Challenges and Opportunities for Food Security Amidst Land-Use Changes in Bangladesh

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Abstract

This study aims to explore the extent of food security in Bangladesh, focusing on the key challenges and opportunities for ensuring long-term food availability and accessibility. Stunting and undernourishment are used as primary indicators of food security. The analysis largely relies on data from the World Bank and FAOSTAT to examine the effects of economic development, population growth, and land-use changes on food security. The regression results indicate that higher import dependency correlates with increased levels of stunting, while higher GDP per capita is linked to lower levels of both food security indicators. This emphasises the importance of promoting domestic agricultural production and economic development to improve food security in Bangladesh. This study also concluded that policies aimed at reducing reliance on international trade and addressing inefficiencies in land use could further enhance food security.

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1. Introduction

Climate change is probably the most important environmental challenge that humanity is facing today. The Earth's climate system is undergoing a period of unprecedented change, where climate change exacerbates existing vulnerabilities and threatens food security for the most vulnerable communities (Mbuli et al., 2021). Food security exists when “all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (Matemilola & Alabi, 2021). This is a particularly urgent challenge in developing countries such as Bangladesh, where agriculture is the backbone of the economy and millions of people depend on natural resources for their livelihoods (Hoque et al., 2019). Extreme weather events, such as heat waves and floods, are becoming more frequent and intense, causing severe consequences. These consequences are expected to worsen as the global population continues to grow to 9.7 billion by 2050, placing huge pressure on food availability (United Nations, n.d.). In Bangladesh, this vulnerability is amplified by the high population density and the dependence on agriculture for many citizens. Almost half of all the workers in Bangladesh are directly employed in the agricultural sector (World Bank, 2016).

More than 60% of the total land area is used for farming, a percentage that has been increasing for the past decade (World Bank, n.d.-a). However, there is some inconsistency in the data regarding the trend in arable land. While World bank indicates an increase, others suggest a decrease in arable land due to factors like soil salinisation and rising sea levels (Hossain et al., 2019; Islam & Hassan, 2011). For example, roughly 63% of the cultivable area in the coastal zone is suffering from soil salinisation, and it is predicted that a one-metre rise in sea level will cause nearly 20% of Bangladesh's land area to be submerged, forcing between 20 and 30 million people out of the coastal zone (Hoque et al. 2019). This indicates a research gap that needs further exploration. It is predicted that climate change will have significant impacts on food security and farming profits in developing countries, such as Bangladesh, with a disproportionate impact on the well-being of the poor in rural areas (Jalal et al., 2021). In many cases, it is the poorest households that bear the brunt of climate change impacts because they live in more vulnerable regions. People who are already vulnerable are also most at risk of food insecurity due to loss of property and inadequate insurance coverage (Food and Agriculture Organisation of the United Nations [FAO], 2006).

Up until the beginning of the 1990s, the Bangladeshi government adopted a self-sufficiency programme in order to ensure national food security. Food security has been seen by the government as a key element in the country's development (Clapp, 2017). However, the government changed their strategy to self-reliance in 1993, meaning Bangladesh was importing food from the world market when prices were lower than the costs of growing domestically, thus freeing up land for other land uses (Deb et al., 2009). Governments' interest in food self-sufficiency returned after the 2007-08 food crisis. According to a study of the 2008 global food price crisis, 25% of Bangladeshi households suffered from food insecurity at the end of 2008 (Mohsin & Rahaman, 2014). During the crisis, food-exporting countries subsequently implemented export limitations and an export prohibition. Bangladesh struggled to import the required amount of food, and as a result, domestic food prices quickly increased as farmers and consumers stockpiled rice in anticipation of rising prices (Deb et al., 2009). This food crisis disproportionally effected the smallholder farmers, who lack resources to diversify production and do not necessarily benefit from increased food prices at the farm-gate level (Molitor et al., 2017).

Ensuring food security for all citizens is still one of the largest challenges that Bangladesh faces today. Despite the growth in food production, achieving food security is still a severe problem, mainly due to the effects of price increases on the purchasing power of the poor community (Saha et al., 2016). Bangladesh its journey to food self-sufficiency is under threat from climate change. In Bangladesh, establishing self-sufficiency in rice production and preserving stable rice prices have always been associated with food security (Deb et al., 2009). However, food self-sufficiency does not necessarily equal food security. In the late 1990s, Bangladesh achieved an important accomplishment. For the first time in history, food grain output exceeded the targets. Still, domestic food grain production remains vulnerable to the impacts of climate change, keeping in mind the threat of production shortages and insufficient food availability. Furthermore, the increase in grain output did not coincide with a large increase in the availability of other foods (Hossain et al., 2005).

As a result of fast population growth, Bangladesh has experienced rapid urbanisation. As cities expanded, they replaced rural areas, crowding out farms, nature, and low land (Hassan, 2017). The disappearance of some arable land obviously affects food availability and prices, and therefore food security. Food security is usually a matter of “access” instead of “availability.” But despite large economic growth over the past decades, 20 percent, or 16.5 million people, are still food insecure, and 24% of the citizens live below the national poverty line (World Food Programme, 2022).

There is a need to critically examine the projections regarding agricultural productivity. While some studies predict a decrease in productivity due to salinity intrusion, droughts, and other adverse climatic conditions (van Scheltinga et al., 2023), other sources suggest potential increases or at least uncertainty about the future trends in productivity (Mozumdar, 2012; Rahman & Anik, 2020). This presents another research gap where further investigation is required to clarify these projections and understand the underlying factors influencing productivity.

This thesis will explore to what extent Bangladesh has been achieving food security for all its inhabitants, and what the key challenges and opportunities are for ensuring long-term food availability and accessibility for its population. This will be studied through the following sub-questions:

- What are the effects of climate change on the food security of smallholder farmers in Bangladesh?
- How is climate change affecting agriculture in Bangladesh, and what is the impact on food security?
- To what extent will projected population growth in Bangladesh in the coming decades threaten food security?
- To what extent do changes in arable land, food imports, and rice yield influence food security in Bangladesh, compared to neighbouring countries?

This thesis is organised as follows: Chapter 2 presents a background to the study and a literature review. Chapter 3 informs about the research methodology of this study, including the data used for the analysis and the applied descriptive statistics in Stata. Additionally, a comparative analysis with Vietnam, Laos, and Cambodia is included to be able to provide insights into food security challenges faced by neighbouring countries with similar conditions. Observing the patterns in these countries aims to distinguish relationships specific to Bangladesh's situation and increase empirical credibility. These countries, like Bangladesh, are very vulnerable to climate change and heavily reliant on agriculture, which makes them an appropriate choice for a comparative analysis. Chapter 4 presents the regression results, followed by an analysis and recommendations in Chapter 5, and a conclusion in Chapter 6.

2. Theoretical framework

2.1 Constraints for small-scale farmers

Understanding how climate change threats impact different scales of farming is important for ensuring food security. The agricultural landscape in Bangladesh is characterised by large differences in scale and resources. Small-scale farmers, often referred to as smallholders, usually own or manage land parcels smaller than two hectares (Samberg et al., 2016). In contrast, large-scale farms can own dozens or even hundreds of hectares. This significant difference in land size translates into resource availability. In Bangladesh, 99% of the farms are small-scale and fragmented, with an average farm size of less than one hectare (Ali et al., 2020). The small-scale agricultural sector plays a crucial role in providing livelihoods in Bangladesh, emphasising the significance of this type of agriculture. Despite the importance of small-scale agriculture, it faces many hurdles that limit its effectiveness in addressing the correlated crises of food insecurity and poverty.

Production and market focus also differ between scales. Smallholders typically cultivate a wider variety of crops, including staple foods such as rice and vegetables, for their own livelihoods and local markets (Ferris et al., 2014). Crop diversification is a strategy that smallholder farmers employ to reduce their vulnerability to climate change (McCord et al., 2015). This diversification can provide a safety net if a certain crop fails due to climate shocks.

Market forces have encouraged large-scale farms to focus on monoculture production for national or international markets, increasing their vulnerability to price fluctuations and extreme weather events (Figuerola et al., 2014). However, according to Sheng et al. (2014), large-scale farms are more likely to adopt advanced technologies, which can improve efficiency and potentially mitigate some climate risks. Smallholders, due to a lack of financial resources, limited access to climate information, lower socioeconomic and educational status, and many other constraints, often struggle to access and invest in technologies such as drought-resistant seeds or irrigation systems (Cohn et al., 2017; Phillipo et al., 2015; Salami et al., 2010). Large-scale farms, with their greater financial resources, therefore have more flexibility to adapt. Unlike large-scale farmers, who often have access to insurance, small-scale farmers lack this safety net. This exposes them to significant income inconsistencies, as their earnings can fall due to market surpluses or crop failures, even when prices are high (Food and Agriculture Organisation of the United Nations [FAO], 2006).

If smallholder farmers fail to respond to climate change, it creates a vicious cycle of low productivity and poverty that exacerbates smallholder vulnerability. The limited adaptive capacity of these farmers, given the growing uncertainty in weather patterns, therefore affects the survival of these small-scale farmers, who produce mainly for the local market and are therefore crucial for community food security (Mbuli et al., 2021). This section links to the research question on the effects of climate change on food security by highlighting the importance and vulnerabilities of smallholder farmers, which are important for understanding the implications for local food security.

2.2 Effects of climate change on agricultural production

Rising sea levels are causing saltwater intrusion further inland. This intrusion contaminates freshwater sources that are used by farmers for irrigation and directly salinizes coastal soils. Additionally, changes in precipitation patterns are exacerbating this problem. Reduced rainfall decreases the natural flushing of salts from the soil (Li et al., 2018). Due to climate change, the impact of rainfall-induced leaching differs more over time and is becoming more unpredictable. The percentage of saline soils in Bangladesh has increased from less than 1% in 1990 to 33% in 2015, mainly as a result of sea water intrusion in the coastal areas (Rahman et al., 2018). According to Clarke et al. (2015), salt accumulation in the soil is mainly due to two main mechanisms: capillary rise and irrigation. Particularly in irrigated regions, capillary rise leads to the buildup of salt from shallow groundwater during the dry season. Because of this, the root zone could be getting a nearly constant supply of salt because soil water is either absorbed by the crop or evaporates at the surface.

The negative effects of seawater intrusion are most apparent after extreme weather events, such as El Niño. These extreme weather events have a substantial impact on water availability and access, and therefore on irrigation and agricultural production (Schneider & Asch, 2020). Salt-sensitive crops, such as rice, are particularly vulnerable to saline soils. Given that rice is the main staple food for nearly every household, it is crucial to maintain rice production without being affected by increasing soil salinity, to ensure food security (I. Saha et al., 2021).

Like the rest of the world, Bangladesh is also experiencing rising temperatures. Projected increases in average daily temperatures of 1.0°C by 2030, 1.4°C by 2050, and 2.4°C by 2100 (Alam et al., 2023) threaten to disrupt agricultural yields. Higher temperatures shorten the growth period for rice, which might seem beneficial as it could lead to more frequent harvests and less water use. However, this advantage is outweighed by the negative impact of heat stress. Rice is very sensitive to temperature changes, especially during flowering and grain development. If it gets too hot, the rice plants suffer from heat stress (M. B. Hossain et al., 2021). In essence, while faster growth cycles might be achievable, the overall yield could significantly decline.

Due to a combination of factors, including a lack of knowledge and reliance on outdated technologies, many farmers have been extracting water without considering the sustainability of groundwater resources. This has led to negative impacts on groundwater levels, which have been showing a very disturbing reduction in many districts in Bangladesh (Dey et al., 2017). To address this issue, it is essential to implement sustainable water management, such as modern irrigation techniques, and educate farmers about the importance of conserving groundwater. This section addresses the research question about how climate change impacts agricultural productivity and, consequently, food security.

2.3 Impact of population growth on future food security

With 1,301 people per square kilometre, Bangladesh has one of the highest population densities in the world (World Bank, n.d.-c). According to Faisal and Parveen (2004), in the past, annual domestic cereal production has often remained below annual domestic consumption, regardless of the strong commitment to food self-sufficiency. In 2050, Bangladesh’s population is expected to exceed 200 million and further strain its biocapacity (Karim et al., 2024). As a result of this population growth, agricultural demand will increase and exacerbate the gap between agricultural production and demand. An increase in production can be achieved either by increasing the cultivable area, by increasing the yield of the crop, or both. Yields can be increased through more intensive land preparation, enhanced seeding, additional application of labour, improved irrigation techniques, and better disease management (Phalan et al., 2016).

With the expected population growth, demand for food grains will increase by over 50%. Currently, approximately 10 million hectares in Bangladesh are dedicated to food grain cultivation. According to Timsina et al. (2018), in Bangladesh, most land suitable for farming is already under cultivation. In fact, cultivable land area is even decreasing over time due to residential and industrial developments. So, the demand for food grains is expected to grow significantly, but crucial resources such as land and water for production will become scarcer (Faisal & Parveen, 2004), threatening food security. This section relates to the research question on how projected population growth will impact future food security. Further on in this study, population data will be integrated with agricultural production data to determine the effects of population growth.

2.4 Impact of urbanisation on food security

Within the same group of countries, a seemingly small increase in urban growth can significantly increase the probability of food insecurity. According to Szabo (2015), urban growth of 1% equals a 27% risk of high food insecurity, but if urban growth increases to 4%, this risk jumps to 89%. Bangladesh's share of the urban population grew at an average yearly rate of 3.13%, from 9% in 1974 to 40.5% in 2023 (Knoema, n.d.). An increase in income and urbanisation tends to increase consumption of different types of food. For example, from 1961 to 2013, the yearly per capita wheat consumption increased from 8.6 kg to 17.5 kg (+102%) (Mottaleb et al., 2017). Their research also reveals that, compared to rural citizens, urban citizens consume 0.05 grammes more wheat per person per day. In comparison, the average daily consumption of rice by urban households is 65.8 g lower than that of rural ones. So, besides the overall increase in food demand, there is also a shift in dietary preferences, particularly towards resource-intensive foods like wheat, which places additional pressure on the food system's capacity to meet the growing demand (Gladek et al., 2017).

Bangladesh's National Food Policy specifically identifies urban slum dwellers as a high priority group to ensure food security. This is because their living conditions have not substantially improved over the last three decades (Bhattacharjee & Sassi, 2021). According to the World Bank, 52% of the urban population in Bangladesh lives in slums (World Bank, n.d.-c). The high concentration of people in urban slums exacerbates food insecurity due to limited access to resources, unstable employment, and inadequate infrastructure. Urban slum dwellers often rely on informal markets. Their situation is further exacerbated by poor storage facilities, such as limited access to refrigeration, leading to higher rates of food spoilage and waste (Kimani-Murage et al., 2014; Tacoli, 2020). This section is relevant to the research question on the effects of land use changes on food security. It emphasises the dual impact of land use changes and altered food consumption patterns. In Chapter 3, data on the percentage of arable land will be analysed to determine the effect of land use change on food security.

3. Methodology

This chapter outlines the methodology employed in this research to investigate how food-secure Bangladesh has been in the past, and if there is a relationship between the loss of arable land, climate change, and food insecurity. This chapter details the data collection methods, data analysis techniques, and ethical considerations involved in the research. All data is collected at a national level. Most of the data in this research was retrieved from FAOSTAT (Food and Agriculture Organisation of the United Nations) and HDX. FAOSTAT provides extensive data on food and agricultural statistics. The World Bank is used as a source for socio-economic indicators such as GDP and population growth. Both FAO data and data from the World Bank are frequently used in scientific research. Additionally, a few datasets were retrieved from Kaggle and IndexMundi. IndexMundi is a data portal with curated data turned into easy visuals. To ensure the reliability of the data from Kaggle, the credibility score and provenance of the datasets were checked.

3.1 Data collection

3.1.1 Data on land use changes in Bangladesh

The World Bank provides data on the percentage of arable land relative to the total land area over a period ranging from 1961 to 2021. However, only data from 2000 to 2021 is used for this research. This decision was made to ensure consistency in the time frame of all datasets used in the analysis. The FAO defines arable land as land that is temporarily covered in crops (double-cropped or triple-cropped areas are counted once), temporary pasture for grazing, land under market or kitchen gardens, and land that is temporarily fallow (FAO, n.d.). Temporary fallow land refers to land left fallow for less than five years. It is important to note that abandoned land due to shifting cultivation is not included in this dataset.

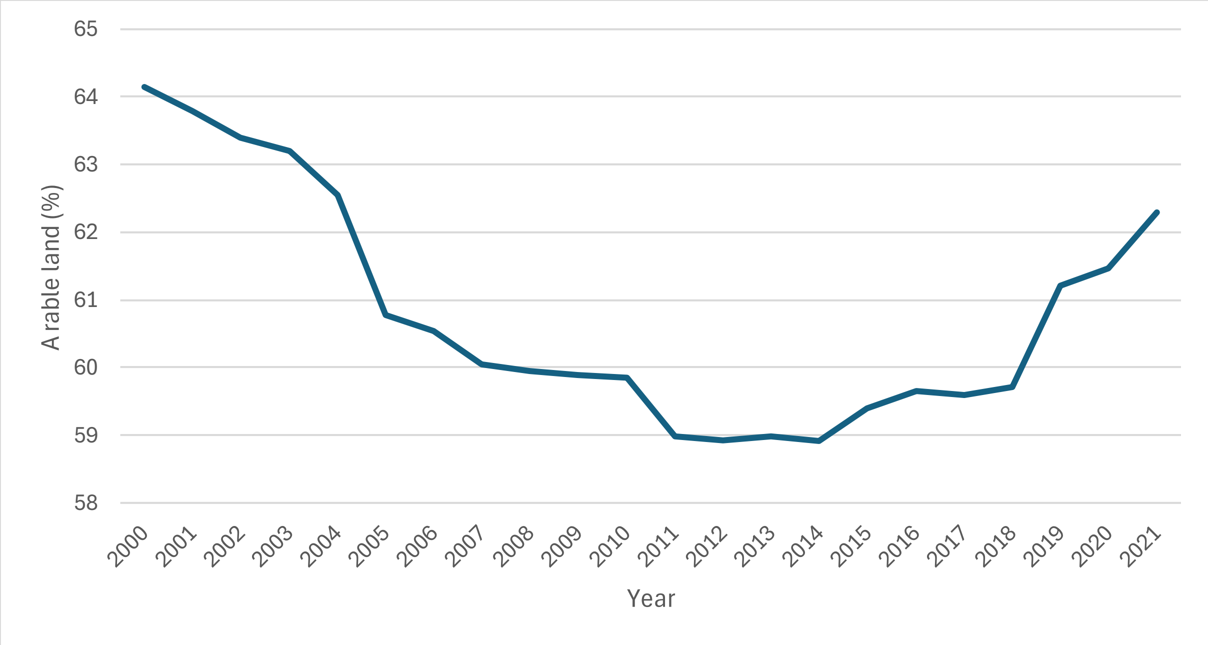

Figure 1: Yearly percentage of arable land in Bangladesh (2000-2021), (The World Bank)

Figure 1 presents a line graph illustrating the percentage of arable land relative to the total land area in Bangladesh from 2000 to 2021. As can be observed in the graph, the percentage of arable land shows a gradual downward trend in the first decade of the study period. These changes could be attributed to population growth, urbanisation, or changes in land use patterns. Hasan et al. (2021), who utilised Land Use Land Cover (LULC) data to analyse land cover changes from 1990 to 2019, found a decrease in both waterbody area and forest area, while urban areas exhibited an increase. These developments naturally affect the size of available arable land. Since 2015, and more prominently since 2019, an increasing trend has been observed. This might be correlated with government interventions, such as the National Agriculture Technology Program and the Integrated Agriculture Productivity Project, that focus on increasing food security and productivity through better agricultural practices and improved technology (Islam, 2020).

Urbanisation in South Asia has been significantly increasing over the past decades due to a shift in economic focus (Swain & Teufel, 2017). As mentioned in Chapter 2, urbanisation rates have a significant impact on food demand and security. Due to the absence of data on urban land as a percentage of total land area, the percentage of urban population is used as a substitute. This is a widely used method in the literature to estimate urbanisation trends and evaluate urban classifications (Balk et al., 2018; Seto et al., 2011). This method is grounded in the close relationship between urban population growth and urban land expansion. Data on the percentage urban population as a percentage of the total population in Bangladesh is retrieved from the World Bank.

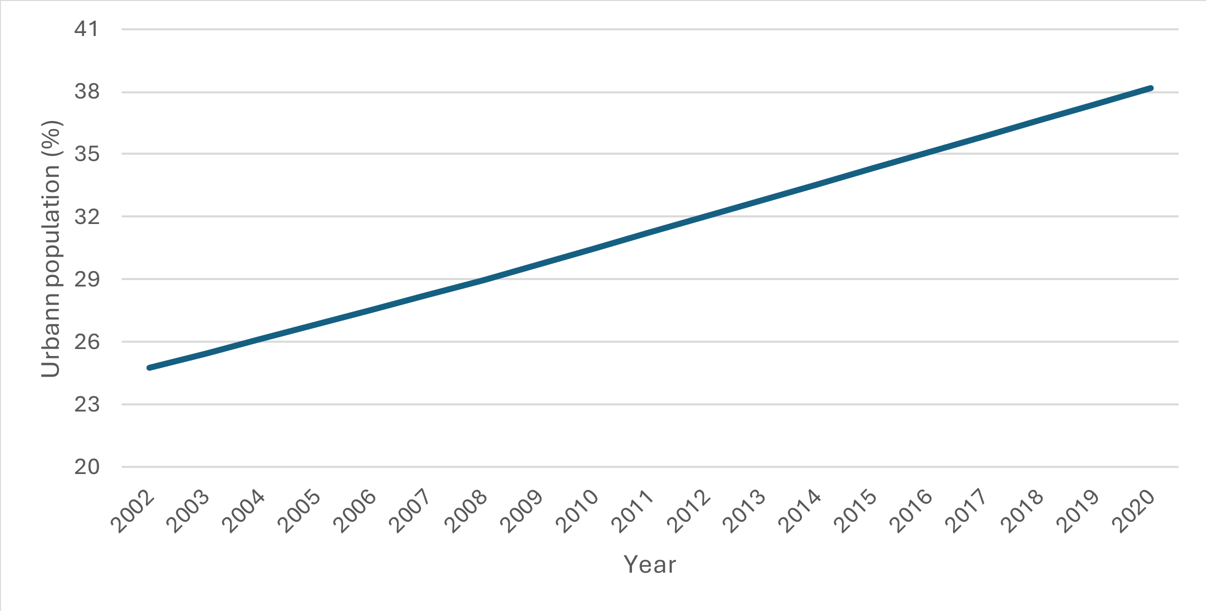

Figure 2:Urban population as a percentage of total in Bangladesh (2002-2020), (The World Bank)

Figure 2 reveals a clear trend: Bangladesh has experienced a steady, what looks like an almost linear, increase in urban population over the past two decades. It's important to note that for some years, data points were estimates from the United Nations Population Division due to lack of data collection during the study period. The urban population grew from 24.76% in 2002 to 38.18% in 2020, an average annual increase of 0.67%. By comparing the data on arable land and urban population, it can be concluded that there is no correlation between these variables. This finding contrasts with expectations based on existing literature. According to previous research, urbanisation often leads to a conversion of agricultural land for urban development, potentially jeopardising food security (De Bruin et al., 2021; Kang et al., 2023). This suggests the need for further research. One possible explanation is that the urban population in Bangladesh is concentrated in very dense areas, requiring relatively little space for urbanisation (Koomen et al., 2023) .

3.1.2 Data on food security in Bangladesh

Data on food security has been obtained from the Humanitarian Data Exchange (HDX), again for a period ranging from 2000 to 2022. A few key indicators are used to determine whether food security exists. First, data on the percentage of children under the age of five who are stunted will be analysed. This indicator, as defined by the World Health Organisation (n.d.), refers to children who are "too short for his or her age and is the result of chronic or recurrent malnutrition." This data reflects the immediate food insecurity of this group.

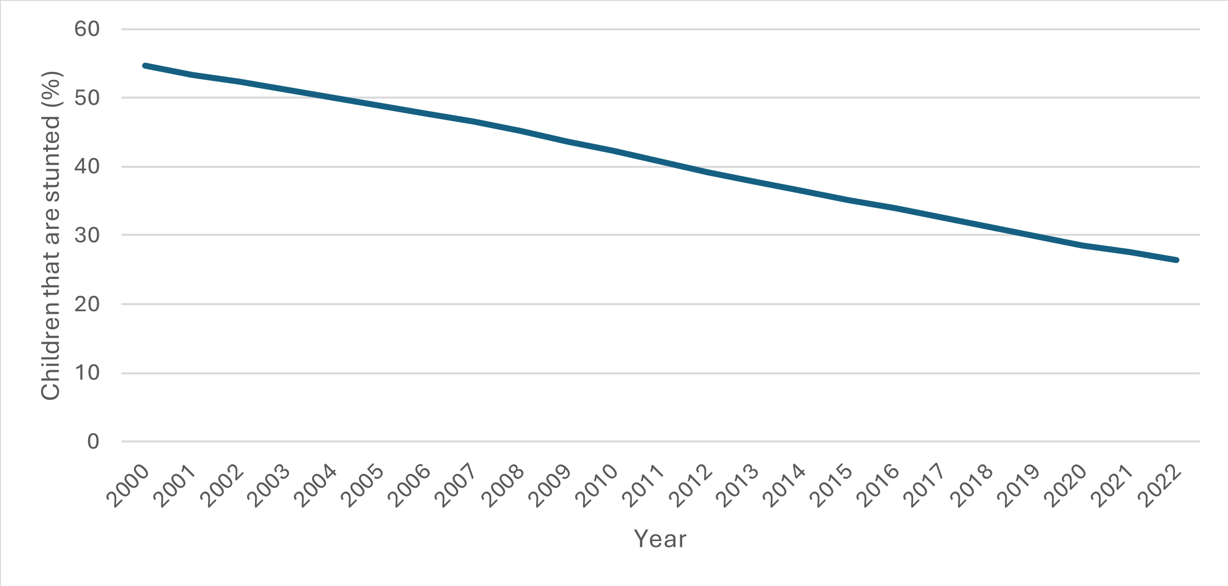

Figure 3: Yearly percentage of children under the age of five that are stunted (2000-2022), (HDX)

Figure 3 graphically shows the data on children who are stunted. The graph shows a strong, relatively constant decline over the study period. This trend suggests improvements in various factors influencing child nutrition. The highest percentage was registered in 2000 at an alarmingly high of 54.7%, while the lowest was in 2022 at 26.4%. Despite strong improvements, this means that still more than 1 out of 4 children are stunted, indicating that ensuring all children get enough nutrition is still a major challenge.

Secondly, the dataset includes the prevalence of undernourishment, expressed as a percentage of the population. This indicator is averaged over three years and contains an annual value from 2000 to 2022. The prevalence of undernourishment is the percentage of the population whose regular food consumption is insufficient to meet the dietary energy levels that are needed to maintain a normal, healthy life. This makes it a useful indicator for establishing food insecurity.

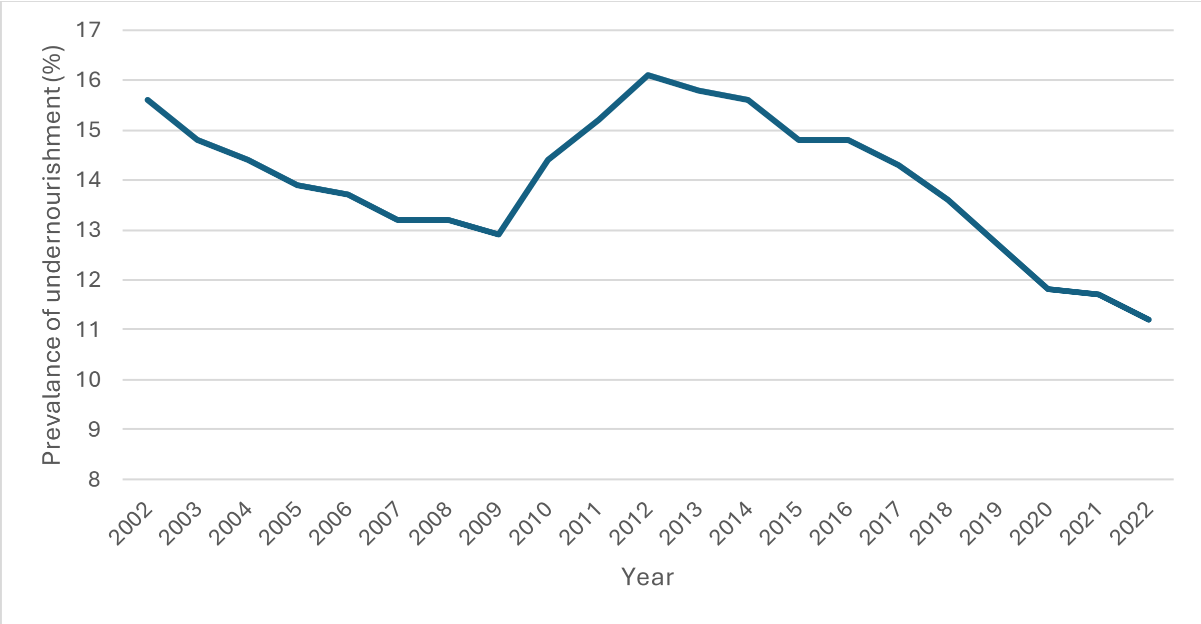

Figure 4: Prevalence of undernourishment in Bangladesh (2002-2022), (HDX)

The graph shows a steady decline in the prevalence of undernourishment since 2012. After the global crisis in 2008, there have been a few years with an increase in undernourishment. Throughout the whole study period, there has been a decrease from 15.8% to 11.2%. Both the percentage of children under the age of five that are stunted and the prevalence of undernourishment, are used in other studies to assess food security (Berra, 2020; Headey and Ecker, 2013; Poudel & Gopinath, 2021). Stunting is a short-term indicator of acute malnutrition and reflects immediate food security concerns, while the prevalence of undernourishment is a long-term indicator used by organisations such as the FAO to measure food insecurity and the ability of a population to access sufficient food over time. This may explain the difference in trends between both variables.

According to the Bangladesh Rice Knowledge Bank (n.d.), rice is the staple food for approximately 135 million citizens, provides around 48% of rural employment, and accounts for about two-thirds of the total calorie supply. Using rice imports relative to rice consumption as a method to measure food security in a country is a common approach in the literature (Baer-Nawrocka & Sadowski, 2019). Given the importance of rice for the population, data on rice yield (in kg/ha) for all four countries were retrieved from the FAO for analysis. This method provides insights into the balance between domestic production and consumption needs, thereby highlighting the reliance on imports to meet food security requirements. Data is retrieved from the Food and Agriculture Organisation of the United States. Data on rice imports is retrieved from Kaggle and data on rice consumption is retrieved from IndexMundi.

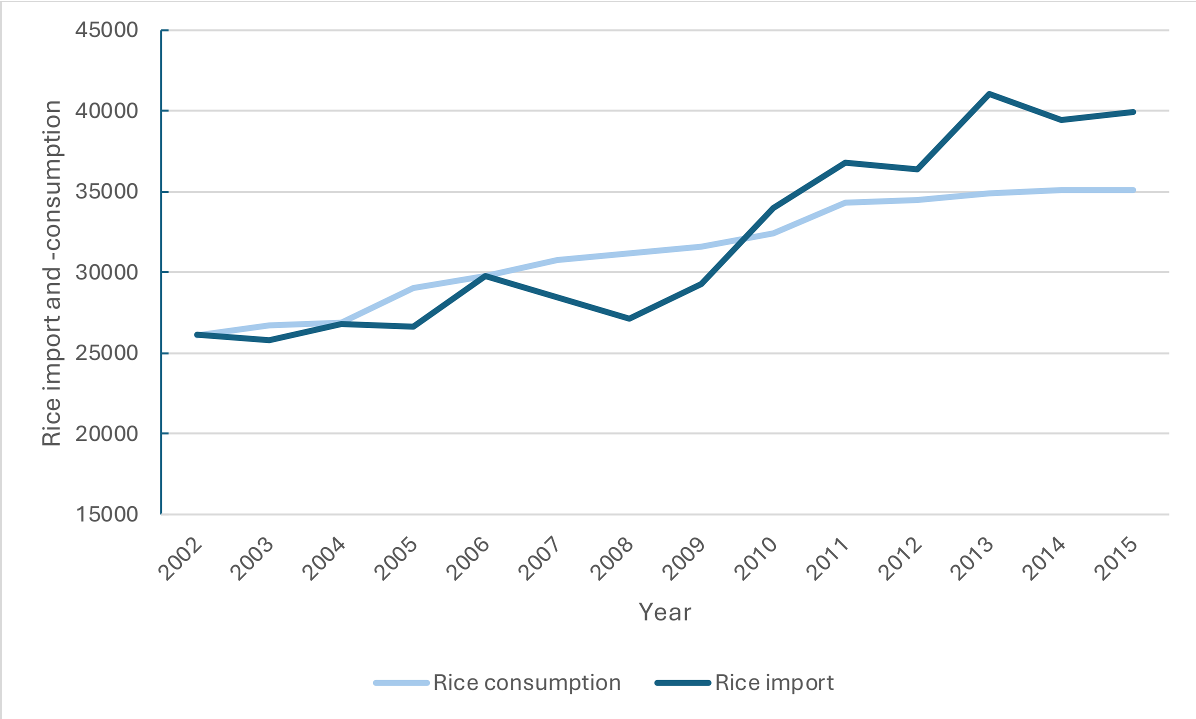

Figure 5: Rice imports relative to consumption in thousand metric tonnes (2002-2015), (IndexMundi; Kaggle)

The data indicates a general increase in rice imports over the years, starting from 26,138,000 kg in 2002 to 39,919,000 kg in 2015. There are some fluctuations, but the overall trend shows an increase in rice imports. The decline around 2008 is most likely the result of the global financial crisis. Rice consumption also shows a consistent upward trend, with consumption increasing from 26,100,000 kg in 2002 to 35,100,000 kg in 2015. This can be the result of both a growing population and higher per capita consumption. Contrary to what you would expect, imports are consumption in most recent years. Despite surpluses in production, Bangladesh keeps importing rice (Abdullah & Ali, 2024). A study by the Food Ministry found that non-human consumption, including pre- and post-harvest rice losses, accounted for 26% of total rice production. Another reason for high import rates is market dynamics, including price fluctuations and stockpiling by large importers, which create artificial shortages. Imports are used to mitigate these market distortions.

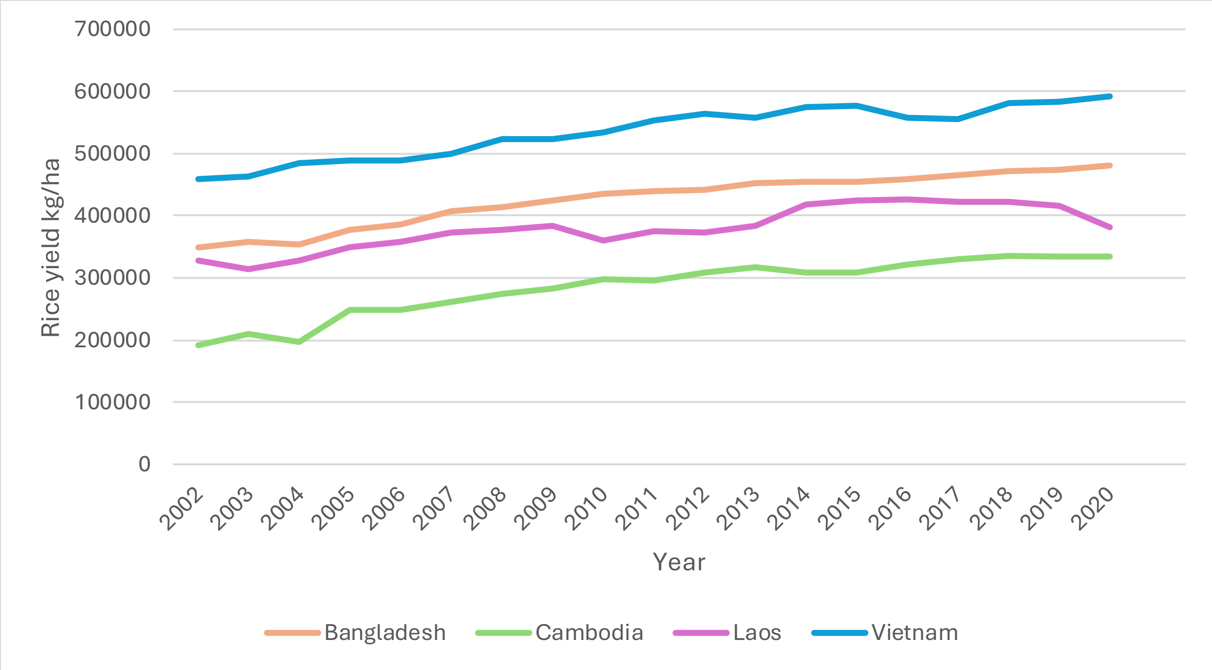

Figure 6: Annual rice yield for Bangladesh, Cambodia, Laos, and Vietnam (2002-2020), (FAO)

Figure 6 shows that throughout the whole period, despite some fluctuations, there appears to be an increasing trend in rice yield across all four countries. This data will be included in the statistical analysis to estimate the effects of trends in rice yield on food security.

To analyse the impact of rice imports on food security in Bangladesh, the cereal import dependency ratio (CIDR) is included in the statistical analysis. This ratio is a 3-year average that indicates how much of the available domestic food supply has been imported and how much comes from the country's own production. It is calculated as follows: *(cereal imports - cereal exports) / (cereal production + cereal imports - cereal exports) * 100*. A high CIDR suggests that a country is more dependent on external sources to meet its needs, indicating lower self-sufficiency. Negative values indicate that the country is a net exporter of cereals. Data on CIDR is retrieved from HDX.

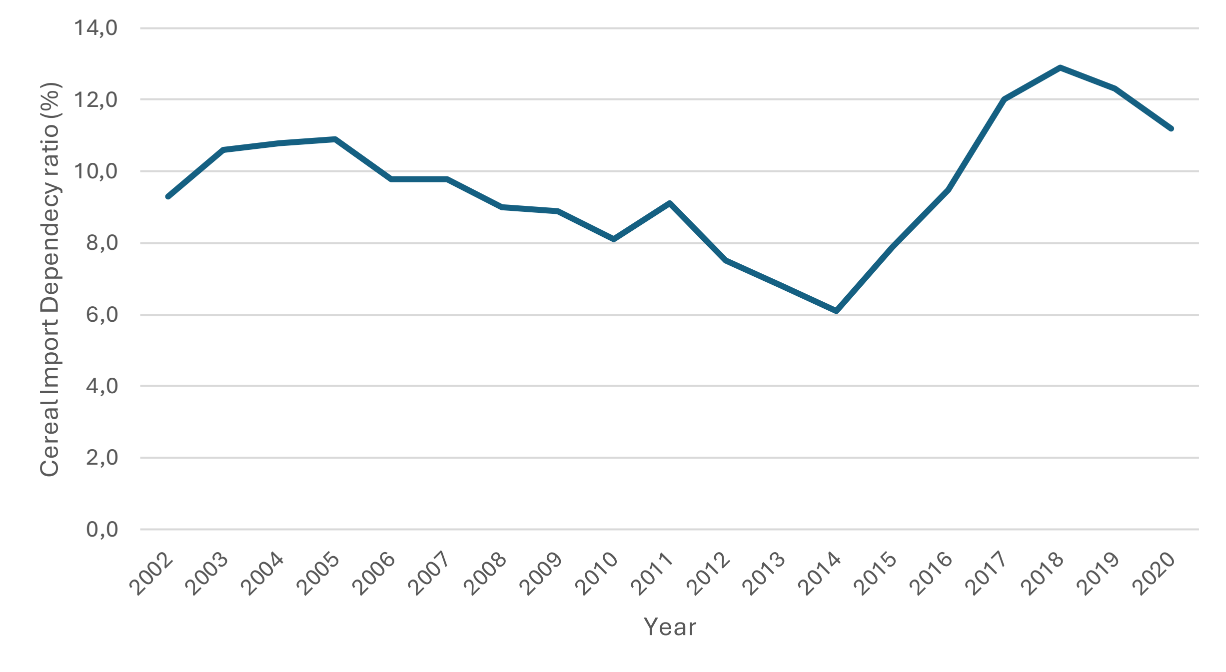

Figure 7: Cereal Import Dependency ratio in Bangladesh (2002-2020), (HDX)

The cereal import dependency ratio for Bangladesh shows some strong fluctuations. Between 2006 to 2014, the ratio declined to a low of 6.1% in 2014, possibly the result of increased domestic production, or high import prices. From 2015 onwards, the import ratio began to rise but decreased from 2019, indicating a continued but somewhat reduced reliance on import.

3.1.3 Data on socio-economic factors

The poverty headcount ratio is a variable used for measuring the extent of poverty within a population. It represents the percentage of the population living below a specified poverty line, in this case, $3.65 a day adjusted for 2017 purchasing power parity (PPP). The $3.65 poverty line is based on national poverty lines in countries classified as lower middle-income. The data for the poverty headcount ratio has been collected through the Household Surveys, typically conducted every five years and available from 1983 to 2022 at the World Bank.

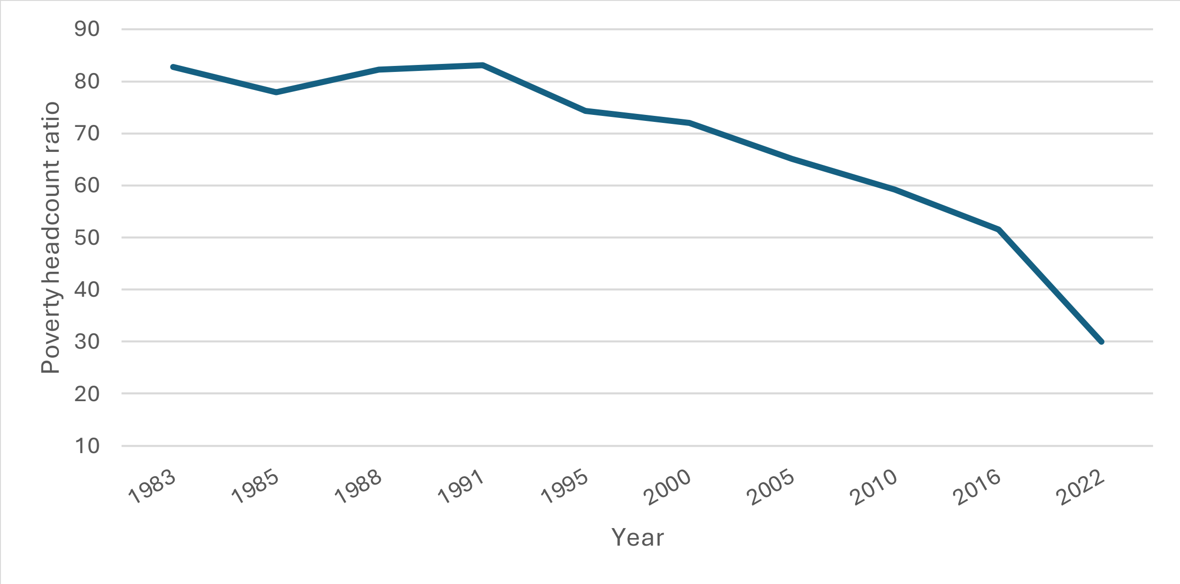

Figure 8: Poverty headcount ratio at $3.65 a day as a percentage of total population in Bangladesh (1983-2022), (World Bank)

Data on the poverty headcount ratio shows a clear downward trend, starting from a peak of 82.7% in 1983 and eventually falling to 30% in 2022. This represents strong progress in poverty reduction, potentially indicating an improvement in overall access to food and basic necessities.

The Gini index is a measure used to quantify income inequality within a population. It ranges from 0 to 100 percent, where 0 indicates perfect equality (everyone has the same income) and 100 implies perfect inequality. The Gini index measures the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. Just as with data on the poverty headcount ratio, the Gini index for Bangladesh is calculated based on the Household Survey data. This data has been retrieved from the World Bank.

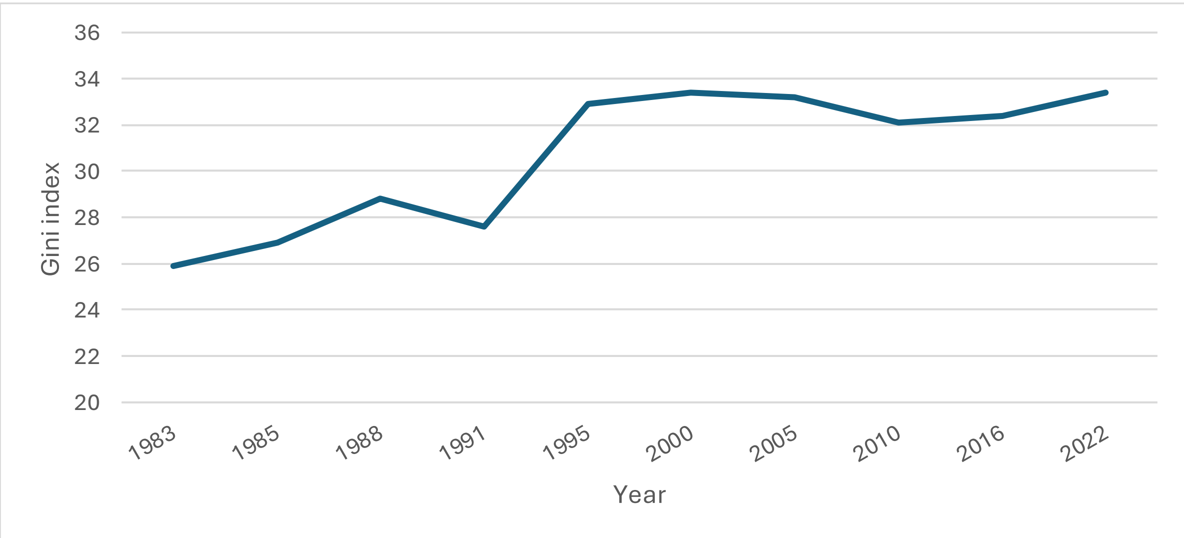

Figure 9: Gini index (%) in Bangladesh (1983-20022), (World Bank)

Figure 9 shows that the Gini index exhibits a varied trend. It decreases slightly to 27.6% in 1991 but then jumps to 32.9 in 1995, indicating a significant rise in inequality during this period. This suggests that the economic gains haven't been evenly distributed across the population.

Despite the reduction in poverty, the Gini index shows that inequality has not seen a corresponding decline. This indicates that economic benefits spread disproportionately towards wealthier segments of the population, resulting in unequal growth. It is possible for the Gini coefficient of a country to rise while the number of people living in poverty decreases. This is because the Gini coefficient measures relative, not absolute, wealth. While the overall decline in poverty is a positive development, high income inequality suggests that those at the lower end of the income spectrum might not be fully benefiting from the economic progress, potentially limiting their access to diverse and healthy food consumption.

3.2 Data analysis

This section outlines the statistical methods employed to analyse the impact of changes in arable land on food security and Bangladesh from 2002 to 2020. To reinforce the findings and explore whether the same relationships between the independent variables and food security hold in other countries, data from Vietnam, Cambodia and Laos were included in the analysis. These three countries, like Bangladesh, are originally predominantly agrarian economies where agriculture plays an important role in the livelihoods of many citizens. These countries share similar climatic conditions, soil types, and agricultural practices, making them suitable comparators for studying the determinants of food security. Incorporating data from these countries strengthens the causal conclusions of the study. By examining the impact of rice yield, arable land, import dependency, population growth, and GDP across all these countries, it controls for country-specific effects and ensures that the observed relationships are not specific to Bangladesh alone.

Given the presence of data for multiple years for all countries, a panel data regression analysis is best suited. A panel data regression allows for both time-invariant country-specific effects and time-varying effects. The analysis started by destringing all variables in Stata and converting them into a numeric format, to make sure calculations and statistical analyses could be performed. To account for potential influences from population growth on the amount of arable land, the population growth rate is included as a control variable in the panel data regression for all countries. The annual population growth rate for year 't', is the exponential rate of growth of the midyear population from year 't'-1 to t, expressed as a percentage. GDP per capita in US dollars is also included in the analysis as a socio-economic control variable. Data on both of these variables is retrieved from the World Bank.

4. Results

To investigate the determinants of undernourishment in Bangladesh, a fixed-effects panel regression model was employed. This type of model accounts for unobserved heterogeneity by controlling for country-specific factors that do not change over time and could have an impact on undernourishment and stunting rates. This chapter presents the results of these regression analyses, which investigate the determinants of undernourishment and stunting across Bangladesh, Vietnam, Cambodia, and Laos. The analysis focuses on the impact of rice yield in kg/ha, arable land as a percentage of total land area, cereal import dependency, population growth, and GDP per capita on the prevalence of undernourishment and stunting. In order to put the findings of the regression analysis in good context, first the descriptive statistics for each variable per country will be discussed briefly. These statistics include the number of observations, mean, minimum, and maximum values for all variables. This helps to indicate similarities and differences between countries and interpret outcomes.

4.1 Analysis of descriptive statistics

Table 1 summarises the variables that are used in the regression analysis, over a 19-year period (2002-2020). N stands for the number of observations for each variable within a country, mean stands for average value of the variable, SD for standard deviation, min for minimum value observed, and max stands for maximum value observed for the variable.

Table 1: Summary statistics: N, mean, SD, min, max, sorted by Country

CountryID					
Bangladesh	N	Mean	SD	Min	Max
Riceyield	19	42.634	4.298	34.902	48.088
Undernourishment	19	11.037	4.429	5.5	19.5
Stunted	19	40.695	7.610	28.6	52.3
Arable land	19	60.37	1.403	58.915	63.402
Pop growth	19	1.264	0.260	.88	1.858
GDP	19	1043.044	614.842	407.963	2233.306
Import dependency	19	9.605	1.849	6.1	12.9
Gini	3	32.567	0.569	32.1	33.2
Vietnam					
Riceyield	19	53.487	4.266	45.903	59.212
Undernourishment	19	14.253	1.169	11.8	16.1
Stunted	19	27.5	5.396	20.4	37.9
Arable land	19	21.017	0.820	20.085	22.346
Pop growth	19	1.007	0.055	.904	1.076
GDP	19	1878.946	1081.923	434.81	3586.347
Import dependency	19	-8.1	9.806	-20.8	10.3
Gini	10	36.27	1.283	34.8	39.3

Laos					
Riceyield	19	37.969	3.519	31.403	42.625
Undernourishment	19	15.721	8.675	5.3	31.4
Stunted	19	41.047	6.657	29.7	48.7
Arable land	19	9.304	0.676	8.128	10.117
Pop growth	19	1.485	0.065	1.365	1.587
GDP	19	1427.795	849.374	313.618	2598.506
Import dependency	19	-1.668	2.286	-4.1	2.7
Gini	4	35.7	2.543	32.6	38.8
Cambodia					
Riceyield	19	28.448	4.641	19.164	33.534
Undernourishment	19	12.426	6.281	4.3	24.3
Stunted	19	35.7	8.225	23.8	48.2
Arable land	19	31.203	1.571	28.325	34.248
Pop growth	19	1.497	0.221	1.132	1.796
GDP	19	926.289	425.315	341.037	1671.385
Import dependency	19	-1.968	3.860	-7.1	3.9
Gini	6	36.065	2.692	33.44	41.14

A few things stand out by looking at these descriptive statistics. Vietnam has the highest average rice yield at 53.487 metric tonnes per hectare, significantly higher than the other countries. This could suggest that the agricultural sector plays a more prominent role in Vietnam's economy compared to other countries. Consequently, changes in agricultural variables might have a greater impact on Vietnam's food security.

Only in Vietnam are the minimum and maximum values close together, indicating a relatively stable and consistent path with possibly little scope for quick food security improvement. All countries have relatively high average scores for 'stunted', indicating significant room for improvement regarding food security. Vietnam again stands out with the lowest value at 27.5%. Bangladesh stands out with 60.37% of its land being arable, far surpassing the other countries. However, the World Bank warns about differences between countries due to varying definitions of land use per country. While differences are most certainly present, it is important to treat this data with caution.

All countries have positive population growth, with Cambodia (1.497%) and Laos (1.485%) having the highest growth. This rapid population increase puts additional pressure on food security in these countries. Vietnam also leads in economic terms, with the highest average GDP at 1878.946 billion US dollars. A remarkable finding is the negative import dependence for Vietnam, Laos, and Cambodia, suggesting that they are net exporters of rice. In contrast, Bangladesh is dependent on some rice imports (9.61% on average) despite domestic production. Even though the import dependency for Cambodia is low, it is still negative.

Vietnam and Cambodia have higher Gini coefficients compared to Laos and Bangladesh, indicating a more unequal income distribution in these countries. However, it is important to note that there are fewer observations for the Gini coefficient in all countries compared to the other variables due to a lack of data. But even with scarce data, the Gini coefficient provides important insights into the disparities within countries.

4.2 Analysis of the regression results

Table 2: Panel regression results for prevalence of undernourishment and stunting

	(1) Undernouri~t	(2) Stunted
Riceyield	0.371	-0.142
	(0.74)	(-0.55)
Arable_land	-0.217	0.0803
	(-0.20)	(0.14)
Import_dep~y	0.263	0.190*
	(2.02)	(2.84)
Pop_growth	22.48*	16.47**
	(2.54)	(3.63)
GDP	-0.00410	-0.00562***
	(-1.69)	(-4.51)
Gini	-1.187*	-0.224
	(-2.86)	(-1.05)
_cons	24.46	33.93
	(0.55)	(1.49)
N	23	23

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

For the first model with undernourishment as a dependent variable (1), the within R-squared value is 0.7592, indicating that approximately 75.92% of the variation in undernourishment within the countries over time is explained by the included variables. The between R-squared is 0.2670, which suggests that this model does not explain much of the variation between countries. This could mean that differences between the countries are driven by factors not included in this regression. The overall R-squared (0.4349) reflects the model's explanatory power across the entire dataset, indicating that 43.49% of the total variation in undernourishment is explained by this model. The F-statistic for the model is 6.83 with a corresponding p-value of 0.0019, meaning that overall the model is statistically significant and the independent variables combined have a significant effect on undernourishment.

For the regression with stunting as the dependent variable (2), the high within R-squared value of 0.9600 shows that 92.95% of the variation in children that are stunted within countries over time is explained by the independent variables. The between R-squared value of 0.7718 suggests a pretty good fit of the model between countries, explaining 77.18% of the variance in stunting across countries. The overall R-squared is 0.8533, indicating very high explanatory power when considering both within and between country variations. The F-statistic (51.95) with a probability > F of 0.0000 confirms that the model is statistically significant and that the independent variables collectively have a significant impact on stunting.

Examining the coefficients of the independent variables, there are some interesting findings. The coefficient for rice yield is not statistically significant for both the prevalence of undernourishment and the number of children who are stunted. This implies that changes in rice yield and domestic production do not have a significant impact on food security. Similarly, arable land has a coefficient of -0.217 and a t-value of -0.20, which indicate that the percentage of arable land is also not a significant predictor of food security in this model. This aligns with literature suggesting that simply increasing the amount of agricultural land is insufficient for improving food security, and that factors such as urbanisation and income play more significant roles (Grafton et al., 2015). In contrast, the import dependency ratio shows a positive and significant relationship with stunting at the 5% level. This suggests that higher import dependency is associated with increased levels of undernourishment, implying that reliance on food imports can negatively impact food security.

The coefficient for population growth has a statistically significant positive relationship with both undernourishment and stunting, indicating that population growth exacerbates food security issues. This finding aligns with expectations, as rapid population growth can place pressure on food resources and contribute to food insecurity. The Gini index has a coefficient of -1.187, significant at the 10% level. A negative coefficient indicates that higher income inequality is associated with lower levels of undernourishment, which implies that more equitable income distribution might improve food security. There is no significant relationship between the Gini index and the number of children who are stunted.

The GDP per capita has a coefficient of -0.00410 for undernourishment that is not statistically significant. However, it does have a significant relationship with stunting at the 1% level. This indicates that economic growth is associated with a decrease in stunting rates, a logical sequence. This is most likely due to improved access to food and healthcare as a result of higher incomes.

5. Discussion

The aim of this research was to explore to what extent Bangladesh has been achieving food security and what the key challenges and opportunities are for ensuring long-term food availability and accessibility for its population. First, a literature review has been conducted to provide a broad understanding of existing knowledge. After this, an exploratory, descriptive analysis was performed for Bangladesh. This initial data exploration was followed by a panel regression to determine the impact of the determinants of undernourishment and stunting in Bangladesh and several comparable, nearby countries (Vietnam, Cambodia, and Laos) to more formally study correlations with possible driving forces. The validity of the study is strengthened by the use of a fixed-effects model that controls for unobserved country-specific factors that could influence the outcomes.

5.1 Analysis of the results

The positive association between import dependency and stunting highlights the vulnerability of the countries to fluctuations in global food prices or disruptions in international trade. This emphasises the importance of the government making policies that improve domestic food production or social safety nets to ensure access to affordable food during external shocks. The negative relationship between GDP per capita and stunting aligns with the findings in existing literature. For example, Świetlik (2018) and Hanif et al. (2018) have demonstrated that higher levels of GDP are associated with higher levels of food security. In fact, the strongest improvements in food security occurred in the countries with the most rapid increase in GDP per capita. The negative relationship highlights the positive impact of economic growth on food security. As incomes rise, people can afford more food and more diverse diets, which naturally contributes to improved health outcomes.

The regression results also reveal that simply increasing arable land does not necessarily lead to improved food security, as shown by the unsignificant relationship between the percentage of arable land, stunting, and the prevalence of undernourishment. Studies have shown that to meet future domestic food requirements, arable land protection policies should be implemented. This need has emerged as a result of expected population growth and the decreasing availability of arable land (Yang et al., 2023). The coefficient for rice yield is also not significant for both the prevalence of undernourishment and stunting. This implies that changes in rice yield (domestic production) do not have a significant impact on food security. In contrast, the import dependency ratio shows a positive and significant relationship with stunting, suggesting that higher import dependency can negatively impact food security. The Gini index shows a significant relationship with undernourishment, suggesting that more equitable income distribution might improve food security. As mentioned in Chapter 1, it is the poorest households that bear the brunt. However, it is important to acknowledge the shortage in data availability for the Gini coefficient. This limited data might affect the reliability of the conclusions drawn related to income inequality.

5.2 Limitations of the study and recommendations for future research

A few limitations must be acknowledged. Firstly, this research focuses on national-level data, which may obscure significant regional variations within the country. Regional disparities, such as employment rates, technological progress, and healthcare access, can play an important role in influencing food security (Opitz et al., 2015). For instance, even with increased national food production, areas with high poverty rates might still struggle with access due to affordability issues. Due to the absence of regional data, this study could not capture these variations. Future studies should therefore aim to obtain regional data to provide a more detailed analysis.

The findings of this study have important policy implications. The negative impact of the import dependency ratio stresses the need for policies promoting domestic agricultural production. Literature indicates that increasing cash crop production has a beneficial effect on food security. However, despite recommending the promotion of cash crop production, the researchers also warn that it should not be considered a complete remedy for solving food insecurity (Rubhara et al., 2020). Economic development appears to be an important driver of improved food security, suggesting that policies aimed at boosting GDP per capita could have significant benefits.

While the focus on countries with similar economic conditions, as done in this study, provides a solid basis, including a broader set of countries with a variety of agricultural systems in future studies could improve the generalisability of the findings. This could reveal additional drivers of food security. Furthermore, investigating the specific causes behind the non-significant relationship between rice yield and food security indicators in this study is an interesting area for future research. Understanding this correlation could reveal inefficiencies within the food system, such as problems related to food distribution, storage, or wastage, which obstruct the translation of increased production into improved food security.

6. Conclusion

This study aimed to explore the extent to which Bangladesh has achieved food security and to identify the key challenges and opportunities for ensuring long-term food availability and accessibility for its population. The analysis focused on the effects of economic development, population growth, and land-use changes on food security indicators, specifically undernourishment and stunting, by using a fixed-effects panel regression model. Data from Bangladesh, along with Vietnam, Cambodia, and Laos, were used to provide a comparative perspective and strengthen the causal conclusions.

Climate change significantly affects the food security of smallholder farmers in Bangladesh. Rising temperatures and the increased frequency of extreme weather events disrupt agricultural productivity. Saltwater intrusion further degrades the arable land, making it difficult for farmers to maintain crop yields. These impacts make already vulnerable smallholder farmers even more vulnerable.

Projected population growth in Bangladesh poses a significant threat to future food security. As the population is expected to exceed 200 million by 2050, demand for food will increase substantially. However, the availability of arable land is decreasing due to urbanisation and other land-use changes, making it challenging for the Bangladeshi government to meet the growing food demand.

The regression results indicate that higher import dependency is associated with increased levels of food insecurity, while higher GDP per capita is linked to lower levels of food security. This emphasises the important role of economic development and the importance of policies aimed at reducing reliance on international trade and global food prices. The lack of significance between the percentage of arable land and both stunting and undernourishment suggests that an increase in arable land does not translate to an increase in food consumption and security.

This study focused on countries with similar conditions, but extending the scope to include a wider range of countries with diverse agricultural systems could enhance the generalisability of the results. Future research should also investigate other potential determinants of food security to provide a more comprehensive understanding of all the factors affecting food security.

In conclusion, the results of this study provide valuable insights for policymakers aiming to improve food security in Bangladesh. By focusing on enhancing domestic agricultural production, reducing import dependency, and promoting economic development, it is possible to achieve significant improvements in food security. By addressing the limitations and recommendations for future research mentioned in Chapter 5, Bangladesh can pave the way for a more resilient and self-sufficient future.

7. Literature

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