**1 Introduction to food security in Sub-Saharan Africa**

The world has committed itself to stopping hunger in the world by 2030. The goal to stop the prevalence of all forms of hunger is specified in Sustainable Development Goal (SDG) number two of the total seventeen SDG's set up in the 2030 Agenda for Sustainable Development. All seventeen goals together provide a blueprint for peace and prosperity for people and the planet [2].

The negative effects of hunger are enormous. Malnutrition and related effects slow down development within whole countries. Hunger has a ripple effect that slow down and freezes development. Especially for children, the effects of malnutrition can last a lifetime. Poor nutrition affects physical and mental development which can have a tremendous negative effect on the development of individuals and hereby the economic output of a country [5].

**1.1 Recent developments**

Since 1990, the prevalence of hunger has fallen across most regions. Globally, hunger has fallen from 14.8 percent in 2000 to 10.7 percent in 2017. But the progress has not been consistent for the whole period. Global hunger reached its lowest levels in 2015 but has now risen to 10.8 and 10.9 percent in 2016 and 2017, see figure 1 [4]. This increase in hunger levels are largely a result of increases in Sub-Saharan Africa and minor increases in South America [5]. Also, the UN FAO has linked the increase of PoU to the rise in conflicts which often leads to famine, and climate factors such as the heavy occurrence of the last El Niño phenomenon. Another import factor could be the higher perceived occurrence of climate extremes which can have decremental effects on the output of agriculture and its assets [6].

**1.2 Sub Saharan Africa**

Chronic undernourishment is widespread throughout the region of Africa, see figure 2. As can be seen in figure 1, 20.1 percent of the population of Sub Saharan Africa is now undernourished, which corresponds to around 250 million people in Africa. The region remains exposed to food crises and famines which are easily triggered by droughts, floods, pest, economic downturns and conflicts [5].

The population of the SSA region is rapidly expanding, namely from 670 million in 2000 to 1.06 billion in 2015, see figure 6. This rapid increase in population combined with the effects of climate change form a dangerous mix of factors. Therefore, Sub-Saharan Africa is the only region of the world, where it is expected that the state of hunger will worsen over the coming decades [7].

Therefore, we take the Sub Saharan region as the scope of this explorative data-analysis about hunger. The goal of this report is to gain more insight in the dynamics of the rising hunger in Africa, what is causing it and which policy options need to be worked out that counteract the current trend of rapid rise of hunger. This knowledge could then be used to form policies that enforce proper food security across the SSA region. Only when the food security is in order, the Sub Saharan Africa region can achieve economic momentum to rise from poverty and catch on with the other parts of the developing world [8].

## 2 Methodology and Research Goal

In this chapter the used methodology and research questions are described. At first, an insight is given in the methodologies used. As second the main research question and sub questions are explained.

### 2.1 Methodology

Within this report, we try to gain more insight behind the data of hunger in Sub Saharan Africa. First, we will clean and analyse the data by selecting the relevant indicators. By means of critical analysis and interpretation of figures and numbers, we try to find relations in the data to obtain useful conclusion for our recommendation to policy makers. Also, relevant primary research on the topic of Zero Hunger and food security will be included to compare our primary research findings.

Python is used as a tool to perform the data analysis within this research. Python as widely used programming language which contains additional packages that are very powerful for data analysis and visualisation purposes. Within our computations in Python, several additional packages have been used. For example, **Plotly** has been used to make our detailed graphics. In Plotly visualisations are displayed in an efficient way and many possibilities to visualize the data are present. **Seaborn** has been used for regression analysis while **Numpy & Pandas** is used for handling large data structures and **Stats** for forecasting purposes. Finally, **scipy** has been used to perform classic statistical analysis, like a t-test. All packages that have been used can be seen below:

### 2.2 Research questions

In order to draft clear policies to end hunger around the world and stopping other negative side effects, five main targets for SDG 2 - Zero Hunger have been set out for 2030 by all United Nations Member States[1]:

* Target 2.1: End hunger and ensure access by all people
* Target 2.2: End all forms of malnutrition, including achieving targets on stunting and wasting
* Target 2.3: Double the agricultural productivity and incomes of small-scale food producers
* Target 2.4: Ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production.
* Target 2.5: Maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species.

The negative effects of hunger are enormous. Malnutrition and related effects slow down development within whole countries. Hunger has a ripple effect that slow down and freezes development. Especially for children, the effects of malnutrition can last a lifetime. Poor nutrition affects physical and mental development which can have a tremendous negative effect on the development of individuals and hereby the economic output of a country [5].

Our main research question has a wide scope because we want to obtain a general overview of hunger and its causes in Sub-Saharan Africa. The sub questions are derived from the UN targets from Goal 2 - Zero Hunger. Only target 2.5, which describes goals for bio diversity is omitted from our analysis.

'To what extent is hunger in sub-Saharan Africa related to environmental hazards and how will this trend develop until 2030 under the effects of climate change?'

To answer this research questions several sub questions are defined:

* (target 2.1) How did food security develop in the last decades for sub-Saharan Africa?
* (target 2.2) what is the development of stunting, wasting overweight, anemia and exclusive breastfeeding in Sub-Saharan Africa?
* (target 2.3) How did the food production develop and how is that related to the grow in population?
* (target 2.4) What has been the historic trend of environmental hazards in sub-Saharan Africa and the impact on food systems?

First the food security and environmental hazards will be looked at separately. The food security is explained by different indicators, such as '% of undernourishment' and the 'Cereal Yield (kg per Hectare)'. As well indicators as the total population combined with the total food production can give a good insight in how the food security has developed the last decades. For the environmental hazards, firstly the impact and frequency of these hazards will be discussed. After this, the impact of environmental hazards on the food systems shall be analysed.

## 3 Data preparation

For our analysis, several databases were used. The most important database within our analysis is the vast World Development Indicator database which contains a lot of information about numerous topics including indicators on hunger. The EMD Environmental Hazard database was used to obtain data on the occurrence of environmental hazards around the world. We also used additional country information from the OECD to group certain countries.

### 3.1 WDI Data

The World Development Indicator set contains a lot of information on undernourishment, stunting, food production and other related topics to this research. However, the WDI Data contains data from all the countries over the world and some aggregated region indicators. Since we only need the countries in Sub-Saharan Africa and the region Sub-Saharan Africa itself (this is just the average of all the countries in Sub-Saharan Africa), we need to select only these entries. Within this research the data of Sub-Saharan Africa was compared with the region 'World', which is a standard region within the WDI dataset.

Unfortunately, the WDI Data does not contain all grouping data about the region of every country. In order to group all countries within Sub Saharan Africa (SSA), another datafile was imported that contains all the countries and all their region information. We used this dataset to extract a list with all the countries in Sub-Saharan Africa. This list was then used to create a DataFrame from the WDI Data containing only the data of those countries and the two regions 'Sub Saharan Africa' (SSF) and 'World' (WLD).

Now that we have the right DataFrame, we can modify the data further to make it specific to the graphs we want to create. This involves procedures like

* Selecting only one or a few indicators
* Selecting only the regions, or only the countries
* Selecting a certain time range
* Melting the data in a long format, which is convenient for plotting the data
* Dropping al the rows where the values are missing

It makes sense to melt the data as one of the lasts steps, because in that way you only use computational power for the data that you want to keep. After having the data melted, it is simple to drop the rows with NA values. The indicators, countries and regions we need differ per graph, therefore this is done before plotting each graph in chapter 4.

**3.2 Environmental hazards data**

To obtain about environmental hazards around the world, the EMD-DAT database on environmental hazards was used. This database, firstly constructed in 1988 by the Centre for Research on the Epidemiology of Disasters (CRED), contains core data on the occurrence and effects of over 22,000 mass disasters in the world from 1900 to the present day. The database is compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies.

Within our research, two versions of this database have been used, namely df\_emd\_world which contains all hazards from 1960 - 2018 around the world. This database was used to construct a comparison between countries with a high/low exposure to climate extremes, **see section 4.4 and 4.5**. The second one is df\_emd which contains all disasters for Africa from 1960 - 2018.

### 3.3 Income group data

To execute an analysis between low & middle-income countries, an extra database with this information was obtained via the OECD. The OECD uses a standard codec for country codes (ISO standard). This database could therefore be link to the EMD and WDI data by merging on the country codes.

## Chapter 4 - Data Analysis

Within chapter, we try to answer our research question by means of several sub questions, see section 2.2. This is mainly done by analysing large datasets and trying to visualise this data by means of appropriate graphs. We try to gain more insight in the causes and effects of persistence of hunger in Sub Saharan Africa. These insights will then be used to advice some further steps take can be taken to start on working towards policies that counteract the rise of hunger in Sub Saharan Africa.

Firstly, the current state of hunger in Sub Saharan Africa will be analysed by looking at the food deficit and the prevalence of undernourishment in Africa compared to the world and distribution of the PoU within countries in the Sub Saharan Africa region, see section 4.1. To answer the second research question, several bar charts has been created that gives an overview of the development of stunting, wasting overweight, anaemia and exclusive breastfeeding in the period of 2010 - 2017, see section 4.2. For the third research question, the cereal yield, population and food index have been analysed, see section 4.3. To answer the fourth research question, several regression analyses are carried out to analyse the development of natural hazards within Africa. A statistical analysis has been carried out to estimate the significance of environmental hazards on the PoU within low & middle-income countries, see section 4.4. Finally, in section 4.5 the future trend of the PoU for Sub Saharan Africa will be estimated and estimations about the future trend of environmental hazards and their impact on the food security will be derived.

### 4.1 State of hunger in Sub-Saharan Africa

As can be derived from the first two graphs presented in chapter 1, the prevalence of undernourishment in Sub Saharan Africa is rising for two consecutive years now. The situation is mainly getting worse in Liberia, the Central Africa Republic, Zambia, Zimbabwe and Madagascar, which all have a PoU higher than 40%. For the SSA region food scarcity is affecting almost 21 percent of the population (more than 250 million people). Without increased efforts, the world could fall far short of achieving the SDG target of eradicating hunger by 2030.

For several charts in which we compare Sub-Saharan Africa to the World functions are used. The called function is 'data\_plot' wherein the 'data\_return' function is called. The 'data\_return' creates a DataFrame for the indicator code given in 'data\_plot' and sets the traces for the plot. In 'data\_plot' several inputs, such as the title and range of the y-ax, are entered. Within this function the layout of the graph is estimated, and the graph gets plotted.

One downside of using the FAO metric of undernourishment is that it only gives information about the population that are below the minimum energy limit, it does not provide information about how far people are under it [4]. To estimate the intensity of undernourishment in the population, ‘the depth of the food deficit' has been plotted. This measure estimates the number of calories an individual need to balance their caloric intake to meet the energy requirements, see figure 3.

Within our data, we see a fall of the depth of the food deficit from 250 kcal in 1992 to 130 kcal in 2016 for the SSA-region. The downwards trend is stabilizing around 130 kcal, which is the effect from the worsening food security situation in the SSA region at the moment.

**4.2 Development of malnutrition indicators**

The five indicators in figure 3 are about healthy nutrition. They are a measure for how Sub-Saharan Africa is doing regarding malnutrition. The malnutrition indicators consist of the following five indicators:

* Stunting
* Wasting
* Overweight
* Anemia
* Exclusive breastfeeding

These indicators are shown in figure 3 in between 2010 - 2017.

Stunting, according to the WHO, is the effect where there is impaired growth and development that children experience from poor nutrition, repeated infection, and inadequate psychosocial stimulation. Children are defined as stunted if their height-for-age is more than two standard deviations below the WHO Child Growth Standards median [7]. We can see that the number of stunting is declining between 2010 and 2017 (from 37,7 to 34,1). However, this is still high compared to the World.

Wasting is the effect where a child has low weight for their age. Unfortunately, there is almost no data on this topic present within our data, but we can see that in 2017 the numbers for Sub-Saharan Africa and the World are the same. Whereas overweight in the World is rising, in Sub-Saharan Africa it is declining, which is good progression.

Anemia is also slightly declining (from 40 in 2010 to 38.9 in 2017), whereas in the World it is rising (from 29.9 in 2010 to 32.8 in 2017). Anemia is a blood disease which is particular dangerous for (pregnant) women and children. Therefor Anemia here is measured for women from the age 15 to 45 in their reproductive age. Although the number in Sub-Saharan Africa may be slightly declining it is still more than 1 in 3 women that suffers from this disease, which is unacceptable.

For the indicator of Exclusive Breastfeeding there is only data for one year within the analysed subperiod. Therefore, we cannot spot a trend but we can see that it differs not that much for Sub-Saharan Africa and the World in the year 2013. Overall, we can conclude that the indicators for malnutrition are worse in Sub-Saharan Africa when comparing it to the World.

### 4.3 Development of food production

When we investigate the cereal yield in kg per hectare we see that it is rising for the World and also for Sub-Saharan Africa. However, the rise in the world is much steeper than the rise in Sub-Saharan Africa. The cereal yield in the World almost tripled in the past fifty years, whereas the cereal yield in Sub-Saharan Africa not even doubled. Farmers in the SSA-region still don’t have access to the modern resources professionalise their farming and increase the output per hectare.

To explore further how the declining food deficit can be explained it is logical to take into account the population growth. We are interested in if there are any differences between population growth and the development of food production. Is food production for example lacking behind on population growth? Or is the food production growing faster than the population growth and is that why the food deficit is declining? To get more insight, we first plot the population growth and food production growth (as an index) of Sub-Saharan Africa and include the World for comparison (figure 6).

If we then want to check if there is a difference in population versus production, we can compare the changes over the years. To do this for Sub-Saharan Africa, we first extract the data about the two indicators for Sub-Saharan Africa. Then we calculate the percental change by diving year t=1 by year t=0, divide year t=2 by year t=1, etc. We do this for both indicators and then divide the change of both indicators by each other over the years. The results of this computations are presented in figure 7. One data point above 1 means that the rate of change in population was that year higher than the change of rate in food production. For a data point below one, it is vice versa. We can conclude that the differences are marginal (the numbers swing between 0.95 and 1.04) and therefore that there is no abnormal difference between population growth and food production growth. This means that the rising hunger in Africa cannot solely be explained from lacking food production in comparison with population growth.

### 4.4 Impact of environmental hazards on food systems

Several analyses have been carried out to estimate the effects of environmental hazards on the food systems. We have run an independent t-test to compare the means of two groups, namely for countries with a high or low exposure to climate extremes on the prevalence of undernourishment within those countries. Furthermore, several trend analyses are carried out to estimate the trend of the impact of environmental hazards in the past 50 years.

For our analysis on the effects of exposure to climate extremes, two different groups have been defined. High exposure countries have been defined as low to middle income countries which have been exposed to hazards for more than four years in the most recent subperiod of 2011 – 2016. Low exposure countries have been defined as low to middle income countries with an occurrence of hazards of four or less during 2011 – 2016.

#### Independent t-test

The results of the independent t-test indicate that there is no statistical significant difference between the average undernourishment in countries that have a high exposure to environmental hazards in comparison to countries with a low exposure to climate extremes. Just because that this t-test is not significant does not mean that climate extremes don't have an impact on the prevalence of hunger and related side effects. The input data of this t-test has its limitation because of the way environmental hazards are measured. These criteria have their limitations because each hazard is weighted equally, hereby exaggerate the effects of smaller hazards like firestorms.

**Impact of climate extremes on food security**

These criteria have their limitations because each hazard is weighted equally, hereby exaggerate the effects of smaller hazards like firestorms. As can be derived from the figure 8, the situation of food security is worse within countries with a high exposure to climate extremes. Of all undernourished people in low to middle income countries, 633 million people live in countries that have a high exposure to climate extremes, whilst only 97 million undernourished people live in countries which are classified as low exposure countries. In 2015, the average of the PoU in countries with high exposure to climate shocks was 3.5 percentage points above that of countries with low or no exposure. The results of our analysis are strongly indicating a relation between the hunger and vulnerability to climate extremes.

**Damage by environmental hazards**

Of all-natural hazards that are stored in the EMD-database, floods, droughts and storms affect the food production the most. In particular droughts cause more than 80 percent of the total damage and losses in agriculture, especially for the livestock and crop production subsectors [8]. This means that if we see a rise of these kind of hazards in our data, this will have higher negative impact on the food systems in the SSA region.

Within figure 9, the total impact of each hazard has been plotted over the period of 1960 – 2017. Especially the effects of floods and droughts are heavily affecting the inhabitants of the SSA-region. We have plotted a trendline that indicates the 95 percent interval for the occurrence of drought over time. From this trendline we can distinct a clear positive trend. Especially large-scale droughts events are affecting more people in the SSA region, which is the hazard with the most impact on agriculture.

When we look at the accumulated costs of hazards around the SSA-region, see figure 10, we can conclude that also the economic impact of climate extremes is rising. For our data, the recorded total damage seem rather marginal to what other literature is reporting over disaster related costs. It is estimated that for the costs of environmental hazards, it is estimated that around 25% is from losses within the agriculture sector. Environmental hazards also hit infrastructures, hereby worsening the access of food for local communities [8]. Where extreme climate events lead to reoccurring disasters, the accumulated costs are even more significant [7]. For example, between 2006 and 2013 the Philippines was struck by 75 disasters – mostly typhoons, tropical storms and floods. The total damage consisted of a total of 3.8 billion USD to the countries agriculture sector [9].

### 4.5 Future of food security in Sub-Saharan Africa

To gain more insight in the future development of food security across the SSA-region, a trend analysis for the frequency of the environmental hazard have been carried out. Also, a forecast has been estimated for the prevalence of undernourishment up to 2030.

Within figure 11, an trend analysis of the environmental hazards around Africa have been constructed. As can be seen from the trend analysis, the frequency of environmental hazards is going up in the period from 1960 to 2015. For the last two years we must consider the limitation of this dataset, because it is possible that for 2015-2017 a lot environmental hazards have not been added to the EMD Database.

Flood cause the most climate-related disasters globally, with flood-related disasters seeing the highest increase of 65% in occurrence over the last 25 years. For storms, the frequency is also going up, although not as high as for floods.

Floods cause more climate-related disasters globally than any other extreme climate event, with flood-related disasters seeing the highest increase – 65 percent – in occurrence over the last 25 years. The frequency of storms is not increasing as much as that of floods, but storms are the second most frequent driver of climate-related disasters.

**Forecast of Prevalence of Undernourishment**

A second forecast is established for the percentage of undernourishment in Sub-Saharan Africa. The forecast has been made using the ARIMA method. Within this method a Autocorrelation and Partial Autocorrelation are created. Based on those figures [10] the forecast is created with a seasonal random walk. Because we want to forecast the unknown the forecasting starts for the year 2017, because data of 2017 is not known. This is why there can be seen a gap between observed and forecasted lines.

As can be seen from the figure the undernourishment is very uncertain, but the general trend will be a rise off the undernourishment in Sub-Saharan Africa. The uncertainty can be explained by the data that is available. The undernourishment is measured once a year, so for this forecast only 17 data points has been used. It can be concluded that the forecast has so much uncertainty in how undernourishment will develop in the coming, that it cannot be stated that it will rise or fall.

## Chapter 5 conclusion

Throughout this report there is described the state of Food Security in Sub-Saharan Africa and how environmental hazards will affect the food security in Sub-Saharan Africa. Therefore, the following main research question has been identified:

*'To what extent is hunger in sub-Saharan Africa related to environmental hazards and how will this trend develop until 2030 under the effects of climate change?'*

The last decades the food security has developed rather well in Sub-Saharan Africa. Prevalence of Undernourishment within the total population of the SSA-region has dropped from 27.5% to 21.3% of the population. Also, the depth of the food deficit has dropped from 250 kcal in 1992 to 130 kcal in 2016 for the SSA-region. These results are promising, but it is alarming that the last few years the prevalence of Undernourishment is rising again and that the fall of the food deficit has now stabilised. The SSA-region is still a long way from the average 10.8% of the world's in 2016.

The analyses of indicators of malnutrition have been compared between the world and Sub-Saharan Africa in the timeframe of 2010-2017. We concluded that stunting, overweight and anemia have declined in Sub-Saharan Africa. Overall, we can conclude that the prevalence of negative side effects of malnutrition is still much worse in Sub-Saharan Africa when comparing it to the World. This means that the development of a lot people, including children, is still affected by the effects of malnutrition hereby crippling communities across the Sub-Saharan region.

When we took a closer look at the food production development. It shows that the food production has risen for around 30% compared with 2004. On the other hand, there can also be seen a relatively even sized grow in population. From our results it turned out that there is no abnormal difference between population growth and food production growth. This means that the current worsening food situation in Africa is not solely an effect of a rapidly growing population.

We a

For the agricultural sector within countries where climate extremes are reoccurring, chances are that the agriculture sector simply do not get the time to recover from previous hazards and prepare for the next. This has to change in the future in order to battle the current rise of hunger in the region. Developing countries within in SSA need to develop more resilient agriculture which can sustain

Conclusion main questions

Part 1: (target 2.4) What has been the historic trend of environmental hazards in sub-Saharan Africa and the impact on food systems?

Part 2: How will these trends develop (environmental hazards)

The forecast for the Prevalence of Undernourishment in Sub-Saharan Africa shows is a very uncertain future in which the prevalence in 2030 could either go towards the 40% or decline to nearly 15%.

The effects of climate change cannot be predicted. To contribute to more food security some possible policies will be mentioned in which the effects of climate change can hopefully be minimized. The first policy would be to make Sub-Saharan Africa more resilient for environmental hazards and effects of climate change. A second policy contains the increasing of Cereal Yield by using more efficient ways of agriculture. For instance, grow crops that can handle droughts or crops that can handle floods (like rice).

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