height describes current nutritional status via a composite index of the two other variables mentioned and is defined by the WHO's Child Growth Standards (Onis and Blössner, 1997). Since the rainfall variable estimating climate variability in the analysis of this study is computed with one-time lag only, the variable of primarily interest will be weight-for-age which measures acute malnutrition. This is based on the assumption that the effect of rainfall variation and the intermediate variable yields or harvest will first be visible in consequences of acute malnutrition. The other two dependent variables, weight-for-height and height-for-age, are used as complements for the analysis of sudden weather hazards but also slower changes over time.

The World Health Organization uses three main systems to compare the health status of children to a reference population of interest (Onis and Blössner, 1997). These three systems are percentiles, percent of median and Z-scores (SD scores). This study uses the first system and the dependent variable is therefore presented in Z-scores[3] (SD scores) which is an internationally acknowledged mode of measurement and according to WHO themselves the most reliable system for further analysis. The scale for Z-scores is linear which means that the statistical relation between the Z-score and the reference distribution around the mean is consistent at all ages. The advantage of this is that results are comparable across indicators and age groups. Thanks to these attributes, a calculation of summary statistics can be enabled and the growth and health status of the children in the population is possible to classify (Onis and Blössner, 1997). All variables used in this study are presented in Table 1 with further description, unit and source of origin.

This study uses an unbalanced panel due to four missing years of observations from MDHS. The district Neno was created as a branch from Mwanza district in 2003 under a decentralization program and is therefore missing values for year 2000 and 2004. The district Likoma has gaps for year 2000 and 2010. Since the reason behind these missing observations most likely is unrelated to rainfall variation these districts are accepted in the final data panel and the regression analysis is performed with the unbalanced panel.

[3] Z-scores are calculated by dividing the deviation of the individual's value from the median value of the reference population of interest with the standard deviation of the same reference population (Onis and Blössner, 1997).

Table 1. Variables used in the regression analysis with description, unit and source.

Variable	**Description**	**Unit**	**Source**
rainfall	Seasonal rainfall	mm	DCCMS
lnrain	Log of seasonal rainfall	mm	DCCMS
onset	Start of rain season, Nov.	mm	DCCMS
cessation	End of rain season, Apr.	mm	DCCMS
drought	1 st.dev < mean	mm	DCCMS
floods	1 st.dev > mean	mm	DCCMS
hfa	Height-for-age	Z-scores	MDHS USAID
wfa	Weight-for-age	Z-scores	MDHS USAID
wfh	Weight-for-height	Z-scores	MDHS USAID

This study uses data of inter-annual rainfall, provided by the DCCMS, to model the variable for climate variability and establish the potential impact on children's health status in Malawi. Multiple ways of using the rainfall data have been evaluated and the main analysis is using logarithmic seasonal rainfall for the years of interest with a time lag effect of one year. The seasons used are therefore 1999/00, 2003/04, 2009/10 and 2014/15. The variables for drought and floods are dummy variables and computed as one standard deviation above or below the mean value of seasonal rainfall for the given year and district.

3.2 Descriptive Statistics

In Table 2, the descriptive statistics of each variable is presented including the number of observations, mean, standard deviation, minimum and maximum value. To ease the interpretation of the regression analysis the main variables used in the model are market bold in Table 2. The full, appended, dataset with all four years of MDSH was merged with the cleaned and sorted rainfall data. The number of observations differ among the variables and this is because all individuals, also the respondent, are kept in the final panel to enable restriction for the subsample analysis. However, for the three dependent variables of interest, missing values and extreme values are excluded to enable more precise results and avoid biased estimates.

Table 2. Descriptive statistics of all the variables used in the regression model.

Variable	Obs	Mean	Std.Dev	Min	Max
lnrain	214 701	6.820987	0.2250044	6.255366	7.410105
rainfall	214 701	934.7977	219.4359	520.8	1652.6
onset	214 701	47.29264	36.951	0	162.73
cessation	214 701	72.56733	54.8071	3.5	428.2
drought	214 701	0.2390254	0.4264893	0	1
floods	214 701	0.2905902	0.4540358	0	1
Height-for-age	26 858	-169.1236	154.499	-600	595
Weight-for-age	26 858	-105.2081	120.1896	-566	600
Weight-for-height	26 877	0.3668564	119.5074	-400	590

3.3 Econometric Specification

The hypothesis that seasonal rainfall variation is causing food insecurity in Malawi is tested by using a two-way fixed effect regression analysis and panel data for 28 districts in Malawi covering the years 2000, 2004, 2010 and 2015. The primarily dependent variables are height-for-age, weight-for-age and height-for-wage and the independent variable is the logarithmic of rainfall, seasonal average rainfall in millimeters. Various independent variables have been investigated (see Table 1) but the natural logarithm of rainfall variation proved to most suitable for the estimated model allowing to use the lin-log system. Based on visits in the field and previous research the estimated model uses district fixed effects and time fixed effects in order to isolate the effect of rainfall on children's health. This study uses the district fixed effects and time fixed effects as controls for omitted factors to evaluate the true effect of seasonal rainfall variation on children's health status in Malawi. The dummy variables drought and floods are included in the extended model. The main dependent variable is weight-for-age which measures wasting, acute malnutrition among children who are below age five. This will be this study's main dependent variable since only one-time lag is taken into account and the results from the previous season's rainfall variation might be give most rapidly feedback in the wasting variable. These stated conditions lay the foundation of the baseline model (1) this study uses.

Baseline Model

$$wfa_{i,t} = \beta_1 lnrain_{i,t} + \beta_2 Z_i + \beta_3 s_t + \varepsilon_{i,t} \tag{1}$$

i = 1,…,28 (number of entities which in this study are districts, a total of 28 districts in Malawi.)

t = 1,…,4 (time period which in this study are four specific years, 2000, 2004, 2010 and 2015.)

Clustered standard errors are applied which means that correlation within an entity, in this study district, is allowed but not across entities. Using clustered standard errors is necessary to avoid the plausible possibility of autocorrelation in $\mu_{i,t}$. This is needed since observations for the same district are not independent when they belong to the same entity (Stock & Watson, 2015). Therefore, correlation within a "cluster" of observations is allowed but not correlation across clusters.

Since this study analyzes districts over time it is suitable to use the two-way fixed effect model that allows for fixed effects and time fixed effects to control for factors that could cause omitted variable bias. With time fixed effects it is possible to control for factors that vary over time but not across entities and with fixed effects it is possible to control for factors that vary across entities but do not vary over time. This helps to eliminate omitted variable bias for the case being studied in Malawi since the time fixed effect will help isolate from trends that vary over time, for example the fact that children's health status in general increases (MDHS, 2010). The districts in northern Malawi are in general wealthier and with higher education than the districts in the southern region. Fixed effects will help control for these factors that vary across entities but not over time.

The components in the error term are the individual specific effect α_i that is constant over time for each district summarized by the district specific effect γ_t that remains consistent for every district for the same year and finally an error term $\mu_{i,t}$. Lastly the error term $\mu_{i,t}$ should be homoscedastic, not autocorrelated.

Error Component Model

$$\varepsilon_{i,t} = \alpha_i + \gamma_t + \mu_{i,t} \qquad (2)$$

The least square (LS) assumptions for panel data studies are conditional mean independence, observations are independently drawn from their joint distribution, large outliers are unlikely and there is no perfect multicollinearity. The first assumption, conditional mean independence, might be intruded in this study since it includes that no omitted lagged effects of variable x is allowed. This study might experience lagged effects due to the delayed effect of rainfall variation on children's health and long-term food security.

The estimated regression model in this study uses the lin-log system where the independent variable is logarithmic and the dependent variable is linear. When the independent variable is logarithmic one percent increase will result in an average increase of β_1 / 100 in the dependent variable. The effect of rainfall variation on weight-for-age translates into an average change of 0.01 β_1. The justification to use the lin-log system is based on previous research and the primary argument that the purpose of this study is supported by using a logarithmic explanatory variable. When the effect of seasonal rainfall variation is examined it is of interest to look at the relative change in precipitation. The lin-log regression model allows estimation of percentage deviation in rainfall within different districts. The log-log system with a logarithmic independent variable and logarithmic dependent variable would have been an alternative approach but the findings from previous research show that the lin-log suits this study and its data material better and therefore it is used. Which model to use is hard to determine by evaluating the coefficient of determination since the variables differ so the judgement in this case relies on evidence from previous studies (Stock & Watson, 2015). The coefficient of rainfall in all regressions will be interpreted with regards to the applied lin-log model.

4. Results

This section presents the main results from the regression analysis followed by additional results for the two subsamples of interest. All regressions are performed within the introduced theoretical and conceptual framework. The key results are shown in Table 3, additional results in Table 4 and 5 and full results can be found in Appendix 1.

The main results from this study find no statistically significant effect of seasonal rainfall variation on neither of the three dependent variables used to measure children's health status. Since the variable for rainfall variation is using one season of time lag this study focuses primarily on acute malnutrition, weight-for-age, as dependent variable. The results from the regression analysis with weight-for-age as dependent variable and the natural logarithm of rainfall as explanatory variable are found in section 4.1 in Table 3. The results from the subsample analysis are found in section 4.2 in Table 4 and Table 5.[4]

[4] The results from the two complementary dependent variables of interest, height-for-age and weight-for-height, are found in Appendix 1 together with additional results with alterations in the explanatory variable of rainfall.

4.1 Main Results

The results in Table 3 show no significant effect of rainfall variation on the dependent variable of interest weight-for-age in general. Regression (1) includes fixed effects with districts as entities but no time fixed effects and regression (2) adds time fixed effects with the four years 2000, 2004, 2010 and 2015. The result from regression (1) indicates an increase in weight-for-age of 0.1796 which also shows statistical significance on 5 % level but when adding time fixed effects in regression (2) the estimate decreases to 0.05604 and is no longer significant.

Table 3. The effect of rainfall variation on weight-for-age with fixed effects and time fixed effects

	(1)	(2)	(3)	(4)
	weight for age	weight for age	weight for age	weight for age
lnrain	17.96**	5.604	9.668	7.970
	(8.212)	(6.787)	(8.618)	(9.663)
drought			2.061	
			(3.432)	
floods				-1.289
				(2.718)
Time fixed effects	No	Yes	Yes	Yes
N	26858	26858	26858	26858
R^2	0.007	0.010	0.010	0.010

*All columns refer to separate regressions. All regressions include district fixed effects and time fixed effects are included if indicated. Clustered standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01.*

Column (3) includes a dummy variable for drought and column (4) includes a dummy variable for floods. Adding these variables does not seem to affect the significance of the results. Based on the results from the regression analysis column (2) - (4) the null hypothesis, $\beta_1 = 0$, cannot be rejected hence it is not possible, within this study, to establish any underlying causality between seasonal rainfall variation and degraded health status for children below age five in Malawi. This does not mean that there is no such relation between these two issues but only that within the set model no significant results can be found. The width of the confidence interval still implicates that the result in Table 3 is within the range of significant outcome and it is therefore of interest to further analyze the sample and instead of mistrusting the model try to investigate the precision. Even though the results lack consistent significant coefficients the economic significance is of great interest and will be further addressed in section 5. There are consistently positive estimates found whose implication in one way contradicts the hypothesis that rainfall variation causes food insecurity. On the other hand it is precisely the variation in rainfall, both increased and decreased amounts, that is examined. With that in mind it is interesting to see this pattern in the results, even though the estimates are insignificant.

The coefficient of determination is very low throughout the whole study which indicates that this model might benefit from additional control variables and perhaps an alternative computation of the explanatory variable since such a low number of R^2 indicates that few results are explained within this model.

The results for the complementary variables of interest, height-for-age and weight-for-height, follow the same pattern and show no significant effect of rainfall variation. To follow the implications from previous research on rainfall variability in Malawi the results with onset and cessation as explanatory variables are also displayed in Appendix 1. The coefficient for cessation show significant effect on the 5 % level for the main dependent variable, weight-for-age, when excluding the time fixed effects implicating a decrease in weight-for-age when rainfall is increasing. No significant effect is found when adding the time dummies but size and direction of the reduced form estimates is consistent throughout the regressions.

Summarized, the results in column (2) - (4) show no statistically significant effect of rainfall variation on the health indicator weight-for-age. This result is supported by the complementary regressions on height-for-age and weight-for-height in Appendix 1.

4.2 Additional Results

The subsample analysis is performed with two main purposes. Firstly, it is of interest to evaluate if any statistically significant impact of climate variability measured by rainfall variation can be found when restricting the sample to more vulnerable groups. Secondly, the additional aim of this study is to evaluate adaptation ability in Malawi by mapping local resilience within the country and to do so it is of interest to compare the results from the subsample analysis with the main results. The subsample is first restricted to low educated mothers where the definition of low education is in line with incomplete primary in the most recent MDHS report (MDHS, 2015/16). This group is large in Malawi where 12 % of all women age 15 - 49 had no education and 54 % incomplete primary education in 2015/16.

Table 4. The effect of rainfall variation and extreme weather on weight-for-age in subsample 1, mother's education

	(1)	(2)	(3)	(4)
	weight for age	weight for age	weight for age	weight for age
lnrain	10.59	5.031	7.976	23.17
	(10.34)	(8.732)	(14.20)	(14.07)
drought			1.521	
			(6.058)	
floods				-10.57
				(6.265)
Time fixed effects	No	Yes	Yes	Yes
N	11695	11695	11695	11695
R^2	0.005	0.008	0.008	0.009

*All columns refer to separate regressions. All regressions include district fixed effects and time fixed effects are included if indicated. Clustered standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

The results presented in Table 4 from the first subsample show no statistically significant effect of rainfall variation on the dependent variable of interest, weight-for-age. The estimate for the coefficient when restricting to mothers with low education is slightly smaller than for the full sample but the direction remains the same. When adding time dummies it decreases further which is the same as for the main sample. When adding the dummies for drought and floods the estimate increases again. However, since no statistically significant effect of this is established, the comparison is limited to a discussion on the economic significance and potential implications of these results. The estimates lie closely to the size for the results with the main sample and the coefficient of determination is still very low.

The subsample is secondly restricted to underweight mothers where mothers who weight less than two standard deviations below average are included in the sample. Children's body size is more commonly used as proxy for food security since the ones under five years old are considered to be one of the most vulnerable group of a population. However, the mother's weight could be used as an indicator of the quality of household conditions in terms of food supply and therefore serve as as suitable delimitation for the most vulnerable children.

Table 5. The effect of rainfall variation and extreme weather on weight-for-age in subsample 2, mother's weight

	(1) weight for age	(2) weight for age	(3) weight for age	(4) weight for age
lnrain	9.172	1.658	4.330	2.958
	(6.152)	(4.832)	(7.005)	(7.786)
drought			1.358	
			(3.308)	
floods				-0.714
				(3.612)
Time fixed effects	No	Yes	Yes	Yes
N	16712	16712	16712	16712
R^2	0.006	0.009	0.009	0.009

*All columns refer to separate regressions. All regressions include district fixed effects and time fixed effects are included if indicated. Clustered standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

The results presented in Table 5 from the second subsample do not show any statistically significant effect on weight-for-age. The coefficient estimate is slightly smaller than for the full sample but the direction remains the same. When adding time dummies it decreases further which is the same as for the main sample. When adding the dummies for drought and floods the estimate increases again but is still insignificant. The reduced form estimates are consistently positive and in line with the main results and the results from the first subsample.

4.3 Robustness

The robustness of this study is evaluated to make sure small deviations that should not influence the results are under control. The robustness is tested by comparing results with the explanatory variable in both linear and logarithmic formula to exclude large deviations. A challenge for this study is to fulfill the condition of sufficient variation in the independent and explanatory variable over time within entities. This is shown by the large standard error for the rainfall variable in Table 2, descriptive statistics. Having that mentioned, this study motivates that the method and data used are sufficient to reach conclusions regarding the stated research objectives within the given framework.

In terms of internal validity, the importance of time lag effects is evaluated closely since the dependent variable of children's health indicators might experience a delay in relation to the seasonal rainfall variation. These time lag effects could potentially be modelled with better precision and then change the output of this study. This depends on the research objective and angle of incidence whereby the choice of time lag used in this study is motivated and sufficient. The rainfall data is gathered from the Department of Climate Change and Meteorological Services in Malawi. DCCMS collects data from meteorological stations all over Malawi[5] through two different techniques, either manually with a pluviometer[6] or through an automatic rain gauge. The majority of the stations are linked to an automatized system where each days amount of precipitation is reported directly to DCCMS. The manual system is primarily used as a backup during power cuts or when the automatic rain gauge is broken for some reason. Malawi has recently experienced severe issues with the national power grid and daily blackouts (Taulo et. al. 2015) which might result in more frequent usage of the manual system at the meteorological stations and also more imprecise reporting of precipitation. This could contribute to increased measurement errors which is a factor affecting the internal validity.

[5] The meteorological stations in Malawi used in this study are listed in Appendix 2.
[6] A pluviometer is an instrument meteorologists use to collect and measure precipitation.

Attenuation bias in the estimate $\widehat{\beta}_1$ could be caused by classic measurement errors in x which in turn might be one explanation of the insignificant results in this study. Since this study uses fixed effects the potential measurement error will increase accordingly. If 20 % of the observations year 1 are miscoded and another 20 % in year 2 this will accumulate to 40 % miscoding with fixed effects but remain 20 % with OLS. There is more measurement in a model with fixed effects and therefore more bias towards zero.

The external validity of this study is where the followed discussion wishes to focus. Even though the ultimate way to conduct this study would have been an analyze of rainfall variation on children's health with full access to microdata for children for all the years with rainfall data, 1950 - 2015 this study accomplishes its purpose within the given framework. Variables related to climate change have been measured carefully with consideration to all time aspects and the slow changes. However, this study is limited to the four years with individual observations from DHS and it is carried out with confidence within the shown restrictions. Agricultural data included in the model as an instrument variable would improve the analysis since rainfall variation does not directly affect children's health and food security but yields, cereals crops availability and food prices in general do. It is of interest to shift focus and evaluate the precision and reliability of the implications of the results. The reduced form estimates are insignificant but within the width of the confidence interval which imply that better precision is desirable to further improve the external validity of this study.

5. Discussion

The results from this study show no statistically significant effect from seasonal rainfall variation on children's health in Malawi. Within this model, it is therefore not possible to reject $\beta_1 = 0$. Accordingly, it is not possible to determine if there is any causality underlying the relation between climate change and food security. This highlights the need of further research within the field to obtain more statistically significant findings. However, the findings of this study gives some interesting implications. An extended discussion about the size and direction of the reduced form estimates is useful for a deeper understanding of this study's main findings.

By the theoretical framework presented in the second section based on Morduch's conclusions about vulnerability and consumption smoothing in low-income countries, there are several different assumptions to add following this results. Since the result does not allow to reject the null hypothesis that consumption smoothing is possible, the further analysis must allow for discussion about the potential reason for this and the economical significance of the results. Either Malawians are not liquidity constraint, and therefore able to insure themselves to transitory income shocks like seasonal rainfall variation, or other factors that this model did not include are influencing the results. The results imply that rainfall variation has an impact on children's health status in Malawi when analyzing the the size and direction of the estimates. An increase in annual average rainfall seems to increase weight-for-height. This study is carried out with confidence that the controls for omitted variable bias are sufficient and motivated within the framework. It is wise to discuss potential omitted indicators but also the accuracy and precision of the model used in this study. Omitted factors that could be interesting to add in future research are soil quality, subsidies on fertilizers, nitrogen deficit, malaria and other diseases. These examples were frequently mentioned in meetings with both locals and experts during the field experience in Malawi 2018. Another noteworthy factor is the suitability of the model for this study, data and case in particular. Time fixed effect does not only correct for omitted variable bias but may also remove other variables that are important to the variance of the regression which risks to cause bias in the estimate $\widehat{\beta}_1$. The time effects are in this case statistically significant and there is thereof no reason to doubt the capability of this choice of method.

Based on previous findings evaluating the precipitation patterns in Malawi it is of importance not only to examine seasonal rainfall in absolute numbers but also the timing of onset and cessation (Ngongondo et al. 2014). This study finds no significant results when looking into this factor but it might be relevant for the food security outcome in Malawi since the length of the growing season is highly dependant on this. It is therefore important to allow further research of the potential consequences of climate variability and disruption of the rainfall pattern in Malawi.

The determination of the rainfall variation was carefully performed and it would be interesting to experiment further with the rainfall variable and the meteorological stations to see if more within variation could be generated and give this study more statistically significant results. If MDHS would exist for several years that would also be interesting to include in the model since rainfall data for Malawi can be found from 1950 through DCCMS. Alternative ways of computing the variable for rainfall variation may also be thought-provoking and show different results than this study does. An approach could be to calculate days of rainfall per season instead of average precipitation per season and district. This might increase the precision of the variable for climate variability and add on higher external validity for future studies within this field. Another way would be to look into deviation on the peaks of each season and analyze whether any extreme weather did occur. According to Ngongondo et al. 2014 it is the intensity of precipitation that changes, not the absolute amount of millimeters captured in the rain gauge during that season.

There is an emerging consensus that capacity building is key to better political and economic decisions related to climate change adaptation and therefore a way towards more sustainable solutions. Adaptive capacity has to be enhanced in order to reach the goals stated in the 2030 Agenda for Sustainable Development. Capacity building and adaptation can help reduce vulnerability to climate variability both by decrease sensitivity but also by introducing new ways to benefit from the current circumstances and opportunities of climate change. Growing new crops that before were unsuitable due to the weather is a great way of building capacity and allowing adaptation for the population. There are multiple ongoing projects where these ideas among many others are being implemented around the world, including Malawi. One example is the National Adaptation Program that was discussed during COP21 in Paris where Tawonga

Mbale, Acting Director of the Department of Environmental Affairs in Malawi, shared her view from the Malawian government. Learnings from projects like the NAP are underlining the aim of this study; to map local ability to adaptation and encourage further interdisciplinary research to increase resilience to climate change and assist the process of making the right prioritizes to enable efficient and successful projects and decisions.

Weather variability in Malawi is an established pressing issue for both the people, politicians and stakeholders within all sectors. Many studies on rainfall variation and climate variability have been conducted in Malawi but most of them are restricted within their field of expertise. This creates a gap that interdisciplinary studies could bridge by sharing and transferring knowledge for deeper understanding and better learning of this complex issue.

6. Conclusion

This study examines the effect of seasonal rainfall variation on children's health in Malawi to allow further understanding of the relation between climate change and food security. To analyze the question of interest, a regression model is estimated using panel data for all 28 districts in Malawi covering the years 2000, 2004, 2010 and 2015. The regressions include district fixed effects and time fixed effects to eliminate omitted variable bias and isolate the effect of seasonal rainfall variation on three main indicators measuring children's health in Malawi. Furthermore, the study analyzes two subsamples to enable a deeper discussion and more detailed conclusions. The first subsample is restricted to children with low-educated mothers. The second subsample is restricted to children with underweight mothers.

The main results find no statistically significant effect of seasonal rainfall variation on children's health in Malawi for the evaluated time period and the results from the subsamples show no statistically significant effect of seasonal rainfall variation on children's health either. The size and direction of the reduced form estimates imply a positive relation between rainfall and weight-for-age. This leads to the main conclusion that further research should be emphasised and conducted within this field. It is still a question with economical significance and of great importance not only to the children and the population in Malawi but also to the global issue on climate change and food security. Risk mitigation strategies and consumption behaviour are closely linked to resilience and capacity building whereby better opportunities to tackle exogenous shocks and handle idiosyncratic risk will probably result in efficiency gains both for households and society. Hence, there is a need of facilitating interdisciplinary research combining studies on weather hazards and climate variability with social science and economics to better understand the complex relation between these two challenges society is facing today. The question of interest, *How does seasonal rainfall variation affect health status for children below age five in Malawi?,* cannot be answered clearly in this study, within this model and with this data. However, there are implications that increased rainfall could lead to increased weight-for-age since the estimates are consistently positive throughout the study. The additional objectives also remain for future research to approach but the trend in the results has the same direction as for the main objective. The implications prove that this research could be truly reliable and useful with improved precision. Previous studies tend to focus on certain sectors, geographies or years whereby this study contributes with a broader perspective analysing all districts in Malawi during four years including a narrowed down subsample to energize a more nuanced discussion about the issue of food security and climate change both in Malawi and globally. Based on the findings from this study's analysis, it is clear that further research is needed to evaluate the complex relation between food security and climate variability in countries like Malawi but also worldwide since global warming is something affecting all countries in the world. To enable a clear and fact-based discussion about this relation it is highly important not to rush into conclusions but to investigate closely both recent and historical trends.

Finally, it is of great importance to remember that even though this study cannot find strong evidence that climate change causes food insecurity in Malawi, rainfall variation might still influence the wellbeing of the population through other systems than those presented in this model. Keeping more than one thought in mind at the same time is key to understand complex issues like the current situation in Malawi.

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Appendix 1

Results and regressions for all three dependent variables are presented below in table 6 and 7. Table 8 - 10 shows the results from regression analysis with rainfall onset and cessation as alternate explanatory variables. Full description of each regression analysis is available in the information above each table. Definitions of all variables are found in Table 1, section 3.1 Data. Interpretations and comments on the relevant results are included in section 4.

Table 6. The effect rainfall variation and extreme weather on height-for-age, full sample

	(1)	(2)	(3)	(4)
	height-for-age	height-for-age	height-for-age	height-for-age
lnrain	36.99**	2.048	19.50*	-7.206
	(16.97)	(10.19)	(11.27)	(11.62)
drought			8.847**	
			(3.958)	
floods				5.042
				(4.327)
Time fixed effects	No	Yes	Yes	Yes
N	26858	26858	26858	26858
R^2	0.014	0.027	0.027	0.027

*All columns refer to separate regressions. All regressions include district fixed effects and time fixed effects are included if indicated. Clustered standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

Table 7. The effect lnrain and extreme weather on weight-for-height, full sample

	(1)	(2)	(3)	(4)
	weight-for-height	weight-for-height	weight-for-height	weight-for-height
lnrain	-4.018	6.207	-2.688	15.81*
	(7.133)	(5.073)	(8.270)	(7.866)
drought			-4.511	
			(3.415)	
floods				-5.230
				(3.142)
Time fixed effects	No	Yes	Yes	Yes
N	26877	26877	26877	26877
R^2	0.008	0.012	0.012	0.012

*All columns refer to separate regressions. All regressions include district fixed effects and time fixed effects are included if indicated. Clustered standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

Table 8. The effect of onset and cessation on weight-for-age, full sample

	(1)	(2)	(3)	(4)
	weight-for-age	weight-for-age	weight-for-age	weight-for-age
onset	-0.0521		-0.0419	
	(0.0384)		(0.0487)	
cessation		-0.0420**		0.0222
		(0.0168)		(0.0177)
Time fixed effects	No	No	Yes	Yes
N	26858	26858	26858	26858
R^2	0.006	0.006	0.010	0.010

*All columns refer to separate regressions. All regressions include district fixed effects and time fixed effects are included if indicated. Clustered standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

Table 9. The effect of onset and cessation on weight-for-age, subsample 1

	(1) weight-for-age	(2) weight-for-age	(3) weight-for-age	(4) weight-for-age
onset	-0.0341		-0.0208	
	(0.0625)		(0.0781)	
cessation		0.0336		0.0949***
		(0.0232)		(0.0276)
Time fixed effects	No	No	Yes	Yes
N	11695	11695	11695	11695
R^2	0.005	0.005	0.008	0.009

*All columns refer to separate regressions. All regressions include district fixed effects and time fixed effects are included if indicated. Clustered standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

Table 10. The effect of onset and cessation on weight-for-age, subsample 2

	(1) weight-for-age	(2) weight-for-age	(3) weight-for-age	(4) weight-for-age
onset	-0.0497		-0.0406	
	(0.0324)		(0.0397)	
cessation		-0.0197		0.0221
		(0.0208)		(0.0265)
Time fixed effects	No	No	Yes	Yes
N	16712	16712	16712	16712
R^2	0.006	0.006	0.009	0.009

*All columns refer to separate regressions. All regressions include district fixed effects and time fixed effects are included if indicated. Clustered standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

Appendix 2

All districts and meteorological stations in Malawi that are used in this study are listed below.

Table 1. Districts in Malawi, 28 districts in total.

district code	district name	region code	region name
1	Chitipa	3	North
2	Karonga	3	North
3	Rumphi	3	North
4	Mzimba	3	North
5	Nkhata	3	North
6	Likoma	3	North
7	Kasungu	2	Central
8	Dowa	2	Central
9	Ntchisi	2	Central
10	Mchinji	2	Central
11	Lilongwe	2	Central
12	Dedza	2	Central
13	Nkhotakota	2	Central
14	Salima	2	Central
15	Ntcheu	2	Central
16	Balaka	1	South
17	Mangochi	1	South
18	Machinga	1	South
19	Zomba	1	South
20	Neno	1	South
21	Mwanza	1	South
22	Phalombe	1	South
23	Chiradzulu	1	South
24	Blantyre	1	South
25	Thyolo	1	South
26	Mulanje	1	South
27	Chikwawa	1	South
28	Nsanje	1	South

Table 2. Meteorological stations in Malawi, 73 stations in total.

station name	region	district	long.	lat.
dedza met	central	dedza	34.25	-14
mtakataka Airwing	central	dedza	33.72	-14.22
Thiwi Agric	central	dedza	34	-14
dedza RTc	central	dedza	34.33	-14.38
dowa Agric	central	dowa	34	-13.65
madisi Agric	central	dowa	34	-13
mponela Agric	central	dowa	33.75	-14
kasungu met	central	kasungu	33	-13
mwimba Research	central	kasungu	33.45	-13.08
chitedze met.	central	lilongwe	34	-14
dzalanyama Forest	central	lilongwe	33.6	-14
k.I.A met	central	lilongwe	34	-14
kasiya Agric	central	lilongwe	34	-14
nathenje Agric	central	lilongwe	34	-14
Sinyala Agric	central	lilongwe	34	-14
mchinji Agric	central	mchinji	32.92	-14
mkanda Agric	central	mchinji	32.95	-14
Tembwe Agric	central	mchinji	32.87	-13.82
dwangwa Illovo.	central	nkhotakota	34	-12
nkhotakota met	central	nkhotakota	34	-13
mlangeni njolomole	central	ntcheu	34.53	-14.68
ntcheu - nkhande	central	ntcheu	35	-15
ntchisi Agric	central	ntchisi	34.02	-13.03
lifuwu	central	Salima	34.58	-13.67
Salima met	central	Salima	35	-13.75
chitipa met	north	chitipa	33	-9.7
karonga met.	north	karonga	33.88	-9.95
lupembe	north	karonga	34	-10
Vinthukutu Agric	north	karonga	34.2	-10.42
bwengu Agric.	north	mzimba	33.92	-11.07
chikangawa forest	north	mzimba	33.8	-11.85
Euthini Agric.	north	mzimba	33.42	-11.45
mbawa Res. Stn	north	mzimba	33.4	-12
mzimba met	north	mzimba	33.6	-11.9
mzuzu met.	north	mzimba	34	-11.45
Zombwe Agric	north	mzimba	34	-11
chintheche Agric	north	nkhata	34.17	-12

nkhatabay met.	north	nkhata	34.3	-12
bolero met	north	rumphi	34	-11
Rumphi Agric	north	rumphi	34	-11
balaka Agric	south	balaka	35	-15
phalula Agric	south	balaka	34.95	-15
Toleza Farm	south	balaka	35	-15
chichiri met.	south	blantyre	35	-16
chileka Airport	south	blantyre	35	-16
mpemba Vet	south	blantyre	35	-16
chikwawa Agric	south	chikwawa	35	-16
nchalo Illovo	south	chikwawa	35	-16
ngabu met.	south	chikwawa	34.95	-16.5
chiradzulu Agric	south	chiradzulu	35	-16
chikweo Agric.	south	machinga	36	-15
liwonde Township	south	machinga	35	-15
ntaja met.	south	machinga	36	-15
mpilipili (makanjira)	south	mangochi	35	-14
mangochi met.	south	mangochi	35	-14
monkey bay met.	south	mangochi	35	-14
namiasi Agric	south	mangochi	35	-14
namwera Agric	south	mangochi	35.5	-14
nankumba Agric	south	mangochi	34.8	-14.35
mimosa met.	south	mulanje	36	-16
mulanje Agric	south	mulanje	36	-16
Thuchila Agric	south	mulanje	35.25	-15.95
mwanza Agric	south	mwanza	35	-16
neno Agric	south	neno	34.65	-15.4
makhanga met	south	nsanje	35	-17
nsanje Agric	south	nsanje	35	-16.95
naminjiwa Agric	south	phalombe	36	-16
bvumbwe met.	south	thyolo	35	-16
Thyolo Agric	south	thyolo	35.22	-16.15
chancellor college	south	tomba	35	-15
chingale Agric	south	zomba	35	-15
makoka met	south	zomba	35	-16
Zomba RTc	south	zomba	35.32	-15.4