Agricultural Productivity and Domestic Food Availability in Bangladesh

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Honours and Masters in Agricultural Economics

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Author’s Declaration

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

Masuka Rahman
Abstract

This thesis sheds light on the economic aspects of agricultural technological progress in meeting the challenges of sustainable food security in rural Bangladesh. The key question at the heart of this research is to explore how Bangladesh could increase its food production in a sustainable manner to feed its ever increasing population in the long run, despite facing increased natural resource constraints and increasing climate variability. One well demonstrated method by which to increase food production using fewer resources is to increase the productivity of factors of production. The impact or relationship between productivity and long-run sustainable output growth can be captured or measured with the growth accounting framework pioneered by Solow (1956, 1957).

This thesis concentrates particularly upon household level crop productivity by empirically estimating medium term growth in eight different regions of Bangladesh. This is because statistical research conducted from a macro perspective on growth accounting will never be able to offer a complete account of the growth process, but case studies based on field surveys can provide an important (or perhaps a deeper) complementary understanding of agricultural productivity.

The findings of this study, using secondary source-based data, show a very low level of average total factor productivity (TFP) growth, of only 0.24 per cent per year between the 2009-2014 period. In addition, empirical results of TFP growth in diverse regions of Bangladesh show considerable variation, ranging from on an average 0.38 to 0.14 per cent per annum during the same period. In addition, a combination of primary and secondary source-based TFP growth analysis shows TFP grew at an average of 0.46 per
cent per annum in the Mymensingh district of Bangladesh during 2009 to 2015. This relatively impressive performance sets a benchmark target for other regions. Although achieving similar TFP growth levels across the regions may be difficult mainly due to environmental differences, minimizing the TFP growth gap through appropriate policy initiatives will make a valuable contribution to food security in Bangladesh.

Overall, the findings in this thesis suggest that agricultural output growth in all the study areas are technology or TFP driven, including sustainable food production.
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I would like to thank all of the people closest to my heart. With deep love and gratitude, I acknowledge my husband, Mohammad Zakirul Huda; my children, Zawad and Joyee; who have been incredibly understanding and supportive of what I aspire to do. My sincere and heartfelt gratitude to my beloved parents (Mizanur Rahman and Raushon Ara), whose hardship has brought me here; and who always taught me to fight honestly against any adversity. I would like to acknowledge my sister Masuma, her daughter Mohima, and Babu for their all sacrifices and care to our parents, in absence of me. I would like to thank my Father in law, Md. Ruhul Amin for his inspirations, patience and prayers towards the success of my higher study. At this point, thanks also go to Neamul, Ishad, Happy and Lutfur for their good wishes.

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Dedication

To my beloved parents and my only sister
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<th>Full Form</th>
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<tr>
<td>AP</td>
<td>Asia and the Pacific</td>
</tr>
<tr>
<td>BADC</td>
<td>Bangladesh Agricultural development Corporation</td>
</tr>
<tr>
<td>BARC</td>
<td>Bangladesh Agricultural Research Council</td>
</tr>
<tr>
<td>BARI</td>
<td>Bangladesh Agricultural Research Institute</td>
</tr>
<tr>
<td>BBS</td>
<td>Bangladesh Bureau of Statistics</td>
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<tr>
<td>BCIC</td>
<td>Bangladesh Chemical Industry Corporation</td>
</tr>
<tr>
<td>BRRI</td>
<td>Bangladesh Rice Research Institute</td>
</tr>
<tr>
<td>CARE</td>
<td>Cooperative for Assistance and Relief Everywhere</td>
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<tr>
<td>DAE</td>
<td>Department of Agricultural Extension</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
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<tr>
<td>GAP</td>
<td>Good Agriculture Practice</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GR</td>
<td>Green Revolution</td>
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<tr>
<td>HYV</td>
<td>High Yielding Variety</td>
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<tr>
<td>GOB</td>
<td>Government of Bangladesh</td>
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<tr>
<td>IFPRI</td>
<td>International Food Policy Research Institute</td>
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<tr>
<td>IPCC</td>
<td>The Intergovernmental Panel on Climate Change</td>
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<tr>
<td>IRRI</td>
<td>International Rice Research Institute</td>
</tr>
<tr>
<td>MDG</td>
<td>Millennium Development Goal</td>
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<tr>
<td>MOP</td>
<td>Murat of Potash</td>
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<tr>
<td>NFP</td>
<td>National Food Policy</td>
</tr>
<tr>
<td>NKEA</td>
<td>National Key Economic Area</td>
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<tr>
<td>OWG</td>
<td>Working Group on Sustainable Development Goals</td>
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<tr>
<td>PTE</td>
<td>Economic Transformation Programme</td>
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<tr>
<td>SDG</td>
<td>Sustainable Development Goal</td>
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<tr>
<td>TFP</td>
<td>Total Factor Productivity</td>
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<tr>
<td>TSP</td>
<td>Triple Super Phosphate</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
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<tr>
<td>USAID</td>
<td>The United States Agency for International Development</td>
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<tr>
<td>VDSA</td>
<td>Village Dynamics in South Asia</td>
</tr>
<tr>
<td>WB</td>
<td>The World Bank</td>
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<td>WFP</td>
<td>World Food Programme</td>
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Chapter 1  Study Overview

1.1  Introduction

It is widely recognised that future food security is challenged by an increased population growth; the severity of which varies across regions of the world. For example, the number of undernourished people in the world increased from 777 million in 2015 to an estimated 815 million (11 per cent of global population) in 2016 FAO (2017). On top of that, food insecurity poses further challenges, including how to increase food production by at least 50 per cent more than the current production capacity to feed the growing global population, which is projected to rise to around 10 billion by the year 2050 (FAO, IFAD, UNICEF, WFP and WHO 2017, UN 2015a). Food security issues are arguably most severe in Asia, and particularly South Asia; with about 520 million people living with food insecurity in Asia (which is two-thirds of the global population of food insecure people) of which 281 million reside in South Asia (UN 2015a, FAO, IFAD, UNICEF, WFP and WHO 2017). The United Nations states that a doubling of food productivity in South Asia could lift more than 16 million additional people out of poverty, create 13 million additional jobs and increase household incomes by 11 per cent; ultimately eliminating hunger by 2030 (UNSCAP 2016). This suggests that food policy makers, especially in South Asia, need to foster “productivity growth” in the agricultural sector, at a sufficiently rapid rate to meet the food demands of the populations of today and generations to come.

Despite continuous policy initiatives towards mitigating hunger, on the supply side food policy makers are faced with accelerated water and land scarcity, depletion of natural resource stocks, biodiversity degradation, deteriorated environmental quality and more
frequent and severe weather events (FAO 2017). Specifically, by 2050 the food production systems across Asia will face extreme competition for resources to support increasing food demand. Over the past half a century, global gross agricultural output has more than tripled in volume (Fuglie, Wang, and Ball 2012) through the Green Revolution technology and production intensification through the adoption of modern crop varieties, increased use of pesticides and fertilizers, mechanization and improved irrigation coverage (Burney, Davis, and Lobell 2010; Evenson and Gollin 2003; Kendall and Pimentel 1994; USAID 2011).

Consistent with its physio-cultural endowment (Hayami and Ruttan 1971), technical change in Asia, a continent which is severely land constrained, has been biased strongly towards land saving technologies. This bias is reflected in a land saving shift in the production of agricultural output (Murgai, Ali, and Byerlee 2001) through application of fertilizer and irrigation. However, from an agronomic point of view, excessive and unbalanced use of agro-chemicals over the same period has led to declines in soil productivity, loss of bio-diversity and contamination of surface and ground water (Rahman and Thapa 1999; Hossain and Kashem 1997; and Rahman 2005).

Concerns related to the impacts of adaptation and mitigation measures on food systems have become real and more pressing. Moreover, from an economic point of view, due to the constraints of diminishing returns, long-term food production sustainability is hampered by stagnating or declining yield and productivity (Hobbs and Morris 1996; Ruttan 2002; Chang et al. 2001; Alston, Babcock, and Pardey 2010). These concerns suggest the need for more innovative approaches which lean towards resource conservation measures, minimum tillage, and integrated pest management (Nkonya et al. 2008) by maintaining intergenerational equity in the distribution of natural resources.
In addition to the above constraints, the Intergovernmental Panel on Climate Change (IPCC) has forecast that decreases in crop yields of 10 to 25 per cent and more may be widespread by 2050, due to the impacts of climate change on agriculture (Porter et al. 2014). This forecast is based on many studies (i.e., FAO 2008b; Rosegrant et al. 2008; Lobell et al. 2011; Thornton and Cramer 2012; cited by Taylor et al. 2016) which have indicated that agriculture productivity is likely to be adversely affected by climate change in coming decades. Responding to the evidence, food security research has shown an enhanced focus on agricultural productivity in the context of global climate changes and limited resources for farmers, including increased vulnerability from climate change-related events such as floods, hurricanes and, droughts (Bashir and Schilizze 2013).

Agricultural productivity growth depends, among other factors, on continued biotechnological and genetic innovations; to develop stress tolerant crop varieties (tolerant to salt, drought and, submergence), and to increase yields and resource efficiencies (Rosegrant, Agcaoili-Sombilla and Perez 1995).
While technological change is an option for sustainable food production, it can be constrained or limited by differences in socio-cultural and agro-climatic contexts, as well as institutional and infrastructural issues. For example, Alauddin and Sharma (2013) found that differences in technology diffusion were the key factor driving inter-district differences in crop productivity in Bangladesh. From a sectoral development perspective, a reduction in regional disparities in agricultural productivity is also crucial (Esposti 2011). Indeed, in any country, raising foodgrain productivity requires improved development of location-specific technology development and diffusion throughout the country. A regional variation in growth of food production is not unique to Bangladesh. Moreover, the use of aggregate data for the whole agriculture sector will tend to mask significant disparities between highly productive and poorly productive regions. It is important to recognise that regional disparities in crop productivity, and the reasons behind these differences, are important factors which can impede national goals of food security. This research draws on national and international literature on food productivity growth in the adversely affected regions of the world, particularly the agricultural economic literature on food security and TFP growth.
One major issue facing the production of any output, particularly in an input-output context or framework, is escaping the constraint of diminishing returns to factor inputs such as capital and labour (which will be discussed in greater detail in Chapter 2). According to Solow (1956), diminishing returns to factor inputs can be minimized with higher productivity growth of capital and labour. The mechanics on to minimize diminishing returns to factor inputs can be found in Solow (1956, 1957) growth analysis. Solow (1957) empirically tested his 1956 growth analysis on the USA, and repeated that technological progress (in terms of TFP growth) accounted for Seventy eight of US growth per worker over the first half of the twentieth Century. The Solow (1956, 1957) growth model has become the standard and most widely used approach to quantify the contribution of technological progress to output growth. This thesis will utilize Solow (1957)’s growth accounting framework to quantify the impact of TFP growth on the agricultural output in various villages in Bangladesh covering the period 2009-2015.

1.2 Focus of the study: Why is it important to take Bangladesh as a case study?

When considering countries’ relative rankings on food security, as of 2017, Bangladesh was in the 89th position (Global Food Security index 2017); the worst performer among South Asian countries. Historical evidence suggests that in almost every year prior to independence in 1971, Bangladesh experienced a general scarcity of foodgrains, with related adverse impacts of natural disasters, widespread poverty and income inequality (Islam 2012). On two occasions following independence in 1971, in 1972/73 and more recently in 2007/08, the country suffered enormously from global food crises that resulted
in famine. Although those two phenomena gained the attention of national and international policy makers, food insecurity is neither a new phenomenon nor is only associated with external economic shocks to the over populated, resource constrained, and weather prone Bangladesh. At present, approximately 25 per cent of the population in Bangladesh remains food insecure and 36 per cent of children younger than 5 years of age suffer from chronic malnutrition and stunting (WFP 2018). Additionally, high domestic prices for rice—the staple food crop—heighen food insecurity, particularly among the rural poor (USAID 2018). Recurring natural disasters, such as floods and cyclones, continue to exacerbate poverty-related issues, including food insecurity and malnutrition in many parts of Bangladesh (discussed in detail in Section 3.1.2 in Chapter 3). Taking into account all those factors, the urgency to increase agricultural production is without doubt can be put on top of the economic development planning list of Bangladesh. One possible approach in which to increase agricultural output is through technological progress or TFP growth.

This thesis attempts to shed light on the economic aspects of agricultural production progress toward meeting the challenges of sustainable food security in rural Bangladesh. The key question at the heart of this research is to explore how Bangladesh could increase its food production in a sustainable manner to feed its ever-increasing population in the long run, given increasing natural resource constraints as well as increasing climate variability. One well demonstrated method by which to increase food production using fewer resources is to increase the productivity of factors of production. The relationship between productivity and long-run sustainable output growth can be captured or measured with the growth accounting framework pioneered by Solow (1956, 1957). Accordingly,
positive and long-run growth of output hinges on productivity growth or technological progress; without productivity or technological progress, output growth would cease as a result of diminishing returns to factor inputs. In the economic literature, productivity growth or technological progress is captured by the total factor productivity (TFP) concept. While technological progress is a critical option for overall national food productivity growth, improving TFP growth of smallholder farms is an important pathway in which to achieve food security in the face of growing population pressure, arable-land scarcity and climate variability. However, integrated analyses of food security at household level are still scarce (Van Wijk et al. 2014). Hence, this thesis concentrates particularly upon household level crop productivity by empirically estimating medium term agricultural TFP growth, taking different regions of the country into account. In order to understand the effectiveness of government policies in Bangladesh, regarding improving agricultural productivity, this study investigates the effectiveness of these policies at a disaggregated level. It is important to note that this thesis seeks only to consider the availability, accessibility and sustainability aspects of food security of farming householders in Bangladesh.
The rate of agricultural TFP growth is an important indicator of the ability of food production systems to meet increasing demand. However, the average agricultural TFP growth in Bangladesh during 2001 to 2011 is 0.024 per cent per year (Murdoch Commission 2015), which is an issue of concern in terms of food security. By empirically estimating the household level TFP growth in regional Bangladesh, this research attempts to contribute to the understanding of important issues at the forefront of Bangladesh’s food security. These issues include technological progress, agricultural research, development and extension policies, sustainable production, linkages between food security and crop productivity, and regional variation in the designing and implementing of food and agricultural policy approaches. All these issues are of importance for attaining long term sustainable food security. To this end, considering appropriate TFP growth as an important factor in ensuring increased food production for household food availability, and generating extra income for further food purchases, this study aims to investigate the agricultural TFP growth-food security nexus in diverse regions of Bangladesh with different agro-climatic conditions, utilizing household data. (A map of Bangladesh, indicating study regions is given in Figure 4.2 of Chapter 4, page 124).

1.3 Objectives and research questions

and Salim (2013), Alam et al. (2014). A detailed literature review is presented in section 6.1 of Chapter 6. Although there are a number of studies (see section 6.1, pp 156-158, in Chapter 6) conducted on TFP growth in Bangladesh, there are some important areas that many of these studies did not cover. These are:

(i) None of the TFP growth studies focused exclusively on food security and sustainability;

(ii) None of the studies uses a more direct approach pioneered by Solow (1956, 1957) to measure TFP growth on the agricultural sector. As such, it is highly appropriate (perhaps long overdue) to further the literature on sustainable food production with other alternative approaches, like the Solow (1956) growth accounting framework;

(iii) Studies on regional variations in TFP performance are very rare; and

(iv) TFP growth studies are not up to date (the latest time period covered is up to 2011). As such, an update is long overdue.

At the outset of the above-mentioned research gaps, a series of relevant research questions are raised:

(i) Are the farm product-producing households which are targeted in this study achieving their full potential from their limited (especially land) resources?

(ii) Does food TFP growth vary across different regions of the country? If so, what are some of the factors causing in the variations? What inferences can be drawn from the results?
It can be argued that it is imperative to deal with these questions as they all are relevant to the development of sustainable food security in Bangladesh.

1.4 Contribution of the thesis to the scholarly literature

This thesis, by analysing medium term TFP growth at a disaggregated level, aims to contribute to three areas of scholarly enquiry. The first area of contribution is the attempt to focus directly on the concept that if household food productivity growth is found to be positive, this indicates that household level food availability and food accessibility is likely to be ensured as predicted by the Solow (1956, 1957) growth accounting method discussed in Chapter 2. This study aims to achieve an in-depth understanding of how TFP growth affects farm production. The motivation behind this approach is that research conducted from a macro perspective on growth accounting will never be able to offer a complete account of the crop productivity growth process, and this regionally based case study will provide an important (or perhaps a deeper) complementary role. Moreover, as research on agricultural productivity using survey-based data is limited, it is deemed worthy to contribute to the area of TFP growth analysis.

The second contribution of this study is that, it takes into consideration the government policy initiatives to achieve food productivity growth and food security in diverse regions. It is important to note here that this research is neither an agronomic analysis, nor does it aim to cover the socio-political aspects of food production; rather, it involves a household level agricultural economic study of diverse regions to reveal a new window or dimension of food security.
From a methodological point of view, the third contribution is that this thesis employs the model which is most commonly used by economists to estimate technological change, but which is very rarely used for a micro level study (using a blend of primary and secondary data) of a specific sector. By introducing the Solow (1956, 1957) growth accounting framework, represented by the constant returns to scale Cobb-Douglas production function, to investigate the capacity of foodgrain producers (by utilizing farm level panel data) in a particular sector of the economy (crop production), this study helps to make a substantial contribution to empirical research on agricultural productivity. Moreover, by extending coverage of data for the period 2009 to 2015, in estimating the medium term agricultural TFP growth of food producing householders, this study attempts to provide a distinct basis for TFP growth analysis.

1.5 Thesis outline

The thesis is consists of seven chapters. Chapter 2 introduces the theoretical framework to conduct the empirical analysis found in Chapter 6. Chapter 2 discusses two key concepts used in the study: food security, and productivity growth, to understand the direction of causality between these two variables.

Chapter 3 provides a brief overview of the Bangladesh agricultural sector and, structural changes; and provides a background for the economic analysis found in the following chapters. This chapter is broadly divided in four major sections. The first section highlights the nature of Bangladesh agriculture. Discussion of this section focuses on the agroecology, and background of the agricultural economy of Bangladesh. The performance of foodgrain production is discussed in the second section. The third section looks at the
evolution and development of agricultural policies (i.e. discussion of politics and plans containing summaries and tables) with special attention on agricultural research policies. Status of per capita foodgrain availability is focused in the fourth section. The overview discussions found in this chapter are based on historical facts as they pertain to Bangladesh and cannot necessarily be generalised.

Chapter 4 aims to examine the key trends in Bangladesh’s agricultural land use pattern- at both the aggregate (national) level and the disaggregated level. As in earlier discussions, land is presented as the most constrained resource in Bangladesh; this chapter attempts to investigate this issue in detail. The chapter is broadly divided into three parts. The first part of the chapter seeks to analyse the land utilization and distribution patterns and land policies with available national land survey data. In the second part, the disaggregated land ownership and distribution patterns are examined. In doing so, survey data are used. In the third part, further light is shed on the issues associated with irrigated land and relevant government policies.

Chapter 5 endeavours to examine labour use patterns in crop agriculture in Bangladesh. This chapter specifically seeks to gain insights into the functioning of agricultural labour markets in rural areas. The discussion is divided into three distinctive parts. The first part critically describes the distinctive features of agricultural labour with available national level data. The second part elaborates on the characteristics and socioeconomic conditions of the sample farmers using both the secondary and primary survey data; and the third part discusses the extension training, on the basis of national data and the field experiences and findings.
Chapter 6 quantifies the agricultural output growth over time and across regions of Bangladesh, using primary and secondary source-based survey data. Analysis is done in two parts: the first part is conducted using secondary source-based farm-survey data. Data variables, data sources, analytical model and the scope of the research are discussed in this chapter. The empirical assessment is performed by utilizing the Solow (1956)’s TFP growth accounting methodology. Following a same method, the second part of TFP growth estimation is done on the basis of a combination of primary and secondary data of Mymensingh district of Bangladesh. Research findings are discussed using a multidimensional focus.

Chapter 7 summarizes the findings, and on the basis of findings, identifies and discusses briefly the recommended priority areas for policy action. Finally, this chapter suggests some directions for further research in this field of literature.
Chapter 2   Food Security and Productivity Growth

2.1 Introduction

“It is the agricultural sector that the battle for long-term economic development will win or loss”- Gunner Myrdal, Nobel Laureate, Economist.

One of the most pressing economic development issues currently facing many developing and poor economies is producing enough food to feed the growing population. On top of that, almost ten per cent of the world’s poorest people are located in rural areas and engaged primarily in subsistence agriculture. As Todaro (1995, p. 282) puts it “their basic concern is survival”. Traditionally, the role of agriculture in economic development is to provide sufficient low priced food and labour to the expanding industrial economy, which is thought to be more dynamic and leading sector to drive economic development. According to the economic development literature, the capacity for agricultural transformation (as well as rural development) to produce sufficient and sustainable low-priced food hinges on three fundamentals: (i) accelerated output growth through technological and institutional (i.e. government policies) development to increase the productivity of small farmers; (ii) increasing domestic demand for agricultural output driven by strategy which focuses on employment oriented urban development, and (iii) to diversified non-agricultural, labour-intensive rural development activities that are supported by the farming community. Due to the size and nature of this thesis, this study focuses exclusively on the first one. The primary aim of this thesis is to explore the impact of technological progress (captured by TFP growth) on the output growth of the food producing sector.
Accordingly, the primary aim of this chapter is to provide a framework in which to understand the logic and importance of technological progress (productivity growth) as an engine in which to drive sustainable food production. To this end, the growth accounting framework pioneered by Solow (1956) will be discussed for quantifying the impact of technological progress on agricultural output growth in Bangladesh. Prior to discussing the mechanics of the Solow (1956) growth analysis, it is necessary to start the chapter with the notion of food security.

2.2 Food security

In an attempt to conceptualize food security, the discussion of this section endeavors to investigate the issue of food security and its different components. Understanding of the relevant issues will assist in identifying the relevant components of food security that can be improved through crop productivity growth. In addition, discussion of this section concentrates to contextualize a country case and more specifically household food security approach in this thesis. Food security, originated as a concept in 1974, in the discussions of international food problems at a time of global food crisis. Since then food security is an issue of interest for not only researchers and academicians, but also for policy makers and development workers. Food security is a global menace, the intensity of which differs from country to country, and region to region. Justifiably, Bashir and Schilizzi (2013) argued that food security is a complex phenomenon, attributable to a range of dimensions that vary in rank across regions, countries and social groups, and over time.
Food security has been defined differently by different scholars and organizations with different viewpoints. In 1996, the World Food Summit agreed on a comprehensive definition of food security, which is used by the Food and Agriculture Organization (FAO) of the United Nations (UN) as:

“Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (FAO 2010, p.8).

Hence, the definition encompasses four dimensions: food availability, accessibility, utilization and stability (Figure 2.1).

**Figure 2.1 Dimensions of food security**

![Dimensions of food security diagram](image1)


According to Figure 2.1, within a country context, food availability dimension addresses supply side of the food security, which can be achieved when sufficient quantities of food are consistently available to all individuals. Domestic food availability can be ensured through domestic production, commercial imports, and food assistance (aid). Within a country, food accessibility (also called food entitlement) can be ensured when all
households and all individuals within them have adequate resources to obtain appropriate foods for a nutritious diet; depends on household farm and non-farm income, and the prices of food. Food utilization is the proper biological use of food, adequate diet, clean water, sanitation and health care. Effective utilization of food depends largely upon knowledge within household of food storage and processing technique. Food stability is the availability of and access to food, regardless of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food scarcity).

As food security is a multidimensional concept, its status requires the measurement of several indicators that can together capture the various dimensions of food security (Carletto et al. 2013). In addition, Islam (2012) identified four recurring terms of food security: access, availability, utilization, and vulnerability\(^1\) (by his own literature review from 1991-2010, and adapting from Maxwell 1996’s 32 definitions of food security and insecurity, published from 1975 to 1991). Although those aforementioned dimensions did not include the issue of sustainability, the United Nations’ food and agriculture, under the umbrella of Sustainable Development Goal (SDG) of Zero Hunger (SDG 2) considers the fact:

> “Achieving food security requires an integrated approach that addresses all forms of malnutrition, the productivity and incomes of small-scale food producers, resilience of food systems and the sustainable use of biodiversity and genetic resources” (FAO 2017, p.3).

\(^1\) Vulnerability refers to people’s propensity to fall, or stay, below a pre-determined food security threshold (Lovendal, C.R., Knowles, M. & Horii, N. 2004, cited in Islam 2012). Thus, vulnerability is a function of people’s exposure to risks and of their resilience to these.
In a similar instance, Chang, et al. (2001) raised two important questions: (i) can food production continue to keep up with demand in generations to come? (ii) is the prosperity of the current generation at the expense of the future? These concerns reflect the fact that sustainability issue in food security has been receiving attention in recent policies and literature.

Synthesizing the above discussion, six dimensions of food security are identified: (i) availability, (ii) accessibility, (iii) utilization, (iv) stability, (v) vulnerability, and (vi) sustainability. These multi-dimensions of food security imply that no single indicator has the capacity to capture all the other dimensions of food security. Therefore, a combination of measures is required to fully reflect the complex reality of food insecurity. Likewise, food policy consists of setting goals for the food system and its parts, including natural resources, production, processing, marketing, food consumption and safety, nutrition, and determining the processes for achieving these goals (Pinstrup-Andersen 2009; 2002). A detailed analysis of all the aspects of food security is beyond the scope of this thesis, and as such, this thesis concentrates on food availability, accessibility, and sustainability.

Hence, a clarification is required to answer the corresponding question: Why this thesis concentrates only on those aforementioned dimensions? Two justifications for concentrating specifically upon “food availability” issue are: (i) food availability is the essential precondition for overall food security (Kirby and Mac 2009); domestic food production is the main determinant of food availability, and agricultural productivity gain helps in maintaining food balance of a country; and (ii) while focusing on food-producing households, who are mostly subsistence in nature, domestic food availability is the main issue of concern for them. This argument can be justified by Talukder (2005, p.1) as:
“Considering the size of the food production sector in the national economy, and the subsistence nature of the production system, achievement of self-sufficiency through increased production of foodgrain has special significance in the context of Bangladesh.”

While food availability is a necessary precondition for national level food security, it is not sufficient on its own to ensure food security at the household level. Because, consumers, particularly those are in smallholder farms, needs to be able to physically and economically access food supplies in order to become food secure, either through their own production activities, or market purchases. On the basis of the above mentioned second justification of considering food availability in this study, it can be inferred that when household level food availability is taken into consideration, it automatically implies household food accessibility. In such a point of view, the food accessibility issue is covered in this study under the umbrella of food availability. Consequently, the food availability and accessibility dimensions are blended together in this study.

In addition to food availability and accessibility, two justifying causes behind considering the sustainability dimension of food security in this thesis are: (i) as long run food security is an issue, from an agronomic point of view, sustainability of food production depends on the sustainability of natural resources; and (ii) from an economic point of view, it is necessary to investigate how technological advancement helps in maintaining food productivity growth. As discussed in Chapter 1, TFP growth is a viable option to overcome the constraint of diminishing returns of food production, TFP growth measure will be done in Chapter 6. Although the above mentioned three dimensions are covered in this study, food availability is given most emphasis, as TFP growth is directly reflected in this dimension of food security.
This thesis approaches a country as a case study of food security. Therefore, in addition to various dimensions of food security, another relevant question may arise: why this study approaches a single country only? The argument behind this is that, learning mechanism to solve national food security, can be rectified in similar type other countries. Thus, this study will be an extension of knowledge in assessing TFP growth of the food producing sector in a globalized world. Digging further, this study covers household level food security; hence three justifications for considering household level food security are: (i) household is the basic economic unit that acts as both, food producer and consumer; (ii) food availability at a national level does not necessarily assure food security at the household or individual level, mainly due to lack of economic access to food by the poorer households (Alam 2016; Harrigan 2008; Schmidhuber and Tubiello 2007; cited in Alam et al. 2018; Kennedy and Bouis 1993); and (iii) food producing households are likely to respond differently in adopting modern technologies. All of those issues demand investigation at household level food productivity.

Now, for any study on food availability, a key question is: what are the determinants of food availability? The following sub-section attempts to answer this question.

### 2.2.1 Determinants of food availability

Understanding the determinants of food availability will help to contextualize the research agenda. Food supply side demands examination of a variety of social, economic, political, legal and environmental factors to identify the choices and challenges of food availability at individual, community and national levels (Islam 2012). According to the FAO, national level food availability depends upon: (i) domestic food production, (ii) stocks: food held by trader and in government reserves; (iii) trade: food brought into and taken out of country.
through market mechanisms; and (iv) bulk transfers: food brought into (and taken out of) by the government and/or aid agencies.

Food security of many countries relies only on domestic food production, as it is considered to be one of the major sources of food availability. In addition to domestic production, aggregate (national) food availability of a food deficit country can be supported through food imports and/or food aid (Pinstrup-Andersen 2009). In order to minimize dependence on foreign trade, food self-sufficiency through domestic production, is a priority in most countries (Konandreas et al. 2000). In light with the central framework of this thesis, it is necessary to identify the determinants of domestic food production, both at aggregate and disaggregated level. A country’s capacity to produce its own food depends on its resource endowments, climate, natural capital, policies, and on the productivity with which the available resources are employed. At disaggregated (micro) level household food security refers to the ability of a household to produce and/or purchase the food needed by all household members to meet their dietary requirements (Ecker and Breisinger 2012). Subsistence or smallholder farmers cultivate agricultural products sufficiently to feed a household. Surplus harvests, which are often very limited, are sold or traded. However, resource constrained rural smallholders often suffer from food insecurity in developing countries.
Figure 2.2 A conceptual framework of food security

Food Security (National, household, individual)

Food availability

- Natural
  - Rainfall
  - Soil quality
  - Water quality
- Physical (natural)
  - Food stockholding
  - Food and nonfood imports
- Export earnings
- Foreign aid
- Infrastructure
- Physical (farm/household)
- Farm implements
- Livestock ownership
- Landownership, access
- Other physical assets
- Human
  - Labor supply
  - Education
  - Household size and gender

Production

- Farm
- Nonfarm
- Research
- Technology
- Extension
- Input use
- Irrigated area
- Cropping session
- Cropping diversity
- Input and output prices

Income

- Farm
- Nonfarm
- Crop income
- Wage income
- Self-employment
- Migrant income
- Producers prices
- Access to physical, natural, human, financial, social capital
- Private transfer
- Public/NGO safety nets/Social protection interventions

Consumption

- Food
- Nonfood
- Food expenditure
- Nonfood expenditure
- Consumer prices
- Income transfer programs/food based interventions

Health and nutrition

- Child
- Adult
- Access to health services
- Safe water supply
- Sanitation
- Dietary quality
- Education
- Intrahousehold food distribution
- Caring practices
- Food-based interventions
- Behavior change communications interventions

Markets

- Agricultural input
- Agricultural output
- Labor and nonfarm
- Market access
- Market development
- Market stabilization
- The trade regime

Economic, social, political, legal and environmental settings
Source: IFPRI; Cited in Ahmed et al. 2013, p.6.
Seeking further to identify the determinants of farm level food availability, the International Food Policy Research Institute (IFPRI) developed a conceptual framework (Figure 2.2) of food security. Figure 2.2 shows that research, technology, extension, input use, irrigated area, cropping season, crop diversity, input and output prices are the important determinants of food availability (also accessibility) at farm level. In addition, research, technology, extension and irrigation are broad facilitating issues for the production environment. The later issues depend on public policy initiatives and budget allocation/investment. Cropping patterns, crop diversity and, input choices are still farmers’ choice. Hence, land ownership and farm implements are important determinants of food availability. Labour supply, education and farm size are important indicators of human resources that can influence food availability. Labour resources can be utilized more effectively in farming through skill development. Farm size also reflects the strength of farming households as it is an indication of availability of household labour input. Farmers have no control over natural resources, but they can utilize them with better management and appropriate technology. Thus, a holistic intervention can help in improving the farm level food production environment.
Bashir and Schilizzi (2013)’s meta-analysis of literature (covering studies 20 each from Asia and Africa, for the period of 2001-2012) highlighted a framework for determinants of household level food availability in African and Asian countries (Figure 2.3). The components of food availability are divided into a combination of self-production and market purchase. Further, on the basis of existing literature, determinants of the former component are: technology adoption, input price, input availability, credit availability, education, age, farming system and farm size (Table 2.1). Management of all the combined influential tools helps in better farm production for household level food availability.
Market purchase sub-components of food availability are beyond capacity of this thesis, hence therefore, excluded from discussion.

Table 2-1 Household food availability related major areas studied on Asian and African countries

<table>
<thead>
<tr>
<th>Research context</th>
<th>Studies on Asian countries</th>
<th>Studies on African countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land quality</td>
<td>Mendola 2007</td>
<td>Feleke et al. 2005</td>
</tr>
<tr>
<td>Food crops</td>
<td></td>
<td>Paul et al. 2018</td>
</tr>
</tbody>
</table>

Source: cited in Bashir and Schilizzi (2013) and author’s self-literature review.
Table 2.1 reflects studies conducted on determinants of food availability in Asian and African countries, those are cited in Bashir and Schilizzi (2013) and author’s literature review, require further discussion. The following discussion is based on Table 2.1. Technological progress is one of the vital means of increasing productivity especially for the subsistence farming of developing countries. It has significantly positive effect on the farm productivity hence improving household food security. Moreover, leading agribusiness companies can act as a driving force behind scientific and technological efforts to end food insecurity of smallholder men and women farmers (Gaffney et al. 2019). Technological progress is considered as a crucial determinant by most researchers in improving household food availability situation. The importance of timely supply of credit has been found to be important factor in improving the income of farmers through improving their productivity. In addition, timely availability of (i.e. seed, fertilizer, and irrigation) helps farmers to adopt technology and get optimum level of yield which ultimately help achieving household food availability. Input prices influence the technology adoption and productivity. In this instance, Liu et al. (2018) recommended for increasing input of comprehensive agricultural production capacity, implement the grain saving strategy, and strengthen the innovation of agricultural science and technology. In some cases it was found that higher input prices hinder farmers in applying appropriate doses to their fields resulting in low production. To address food insecurity, Paul et al. (2018) stressed upon agricultural productivity, agricultural sales and household income.

The age of the household head is also important determinants of food security and (Behrman and Wolfe 1984; Babatunde et al. 2010; cited in Anik 2012). Education is a very important factor not only for farm production but also for food accessibility and food utilization. In addition to increasing the productivity of rice and boosting potential output,
education has reduced the production inefficiencies quite significantly in Bangladesh (Asadullah and Rahman 2009). In addition, diversified farming practices enhance the combination of farmers’ knowledge and maximize the use of available resources for a better production of food. The cropping pattern and cropping intensity depends on the fertility of land and size of land holdings. Those two issues are also critical to technical efficiency and productivity. Moreover, Paul et al. 2018 found that consumed and sold food crops as the mainstay of household level food availability in Rwanda. In line with the research aim, the following discussion is limited only within Bangladesh- country specific researches.
2.2.2   Food security researches in Bangladesh context

Bangladesh is a country, where different policy measures have been taken to ensure sufficient domestic food production for establishing food security of the citizens. The declared goal of the National Food Policy document-2006 of Bangladesh recognized that availability of food at household level depends on the household's capacity to produce or acquire food, household food stockholding, and availability of food at local markets. To meet the growing food demand, Gautam and Faruqee (2016) stressed upon the improvements in technology and efficiency, policy reforms, and investments in rural infrastructure. Rao (2007)’s review of literature on food availability in Bangladesh, before 2007 revealed following six important determinants of food availability: (i) comparative advantage, (ii) internal market and external market integration, (iii) the global food market structure and imbalance, (iv) agricultural liberalization and the poor, (v) the economics of dynamic advances, and (vi) access to inputs. Further relevant crosscutting dimensions of food availability, identified by Rao (2007), include governance and institutions, infrastructure, environment, women, and disadvantaged groups. A critical investigation of food security (studies on food availability specifically after 2007) literature of Bangladesh suggests what has been done so far.
Table 2.2 reveals that eight researches (Begum and D’Haese 2010, Kashem and Faroque 2013, Ahmed et al. 2011, Karim et al. 2010, Kabir et al. 2016, Hossain and Jahan 2014, Mendola 2007, Talukder 2005) have been conducted in the field of national level food grain availability in Bangladesh. Food price volatility in the international and domestic markets adversely affects food security. Three relevant literatures (Ahmed 1979; Hossain and Deb 2009; and Chowdhury et al. 2010) are found in relation with food price volatility. Only a five studies (Rahman and Rahman 2009; Rahman 2009; Rahman 2010a; 2010b; and Mendola 2007) were carried out in respect of land use and crop diversification in Bangladesh; where land size, and land fragmentation were emphasized. Sustaining irrigation is vital for ensuring future food security in the face of population growth and a changing climate in Bangladesh, and ten researches (Roberts et al. 2007; Parvin and Rahman 2009; Hossain 2009; Brammer 2010; Akanda 2001; Alauddin and Sharma 2013; Amarasinghe et al. 2014; Misra 2014; Mainuddin et al. 2015; Gain, Giupponi, and Benson 2015) were conducted in this ground. Some researches of irrigation in relation with food security are based on specific location of the country, and some others are based on spatio-temporal perspective. Seasonal hunger, termed as “monga”, exists in Bangladesh, and people have to take strategies to cope with it. Review of the literature (in Table 2.2) shows, seasonality of household food security and nutritional status, and relevant public policies are of interest among scholars (Hillbruner 2008; Ahamad and Khondker 2010; Chowdhury, Mobarak, and Bryan 2011; Khandker, and Mahmud 2012; Paul, Hossain, and Ray 2015). Currently climate change is one of the biggest concerns of the national food security in Bangladesh, that was highlighted by nine researches (Ali and Sircar 2010; Rashid and Islam 2007; Yu et al. 2010; Sala and Bocchi 2014; Rahman et al. 2014; Tirado et al. 2010; Iftekhar and Islam 2004; Béné et al. 2015; Timsina and Shrestha 2014). By extending
microcredit to farmers, the level of inefficiency in crop production can be reduced and supply of food increased. Only one study of Wadud (2013) is found in microcredit and its relevance with food availability in Bangladesh. Further cross-cutting issues cover: gender, climate change, governance and management of food security policy in Bangladesh.

**Table 2-2 Studies in relation to food security in Bangladesh and relevant issues after 2007**

<table>
<thead>
<tr>
<th>Research context</th>
<th>Research studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food market and food prices</td>
<td>Ahmed (1979), Hossain and Deb (2009), Chowdhury et al. (2009), Nuimuddin et al. (2010)</td>
</tr>
<tr>
<td>Land resource use and crop diversification</td>
<td>Rahman and Rahman (2009), Rahman (2009), Rahman (2010a; 2010b), Mendola (2007)</td>
</tr>
<tr>
<td>Climate change</td>
<td>Ali and Sircar 2010; Rashid and Islam 2007; Yu et al. 2010; cited in Sala and Bocchi (2014), Rahman et al. (2014), Tirado et al. (2010), Iftekhar and Islam (2004), Béné et al. (2015), Timsina and Shrestha (2014) are some of those</td>
</tr>
<tr>
<td>Microcredit</td>
<td>Wadud (2013)</td>
</tr>
<tr>
<td>Cross-cutting issues</td>
<td>Alam et al. (2018), Ara Parvin and Reazul Ahsan (2013), Harris-Fry et al. (2015) and Tirado et al. (2010); for gender specific research</td>
</tr>
</tbody>
</table>

Source: Author’s compilations.
In addition to the above literature, other researches have showed an indirect relationship between food security and technology. For instance, education indirectly affects food security, as it has a direct positive effect on increasing the productivity of rice, boosting potential output, and reducing production inefficiencies (Asadullah and Rahman 2009), those ultimately mitigate food insecurity. In terms of level (international/ national/ local/household) of food security research in Bangladesh, with the exception of Anik (2012) and Alam et al. (2018), most researches have been conducted at a national level.

Bashir and Schilizzi (2013) highlighted that agricultural technology adoption has had a significant positive effect on the wellbeing of farming households in Bangladesh. Additionally, the World Bank (2009) identified three vital areas for enhancing agriculture productivity for food security in Bangladesh: (i) focus on bio-technological research to develop high yielding rice varieties that are resilient to specific agro-ecological conditions, especially in saline and mongo affected areas; (ii) more demand-driven and efficient agriculture extension systems to promote new technologies and solve farmers’ location-specific problems; and (iii) strengthened research-extension-market linkages.

There is also a research gap in dealing with crop productivity and the food availability together; and dealing those variables at a regional and household level study. This research is based on the notions that: (i) if food productivity growth is positive, then food availability is ensured for longer to medium run; and (ii) as mentioned earlier, household food security is mostly covered by home grown food of food producing householders. This study is an attempt to continue a long line of research on agricultural productivity growth in relation with food security, dating from Hayami and Ruttan (1971), to Craig, Pardey, and Roseboom (1997); and Wiebe et al. (2001; 2003); Chang and Zepeda (2001); Avila
and Evenson (2010); Fuglie (2012). The following section attempts to determine the direction of causality between food availability, and crop productivity (technological progress).

2.2.3 Food security and agricultural productivity

The dire prediction of Malthus (1798, p. 466), “population growth would inevitably outpace food production- unless checked by moral restraint, vice, or misery”, never came to fruition due to technological advancement. Thus, improving agricultural productivity has been recognized as the world’s primary defense against the Malthusian crisis (Gathala et al. 2011). If a country fails to achieve, or sustain productivity growth in agriculture, it tends to suffer from high levels of poverty and food insecurity. In the same way, Baldos and Hertel (2014) mentioned that without agricultural productivity growth, there could be a substantial setback on food security improvement. In the same stance, Thirtle et al. (2001) reported that for every one per cent increase in agricultural yields translates into a 0.60–1.2 per cent decrease in the numbers of absolute poor households that cannot afford basic needs for survival. Likewise, Majumder et al. (2016) found that there exists potentiality for substantial increases in rice production by increasing technical efficiency and reducing postharvest losses. Agricultural growth is often pro-poor and has typically strong linkage effects driving overall growth and contributing to lower food prices; Hristiaensen et al. 2011, Delgado et al. 1998; Diao et al. 2010; cited in Ecker and Breisinger 2012). In this point, Thirtle et al. (2001) explained the linkage between agricultural productivity and food security more elaborately, which is summarized in Figure 2.4.
Figure 2.4 Linkages between R&D, technology, growth, productivity and poverty

Source: Thirtle et al. (2001, p.3).

Figure 2.4 shows, as long as productivity keeps growing, agriculture produces jobs, both as self-employment for small farms and as wage labour on large farms. At the same time, agricultural productivity growth lowers food prices for consumers, increases income for producers; and helps generate multiplier effects on the rest of the economy as demand for other goods and services increases. Moreover, increases in agricultural productivity allow natural resources to be diverted to expand the non-agricultural sector of the economy (O’Donnell 2012). As shown in Figure 2.4, agricultural productivity growth has a direct effect on farm households; as it increases in farm supply, which in turn increase the amount of food they retain for home consumption and market surplus for income generation. Thus, increasing crop productivity growth is essential for the food producing farmers. In this regard, FAO (2004) stated that food production directly ensures food availability. The UN (2015b) also mentioned that eradicating poverty and hunger are integrally linked to boost food production, agricultural productivity, and rural incomes. Based on the above discussions, it would be good if researchers and policy makers arrived at a consensus to drive the direction of causality between crop productivity growth and
food availability. Before elaborating theoretical aspect of Solow (1956, 1957)’s growth model, the next section provides a brief overview of existing literature on TFP growth measurement on the agriculture sector from an international perspective (cross-country, cross region).

2.3 A brief overview on TFP growth in the agriculture sector

Productivity analysis is a popular topic, which attracts mass attention in the economic literature due to its importance in driving higher output growth. Agricultural productivity growth has been the subject matter for intense research over the last five decades (Rao and Coelli 2005). This section reviews the empirical research in measuring agricultural TFP growth using different methods in both scopes of cross-countries, and cross-provinces/states/regions within a specific country.

Differences in agro climatic conditions, human capital, and infrastructure appear to contribute to a spread in agricultural productivity across countries (Chavas 2001). Hayami and Ruttan (1971)’s separate analysis on technologies of developed and developing countries raised first the question of how agricultural productivity varies across countries. Diverse methods have been used by researchers to estimate agricultural TFP across countries/regions. For instance, in a review on cross-country/region productivity covering period from 1993 to 2003, Rao and Coelli (2005) found 11 (Bureau et.al. 1995; Fulginiti and Perrin 1997; Lusigi and Thirtle 1997; Rao and Coelli 1998; Amade 1998; Fulginiti and Parrin 1999; Chavas 2001; Suhariyanto et.al 2001; Suhariyanto and Thirtle 2001;
Trueblood and Coggins 2003; Nin et. al. 2003) out of 17 studies used the Malmquist data envelopment analysis (DEA) method, five studies (Fulginiti and Perrin 1993; Craig et.al. 1997; Fulginiti and Perrin 1998; Wiebe et.al. 2000; Fulginiti and Perrin 1999) used the Cobb-Douglas production function, and one (Ball et. al. 2001) used the Fisher Index. Finally, Rao and Coelli (2005) constructed the Malmquist TFP index using FAO database of 93 countries, covering the period 1980-2000.

The Malmquist TFP studies are relatively new and provide some insight into the relative ranking of countries in terms of TFP growth. The combination of inputs is allowed to vary along an efficient frontier to partition changes in productivity into technical change, and efficiency change components. The efficiency change measures change in the difference between the “average practice” and the “best practice” productivity frontier. Using this approach a number of researches have been conducted across countries, provinces or regions within a single country; those are presented in Table 2.3.

Table 2-3 Review of analyses of agricultural TFP growth

<table>
<thead>
<tr>
<th>Methods/ Author</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malmquist DEA index for cross country</td>
<td></td>
</tr>
<tr>
<td>Rezek, Campbell, and Rogers (2011)</td>
<td>39 sub-Saharan African countries from 1961 to 2007</td>
</tr>
<tr>
<td>Luenda et al. (2007)</td>
<td>116 countries for a period from 1961 to 2001</td>
</tr>
<tr>
<td>Belloumi and Matoussi (2009)</td>
<td>16 Middle East and North African countries for the period from 1970 to 2000</td>
</tr>
<tr>
<td>Continued Table 2.3</td>
<td></td>
</tr>
<tr>
<td>Obeniyi (2011)</td>
<td>13 Economic Community of West African States from 1971 to 2007</td>
</tr>
<tr>
<td>Methods/ Author</td>
<td>Data</td>
</tr>
<tr>
<td>----------------</td>
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</tr>
<tr>
<td>Nin-Pratt, Yu, and Fan (2010)</td>
<td>Between China and India</td>
</tr>
<tr>
<td>Nin-Pratt, Yu, and Fan (2008)</td>
<td></td>
</tr>
</tbody>
</table>

**Malmquist DEA index for cross-provinces/ cross regions**

<table>
<thead>
<tr>
<th>Country</th>
<th>Author</th>
<th>Data Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>Rahman (2007)</td>
<td>3 districts (agro-ecological zones)</td>
</tr>
<tr>
<td>China</td>
<td>Mao and Koo (1997)</td>
<td>29 provinces during time 1984 to 1993</td>
</tr>
<tr>
<td></td>
<td>Po-Chi et al. (2008)</td>
<td>29 provinces during time 1990-2003</td>
</tr>
<tr>
<td>Ukraine</td>
<td>Lissitsa and Odening (2005)</td>
<td>In different geographic regions and across agricultural enterprises</td>
</tr>
<tr>
<td>India</td>
<td>Chaudhury (2016)</td>
<td>State level</td>
</tr>
<tr>
<td></td>
<td>Bhushan (2005)</td>
<td>6 states of India</td>
</tr>
<tr>
<td></td>
<td>Kumar and Mittal (2006)</td>
<td>Different states</td>
</tr>
<tr>
<td></td>
<td>Teruel and Kuroda (2005)</td>
<td>Cross provinces</td>
</tr>
</tbody>
</table>

**Tornqvist-Theil indexes for growth accounting**

<table>
<thead>
<tr>
<th>Methods/ Author</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross states/ provinces/districts</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>Mukherjee and Kuroda (2003)</td>
</tr>
<tr>
<td></td>
<td>Fan, Hazell, and Thorat (1998)</td>
</tr>
<tr>
<td></td>
<td>Chand, Kumar and Kumar (2011)</td>
</tr>
</tbody>
</table>

**Country specific**

**Stochastic Frontier Analysis (SFA)**

<table>
<thead>
<tr>
<th>Methods/ Author</th>
<th>Data</th>
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</thead>
<tbody>
<tr>
<td>Cross country</td>
<td>Rae et al. (2006), Li, You, and Feng (2011), Bharati and Fulginiti (2007)</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>Coelli, Rahman, and Thirtle (2003)</td>
</tr>
<tr>
<td>Output Distance Function</td>
<td>Brümmer, Glauben, and Lu (2006)</td>
</tr>
</tbody>
</table>

Continued Table 2.3

<table>
<thead>
<tr>
<th>Methods/ Author</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobb-Douglas Frontier</td>
<td>Kalirajan, Obwona, and Zhao (1996)</td>
</tr>
<tr>
<td>Frontier Production Function</td>
<td>Fan (1991)</td>
</tr>
</tbody>
</table>
Table 2.3 shows that using the Malmquist DEA index for examining cross region/cross province agricultural TFP growth, there is only one study on Bangladesh, three studies on China, two studies on India, and two on Philippines.

The Tornqvist TFP index, which requires data on input prices is used for calculating agricultural productivity, has been used for multi-country production studies only by Fuglie (2010). Because of data limitation, there are very limited studies using this technique. In addition to the Malmquist TFP index method, the Tornqvist-Theil (T-T) growth accounting indexes are also used in cross-country, and cross-region within country agricultural productivity estimates. The measure of output in the T-T index provides an efficient approximation of the quantity in the sense of avoiding the problem of changing relative prices, satisfying the time-reversal test, and satisfying the factor-reversal test.
Hence, Fuglie (2010) brought together several country-level case studies for each year from 1961 to 2007 that have acquired representative input cost data to construct agricultural TFP growth, and apply their average cost-share estimates to other countries with similar agriculture in order to construct aggregate input indexes for these countries. Table 2-3 shows that in India there are three studies in different time using T-T index; whereas, there are eight studies in Bangladesh using T-T index method (shown in Table 6.1, pp. 156-158, Chapter 6).

The Stochastic Frontier Approach (SFA) production function, originally proposed by Meeusen and Broeck (1977), in addition to the random error in a traditional regression model, includes an unobservable random variable in identifying technical efficiency of production of individual farms. The error term is decomposed into two components: one stands for random noise, and the other is for technical inefficiency. The most important potential advantage of SFA is that it can separate noise in the data from genuine variations in efficiency. With SFA, the variability in production data can be captured in standard errors around the estimated efficiency scores, saying about confidence intervals. Table 2.3 also reveals that a significant number of studies have been carried out using SFA in both cross-country, and country specific agricultural TFP analysis.

Although there are many different approaches used by various authors to estimate TFP growth levels, this thesis employs the Solow (1956)’s growth approach because of its mechanical rigor (Denisons 1962; Jorgengon and Griliches 1967) and ideal technique for empirical analysis (Kedrick 1961, 1973; Denisons 1962, 1967, 1974). A details of the theory of Solow (1956)’s growth model is discussed in the following section.
2.4 Productivity growth and production of food

In order to understand the logic and importance of productivity growth on the agricultural production, this section starts with the analysis of the neoclassical production function. The neoclassical growth model of Solow (1956) takes the rates of saving, population growth, and technological progress as exogenous. Capital and labour inputs are paid at their marginal products. The logic of the Solow (1956) growth model\(^2\) can be captured by the standard Cobb-Douglas production function at given time \(t\) of the following type:

\[
Y_t = F(K_t, A_t, L_t)
\]  \hspace{1cm} (2.1)

Where, \(Y\) is the aggregate level of output, \(K\) is capital, \(L\) is labour, and \(A\) is the level of technology. In the process of empirical accounting, technological progress \(A\) is captured by total factor productivity (TFP) growth (further discussed in Chapter 6).

Hence, the output expresses in this study as a measurement of food security. This is based on the assumption that the more the food production, the more food security achievement. Increased food production can be achieved either by increased input, or by increased productivity (TFP growth). The former option however is not sustainable according to Solow (1956)’s theory; and the situation could become worse by resource constraints and exogenous factors like resource degradation, adverse weather events, and climate change. The latter option would be better, as maximum output is achieved with less input use. It will also help to overcome or minimize the exogenous factors.

\(^2\) The model gets its name from the independent work of Solow (1956). This thesis uses “Solow (1956) model”.
Following the assumptions and logic put in place by Solow (1956), it is possible to trace the relationship between factor input and higher output growth brought about by higher crop productivity. In a similar way, for instance, Fan et al. (2012) emphasized two issues which are crucial if crop productivity is to be increased with efficient resource use, while limiting environmental degradation: (i) efficient management to change suboptimal crop and soil management practices using existing agricultural sciences and technologies, and (ii) advances in crop productivity through development of new high yielding crop varieties that use less inputs and are more resistant to drought, heat, submersion, and pests and diseases (Figure 2.5). The upward direction from point A to point B and to point D in Figure 2.5 is driven by improvement in productivity of both, capital and labour inputs, through application of improved technologies.
Figure 2.5 Conceptual model for optimal crop production to achieve synchronously increasing crop productivity, improving resource use efficiency

![Diagram](image)

Note: (A) The current status in crop productivity on farm fields, (B) scenario of crop productivity upon application of the existing technologies, (C) scenario of crop productivity upon improved management in existing technologies, (D) scenario of crop productivity upon improved management of input and improved technology.

Source: Modified from Fan et al. (2012, p.18).

Equation 2.1 can be rewritten as,

\[ Y_t = A_t K_t^\alpha L_t^{1-\alpha} \]  

(2.2)

Here, \( \alpha \), and \( 1-\alpha \) denotes capital’s and labour’s relative share in the total value of output respectively, and \( \alpha \) is a positive fraction \( (0 < \alpha < 1) \). It implies that the production function is linearly homogeneous in degree of 1, in other words, it is a constant returns to scale.
production function (details is given in Chapter 6). In addition, Labor ($L$), and technology ($A$) are assumed to grow exogenously at constant rates, $n$, and $g$ respectively:

$$L_t = L_0 (1 + n)^t$$  \hspace{2cm} (2.3)$$

$$A_t = A_0 (1 + g)^t$$  \hspace{2cm} (2.4)$$

Moreover, the model assumes marginal products of capital and labour are positive:

$$F_k, F_L > 0$$  \hspace{2cm} (2.5)$$

Another assumption is that, successive increments in capital or labour will decrease the flow of output. In other words, marginal productivities of factor inputs are diminishing:

$$F_{kk}, F_{LL} < 0$$  \hspace{2cm} (2.6)$$

The model assumes that a constant fraction of output, $s$, is devoted to investment. Defining $y$ as the output per effective unit of labor, $y = Y/AL$ and $k$ as the stock of capital per effective unit of labour, $k = K/AL$, and $\delta$ the rate of depreciation, then $k$ is governed by:

$$k_t = sf(k_t) - (\delta + n + g)k_t$$  \hspace{2cm} (2.7)$$

The Equation 2.7 implies that $k$ converges to a steady-state value $k^*$ defined by

$$sk^* = (n + g + \delta)k^*$$  \hspace{2cm} (2.8)$$
This implies, the steady-state capital-labor ratio is positively related to the rate of saving and negatively to the rate of population growth. Substituting (2.8) into the production function and taking logs, per capita income is:

\[
\ln \left( \frac{Y_t}{L_t} \right) = \ln A + gt + \frac{\alpha}{1-\alpha} \ln(s) - \frac{\alpha}{1-\alpha} \ln(n + g + \delta)
\]  

(2.9)

Thus the Solow (1956) growth model predicts that, in steady-state equilibrium, the level of per capita income will be determined by the prevailing technology, as embodied in the production function, and by the rates of saving, population growth, and technical progress, all three of which are assumed exogenous (Solow 1956).
Figure 2.6 shows that capital to effective labor ratio increases when $sf(k)$ exceeds that of $(\delta + n + g)k$, and decreases if $sf(k)$ is below $(\delta + n + g)k$. This is based on assumption that the marginal product of capital exceeds that of $(\delta + n + g)k$ when the capital to labor ratio is small. When, the marginal product of capital declines below $(\delta + n + g)k$, the capital to labor ratio increases. As such, capital per worker rises when $k$ is initially less than $k^*$, and falls when $k$ exceeds $k^*$. At the steady state, $k^*$, the capital to effective labor ratio is constant. This implies that, regardless of the starting point, the economy will converge to the steady path, where each variable in the model is growing at a constant rate. The shape of the $sf(k)$ curve therefore satisfies Inada conditions\(^3\) (Taylor 2007).

The variable in the model which has policy implications is the savings rate, $s$, as it can shift the curve upwards pushing aggregate output growth higher. However, a higher savings rate only results in a temporarily higher output per person and not a higher rate of growth (Solow 1988). In figure 2.6, the impact of $s$ on growth of output per worker is reflected in a shift of the investment curve from the original $sf(k)$ curve to the new $s_1f(k)$ curve. At this new level, $s_1f(k)$ exceeds $(\delta + n + g)k$ as shown in figure 2.6; capital will continue to rise from $k^*$ until it reaches the new constant value as represented by $k_1^*$. Long run growth will thus cease once the economy reaches the steady state by exceeding $(\delta + n + g)k$. Furthermore, investments are subject to diminishing returns as capital depreciates ending economic growth (Aghion and Howitt 1998).

Thus the Solow (1956) model shows the limitations of capital accumulation as it is subject to the constraints of diminishing returns, and long run growth is independent of savings (Solow 1994). This implies that permanent increases in the saving rate will only have a temporary

\[^3\text{Inada (1963) imposed the technological restrictions that } f''(k) \to \infty \text{ as } k \to 0 \text{ and } f'(k) \to 0 \text{ as } k \to \infty.\]
increase in the growth rate of output per worker. In short, a change in saving rate will only have a level effect but not a growth effect. Overall, the model suggests that sustained increase in output can only be achieved through increasing the rate of change in technological progress by maintaining a positive growth of technological progress. A survey of TFP growth literature can be found in Appendix E.

2.5 Summary and conclusion

This chapter has briefly surveyed a number of issues relating to different aspects of food security, and crop productivity growth. In addition, the theoretical connotations of food security and crop productivity are explained. On the basis of literature survey on cross country/cross region within a country agricultural TFP growth, different methodologies with their advantages and drawbacks are identified. Overall discussion revealed that there is lack of a consensus in using the particular method in estimating agricultural TFP growth. Emphasis is given on the Solow (1956, 1957) growth accounting approach. Following the assumptions and logic put in place by Solow (1956, 1957), it is possible to trace the relationship between factor input and higher output growth brought about by higher crop productivity. In achieving sustainable food security, food production might hold a prominent example of how technological progress ensures output to be maintained over time even when facing depleting natural resources.
As Bangladesh today is facing a steady decline in natural resource base with increased food demand, an investigation into the state of technological progress in the country’s crop sub-sector is useful. Acknowledging the technological progress made, this review chapter, however, stresses the importance of outlining government policy actions towards domestic food production. However, the historical context need to be first understood in order to get a clear and through picture about the role of crop sub-sector in Bangladesh’s food security achievement over time, and it is done in Chapter 3.
Chapter 3  Overview of Food and Agriculture Situation in Bangladesh

3.1  Introduction

The central objective of this chapter is to provide a qualitative account on agricultural output and capital input of Bangladesh, which will add additional rigor to the analysis found in Chapter 6. Throughout chapter, three relevant key questions are dealt: (i) how the agroecology and agricultural economy of Bangladesh is? (ii) how well the foodgrain producing sector is performing to support the food demand? And (iii) how well the government support policies are doing in improving crop productivity for supporting relevant aspects of domestic food availability? To this end, this chapter seeks to address five interrelated issues of Bangladeshi agriculture: first, the agroecology and agricultural economy; second, structural transformations; third, the performance of foodgrain production; fourth, the evolution of agricultural policies related to capital inputs; and fifth, per capita foodgrain availability. The overview found in this chapter is based on historical facts as they pertain to Bangladesh and cannot necessarily be generalised.

3.2  Agricultural production in Bangladesh

The topography and soils, water and land resources critically influence the complex physical and environment surrounding Bangladesh agriculture (Alauddin and Hossain 2001). Bangladesh is located between 200 34’ and 260 38’ north latitude and between 880
01’ and 920 41’ east longitude. It is one of the largest deltas of the world with a total area of 147,570 sq. km. with 22.22 km. territorial water. The country is surrounded by India on the west, north, and east, by Myanmar in the southeast, and by the Bay of Bengal in the south (the location of Bangladesh is given in a map in Appendix A). Bangladesh is a lower riparian country in the floodplains of the Ganges, the Brahmaputra, and the Meghna rivers and their tributaries. Geographically, the land of the country is a remarkably flat, low-lying, alluvial plain, where 230 networks of rivers and canals have passed through (with a total length of 24,140). Bangladesh has a coastline of about 580 km along the bank of the Bay of Bengal, with 7 per cent of its land which lying permanently under water (Haque 2011).

The climate of Bangladesh is characterized by high temperatures, heavy rainfall, high humidity, and fairly marked seasonal variations. The three main seasons are Summer (March-May), Rainy season (June-September) and Winter (December-February). The mean annual temperature is 25.8°C, and the climate is suitable for crop cultivation throughout the year (FAO 2017). A crop calendar of Bangladesh is presented in Appendix D. The quantity of rainfall varies from an annual average of 1200 millimetres to 5500 millimetres. The land use pattern of the country is influenced by its agroecology, soil physiographic and climatic factors. Growth rates of production and yield vary among regions (Alauddin and Hossain 2001). According to the variations of ecological factors and agricultural potential, the total land area of Bangladesh has been classified into thirty Agro-Ecological Zones (AEZs), as shown in Appendix B; and accordingly, a variety of production technologies and farming systems are developed and adopted.
3.2.1 Overview of the agricultural economy

Agriculture is a large producing sector of the economy of Bangladesh, and agriculture plays a key role as a supplier of food and, source of livelihood, employment, and growth. Foodgrain production is a particularly important component of food security of Bangladesh, and agricultural productivity is critical to the country’s ability to meet food security and economic development objectives in the face of rapid population growth. Bangladesh’s agriculture is mainly divided into four sub-sectors: crops, horticulture, fishery and livestock. Since the early 1970s, the crop sub-sector has maintained a constant share of over 75 per cent of total agricultural value added while the remainder is made up of the combined shares of livestock, fisheries and forestry (Alauddin and Hossain 2001). Rice serves as both, subsistence and cash crop.

Bangladesh is predominantly a rural society, populated by peasant small holders; those produce food for their subsistence. Of about 25 million households, around 15 million (61 per cent) are dependent on agriculture, and these are living in the rural areas of Bangladesh (GOB 2015b). Bangladesh therefore remains a predominantly rural society. Housing about 2.19 per cent of the world population on 0.029 per cent of land area, Bangladesh has population pressure on land and other natural resources to produce food and other developmental needs (Kumar, Mittal, and Hossain 2008; Alauddin and Hossain 2001; Rahman 2007). The agrarian structure in Bangladesh is represented largely by the households that own and/or cultivate small and marginal holdings. The small land holdings of the food-producing householders however, often cannot be regarded as sufficient means of livelihood option. This issue is discussed in detail in following chapter.
The increasing output to meet the growing food demands of today’s and tomorrows’ increased population (with the population increasing at a rate of 1.2 per cent per year, GOB 2017a), with severe resource constraints, must rely on the food supply base. The supply base of food has shifted from an extension of area planted to intensification of production (Bayes 2007; Jahan 1997). Situation is further worsened because; every year agricultural land and crop land is decreasing at a rate of 0.44 per cent and 0.73 per cent respectively (Hasan et al. 2013). Moreover, agricultural lands are degraded by unsustainable farming practices as the production environment has been suffering with widespread soil nutrient depletion experienced in many agroecological regions (Rahman 2010a). Alauddin and Tisdell (1991) raised concern that the productivity growth from green revolution technology is declining and that this trend is a threat to sustainable economic development in Bangladesh. Sustainability of agricultural growth is under threat as the productivity of fertilizers (resulted soil nutrition depletion) and pesticides declines over the years (Coelli, Rahman, and Thirtle 2003). One of the challenges now is, to meet the country’s food self-sufficiency requirements by the year 2030, which requires High Yielding Varieties (HYV) of rice and wheat productivities to continue to grow at a rate of 10 per cent or more per decade (Faisal and Parveen 2004).

Alarmingly, the food production situation is changing, and Bangladesh is facing challenges and issues, which are likely to be significantly different from those in the past. For example, 70 per cent of the land of Barisal and Khulna divisions are affected by different degrees of salinity, which reduces agricultural productivity (Rahman and Ahsan 2001). Also, the yield level of many food commodities is still below the potential due to inefficient management and utilization of productive inputs. For instance, the rice productivity of 3.6 metric tonnes per hectare (GOB 2015b) is far below the attainable yield
of 8 - 10 metric tonnes per hectare in the dry season (Boro) and 5 - 6 metric tonnes per hectare in the wet season (Transplanted Aman) in farmers’ field experiments (Quais et al. 2015).

The problem is further exacerbated by climatic hazards. Crop production in Bangladesh is being adversely influenced by erratic rainfall, temperature extremes, sea-level rise, increased salinity, drought, floods, river erosion, and tropical storms. Greater risk of drought combined with increasing extraction of groundwater resources exacerbates the impact of drought on crop yield (Alauddin and Sharma 2013). The government of Bangladesh is concerned that, by 2050, the dry season (November–May) water deficit will rise to 24.6 per cent from 9.4 per cent in 2025 and on the other hand, the wet season (June–October) water surplus will increase to 29.7 per cent from 8.9 per cent over the same period (WARPO 2002, p.13). Islam et al. (2008) estimated that a 1°C increase in maximum temperature at vegetative, reproductive and ripening stages there was a decrease in aman rice production by 2.6, 48.2 and 15.7 metric tonnes respectively. In addition to the above discussion, a dig down further the performance of agricultural sector to the economic growth in Bangladesh assists improving understanding of the trend of food producing sector.

3.3 Sectoral contribution to GDP

The relative sectoral growth rates of productivity are important determinants of structural transformation of economies. The direct contribution of agriculture to the overall economy and the changing role of agriculture are reflected in the sector’s performance and composition in terms of Gross Domestic Product (GDP). The primary source of
agricultural growth in Bangladesh is crop production and performance of crop production dominates the trend of agriculture sector. The crop sub-sector largely determines the rate of progress in the sector.

The sectoral share of agricultural value added in GDP over the years since the early 1970s reflects a steep declining trend over the years (Figure 3.1). This trend is part of the structural transformation (discussed in sub-section 3.3.1) process of development, and does not indicate that agriculture is becoming irrelevant. Bangladesh’s declining value added agricultural product is not unique, as many newly industrialized countries, such as Malaysia, have experienced this trend. For instance, gross value added in agriculture as percentage of GDP in Malaysia was 35 per cent in 1960s, declined to 23 per cent during 1980s, and declined further to 8 per cent in 2005 (Szirmai 2012). In a transforming economy, generally, agriculture’s role changes from being a direct primary contributor to economic output to making a more leveraged contribution through powerful farm-nonfarm linkages. While there has been an accompanying declining trend in agricultural employment along with rising wages, about 45 per cent of the total labor force continues to be employed in the agricultural sector of Bangladesh.
Table 3.1 reveals (except 2000 onward) slow economic growth in Bangladesh, which has involved a slower and uneven share of agriculture in GDP growth. Meanwhile, the share of manufacturing and industry in GDP rose significantly. In the period 1990-2000, total agriculture grew at 2.6 per cent a year. However, in recent years (2000-2016), the growth performance of the agriculture sector is better than earlier (4.30 per cent), due to favourable weather and more convenient policy initiatives of the current Awami League government towards this sector (further elaborated in section 3.5 of this chapter).
Table 3-1 Trends in sectoral GDP Growth 1973-2016, Bangladesh, in per cent

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<tbody>
<tr>
<td>Overall GDP</td>
<td>4.90</td>
<td>4.80</td>
<td>4.09</td>
<td>4.70</td>
<td>6.00</td>
</tr>
<tr>
<td>Growth Rate at Market Prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>2.40</td>
<td>3.00</td>
<td>2.46</td>
<td>2.60</td>
<td>4.30</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>7.80</td>
<td>2.60</td>
<td>5.27</td>
<td>7.20</td>
<td>8.50</td>
</tr>
<tr>
<td>Industry</td>
<td>7.90</td>
<td>4.80</td>
<td>4.99</td>
<td>7.30</td>
<td>8.20</td>
</tr>
<tr>
<td>Services</td>
<td>7.40</td>
<td>6.50</td>
<td>5.01</td>
<td>4.20</td>
<td>5.80</td>
</tr>
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</table>


Hence, a closer look into the year to year agricultural value-added growth helps provide a clearer understanding of the performance of the agriculture sector. The performance of the agriculture sector shows a fluctuating trend. However, the growth performance in 2007 and 2010 was impressive, at 6.7 per cent and 6.2 per cent respectively (Figure 3.2). Nevertheless, this impressive performance continues to be peppered with periodic shocks, as in 2012–13, when the overall growth rate dropped because of unfavourable weather. The periodic shocks underscore the continuing vulnerability of Bangladeshi agriculture to climate shocks.

Figure 3.2 Annual agricultural value added growth in per cent, Bangladesh, 1971-2015

Considering the decreasing trend of agricultural value-added trend, the next sub-section examines the trend in the structural performance of the economy of Bangladesh.

3.3.1 Structural change

With the declining trend of agricultural value-added percentage to GDP, Bangladesh’s agriculture sector has undergone considerable change over the last few decades, which has a consequence on the overall economy. While continuing to grow in absolute terms, the size of agriculture has declined relative to the rest of the economy. Economic growth depends on structural changes in output, employment and foreign trade. Typically, the share of agriculture in the economy in terms of both output and employment declines during the initial stages of economic development. Economic literature, including Johnston and Mellor (1961), Delgado (1998), and Timmer (2002), has clarified the role of agriculture in economic development as: (i) providing labour for industrial work force; (ii) producing food for expanding populations with higher income; (iii) supplying savings for investment in industry; (iv) enlarging markets for industrial outputs; (v) providing foreign currency from export earnings to pay for imported capital goods; and (vi) producing primary materials for agro-processing industries. The decline in the importance of agriculture remains pervasive and uniform.

During the past approximately five decades, the Bangladesh economy has faced structural transformation in terms of GDP contribution and labour employment. Table 3.2 and Table 3.3 report data for structural change in output and the labour force in Bangladesh respectively, during the last 45 years. These show that the share of agriculture in output declined from 55 per cent in 1975 to above 17 per cent in 2010-2015. During the same period, the share of industry in output increased from 10 per cent to 28 per cent and the
share of the service sector from 35 to 54 per cent respectively. The growth of agricultural 
production has contributed to industrialization and the economic development in 
Bangladesh. Thus, the service sector has shown the most significant growth in GDP 
contribution in Bangladesh in recent years.

Table 3-2 Sectoral shares in GDP of Bangladesh, 1975–2015, in per cent

<table>
<thead>
<tr>
<th>Period</th>
<th>Agriculture</th>
<th>Industry</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975*</td>
<td>54.6</td>
<td>10.50</td>
<td>34.90</td>
</tr>
<tr>
<td>1980-85 (average)**</td>
<td>43.53</td>
<td>9.40</td>
<td>47.20</td>
</tr>
<tr>
<td>1990-95 (average)**</td>
<td>35.99</td>
<td>10.59</td>
<td>53.42</td>
</tr>
<tr>
<td>2006-09 (average)***</td>
<td>18.65</td>
<td>26.17</td>
<td>55.17</td>
</tr>
<tr>
<td>2010-15(average)***</td>
<td>17.18</td>
<td>28.54</td>
<td>54.29</td>
</tr>
</tbody>
</table>


* Constant price base year: 1973
**Constant price base: 1985
*** Constant price base year: 2005-06

In terms of sectoral shares of employment in Bangladesh, there has also been a significant 
change in the occupational structure of the labour force. Table 3.3 shows the sectoral share 
in employment in Bangladesh. During the early 1970s, above 56 per cent of the population 
was engaged in agricultural occupations, followed by the industry (7.5 per cent) and 
service (35.8 per cent) sectors. Increased incidence of multiple cropping permitted by 
 improved irrigation has led to an increase in the effective area under cultivation and 
resulted in significant employment gains during the rabi season. However, because of the 
shift of labour from low productive agriculture to high productive non-agriculture sector,
the share of employment in agriculture has gradually decreased over decades. Despite this trend, in terms of distribution of the employed population by broad economic sectors, the largest proportion is still in agriculture. Until the later 2000s, the share of agricultural labour remained more than half (more than 50 per cent) of the employed labour force in Bangladesh. According to the average of the labour force surveys for the year 2013 and 2015\(^4\), this share is below half of the employed population; i.e. employed populations in agriculture, industry and service are 43.9, 2.3 and 35.5 per cent respectively (GOB 2017a).

**Table 3-3 Sectoral share in employment in Bangladesh (per cent), 1973-2015**

<table>
<thead>
<tr>
<th>Period</th>
<th>Agriculture</th>
<th>Industry</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973-75</td>
<td>56.7</td>
<td>7.5</td>
<td>35.8</td>
</tr>
<tr>
<td>Average of 1991 and 1996</td>
<td>50.9</td>
<td>10.05</td>
<td>39.05</td>
</tr>
<tr>
<td>Average of 2013 and 2015</td>
<td>43.9</td>
<td>2.29</td>
<td>35.5</td>
</tr>
</tbody>
</table>


The important finding is, while agriculture’s GDP share has fallen drastically since independence, its employment share has not fallen by as much, and significantly, it continues to employ some 42.7 per cent of the labour force (GOB 2017b). As a result, average agricultural labour productivity has not increased much. This situation matches with the

\(^4\) The Labour Force Survey in Bangladesh is usually conducted by the Bureau of Statistics of Bangladesh with technical support of the World Bank and International Labour Organization (ILO) of the United Nations (UN).
Lewis’ (1954) theory that in any over-populated country where natural resources are relatively less than other countries, the marginal productivity of agricultural labour is negligible, zero, or even negative. In contrast, transfer of labour from agriculture in itself requires an increase in agricultural productivity that can arise only from technological innovation. In this instance Ruttan et al. (1978, p. 46) pointed out that:

“Increases in output per worker can only be achieved through increased land productivity, only if the rate of increase in output per hectare (through biological technology) exceeds the rate of change in the number of workers employed per hectare.”

Large gaps in labour productivity between the traditional and modern parts of the economy are a fundamental reality of developing societies (McMillan and Rodrik 2014) and Bangladesh is not an exception. Also this situation matches with the argument that in poor countries, where economy-wide efficiency is low, subsistence food requirements lead workers who are relatively unproductive in agricultural work to nonetheless select into the agriculture sector (Lagakos and Waugh 2013). The agricultural labour force is discussed in more detail in Chapter 5. The next section attempts to elaborate the performance of the crop sub-sector in terms of production and yield of major cereals (food staples- rice and wheat) in Bangladesh.

3.4 Performance of the crop sub-sector in agriculture

Considering the importance of crop production in attaining food security, this section attempts to show the performance of the crop production sector in Bangladesh. The data presented in Table 3.4 reveal agriculture’s massive and impressive achievements due to
technical change in Bangladesh over about 30 years. A comparison between the period of 2013-2016 and the period of 1982-85 is considered, in the sense that between the two time periods the GR technology and economic reform policy were already effective and at mature stage. Table 3.4 reveals that the total cropped area (including multiple cropping) increased by 11.7 per cent between the two time periods, while net cropped area declined by 8.3 per cent, with an increase in cropping intensity of 24.9 per cent. The incidence of multiple cropping land increased by the expansion of irrigation facilities (from 14.7 per cent of total cropped area in 1982-85 to 49.3 per cent in 2012-15), which allows the growing of additional crops on seasonally fallow land during the dry winter season. Ultimately, this resulted in higher agricultural output growth. Even, for the period 1961-64 to 1974-77 (the very initial stages of GR), Chaudhury (1981) found intensive land use pattern, as the main source of growth of output and employment in Bangladesh agriculture, by increasing both yield and labour input per unit of land.

Moreover, the promotion of HYV and liberalization of input markets have resulted in advanced technology adoption. The area under HYV rice rose significantly from 25.6 per cent of total rice area in 1982-85 to nearly 78.0 per cent in 2015-16 (Figure 3.5 shows the scenario). Increased use of fertilizer (almost 567.4 per cent increment between the periods mentioned in Table 3.4) and massive expansion of irrigation area resulted in increased average yield from 2.1 metric tonnes per hectare, to 3.1 metric tonnes per hectare. Thus, all the past yield achievements in the Bangladesh crop sector indicate the innovation and adoption of land saving technologies. In this instance, Alauddin and Hossain (2001) mentioned that the process of intensification has led to a substantial increase in the overall annual yield per cultivated hectares. The total foodgrain production increased by 127 per cent during this time, i.e. from 15.7 million metric tonnes in 1980s to 35.6 million metric tonnes in
This transition is particularly remarkable, considering the severe land constraint in Bangladesh, with negligible labour productivity. This can be justified by Hayami and Ruttan (1971) who argued that depending on the factor endowment of a country technical change may be induced primarily either to save labour, or to save land (biotechnological technology). Yudelman, Banerji, and Butler (1970) also recommended for land saving technology, in the form of yield increase.

The improved performance of agriculture owes a significant debt to the proactive economic and social policies (Gautam and Faruqee 2016) of the government of Bangladesh. The policy measures that have had a salutary impact on agricultural growth of Bangladesh include, prioritizing Green Revolution (GR) technology with significant impact on the production of rice and wheat, more so in the former. It also contributed to increased income and helped the country achieving a higher food-population balance (Hossain 1988). The process of GR technology adoption has undergone significant transformation in the form of increasing intensification of agriculture following a gradual decline in net cultivated area, cropping pattern and output mix (Alauddin and Hossain 2001). These changes have shifted the supply base of agriculture from being primarily area-based to primarily productivity-based in recent years (Jahan 1997).
### Table 3-4 Selected indicators of technical change in Bangladesh agriculture, 1982-2016

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cropped area (MH)</td>
<td>1.32</td>
<td>1.48</td>
<td>11.72</td>
</tr>
<tr>
<td>Net cropped area (MH)</td>
<td>0.86</td>
<td>0.79</td>
<td>-8.33</td>
</tr>
<tr>
<td>Rice area as percentage of total cropped area</td>
<td>79.10</td>
<td>77.13</td>
<td>-2.29</td>
</tr>
<tr>
<td>Area under HYV rice as percentage of total rice area</td>
<td>25.60</td>
<td>78.04</td>
<td>204.84</td>
</tr>
<tr>
<td>Area under Hybrid rice as percentage of total rice area</td>
<td>-</td>
<td>5.69</td>
<td>-</td>
</tr>
<tr>
<td>Average rice yield (metric tonnes/ha)</td>
<td>2.11</td>
<td>3.05</td>
<td>44.55</td>
</tr>
<tr>
<td>Total food grain production (million metric tonnes)</td>
<td>1.57</td>
<td>3.56</td>
<td>126.67</td>
</tr>
<tr>
<td>Cropping intensity (%)</td>
<td>153.20</td>
<td>191.33</td>
<td>24.89</td>
</tr>
<tr>
<td>Single cropped area (MH)</td>
<td>0.46</td>
<td>0.24</td>
<td>-49.02</td>
</tr>
<tr>
<td>Double cropped area (MH)</td>
<td>0.33</td>
<td>0.39</td>
<td>13.77</td>
</tr>
<tr>
<td>Triple cropped area (MH)</td>
<td>0.07</td>
<td>0.16</td>
<td>61.99</td>
</tr>
<tr>
<td>Irrigated cultivated area (MH)</td>
<td>0.20</td>
<td>0.73</td>
<td>273.85</td>
</tr>
<tr>
<td>Irrigated area as percentage of total cropped area</td>
<td>14.71</td>
<td>49.32</td>
<td>235.28</td>
</tr>
<tr>
<td>Chemical fertilizer use (kg/ha)</td>
<td>45.00</td>
<td>300.31</td>
<td>567.36</td>
</tr>
<tr>
<td>Total population (million)</td>
<td>71.00</td>
<td>159.08</td>
<td>124.05</td>
</tr>
<tr>
<td>Food grain availability (gm/ per capita/day) from domestic production</td>
<td>459</td>
<td>594</td>
<td>29.41</td>
</tr>
</tbody>
</table>


Note: *Aus* is a rice that is, sown in March–April and harvested in the summer; *aman* is a rice that is, sown or transplanted in spring or summer and harvested in November–December; *boro* is a rice that is, grown in October–March dry season. MH= million hectares; ha = hectare; kg = kilograms.
In addition to GR technology adoption, gradual process based and well-designed sequencing of various steps of agricultural input market reform is a crucial factor for the success in foodgrain production in Bangladesh (Ahmed 1995). In the same instance, for improved total factor productivity (TFP) gain, Alam et al. (2014) identified that the government-initiated reform policy, which resulted in enhanced farmers’ accessibility to new high yielding seed varieties, modern technology, and market information; those all may have contributed. Thus, the diffusion of best practice technology permitted the country to ensure an adequate aggregate food supply. However, concerted government efforts to achieve rice self-sufficiency have created both an atmosphere of optimism and concerns about whether this achievement is sustainable in the long-run.

3.4.1 Crop cultivation

Bangladesh’s agriculture is a virtual monoculture in rice production, and so rice production performance largely determines the rate of progress in the agriculture sector, and to a significant extent, that of the non-agricultural sectors. In fact, the entire growth in crop production is due to the growth in foodgrain production, particularly rice. Figure 3.3 compares the acreage share between period 1 (average of 1994-95 to 1998-99), and period 2 (average of 2010-11 to 2014-15). It is revealed from Figure 3.3 that the share of rice cultivation increased from 76 per cent to 79 per cent; the share of jute cultivation area also increased by 1 per cent (from 4 per cent to 5 per cent), but the share of wheat decreased from 6 per cent to 3 per cent, and area share of oilseed cultivation, fell 1 per cent.
There, however, exists policy controversy. The dominating crop rice has several competing crops, as found in Table 3.5. As the farming system of Bangladesh is primarily of a subsistence nature, rice is mostly produced all over Bangladesh. In addition, the government of Bangladesh promotes the production of rice to achieve rice self-sufficiency for ensuring food security. On the other hand, the government of Bangladesh has undertaken a crop diversification policy. Therefore, there is competition in the allocation of land resources for crop production. Ultimately, farmers make their production decisions in consideration of meeting their household food demands by farm production as well as considering the cost effectiveness of farm businesses. In recent years, realizing the necessity of making farming a profitable business, farmers are becoming more interested to grow high value crop to increase farm earnings.
### Table 3-5 Rice and wheat with competing alternative crops in Bangladesh

<table>
<thead>
<tr>
<th>Growing Season</th>
<th>Competing Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boro</strong> – Winter crop (Oct 17 – March 18)</td>
<td><em>Boro</em> rice, potato, wheat, maize, sugarcane, cotton, mustard, lentils, onions, soybeans, groundnuts, and vegetables</td>
</tr>
<tr>
<td><strong>Aus</strong> – Summer crop (March 18 – July 18)</td>
<td><em>Aus</em> rice, jute, maize, mung beans, ginger, chili, onions, groundnuts, and vegetables</td>
</tr>
<tr>
<td><strong>Aman</strong> – Monsoon crop (July 18 – Oct 18)</td>
<td><em>Aman</em> rice, cotton, jute, black gram, and soybeans</td>
</tr>
<tr>
<td>Wheat</td>
<td><em>Boro</em> rice, Potato, maize</td>
</tr>
</tbody>
</table>

Source: Crop Calendar of *Krishi* (Agriculture) Diary

Rice is grown throughout Bangladesh, except in the hilly southeastern region. Planting, however, can vary considerably according to the season. *Boro* rice is cultivated in most growing areas except for the saline soil coastal zone (Figure 3.4). The low yielding *aus* rice crop is cultivated mainly in isolated pockets of the west and the south during the summer. The monsoon season rain-fed *aman* rice crop is the most widespread, as it also includes the coastal zone. A late monsoon can affect the size of the *aman* planted area, and a lack of rainfall during summer can also reduce the *aus* area. However, *boro* rice is generally less susceptible to adverse weather conditions.
Figure 3.4 Rice cropping patterns of Bangladesh, 2009-2011

Source: Gumma et al. (2012, p. 28).

Farmers grow either modern, hybrid or local varieties of rice in their plots (Table 3.6). The yield of boro rice is higher than other rice due to intensive use of modern rice cultivation technologies and full dependency on irrigation water. Boro is comprised of local, high yielding and hybrid varieties. There are two types of aman, broadcast aman (b. aman) and transplanted aman (t. aman). T. aman is further categorized as local, HYV and hybrid. Aus involve traditional strains but more often includes HYVs. Modern varieties cover 98 per cent area in boro, 70 per cent in aman and 75 per cent in aus. While boro is fully irrigated, only 5 per cent and 7 per cent area of aus and aman are under supplemental irrigation.
Table 3-6 Rice varieties by technological status and yield performance

<table>
<thead>
<tr>
<th>Rice varieties</th>
<th>Characteristics</th>
<th>Yield performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid</td>
<td>Bred from two very different parents to achieve greater vigor and yield</td>
<td>15 to 20 per cent more yield compared to that of its conventional HYV counterparts (Biswas 2017)</td>
</tr>
<tr>
<td>Modern or HYVs</td>
<td>Plant height is a dwarf (short/strong); leaves erect (straight); high nutrient uptaking capacity, and, higher yields</td>
<td>High</td>
</tr>
<tr>
<td>Local</td>
<td>Long and weak plant heights; flat leaves; and low nutrient up taker</td>
<td>Low</td>
</tr>
</tbody>
</table>

Source: Author’s explanation.

In Bangladesh rice yields range from 0.9 metric tons per hectare for local varieties (Aus crops) to 3.79 metric tons for HYV (Boro crops) and as mentioned in Table 3.6, hybrid rice yield is 15 to 20 per cent more than HYVs. Generally, total rice yields have been increasing as more farmers are adopting hybrids and high yielding varieties (HYV) are investing in mechanization, fertilizers, and other agrochemicals. While during 1982-84 nearly 26 per cent of the total rice area was under HYV (Alauddin and Tisdell 1991), this reached about 50 per cent in 1994, and reached at 85 per cent by 2014-15 (Figure 3.5).
Considering the importance of rice production performance in the growth of agricultural sector, the acreage, production and yield of rice by different varieties and seasons are discussed in detail in the following section.

### 3.4.2 Review of rice production performance

Both price and non-price factors determine the supply responsiveness of farmers’ crop production. Among the non-price factors affecting the performance of crop production are the production possibilities, agronomic considerations, availability of production inputs and farmers' accessibility to resources and willingness to increase production within the prevailing agro-economic condition. Production of rice by type (seasons) during the period 1994-95 to 2014-15 is shown in Figure 3.6. *Aus* rice production trends are relatively flatter than *aman* and *boro*. From the year 1997-98 *boro* rice started playing a dominating role over other the two rice seasons in total rice production.
Figure 3.6 Rice production trend by type in Bangladesh from 1994-2015


For comparing performances of rice by area, production and yield performance over time, two averages of years are considered: Period 1 (average of 1994-95 to 1998-99, the mature HYV adoption stage) and Period 2 (average of 2007-08 to 2014-15, the hybrid adoption stage). Before the Period 2 there was no practice of hybrid boro production in Bangladesh; thus, this comparison will differentiate the two segments of time in rice production. The following discussion will be based on comparisons between Period 1 and Period 2.

Figure 3.7 Comparison between Period 1- and period 2 in terms of share of rice cultivated area by variety in Bangladesh


In terms of land allocation, rice production is dominated by all *boro* rice. The total rice area increased from 10.09 million hectares to 11.32 million hectares (12.15 per cent) from period 1 to period 2 (GOB 2015b). Figure 3.7 shows the area share for three different rice seasons, where *boro* rice dominates over the two other rice seasons in both periods. The area shares of *boro* rice increased by 62.47 per cent (from 2.92 million hectares to 4.75 million hectares) between the two time periods. From 2007-08 onwards, in addition to local and modern varieties, hybrid *boro* is also popularized in Bangladesh and figure shows that about 6 per cent of the total area covered by hybrid *boro* during the Period 2. As the *boro* season is less susceptible to weather, farmers are increasingly interested in producing *boro* rice.

### Table 3-7 Area, production and yield of *boro* rice in Bangladesh, period 1 and period 2

<table>
<thead>
<tr>
<th>Period</th>
<th>Area (million hectare)</th>
<th>Production (million metric tonnes)</th>
<th>Yield (metric tonnes/hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local</td>
<td>HYV</td>
<td>Hybrid</td>
</tr>
<tr>
<td>Period 1</td>
<td>0.24</td>
<td>2.68</td>
<td>-</td>
</tr>
<tr>
<td>Period 2</td>
<td>0.08</td>
<td>3.97</td>
<td>0.69</td>
</tr>
</tbody>
</table>


Total rice production in Bangladesh in Period 1 was about 18.11 million metric tonnes which increases to 32.11 million metric tonnes in Period 2. In terms of production, *boro* rice contributed 43.30 per cent of the total rice production during Period 1 and this increased to 56 per cent in Period -2. As compared between Table 3.7, Table 3.8 and Table 3.9, in terms of yield (tonne/hectare) *boro* rice is highest (*boro* varying between 2.73 and 3.81 ≥ *aman*)
varying between 1.54 and 2.20 ≥ *aus* varying between 1.13 and 1.91) and this is another reason for the popularity of *boro* rice. Thus, it is clear that the achievement in *boro* rice production came not only from horizontal expansion of land (at the expense of reductions in other crop area) but also by vertical expansion of technology (HYV and hybrid technology).

Figure 3.7 reveals that *aman* acreage decreased by 1.62 per cent between time Period 1 and Period 2. Table 3.8 shows the area, production and yield trend of *aman* production. The area under local *B. aman* decreased from 0.81 million hectares in Period 1 to 0.38 million hectares during Period 2. Area under local *aman* also decreased from 2.42 million hectares to 1.23 million hectares (49 per cent) within the same time gap. In contrast, the HYV *aman* area increased by (61 per cent), which is more than the decrease in *B. aman* and local *aman* rice area. Production is sensitive to weather, including frequent storms and flash floods, and this is one of the reasons for the decrease in area under *aman* rice production.

### Table 3-8 Area, production and yield of *aman* rice in Bangladesh, period 1 and period 2

<table>
<thead>
<tr>
<th>Period</th>
<th>Area (million hectare)</th>
<th>Production (million metric tonnes)</th>
<th>Yield (metric tonnes/hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B. aman</td>
<td>T.aman</td>
<td>Total (% of total rice)</td>
</tr>
<tr>
<td>Period 1</td>
<td>0.81</td>
<td>2.42</td>
<td>2.38</td>
</tr>
<tr>
<td>Period 2</td>
<td>0.44</td>
<td>1.23</td>
<td>3.84</td>
</tr>
</tbody>
</table>


As evidenced from Table 3.8, total *aman* rice production increased significantly over time because of high yielding *aman* replacing local and *B. aman* varieties. Overall, the yield of HYV *aman* has increased over time (from 2 metric tonnes/hectare to 2.5 metric tonnes/hectare). During Period 1 *aman* rice share was as high as 47 per cent, whereas during Period 2 the significance of this rice has decreased to 37.6 per cent of total rice. This indicates that the importance in *aman* season (in terms of quantity produced) is replaced by other rice season; i.e. *boro*. Overall, despite the contraction of land over time, *aman* production has increased because of technological change (HYV adoption).

**Table 3-9 Area, production and yield of *aus* rice in Bangladesh, period 1 and period 2**

<table>
<thead>
<tr>
<th>Period</th>
<th>Area (million hectare)</th>
<th>Production (million metric tonnes)</th>
<th>Yield (tonnes/hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local</td>
<td>HYV</td>
<td>Total (% of total rice)</td>
</tr>
<tr>
<td>Period 1</td>
<td>1.11</td>
<td>0.45</td>
<td>1.56 (15.48)</td>
</tr>
<tr>
<td>Period 2</td>
<td>0.30</td>
<td>0.74</td>
<td>1.04 (9.20)</td>
</tr>
</tbody>
</table>


The share of *aus* area decreased by 32.8 per cent between time Period 1 and Period 2. This is because the rate of decrease of local *aus* area (73 per cent) is greater than rate of increase of HYV *aus* (64.4 per cent) area. However, despite the decrease in total *aus* area, the production of total *aus* rice shows an increasing trend with increased adoption of high yielding varieties (Table 3.9). The contribution of *aus* rice in Period 1 was 9.6 per cent of the total rice production and this decreased to 6.2 per cent during Period 2. Thus, it seems
that the importance of *aus* in terms of total rice supply of the country is decreasing over time.

The above discussion has shown that the growth in rice production was based mainly on yield increment. In this regard, Alauddin and Tisdell (1991) argued that the yield effect almost entirely accounts for rice output growth. Hossain et al. (2005) also found that almost 90 per cent of the growth in rice production came from the increase in yields made possible through improvement of rice production technology. However, in recent years, the increasing trend of rice yields has followed a sigmoid curve\(^5\), and it seems total production may flatten in near future (Biswas 2017). However, yield-per-hectare figures are of little use, when the amounts of non-land inputs used (such as labour and fertilizer), results differ among farms (Coelli, Rahman, and Thirtle 2002). Thus, to meet the increasing food demand, two things may be needed: innovation in land saving super yielding technologies and non-land input caring technologies for better performance of the crop sector. Further investigation will be undertaken in Chapter 6 to understand the overall performance of production related issues in crop agricultural TFP.

The performance of agricultural production is very much susceptible to weather conditions and the adoption of modern technologies in agricultural production varies across various reasons. Irrigation support of year-round intensive cultivation helps farmers to recover the loss from one crop failure within six months, while earlier they had to wait for a year to recover the losses. This achievement has a smoothening effect on the seasonal variation in rice prices, and the ability of the country to cope with disastrous floods such as those in 1988

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\(^5\) A sigmoid curve is basically a stretched out S shape lying on its side, and can be thought of as having three sections, each of which corresponds to a phase of growth: i) the learning phase (the seeds are developing, moving and growing), ii) the growth phase (crop which was sown is growing and coming to maturity, and every day brings perceptible growth), iii) the decline phase (the harvest has grown to maturity and starts to die).
and 1998 (Hossain et al. 2005). In addition to technological innovation, government support includes the expansion of irrigation facilities in the upland areas, innovative agronomic approaches, appropriate pest and diseases management strategies, policy intervention to subsidies in agricultural inputs and mechanization.

From the above discussion, it seems that the *boro* season is contributing most to food production in Bangladesh. However, *boro* rice production, which is high input, including underground irrigation water demanding, is now an issue of sustainability concern for policy makers and farmers, with respect to the efficient use of irrigation water. While estimating farm level technical efficiency of traditional and HYV rice producers, Sharif and Dar (1996) found that *boro* season cultivation was technically inefficient, relative to cultivation in the *aman* and *aus* seasons at farm level. Also, to save groundwater for *boro* irrigation, Salam (2014) recommend to shift about 20 per cent (around 0.9 million hectare) of *boro* rice areas to *aus*. The same study also suggested location-specific varietal development along with production technologies and partial or supplemental irrigation facilities for the *aus* season.

Although domestic production and per capita availability of major food items such as rice, wheat, potato, vegetables, meat, fish, milk, and eggs, has increased considerably over the past decades, Bangladesh has a deficit in relation to all the food items except rice and potatoes. The emphasis placed on rice production has resulted in an increased dependence on import of high-value foods like pulses and oilseeds; for instance, the country imported oilseeds and edible oil worth Bangladeshi Taka 19.3 billion and 11.2 billion respectively during 2012-2013 (GOB 2015a). Prices of all these commodities remain high; impeding the access of the poor to a more diversified diet. Another issue is the tendency to shift *aus* areas to more profitable
summer vegetables. The government has been providing incentives to produce *aus* rice in place of other competitive crops in order to maintain domestic rice stock at a safe level in the country.

### 3.4.3 Review of wheat production performance

Following rice, wheat is the second most important cereal crop of the *Rabi* (dry) season and it is an indispensable food. Wheat production is highly sensitive to weather conditions. Bangladesh does not have favourable agro-climatic environments for growing wheat because of the short and mild winter season and heavy soils. Wheat is grown mostly in the north-western region of the country which has a relatively longer winter period. Wheat cultivation is gaining popularity in Bangladesh; the average yield in the country is 2.3 metric tonnes/hectare, which is satisfactory in comparison with other wheat growing neighboring countries; i.e. 2.85 metric tonnes/hectare in India and, 2.54 metric tonnes/hectare in Pakistan. With the exception of a few years, there has been a gradual decrease in the area, production, and yield of wheat in Bangladesh. Constraints in crop rotation to accommodate wheat in a triple cropped land and short duration of desirable low temperatures during winter are the main reasons behind less cultivation of wheat in Bangladesh.

#### Table 3-10 Area, production, and yield performance of wheat in Bangladesh, period 1 and period 2

<table>
<thead>
<tr>
<th>Period</th>
<th>Area (million hectares)</th>
<th>Production (million metric tonnes)</th>
<th>Yield (metric tonnes/hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period 1</td>
<td>0.75</td>
<td>1.42</td>
<td>1.89</td>
</tr>
<tr>
<td>Period 2</td>
<td>0.41</td>
<td>0.99</td>
<td>2.41</td>
</tr>
</tbody>
</table>


Rainfall in late-September 2002 delayed the cultivation of wheat and some land was diverted to other crops, resulting in a wheat acreage reduction of 8.15 per cent compared to the previous year. In total, production in 2002-03 was 26.69 million metric tons (3 per cent higher). However, wheat area coverage declined due to the diversion of wheat land to potato and maize. Also, constraints in crop rotation to accommodate wheat in a triple cropped land, and the short duration of desirable low temperature during winter resulted in a decline in the area allocation for wheat by 13 per cent (0.56 million hectares).

Although wheat production may gain some yield advantage due to monsoon floods, both the area and production of wheat have been decreasing over the past years due to changes in ecological factors. For wheat, the target area set by the DAE was 0.4 million hectares and actual plantation slightly exceeded the target. Total production of wheat was 0.85 million metric tonnes. The area achievement of wheat fell short of earlier years, but the yield of wheat improved because of the relatively prolonged cold period during winter. Wheat production performance in terms of area, production and yield is presented in Table 3.10. In 2011-12 wheat plantation achieved its target of 0.38 million metric tonnes. In the south-western region, some setbacks in wheat production were received in 2014-15. According to DAE, in 2016-17 wheat plantation fell short of the target area by 0.03 million hectares, and it is expected that wheat production targets are not likely to be achieved.

The aim of the next section is to explore the role of government in achieving agricultural production growth in Bangladesh. Particular interest is to investigate how agricultural policies are influenced under different macroeconomic policies with different political views.
3.5 Agrarian policies in promoting growth in agriculture

Government programmes and policies affect agricultural productivity. For example, agricultural output and input prices affect the technology chosen by farmers, and thus drive observed productivity patterns (Fulginiti and Perrin 1993). In this thesis, input costs are considered as capital cost. Therefore, it is imperative to discuss agricultural input policies of Bangladesh in a historical perspective. Bangladesh became an independent country on 16 December 1971, when, after a violent liberation struggle, it seceded from Pakistan. Bangladesh’s present and future cannot easily be understood without reference to Bengal’s earlier conquest by the Mughals and later by the British, and to the anticolonial struggles that led first to the formation of Pakistan and later to the liberation of Bangladesh. Since independence, Bangladesh has undergone significant political and economic changes. In addition, government aims and policies for agricultural development in Bangladesh have varied over the five decades since independence. Persistent political instability is a cause behind the unsustain progress of agricultural development of the country. This section briefly reviews the policies and objectives in agrarian planning during the last five decades.

The economy of Bangladesh has experienced significant shifts in trade, fiscal, industrial, agricultural and financial policies over the last five decades (approximately). Almost all governments had a common strategy of achieving and maintaining the status of food self-sufficiency in foodgrain production through modernization of the agriculture sector. Growth and development in agriculture were seen in terms of the sector’s linkages with the overall economic development of the country. Providing agricultural production incentives to create a favourable environment for investment and growth has been a common goal of all the
governments of Bangladesh. Phase by phase policy interventions towards agriculture sector are discussed in detail below (Table 3.11).

Bangladesh agriculture during the 1950s and 1960s was neglected as the economic development of the then government had an industrial bias (Hossain 1996). After independence in 1971, being the country predominantly agricultural country, the then government saw an urgency to rapidly develop the agriculture sector and saw that the country’s development depended on agricultural expansion. The government has pursued a policy of rapid technological progress in agriculture, leading to diffusion of a rice-wheat based GR technology packages, the initial adoption and expansion of which was continued throughout the 1970s and 1980s. Consequently, national policies have been directed towards transforming agriculture through the rapid diffusion of modern varieties of rice and wheat, including the provision of the inputs needed to support such a strategy.

From inception, the then Awami League government under the leadership of Sheikh Mujibur Rahman (1972-75) professed a socialist strategy for development that reinforced an import substitution industrialization (ISI) policy of development. In Bangladesh, the 1970s were characterized by a highly regulated financial system, a narrowly based fiscal regime, an inward-looking trade policy and an overvalued exchange rate regime; despite domestic currency depreciation by 75 per cent in 1975 (Islam and Hassan 2011). Moreover, the government nationalized heavy industries and financial institutions, brought foreign trade under state control, and restricted the role of private investment in the development of the non-farm sector, although retaining agriculture in private ownership (Hossain 1989). In view of the serious setback of the war of liberation on foodgrain production, policy centred
largely on the replacement of traditional and unsustainable agriculture by modern and sustainable agriculture, through structural transformation within agriculture.

Given the existence of a socialistic economic order, and the aim of achieving self-sufficiency in foodgrain production, the agricultural development approaches in the First Five Year Plan (1973-78) aimed to increase smallholder agricultural income, provide productive employment of the rural labour force, improve income distribution, encourage cooperative farming, increase exports and substitute imports with domestic agricultural production. As well, the policy withdrew subsidies on all inputs, with the aim of having a favourable effect on income distribution. The government encouraged the extension of cooperative enterprises in various fields of the rural economy. In 1972 the first initiative towards land reform was undertaken by the Mujib Government (1972-75). The notable aspects of the reform were: (i) reducing the maximum limit of land ownership; (ii) distributing khas (government owned) land among the landless farmers, and (iii) land tax exemption for small land owners (up to 4.01 hectares).

To ensure remunerative prices to the producers by protecting them from external competition, the government restricted or banned some imports and imposed export duties. Restrictions were imposed on the entrance of the private sector in the procurement and distribution of seed, fertilizers, pesticides and all sort of agricultural equipment, so the market was controlled by the government parastatal - the Bangladesh Agricultural Development Corporation (BADC) and cooperative societies. Agricultural credit was handled and disbursed through the nationalized agricultural Bank-Bangladesh Krishi Bank (BKB).
Macroeconomic policy measures were changing frequently with the political instability. Due to expansionary fiscal and monetary policies, the annual average rate of inflation was 21 per cent and the size of the trade deficit was 9 per cent of Gross National Product (GNP) during the period 1973-1980 (Hossain 2000; Hossain 1996). In terms of export development and balance of payment performance, the autarkic trade and exchange rate policy failed to achieve its goal. The input distribution system suffered from numerous problems arising from excessive bureaucratic controls (Ahmed 1995). Furthermore, crop production experienced adverse supply shocks, such as drought, and floods during the early 1970s; which created food shortages. The failure of that development strategy let policy makers to tilt towards a more open economy in the late 1970s. This shift in policy was also facilitated by a change of government in 1975, when the government under General Ziaur Rahman came to power after a series of military coups.
Table 3-11 Qualitative comparison of macroeconomic and agricultural policies under different regimes, in Bangladesh, 1972-2020

<table>
<thead>
<tr>
<th>Regimes</th>
<th>Effective plans</th>
<th>Macroeconomic policies</th>
<th>Agricultural policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mujib period (1972/73-1974/75)</td>
<td>Partial of First FYP*(1973-78)</td>
<td>Expansionary monetary and fiscal policy, state controlled foreign trade</td>
<td>Large subsidies on input, some control over prices</td>
</tr>
<tr>
<td>(Socialistic motive)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Zia period (1975/76-1980/81)</td>
<td>Partial of First FYP (1973-78)</td>
<td>Moderately expansionary monetary and fiscal policy, emphasis on private trade, moderately liberalised foreign trade</td>
<td>Lowered subsidies on inputs and food, no control over agricultural prices, emphasised the role of private enterprise</td>
</tr>
<tr>
<td>(market oriented economic policies)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ershad period (1982/83-1989/90)</td>
<td>Second FYP (1980-85), and Third FYP (1985-90)</td>
<td>Denationalisation of industries, expansionary monetary and fiscal policy, liberalised foreign trade</td>
<td>Encouraged agricultural production, enabled private sector to play an active role in marketing of agricultural inputs and outputs</td>
</tr>
<tr>
<td>(market oriented economic policies)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Khaleda Zia period (1990/91-1995/96)</td>
<td>Fourth FYP (1990-95)</td>
<td>Structural adjustment and economic liberalisation policy continued</td>
<td>Privatization of agricultural input distribution, liberalised and market based agricultural economy</td>
</tr>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Khaleda Zia period (2002/03-2006/07)</td>
<td></td>
<td>Followed trade liberalisation policies</td>
<td>Did not allow direct subsidy to the agriculture sector, in addition to price support the government provided indirect subsidy</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td>Hasina period (2008/09- continued)</td>
<td>Sixth FYP (2011-15), and Seventh FYP (2016-20)</td>
<td>Strengthening Public Private Partnerships (PPP), achieving MDG goals and SDG goals</td>
<td>Crop diversification, infrastructure development, increasing agricultural productivity in a sustainable manner</td>
</tr>
</tbody>
</table>


*FYP= Five Year Plan.
The Zia regime (1976-1981) encouraged private participation and boosted export-oriented industries within the private sector. The new government encouraged food production through large-scale government subsidies, low-interest agricultural credit, and massive labour intensive income generating programmes (mainly manual digging and excavation of canals) in rural areas. In addition, the government withdrew BADC’s activities in retailing and wholesaling of fertilizer at *upazila* level, leading to a large expansion in the number of wholesalers and retailers operating in the market. The Zia government, however, avoided any move towards effective land reforms (Hossain 1996). Unfortunately, those policies did not result in a sustained increase of production and productive efficiency; rather, the gap between demand for and supply of agricultural production widened over the years.

The military government under General Ershad came to a power in mid-1982 through a military coup, forced on the pretext of a deteriorating law and order situation under the Sattar government, which was a continuation of the Zia government after his assassination in 1981 (Hossain 1996). The agricultural policies undertaken by the Zia government gathered momentum during the Ershad regime. Hossain has described aspects of Ershad’s agricultural development strategy as follows:

“Agicultural policies were designed to encourage production, reduce the budgetary costs of agricultural subsidies and enable the private sector to play an active role in agricultural development. A large agricultural credit was made available to farmers to help meet the higher costs of fertilizer and irrigation equipment. The private sector was given the opportunity to compete with the public sector in importing, marketing and servicing minor irrigation equipment and in the wholesale and retail distribution of fertilizer” (Hossain 1996).

At the behest of the World Bank (WB) and the International Monetary Fund (IMF), the government launched strategies leading to a greater market- and export-orientation in 1982
(Islam and Hassan 2011). The policies of the Ershad regime (1982-90) are clearly reflected in the Second and Third Five Year Plans (1980-85) and (1985-90) respectively. The gradual deregulation of the economy allowed private entrepreneurs to import diesel engines without taxes, couple these engines with domestic pumps and pipes, and sell the equipment to farmers (GOB 1989). The mentioned policy changes were accompanied by the complete elimination of subsidies on minor irrigation equipment. Other policy changes included removal of all import duties and standardization restrictions on power tillers. The driving force behind the economic reform policy was that to increase the efficiency of the delivery system, increase easy access by farmers to inputs as a reasonable price and decrease the budgetary burden of subsidy (Azmat and Coghill 2005). Important outcomes of the reform policy were stimulated private trader investment, and lower prices for a broad range of farm inputs, including imported machinery, and materials (such as fertilizer). These helped reduce the key constraint on farmers’ access to more productive input. Together these policy initiatives led to a large-scale shift to higher yielding varieties, and a seasonal shift in favour of the irrigated winter (boro) rice crop, boosting rice productivity (in terms of yield) and agricultural growth. In addition, privatization of fertilizer distribution helped raise their use. Two positive results of the reforms in the 1980s were fiscal savings by cutting subsidies and agricultural intensification (Hasan 2012).
In 1990, the Ershad regime was, in its turn, overthrown by a popular mass uprising to restore democracy. In 1991, through the parliamentary election process, Bagum Khaleda Zia (wife of the founder of Bangladesh Nationalist Party, Ziaur Rahman) came into power. Under the fourth five-year plan (1990-95), structural adjustment and economic liberalization continued as the economic policy focus of the Khaleda government (1991-96). Consequently, during her tenure the agriculture sector policy continued to be liberal and market based, with emphasis on increased use of minor irrigation equipment, fertilizer and HYV seeds (GOB 1989). Moreover, private sector investment in agriculture was further encouraged through a policy of privatization of agricultural input distribution. However, small farmers lagged in accessing credit and other irrigation facilities. Inadequate infrastructural setup in foodgrain storage and transport facilities also hampered the marketing potential of agricultural commodities. The performance of the private sector in maintaining input quality was questioned. Governments need to focus input regulations on fraud and externalities, and allow markets to decide questions about performance (World Bank 1990).

The BNP government introduced duty free imports of fertilizer from 1992. However, in 1995, the open market system for domestically produced urea experienced a major setback because of non-availability of fertilizers at the farm level (Jaim 2015); and to counteract the situation the government took immediate action and re-imposed controls on dealers, with licensing, quotas, and delimitation of sales areas. The government-initiated duty-free import of power tillers, tractors, and supported the buyers with credit, in 1995. In 1992, rural rationing was withdrawn, and statutory rationing was abolished.
Some of the macroeconomic policy initiatives were positively reflected on particularly in the crop sector. The government reduced tariffs on foodgrain imports further in 1991-93. The international diesel price came down from a peak in 1980, so even if reformers cut subsidies on fertilizer, the price fell on the domestic market. Similarly, irrigation equipment became more affordable; as the price of diesel to keep the pumps operating was falling. The input market reforms accelerated the use of fertilizer and tubewell irrigation, which allowed winter cultivation of irrigated rice (the *boro* crop). The ground water irrigation witnessed significant expansion (From 2.65 MHa in 1990/91 to 4.00 MHa in 1996/97) and use of chemical fertilizer increased (from 2 MMT in 1990/91 to 3.02 MMT in 1996/97). A large part of the seed requirement (95 per cent) was met by the private sector during this period (GOB 1996). Despite all policy efforts, inadequate quality seeds, irrigation facilities and extension services, coupled with natural calamities like floods, droughts and salinity, contributed to the sluggish growth of agricultural output during the Fourth Plan period (GOB 1996).

During 1995-97, the government did not draw up a new plan after the Fourth Plan, so there followed a Two Years Plan Holiday. Annual Development Plans (ADP) in the public sector in 1995/96 and 1996/97 were prepared on an ad-hoc basis. During this period, the growth of agricultural output was about 6 per cent, industry 3.6 per cent and services 6.2 per cent. The impressive growth in agriculture was due to significant increases in major crop production. A democratically elected (*The Awami League*) government took over power in June 1996 and a set of coordinated measures were taken to increase investment in both the public and private sectors. This government operated development strategies under the fifth five-year plan (1997-2002) to develop an integrated agriculture through more efficient utilization of available land and water resources for sustainable agricultural
growth (GOB 1996). The plan had a provision of public sector interventions, with strengthened institutional and financial capacities of the government, to make up any case of input market failure. For example, to maintain the quality of fertilizer, control production, import and marketing of adulterated/low quality fertilizer, post-landing inspection of imported fertilizer, fertilizer inspection and fertilizer analysis, guidelines were prepared. A target to a maximize income from agriculture through effective and efficient utilization of the country’s resources and the revitalization of the sector’s contribution to the national economy National Agricultural Policy (NAP), was first introduced during this period.

The Bangladesh Nationalist Party (BNP) returned to power again in 2002 for five years (2002-2007). During this administration, the trade liberalization policies of the World Trade Organization (WTO) were broadly followed. Though the policies did not allow direct subsidy to the agriculture sector, in addition to price support policy the government provided indirect subsidy through providing electricity for irrigation at a subsidized rate, as well as investment subsidies to poor and marginal farmers through offering a concessional rate of interest at 1.5 per cent per annum for credit (WTO 2010). Indirect subsidy was also provided to farmers through imported urea and non-urea fertilizer. However, there is evidence that despite subsidies, the fertilizer price was artificially increased by the oligarchic behavior of importers and distributors (Barkat et al. 2010).
The BNP government monitored the fertilizer production and marketing system. Special emphasis was given to maintaining balanced use of fertilizer and water and sustainable use of resources. The National Food Policy (NFP) 2006 and its Policy Plan of Action (PoA) 2008 provide the policy framework for promoting agriculture, food security and nutrition. To ensure implementation of the Plan of Action (PoA), the Country Investment Plan (CIP) for agriculture, food security, and nutrition was prepared in 2010. After the completion of the BNP administration, in January 2007 an unelected military-backed Caretaker Government came in power and continued for a two-year period (Lewis 2011).

The sixth five-year plan (FY2011-FY 2015) focused on raising productivity as the key to increasing agricultural production. The plan emphasized improving the enabling environment for agribusiness development by enhancing production scale, focusing on quality and standards for export markets, and developing private trade logistical assets such as cold storage facilities, and rural infrastructure. Subsidies on various inputs were used to protect against rising costs. In response to the increasing cost of urea fertilizer, the Government allocated more budgets for fertilizer subsidies (about 0.7 per cent of GDP in FY2011). The plan has also continued to subsidize diesel, used to run the irrigation pumps, and to encourage banks to expand farm loans (agricultural loans constitute around 6 per cent of total loans). The Bangladesh Central Bank (BCB) continued to make lending to agriculture a priority sector for banks. In addition, food imports became more diversified, which helped to control their cost; in particular, food grains were increasingly imported from Pakistan, Thailand and Vietnam as Bangladesh moved away from traditional-source markets such as India, where export bans on rice have created supply disruptions.
In light of the Sustainable Development Goals of the United Nations, the Seventh Five Year Plan (FY2016-FY2020) was developed. The main focus of the plan is to accelerate transformation from semi-subsistence to commercial farming. For reduction of poverty, as well as improvement of both food and labour productivity, the government is mindful of the need to motivate farmers to diversify agricultural production towards increased production of cash crops.

3.5.1 Agricultural policy documents

Agricultural policies have basically mirrored the stance taken by the government of the day on macro policies. Agricultural and related policies are official documents formulated by the government to set as the strategic direction of the sector in Bangladesh. There are a plethora of policy/strategy documents relevant to broad agriculture and rural development in Bangladesh (Mandal 2006). The crosscutting policies include those related to land, water, food and rural development.
## Table 3-12 Crop Agriculture Sector Related Policy Matrix, Bangladesh, 1973-2020

<table>
<thead>
<tr>
<th>Sub-sector policies</th>
<th>Major goals and policy thrusts</th>
<th>Implementing ministry</th>
</tr>
</thead>
</table>
| 1. First Five Year Plan-FY 1973-FY 1978 | • adapted seed-fertilizer-irrigation technology  
• Withdrew subsidies on all inputs with the aim of having a favourable effect on income distribution.  
• As institutional management, BADC as a government monopoly alone handled import, domestic procurement, and distribution of fertilizer.  
• Under a monopoly system, policy options included fertilizer subsidies, regulated trade, and controlled prices. The policy aims to eliminate the unjust practice of benefit being monopolized by more influential and privileged people and region. | Ministry of Planning |
<p>| 2. Second Five Year plan-FY 1980-FY 1985 | With the prescription of reform policy, the government liberalized input import and distribution system; allowing private sector.                                                                                                  | Ministry of Planning |
| 3. Third Five Year Plan-FY 1985-FY 1990 | Reform policy further strengthened with market deregulation, private participation in agricultural input and output market                                                                                                | Ministry of Planning |
| 4. Fourth Five Year Plan-FY 1990-FY1995 | Adoption of modern varieties increased but their yields have fallen. Unbalanced use of fertilizers and depletion of organic matter affected soil fertility and yield.                                                                | Ministry of Planning |
| 5. Seed policy, 1993 | Breeding of crop varieties suitable for high input and high output agriculture, multiplication of quality seeds, balanced development of public and private sector seed enterprises, simplification of seed important for research and commercial purposes, provision of training and technical supports in seed production, processing and storage monitor, control and regulate quality and quantity of seeds. | Ministry of Agriculture |
| 6. New Agricultural Extension Policy (NAEP)- 1996 | Provision of efficient decentralized and demand led extension services to all types of farmers, training extension workers, strengthening research-extension linkage, and helping environmental protection | Ministry of Agriculture |</p>
<table>
<thead>
<tr>
<th>Sub-sector policies</th>
<th>Major goals and policy thrusts</th>
<th>Implementing ministry</th>
</tr>
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<tbody>
<tr>
<td><strong>Continued Table 3.12</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Seed Rules- 1997</td>
<td>Delineation of rules and regulations regarding changing functions and of national seed board, registration of seed dealers, seed certification, marking truthful labels, and modalities of seed inspection.</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>10. National Agriculture Policy- 1999</td>
<td>Food security, profitable and sustainable production, land productivity and income gains, IPM, smooth input supplies, fair output prices, improving credit, marketing, and agro-based industries, protecting small farmers interest</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>11. Agricultural Extension Manual-1999</td>
<td>Annual crop planning, seasonal extension monitoring, participatory technology development and rural approval partnership, technical audit, attitude and practice surveys</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>12. National Agricultural Policy- 2013</td>
<td>To face challenges of decreasing natural resource, climate change, frequent natural hazards, input and food price hikes. it was felt considered important to update the National Agricultural Policy, 1999. Considering those issues, NAP, 2013 has been finalized in the same light of NAP 1999.</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>13. Sixth Five Year Plan- FY 2011-FY 2015</td>
<td>Raising crop productivity, strengthening public-private partnership in developing agricultural input and output market Stressing upon research and extension</td>
<td>Ministry of Planning</td>
</tr>
<tr>
<td>14. New Agricultural Extension Policy-2016</td>
<td>provide efficient, effective, coordinated and decentralized, demand responsive and integrated extension services to help farmers to access and utilize better know how, improve productivity, optimize profitability and ensure sustainability thereby ensuring the wellbeing of their families.</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>15. DAE-Strategic Plan- 1999-2002</td>
<td>Adoption of Revised Extension Approach, assessment of farmers’ information needs, supervision, use of low or no cost extension methods, promotion of food and non-food crops, and mainstream gender and social development issues into extension service delivery.</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>Sub-sector policies</td>
<td>Major goals and policy thrusts</td>
<td>Implementing ministry</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
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<tr>
<td>Continued Table 3.12</td>
<td></td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>16. National Rural Development Policy-2001</td>
<td>Improving income and employment of rural people, ensuring participation of rural people in the development process, improvement of rural infrastructure and marketing facilities, local level planning, training of youths and women, and development of disadvantaged, small minority communities and hill tract regions.</td>
<td>Ministry of Rural Development, Cooperatives</td>
</tr>
<tr>
<td>17. Plan of Action on National Agricultural Policy-2003</td>
<td>Reviewing NAP and its implementation, setting out strategies and actions, and identifying institution and program framework</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>18. Actionable Policy Brief-2004</td>
<td>Prioritize immediate medium-term and long-term policy measures with respect to seed, fertilizer, land, irrigation, mechanization, marketing, agricultural research and extension with a view to increasing labor and water productivity, investment in agriculture and improve risk management.</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>19. Agriculture and Rural Development section, PRSP-2005</td>
<td>Creation of enabling environment and playing supportive roles for intensification of major crops i.e. (cereals) diversification to high-value non-cereal crops, (i.e. fruits and vegetable) development of non-crop enterprises (i.e. livestock, fishery, poultry), and promotion of rural non-farm economy, and outlining a policy matrix on future actions.</td>
<td>Ministry of Planning</td>
</tr>
<tr>
<td>20. National Food Policy-2006</td>
<td>Ensuring dependable food security system, adequate and stable supply of safe and nutritious food at affordable prices, increasing access and food purchasing power of people</td>
<td>Ministry of Food and Disaster Management</td>
</tr>
<tr>
<td>21. National Land Use Policy-2001</td>
<td>Minimizing loss of cropland, stopping indiscriminate use of land, preparing guidelines for land use for different regions, rationalizing land acquisition, and synchronization of land use with natural environment</td>
<td>Ministry of Land</td>
</tr>
<tr>
<td>22. Environment Policy 1992 and -implementation Programme</td>
<td>Protection of environment, identification, and control of pollution, sustainable use of natural resources and participation in all international initiatives to protect environment</td>
<td>Ministry of Forests and Environment</td>
</tr>
<tr>
<td>Sub-sector policies</td>
<td>Major goals and policy thrusts</td>
<td>Implementing ministry</td>
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</tr>
<tr>
<td>Continued Table 3.12</td>
<td></td>
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<tr>
<td>23. National Sustainable Development Strategy</td>
<td>To formulate and implement a sustainable development strategy addressing environmental issues.</td>
<td></td>
</tr>
</tbody>
</table>

Source: Mandal (2006), and updated by author.
Table 3.12 illustrates the different policies regarding crop sector agriculture; their major policy goals are also listed, to help understand at a glance the policy directions of the country at a given time. As can be seen from Table 3.12, the government of Bangladesh has adopted different policies at different times to strengthen the sector, with various strategies aimed at saving the producer-farmer, the environment, the market and the economic conditions.

The main agricultural policy was first developed in Bangladesh in 1999 and revised in 2013. In the National Agriculture Policy 2013, emphasis has been given on ensuring food safety, innovative improvement for e-agriculture, promoting urban agriculture and homestead gardening, yield gap minimization, expansion of irrigation facilities and farm mechanization, quality seed production and distribution, supply of quality inputs, quality horticultural crop production, and popularization of good agricultural and Integrated Pest Management practices. As technological progress is deeply rooted in the strength of agricultural research and development, the next sub-section emphasizes relevant policies of Bangladesh.

3.5.1.1 Agricultural research policies

The importance of technological change has been explored since Adam Smith (1776). There exist causal chains that cover the relationships from agricultural Research and Development (R&D), to agricultural productivity growth, to GDP per capita, to inequality, to poverty reduction and food security (Thirtle, Lin, and Piesse 2003). It is proven that research-led technological change in agriculture generates sufficient productivity growth which has a substantial impact on rural poverty by increasing both production and employment. Lipton (1977) and Mellor (1961) argues in the same way
that agricultural research and development has a significant contribution towards reducing rural poverty in developing countries. Again, empirical evidences from the study of Kerr, John M, and Shashi Kolavalli; cited in Thirtle, Lin, and Piesse 2003) shows that research-led technological change has propelled famine-plagued, food insecure Asian countries into food self-sufficiency.

Returns to agricultural R&D expenditures are positive and substantial for agricultural productivity and growth. Investment in agricultural research and extension are: (i) yields high economic return, (ii) improves the competitiveness of agriculture, (iii) provides food security, and (iv) reduces poverty (World Bank 2005; cited in Islam 2012). In the same instance, the USAID (2011) points out the need to enhance not only by size but also by allocation of funds to agricultural R&D, so as to make research more demand driven, and maximize its impact at field level. While increased and sustained investment in agricultural research is important for efficient and sustainable increases in food production to ensure food security, it is particularly important for Bangladesh, since challenges of food production are acute due to natural calamities, and the trend of decreasing land arability (Islam 2012).

The TFP performance in developing-country agriculture is specifically correlated with national investments in agricultural research and technological improvement, and the country’s ability to develop and extend improved agricultural technology to farmers level (Evenson and Fuglie 2010; Coelli, Rahman, and Thirtle 2003). Similarly, Salim and Hossain (2006) and Rahman and Salim (2013) identified investment in research and extension as one of the major contributing factors to bridge the yield gap, trigger technological change, and stimulate dynamism in the agricultural sector. Measuring TFP growth during period 1961–92, Coelli, Rahman, and Thirtle (2003) found little
scope for improving productivity by improving efficiency alone and suggested for new technological innovation. Moreover, Alauddin and Tisdell (1991) expressed concern regarding declining productivity growth, and its negative consequence on sustainable economic development in Bangladesh. Besides, Jahan (1997) suggested for increased investment in research, extension, and other infrastructural developments to increase TFP growth.

Agricultural research and extension are to a significant extent “public goods” in which the government needs to perform the leading role, and Bangladesh, is not an exception. A measure of prioritising concern for agricultural R&D can be understood by the trend of budgetary allocation for the sector. The budget allocation for agricultural research in Bangladesh is considered suboptimal and is very low compared to the average for developing countries (FPMU 2016). Promotion of agricultural research is being constrained by low budgetary allocations for research facilities as evidenced from Table 3.13.

Table 3-13 Budget allocation towards agricultural R&D, Bangladesh, 2010-2016

<table>
<thead>
<tr>
<th>Year</th>
<th>R&amp;D expenditures in Agriculture (In million Bangladeshi Taka)</th>
<th>% of budget towards Agriculture research</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010/11</td>
<td>33</td>
<td>0.25</td>
</tr>
<tr>
<td>2011/12</td>
<td>37</td>
<td>0.22</td>
</tr>
<tr>
<td>2012/13</td>
<td>45</td>
<td>0.23</td>
</tr>
<tr>
<td>2013/14</td>
<td>59</td>
<td>0.23</td>
</tr>
<tr>
<td>2014/15</td>
<td>51</td>
<td>0.25</td>
</tr>
<tr>
<td>2015/16</td>
<td>73</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Source: FPMU (2012-17).

Table 3.13 shows that expenditure for agricultural research is increasing in size (monetary term) since 2010/11 to 2015/16, however, despite slightly upward trend in
budgetary share, it remains negligible (ranging from 0.22 to 0.28 per cent) in almost all years. This trend justifies the truth of the World Bank (2005) study, which clearly indicates that agricultural research has received low priority from policymakers in terms of budgetary resource allocation at the national level. Moreover, because of its poor performance of agricultural governance, the role of government in agricultural research is minor and declining, while the capacity for existing funding to be useful is negated (Islam 2012). Therefore, agricultural research innovations need to be up scaled in order to allow the ‘technological breakthrough’, which is needed to secure required intensification, diversification, sustainability, and resilience of national agriculture.

The agricultural research system in Bangladesh, dominated by the public sector (under the National Agricultural Research System (NARS)\(^6\), continues to face shortages and volatility in its funding, weak management, and ineffective institutional arrangements for undertaking high-quality and relevant research (Pullabhotla and Ganesh-Kumar 2012).

The government of Bangladesh has been trying to avoid the existing weaknesses, fragmentation and duplication by building greater coordination and integration among different research organizations. This intension is reflected in approval of BARC Act in 2011, which aims at improving the efficiency of the research system (by minimizing duplication of efforts), improving efficiency of fund allocation, and quality of research. Similarly, the BARI Act is approved in 2017 to increase the capacity of the institute

\(^6\) NARS consists of its apex body the Bangladesh Agricultural Research Council (BARC) and 10 agricultural research institutes e.g. Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Bangladesh Jute Research Institute (BJRI), Bangladesh Institute of Nuclear Agriculture (BINA), Bangladesh Sugarcane Research Institute (BSRI), Bangladesh Livestock Research Institute (BLRI), Bangladesh Fishery Research Institute (BFRI), Soil Resource development Institute (SRDI), Bangladesh Forest Research Institute (BFoRI), and Bangladesh Tea Research Institute (BTRI). The agricultural universities, NGOs and private sectors though not integrated but linked with NARS in terms of research collaboration.
alongside streamlining its research activities. Moreover, the government of Bangladesh is focusing on coordinated research by public and private partnership, which is reflected in the 7th Five Year Plan. It can be for example, carried out between NARS institutes and local seed companies or NGOs like BRAC as well as between NARS institutes and international agriculture research centres e.g. Consultative Group on International Agricultural Research-CGIAR (FPMU 2016).

The government of Bangladesh is much concerned in prioritizing agricultural research for vulnerable areas in Bangladesh. Climate change impacts cropping differently in different agro-ecological zones (for example, some areas like hills, coastal zones, haor⁷ and barind⁸ are more prone to suffer from weather and climate change related risks). Responding to the fact, three initiatives are taken at agricultural research policy: first, a new crop zone map has been developed by the Bangladesh Agricultural Research Council with a provision of regularly update. Therefore, priority is being given to carry out more research on addressing the constraints of growing crops in vulnerable areas. For instance, in case of rice, Research institutes (BRRI and BINA) have so far released 10 saline tolerant rice varieties for coastal areas and 4 submergence tolerant varieties for haor areas. Second, the government is emphasising development of crop varieties that are less dependent on irrigation and fertilizers of shorter duration, to allow further intensification, diversification and employment generation during current lean season. Third, stress is being placed upon biotechnological and more sophisticated research for developing low water demanding, climate and disease resistant varieties.

⁷ In Bangladesh, it lies in the floodplain of three great rivers that can be termed as freshwater wetlands. The haor basin is an internationally important wetland ecosystem. It is a mosaic of wetland habitats, including rivers, streams and irrigation canals, large areas of seasonally flooded cultivated plains.

⁸ Barind Tract is the largest Pleistocene era physiographic unit in the Bengal Basin. It is made up of several separate sections in the northwestern part of Bangladesh,
For improving acceptance of agricultural research at farmers’ field, experts are suggesting for research approaches to be oriented toward farming systems or integrated production systems, instead of being commodity-based. Moreover, in response to the changing environment at farm level, it is also recommended for identification, and selection of research programmes by the private sector and NGO. In the same way, priorities are to be evaluated annually to be adapted to the changing needs. Its planning, program monitoring and coordination needs to be strengthened. The supply-driven research needs to be replaced with demand-driven research. The government of Bangladesh emphasizes practicing of research planning and prioritization as bottom-up approach. The government encourages also the promotion of participatory approach for conducting research activities. Moreover, globalization of the economies, price hikes of agricultural commodities, and increase in climate-related vulnerabilities are shifting the research agenda.

3.6 Per capita availability of food grain

This section deals with an examination of the food availability situation in Bangladesh, in terms of crop production. In terms of per capita food availability, despite population growth of 124 per cent over the Period 1(average of 1994-95 to 1998-99) and Period 2 (average of 2007-08 to 2014-15), the per capita availability of food grains increased by 29.41 per cent (from about 459 grams/day to around 594 grams/day). On the basis of recent evidence from Bangladesh the question of overall food supply and self-sufficiency is critically examined using trends in per capita availability of cereal food
items. Compared to Period 1, during Period 2 production of foodgrain is almost doubled. Simultaneously, food availability increased.

**Table 3-14 Foodgrain (rice and wheat) production and availability in Bangladesh, period 1 and 2**

<table>
<thead>
<tr>
<th>Year</th>
<th>Net domestic production (million m.tons)</th>
<th>Private import (million m.tons)</th>
<th>Public distribution (million m.tons)</th>
<th>Internal procurement (million m.tons)</th>
<th>National Availability (million m.tons)</th>
<th>Import as % of total availability</th>
<th>Per capita availability (gm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6 (=2+3+4+5)</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Period 1</td>
<td>17.59</td>
<td>1.29</td>
<td>1.73</td>
<td>0.54</td>
<td>21.16</td>
<td>6.09</td>
<td>459</td>
</tr>
<tr>
<td>Period 2</td>
<td>29.85</td>
<td>2.61</td>
<td>2.00</td>
<td>1.20</td>
<td>35.65</td>
<td>7.33</td>
<td>594</td>
</tr>
</tbody>
</table>

Note: Net production is estimated after 12% deduction for seed, feed, waste etc.

In aggregate terms, domestic food production in Period 2 has increased by 69 per cent compared to the Period 1 level of production. At the same time however, Bangladesh on average imported more than 6 per cent of the total quantity of available food grains during Period 1 compared to an import content of more than 7 per cent during Period 2. Because of climate variability, the country has experienced considerable variability in agricultural production. Fluctuation in domestic production requires varying quantities of imports, to meet the food demands of the growing population. In addition to increased food production, the intensity of food imports (food imports as a percentage of total amounts of food-grains available for consumption) has increased between the two periods. Higher import intensity, in this situation, is the result of the effort to maintain per capita food availability at satisfactory levels. For national food policy, although neither attainment of self-sufficiency nor food security are an essential pre-condition for each other, food self-sufficiency is a prerequisite for a country which has a
subsistent food production system and significant size food production sector in the national economy (Talukder 2005).

Table 3.14 shows that per capita per day availability of foodgrain increased from about 459 grams to 594 grams over the two time periods. The net domestic production started exceeding total requirements of foodgrain from 1999-00, and in 2005-06 there was a surplus production of more than 1.0 million tons (Talukder 2005). Because of floods, droughts and cyclones agricultural production varies from year. At the village and household level, availability is aggravated by annual variation in purchasing power, with the consequence that household food security in unstable.

3.7 Conclusion

This chapter attempted to set a background for the economic analysis found in the following chapters. In order to introduce the socio-political situation, the historical background of the country was surveyed, followed by an overview of the demographics of the rural households that are engaged most heavily in agricultural production. The Bangladesh economy has faced structural changes in the process of its development; and while the share of the agriculture sector in the economy has experienced a decreasing trend, this sector still employs the largest share of the country’s labour force. This has not helped the growth of labour productivity.

The sectoral share of agricultural value added in GDP has experienced a steep declining trend over the years since the 1970s. While there has been an accompanying declining trend in agricultural employment, along with rising wages, about 47 per cent of the total labour force continues to be employed in the agricultural sector, and about 69 per cent
of the total population (108 million) living in rural areas have their livelihoods either fully or partially dependent on agriculture. Growth in agricultural production fluctuated between 1 and 8 per cent in Period 2 (2007-08 to 2014-15) over recent years. Crop being the largest sub-sector of agriculture, is contributing about 75 per cent of the value-added. Rice dominates the crop sub-sector, and its performance heavily influences crop sectoral growth.

Government aims and policies for agricultural development in Bangladesh have varied over the last five decades. Different governments have applied different ideologies in framing policies; however, most have shared the common goal of agricultural development. This has been achieved by maintaining self-sufficiency in foodgrain production through modernization of the agricultural sector. All governments have tried to provide agricultural production incentives to create a favourable environment for investment and growth. Structural adjustment policy, the adoption of the Green Revolution (GR) policy and land reform policies are the most important macroeconomic policies that have helped to transform the sector into a modern one.

A number of important changes have taken place in Bangladesh since the introduction of Green Revolution technology (Alauddin and Tisdell 1991). The net cultivated area fell from 8.80 million hectares in the 1970s to around 7.9 million hectares in the 1990s. Modern technology has managed to accommodate multiple cropping for areas of land (double cropping, or triple cropping annually), and available cultivatable land has expanded to above 15 million hectares. For instance, the triple cropped area (annually) has expanded from 0.7 million hectares to 1.7 million hectares in the 40 years following independence. This has helped offset any crop failure during a given cropping year and illustrates how technology has added significantly to crop production.
The overall yield per hectare of land has risen significantly over time, from 0.9 mmt/hectare during the 1970s to 2.95 mmt/hectare (average of all rice) during the period 2007-08 to 2014-15. Yield increase, along with an almost fourfold increase in agricultural food production, has outstripped the population increase (of 200-300 per cent during the same period), and this has resulted in a 594 gm/day per capita availability of foodgrain.

To here, further research is needed to develop crop varieties which are flood tolerant, resilient to a warmer climate, resistant to drought, and of shorter maturity time so that they may be harvested before the deepening of drought or the full onslaught of floods. As discussed earlier, the needs of the two main rice seasons are quite different. There are many reasons behind the fluctuation of performance in crop production, including climate hazards, the switching tendency of farmers from rice to other high-value crops, and input availability.

Research is also needed to develop new cropping systems which are climate resilient, in the sense that if crops fail fully or partially, planting may be done with other varieties or crops which are more suitable for that period and for that area. Risk management through various means against crop and output failure in non-crop sub-sectors becomes a major issue in adaptation. Insurance raises the problems of moral hazard and adverse selection, but this need to be critically assessed for proper application in the case of climate induced risks. Crop diversification is one way to minimize risks and needs to be encouraged; although the experiences of this country in this regard have not been very positive to date.
Despite the achievements, there are huge challenges ahead to sustain the level of agricultural output needed to feed the nation. Cereal production has become more resilient to natural disasters over time, because of the dramatic changes in the seasonal composition of production. The government of Bangladesh, while trying to cope with the forecasted increasing food demand, has to deal with limited and even decreasing natural resources, climate change and associated frequent natural calamities, and the socioeconomic and political constraints of Bangladesh society.

The concerned Ministry and Departments can address this issue in forthcoming policy documentation to be developed with the vision of sustainable integration of house-cropland-industrial expansion for social, economic and food security (Pray and Ahmed 1991). It needs accelerated investment and innovation in agriculture, especially in research and development (R&D) to enhance smallholder’s productivity and income in a sustainable way in the context of shrinking land resources available for farming. Also, the system needs to include technological innovation and knowledge transfer using Information and Communication Technology (ICT) and e-Agriculture.

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Chapter 4  Land Use Patterns in Bangladesh

4.1  Introduction

This thesis focuses on finding an effective way forward for sustainable use of resources in the severely resource constrained country, Bangladesh. In addition, for analysing total factor productivity (TFP) growth in Bangladesh agriculture, this thesis considered the land rent as one of the capital cost. As part of this aim, this chapter endeavours to highlight the land utilisation patterns in Bangladesh, at both national and household levels.

The central question examined in this chapter is: What is the status of land resource utilisation in Bangladesh? In light of the central framework of this thesis, this question then fosters several different questions at a national level specifically: how is land utilized for crop cultivation and other purposes? What are the agrarian structures in terms of land resources? Is the existing land utilization pattern sustainable for attaining productivity crop growth? Are government efforts for land reform effective? How effectively do irrigation policies help to achieve sustainable use of land in crop production? In particular, interest is paid to the relevant government policies. In doing so, this chapter makes use of a combination of available research studies on the relevant field and available national data. As well, similar questions will be addressed to investigate the household level land utilization patterns in different regions of Bangladesh.
This chapter is divided in three parts. The first part seeks to investigate the overall agricultural land utilisation pattern. This part of the chapter covers aggregate level agricultural land use in Bangladesh, including: (i) land use patterns covering a 30-year period (1984-85 to 2014-15), (ii) land distribution by farm size, (iii) land/agrarian reform policies, and (iv) irrigated land (as irrigation is one of the most important inputs for intensifying farming practice, and a crucial indicator of technology adoption. In the second part of the chapter, the micro-level land ownership and utilization patterns are described on the basis of International Rice Research Institute (IRRI) Bangladesh’s Village Dynamics in South Asia (VDSA) secondary data and primary survey data of Mymensingh district. The impetus behind this is that, this thesis critically investigates the household level TFP growth of the food producing crop sector. The third and final part concludes the chapter.

4.2 Land utilization in Bangladesh

The relationship between the use of land for agricultural production, forestry, pasture and fallow is important in the context of the available natural resource base of a country (Bakker 2011). Closely related to this are patterns of farm activities and livelihoods, leading to many different farming systems (Hall et al., 2001, pp. 8-13). To better understand the land utilization pattern in Bangladesh, Table 4.1 shows relevant data for the years 1984-85, 1996-97 and 2014-15. These year periods reflects the mature stage of Green Revolution (GR) technologies, as stagnation in the adoption of this technology package set in from the late 1980s (Rahman 2007). The main changes, evidenced from Table 4.1, are:
- The percentage of land not available for cultivation has increased from 20 per cent (3 million hectares) in 1984-85 to nearly 27 per cent (4 million hectares) in 1996-97. Whereas, it is decreased by 25 per cent (more than 3 million hectares) in 2014-15 from 1996-97.

- Forest area has increased marginally between the first two time periods but significantly increased in between later periods- this might have been due to the government’s initiative regarding the social forestation programme, which increased tree plantations to offset the decrease in forest area.


- Net cropped area has declined from 8.64 million hectares in 1984-85 (nearly 60 per cent of the total) to 7.85 million hectares in 1996-97 (53 per cent of the total). However, it has increased again, to 7.93 million hectares in 2014-15 (almost 54 per cent of the total).

- Net cultivable area has decreased from 9.42 million hectares (65 per cent of the total) in 1984-85 to 8.74 million hectares (59 per cent) in 1996-97, and further reduced by 1 per cent (8.56 million hectare) in 2014-15. Diversions into other uses, such as housing, road, industrial infrastructures and other uses, might have caused a further fall in cultivable land availability. For instance, some 220 hectares of arable land is being lost daily to road construction, industry and houses (Islam et al. 2004, cited in Hasan et al. 2013).

- The increase in total land area between periods is a good sign, which might be a result of reclamation of char lands and landslides.
Table 4-1 Land utilization in Bangladesh: 1984-85, 1996-97 and 2014-15

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Area (million hectares)</th>
<th>Percentage of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land not available for cultivation</td>
<td>2.91</td>
<td>4.02</td>
</tr>
<tr>
<td>Forest</td>
<td>2.14</td>
<td>2.15</td>
</tr>
<tr>
<td>Cultivable waste</td>
<td>0.29</td>
<td>0.50</td>
</tr>
<tr>
<td>Current fellow</td>
<td>0.49</td>
<td>0.39</td>
</tr>
<tr>
<td>Net cropped area</td>
<td>8.64</td>
<td>7.85</td>
</tr>
<tr>
<td>Net cultivable area</td>
<td>9.42</td>
<td>8.74</td>
</tr>
<tr>
<td>Total land area</td>
<td>14.48</td>
<td>14.91</td>
</tr>
</tbody>
</table>


The above discussion with available national data clarifies how land is utilized for different purposes in Bangladesh. It is an issue of concern that the loss of cultivated land creates major constraints on agricultural production and significantly affects food supply and availability. The next sub-section depicts the land distribution pattern by farm-size, to identify out the agrarian structure. Special emphasis is placed on the problem of land fragmentation.

4.2.1 Land distribution by farm size

Land is the major source of wealth and livelihood in rural Bangladesh. The country’s agricultural setting is dominated by smallholders who play a major role in food security, both in fulfilling their own food security needs and in supplying some portion of their food production to the market. Continuous high population growth has made Bangladesh an extremely land-scare country, and land (expansion) can no longer be counted on as an important source of growth of agricultural production (Hossain 1988). In this context, earlier discussion in Chapter 3 showed that from inception, the
government of Bangladesh has been emphasizing increasing yield per hectare, rather than increasing cropped area by shifting from local varieties to the high yielding varieties (HYV) to attain food self-sufficiency. However, several challenges to the continuation of the trend have emerged. The (increasingly) unfavourable land to rural household ratio is throwing many additional households into the agricultural labour market through landlessness and reduction of farm size (GOB 1989). In addition to rapid population growth, landlessness is increased due to consequent loss of farmland to urban and settlement expansion, effectiveness of the law of inheritance, riverbank erosion, active land market and sale of farmland to meet social expenses and to purchase farm inputs and food (Khan 2004; cited in Ali 2007). Landless people depend mainly on selling their labour or rely completely upon rented land for their livelihood. Again, with the increment of population, Bangladesh is experiencing increased numbers of operational holdings. Therefore, access of the rural poor to land resources is becoming increasingly limited (Alauddin and Tisdell 1991).

Given this situation, the outcomes at national level, as identified in Table 4.2 are:

- During the 1983-84, 1996 and 2008, agricultural survey years, the average per capita net cultivated area was 0.10 ha, 0.06 ha and 0.07 respectively.
- Recently (2017) the World Bank estimated that the land to person ratio is 0.05 hectares, which is one of the lowest in the world.
- The percentage of landlessness increased significantly, by 17 per cent, during 1984 to 1996 period, whereas it is decreased by 6 per cent during 1996 to 2008.
- The number of farm holdings increased by 17.5 per cent between 1983-84 and 1996, and further increased by over 26 per cent between 1996 and 2008. This resulted in a reduction in average farm size, to 0.30 hectare. Such a small farm size is unlikely to sustain livelihoods (Rahman 2010 a, b).
- In 1983-84, about 25 per cent of landowners owned between 1.01 to 3.03 hectares (medium farm category) of land, which reduced to 17.6 per cent in 1996 (−16.3 per cent change), and further reduced to 14.19 per cent (−13.7 per cent change) in 2008.

- The above clearly reveals that the number of landless, small and marginal farmers has increased dramatically, at the expense of a reduction in the number of medium and large farmers.

In addition, Table 4.2 identified the situation at regional level, especially in the study districts of this thesis. Those findings are:

- Highest number of farm-holding (653000) is found in Mymensingh district and the lowest (141,000) is in Madaripur district.

- In terms of Total cultivated land Mymensingh district was found to be the highest also. That is 0.31 Million hectare. Total cultivated land is the lowest in Madaripur district.
Table 4-2 Land ownership situation in Bangladesh, 1983/84, 1996 and 2008

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of farm holdings (in 000')</td>
<td>10,045.00</td>
<td>11,798.00</td>
<td>14,871.00</td>
<td>174.00</td>
<td>453.00</td>
<td>141.00</td>
<td>271.00</td>
<td>267.00</td>
<td>653.00</td>
<td>213.00</td>
</tr>
<tr>
<td>Total cultivated land (MH)</td>
<td>8.16</td>
<td>7.19</td>
<td>7.61</td>
<td>0.09</td>
<td>0.23</td>
<td>0.06</td>
<td>0.07</td>
<td>0.14</td>
<td>0.31</td>
<td>0.07</td>
</tr>
<tr>
<td>Per capita owned land (ha)</td>
<td>0.16</td>
<td>0.11</td>
<td>0.11</td>
<td>0.09</td>
<td>0.08</td>
<td>0.11</td>
<td>0.12</td>
<td>0.09</td>
<td>0.10</td>
<td>0.11</td>
</tr>
<tr>
<td>Per capita net cultivated area (ha)</td>
<td>0.10</td>
<td>0.06</td>
<td>0.07</td>
<td>0.07</td>
<td>0.09</td>
<td>0.12</td>
<td>0.09</td>
<td>0.10</td>
<td>0.07</td>
<td>0.14</td>
</tr>
<tr>
<td>Average farm size (ha)</td>
<td>0.93</td>
<td>0.68</td>
<td>0.30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Households renting in land</td>
<td>-</td>
<td>32.30</td>
<td>36.80</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Agricultural labour households (% of farm holdings)</td>
<td>39.77</td>
<td>35.60</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>Percentage of:</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small farms (0.02–1.01 ha)</td>
<td>70.34</td>
<td>79.87</td>
<td>84.27</td>
<td>66.79</td>
<td>49.13</td>
<td>50.20</td>
<td>56.27</td>
<td>55.22</td>
<td>50.67</td>
<td>48.08</td>
</tr>
<tr>
<td>Medium farms (1.01–3.03 ha)</td>
<td>24.72</td>
<td>17.61</td>
<td>14.19</td>
<td>11.73</td>
<td>7.46</td>
<td>7.06</td>
<td>2.29</td>
<td>10.54</td>
<td>7.92</td>
<td>3.01</td>
</tr>
<tr>
<td>Large farms (above 3.03 ha)</td>
<td>4.94</td>
<td>2.52</td>
<td>1.54</td>
<td>0.82</td>
<td>0.67</td>
<td>0.42</td>
<td>0.08</td>
<td>0.73</td>
<td>0.56</td>
<td>0.13</td>
</tr>
<tr>
<td>Absolutely landless</td>
<td>8.67</td>
<td>10.18</td>
<td>9.58</td>
<td>20.66</td>
<td>42.74</td>
<td>42.32</td>
<td>41.37</td>
<td>33.50</td>
<td>40.85</td>
<td>48.78</td>
</tr>
<tr>
<td>Changes between inter-census periods (in per cent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of farm-holdings</td>
<td>17.45</td>
<td>26.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cultivated land</td>
<td>-11.89</td>
<td></td>
<td>5.84</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small farms (0.02–1.01 ha)</td>
<td>33.35</td>
<td></td>
<td>5.50</td>
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<tr>
<td>Medium farms (1.01–3.03 ha)</td>
<td>-16.33</td>
<td></td>
<td>-13.74</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large farms (above 3.03 ha)</td>
<td>-40.00</td>
<td></td>
<td>-38.88</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average farm size</td>
<td>-26.88</td>
<td></td>
<td>-25.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolutely landless</td>
<td>17.41</td>
<td></td>
<td>-5.56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adoptions of technology and farm efficiency are affected by different tenurial arrangements. There have been mixed findings regarding relationships between farm size, tenancy and adoption of technology. Alauddin and Tisdell (1991) mentioned that tenural arrangements accentuate income inequality, because of differential gains between the owner and the share-cropper. Jahan (1997) mentioned that landlessness prohibits people from using efficient technology, which ultimately reduces the potentiality of achieving TFP growth. Using data from 1970 to 1984, Alauddin and Tisdell (1991) found land ownership concentration to be a serious obstacle to the expansion of HYV areas, which in turn impedes the pace of growth. Similar argument was presented in Alauddin and Hossain (2001), Kamruzzaman et al. (2006), Rahman and Rahman (2009), Rahman and Salim (2013) and Alam et al. (2014), with these studies finding that the average farm size positively influences farm efficiency, which positively influences TFP growth in Bangladesh. In contrast, Hossain et al. (2005) found a negative relationship between the farm sizes. In the same instance, Hossain et al. (2006) mentioned that agrarian structure did not obstruct the adoption of modern rice varieties in Bangladesh or associated efficiency.

In addition, with the increase in the number of operational holdings, fragmentation of land is increasing, which is not only accelerating the pace of degradation and constraining agricultural development, but also discourages farmers from adopting agricultural innovations (Niroula and Thapa 2005). Specifically, the fragmentation of land has had a significant impact on rice production efficiency (Wadud and White 2000). Similar studies of the constraints imposed by land fragmentation on productivity and efficiency in agriculture have reported mixed results in other countries. Blaikie and Sadeque 2000, cited in Niroula and Thapa (2005) mentioned that land fragmentation is
becoming a critical dampener on increasing productivity and sustainability of land resources in Nepal, India and other places. In another study Niroula and Thapa (2007) found that land fragmentation—leading to small plots—has had a negative impact on production efficiency, thereby constraining agricultural development in Nepal. A study by Wan and Cheng (2001) also found that elimination of land fragmentation may potentially lead to a 15.3 per cent increase in China’s foodgrain output. They added that the private benefit of fragmentation is that, by operating plots in different locations, farmers are able to reduce the variance of total output, because the scattering of plots reduces the risk of total loss from flood, drought, fire and other perils and allow the farmers to diversify their cropping mixtures across different growing conditions (Buck 1964; Johnson and Barlowe 1954; Blare et al. 1995; cited in Nguyen et al. 1996). To achieve increased technical efficiency and TFP gain Rahman and Rahman (2009) and Alam et al. (2014) recommended addressing the structural causes of land fragmentation, through modification of the law of inheritance and regulations to prevent land fragmentation. Moreover, the Murdoch Commission (2015) recommended that policy settings in Asia need to transition away from smallholder farms towards greater emphasis on the development of cooperatives and contract farming. Thus, to ensure these smallholder farms remain sustainable in the long term, it is important to ensure more effective mechanization or technological advancement and even land consolidation efforts to improve productivity. The next section investigates whether the government efforts for land reform have been effective in Bangladesh.
4.2.2 Agrarian reform

Government policy has an important role to play improving the factor equalisation role of land rental markets because farming is still dominant as an important source of livelihood in Bangladesh. The concept of land reform in Bangladesh has two different aspects: land tenure reform and land operation reform or land use reform. In agrarian economies like Bangladesh, land reforms, especially land redistribution, can play a pivotal role in reducing poverty and land inequity. Land redistribution policy has to some extent been successful in reducing poverty and land inequity in India (Jha et al., 2005; Mearns 1999; cited in Manjunatha et al. 2013). Before the independence of Bangladesh in 1971, a series of land reforms were undertaken in the 1950s and 1960s, which included tenancy reforms, imposition of ceiling on land holdings, and distribution of public land to the landless (Uddin and Haque 2009; cited in Ahmed 2012; USAID 2011b). Practically, the land tenure question in Bangladesh gained prominence during the postliberation period, when socialist fervour ran high (Taslim 1993).

The first government (Mujib Government) in 1971 announced landholdings ceiling of 13.4 hectares per family. In addition, a policy measure was undertaken to redistribute khas (government owned) land and accreted charland (new land rising from river beds/siltation) by the rivers among those landless and marginal farmers who owned not more than 0.61 hectares of land. The government also declared land revenue tax exemption for farms owning less than 3.3 hectares (Alauddin and Hossain 2001). However, those measures failed to bring tangible improvement in the rural economy, and this pushed the government into taking drastic measures in 1972. The government reduced the land ceiling to 9.3 hectares per family and tried to bring the whole agriculture sector under a cooperative system (Taslim 1993). In political economics
terms, although the motivation for radical land reform was professedly socialist, the underlying economic analysis supporting such a course was often neoclassical in spirit. However, owing to a change in government in 1975, the policy was not implemented.

Before circulating the Land Reform Ordinance in 1984, the most common form of renting in Bangladesh was cropsharing, whereby one of the parties (the landlord) supplies the land and perhaps shared the cost of some inputs like seed and fertilizer, while the other party (the share tenant) supplies all other inputs and undertakes the responsibility of farming. The output is divided between the two in a predetermined proportion (usually 50-50). However, the cropsharing system has been widely regarded as inefficient, along with the land tenure system conducive to such a production arrangement. The deepening crisis in the economy in 1980s and the sharpening of contradictions in the production relations, combined to exert pressure on government to initiate land reform measures. On the basis of the recommendations of the Land Reform Committee (formed in 1983), the government circulated a new Land Reform Ordinance in 1984 for the first time after independence. The aim of the ordinance was to reform the land tenure related law, land holdings and land transfer with two major goals: (i) to ensure increases in agricultural production, and (ii) to establish the basis for better relationships between land owners, and sharecroppers/tenants (Islam 2012). One achievement of the reform policy was the development of crop sharing guidelines which stated that the produced crop should be divided in thirds between the owner and the tenant: one-third-owner: one-third-tenant: one-third-cost sharing basis among the two parties. However, given the existing distribution of power in rural Bangladesh, it proved almost impossible to enforce the provisions of this ordinance (Osmani 2010; cited in Islam 2012). In addition, regarding the land holding policy under the ordinance, the
motive was to reduce the ceiling of (up to) 8 hectares and safeguard the rights of the sharecroppers. However, the provisions of the law have not yet been implemented (Alauddin and Hossain 2001), so marginal farmers have not yet benefited from these policies (Ahmed 2012).

Since 2000, there has been much talk among researchers about improving the equity regarding the distribution of government owned land in Bangladesh, increasing land productivity, implementation of the settlement act, acquisition of excess land (subject to a ceiling), recovering absentee ownership land, modernization of administration, and improving land management (Ahmed 2012). In response, the government formulated the ‘National Land Use Policy -2001’ to reform the system of land administration and related laws; preserve and optimize the use of agricultural land; make suitable government-owned land available for development projects; reduce soil degradation; and establish a data bank for various categories of land. The policy also highlighted the need for carrying out a National Land Zoning Program (NLZP) for integrated planning and management of the country’s land resources. However, to date there is also no visible impact of the policy initiative on the living standards of the rural population.

Redistributive land reform is necessary to accelerate growth in developing countries (Griffin, Khan, and Ickowitz 2002), and Bangladesh is not an exception. Among researchers, the debate about land reform in Bangladesh is still hovering around the question of redistribution of farmland a Marshallian inefficiency paradigm. In fact, the

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In his Principles of Economics, Alfred Marshall hypothesized that the practice of share-tenancy leads to a Pareto-inefficient allocation of labour (Marshall 1890, p. 684). A competitive, fixed-wage firm will hire labour until the value of its marginal product equals the going wage. Whereas, a share-tenant retains only some fraction of his produce in exchange for the use of land, thus receiving at the margin a given share of own marginal output. In deciding the allocation of his labours between fixed wages and share-tenancy, the share tenant will increase his commitment to the latter so long as his share in marginal product
relative efficiency of different tenurial arrangements in Bangladesh is far from clear. In terms of yield (output/ha) achievement, Hossain and Hussain (1977), Shahid and Herdt (1982) and more recently Ahmed (2012) found no difference between share tenants and owner cultivators. However, Mandal (1980) and Talukder (1980) found that tenant farmers obtain a higher yield from their own land than from their rented land. Taslim (1989) found the same result in only one out of three of his research sample districts. In contrast, Jabbar (1977) and Bhuiyan (1987) found the performance of the share tenants to be significantly inferior to that of owner farmers. Alam et al. (2014), Rahman and Rahman (2009), Salim and Hossain (2006) and Coelli et al. (2002) reported that tenancy has a negative impact on technical efficiency.

There seems to be not much hope of substantial gains in terms of total agricultural output, from a land reform that either abolishes tenancy or transfers ownership of rented land to the tenant cultivators (Taslim 1993). Similarly, the empirical results of Rahman (2010a) showed that redistribution of land from large farms to marginal and landless farmers would leave each landless household with only 0.21 ha of land, which is unviable as a livelihood resource. Considering this fact, Alam et al. (2014) suggested undertaking land reform measures aimed at increasing farm size by land consolidation. It is crucial, therefore, to focus on policies that promote land use efficiency. Discussion of these points is continued below by highlighting the effectiveness of irrigation policies for sustainable use of land in crop production.

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exceeds the available wage. Since the marginal products of labour under the two regimes then diverge, labour is clearly inefficiently allocated between coexisting employments.
Irrigated land

While land is extremely scarce, Bangladesh is known to have abundant water resources. Three major rivers, the Ganges, the Brahmaputra, and the Meghna, and their numerous tributaries flow through the country and discharge huge volume of water. In addition to surface water from different rivers, and haors, groundwater is a good source of irrigation in Bangladesh. In recent years, water shortages at both surface and ground level are a growing threat to food production across the country, particularly in drier areas. Expansion of irrigation facilities has been increased the effective supply of land during the dry winter season when a large portion of land has been kept fallow because of inadequate moisture in the soil. However, Hossain (1988) found that different types of irrigation facilities led to a large variation in the diffusion of the new technology (seed-fertilizer-irrigation technology; which was new during that paper’s study period), among different regions of the country.

Irrigation eases land constraints, by increasing cropping intensity to enable farmers to grow an additional boro rice or wheat crop during the dry winter season; which, in conjunction with fertilizer and modern high-yielding rice varieties, significantly raises yields of rice in comparison to rain fed agriculture and takes much of the risk out of the two predominantly rain fed aus and aman rice seasons (Nelson, n d.; cited in Ahmed and Sampath 1992). Without rapid expansion of irrigation, the adoption and productivity of High Yielding Variety (HYV) technology would have stagnated. Adoption of new crop varieties is largely determined by the availability of irrigation facilities. Thus, the state of irrigation and water management facilities is a function of the state of development of rural infrastructure. The main focus of irrigation expansion programs in Bangladesh is on small-scale irrigation systems, including low lift pumps,
deep tubewells, and shallow tubewells. Farmers need government protection against flood in the wet season, irrigation in the dry season, supplementary irrigation in the wet season, protection against salt-water intrusion in coastal areas, proper drainage both in the wet and dry seasons, and protection against river erosion and water-related hazards.

The Bangladesh Water Development Board (BWDB), established in 1959, working under the Ministry of Water Resources, is responsible for developing and maintaining water resources projects, management and mitigation of river bank erosion, stakeholder participation in project planning, design and implementation, environmentally friendly development and promoting food production by surface water irrigation. To increase crop production and make agriculture more productive, a well-planned irrigation management system is essential; and considering this fact, the Government has promoted the increased use of surface water and the reduced use of groundwater for irrigation. To assist with water efficiency, strategies have included rainwater harvesting, greater use of surface water, and irrigation at night, use of solar power, and incentives for the cultivation of less water-intensive crops, especially in the barind area, along with discouraging the use of ground water.

Throughout the 1980s, a series of reforms in the input market — including liberalization of restrictions on tubewell siting, removal of import restrictions on pumps and small diesel engines, and privatization of fertilizer distribution and import — triggered a rapid increase in irrigated dry season cultivation. The total irrigated area has expanded rapidly since 1989, encouraged by the liberalization in the import of diesel engines, the reduction in import duties and withdrawal of restrictions on standardization of irrigation equipment, and the replacement of draft power with power tillers to facilitate farm operations. The resulting widespread availability of shallow tube wells and fertilizers
has enabled Bangladeshi farmers to expand the previously negligible dry-season rice crop (the *boro* crop) to one that now accounts for 7.5 million metric tons of rice; about 40 per cent of total rice production (FPMU 2016).

Irrigation coverage had increased substantially in the 2000s, from 26 per cent in 1996-97, to 49 per cent in 2014-15 (Figure 4.1); reflecting important public infrastructure development efforts by the government. Construction of irrigation pipelines, introducing Alternative Wetting and Drying (AWD) methods, repairing old deep tube wells, and infrastructure development are some of the initiatives undertaken by the government to increase irrigation area coverage. In addition, the government is focusing on expanding rain-fed *aus* rice production, encouraging the introduction of saline and submergence-resistant rice varieties.

Moreover, in recent years, in consideration of the issues of deepening groundwater tables and declining aquifer level, along with arsenic water contamination, the Government of Bangladesh has been very much concerned with improving water management and infrastructure for irrigation, and this is addressed in a number of policy documents. For example, the National Food Policy (NFP, 2006) and its Plan of Action (NFP-PoA, 2008-2015) stressed the importance of increased irrigation coverage, improved delivery and efficient use of safe irrigation water, reduced dependency on groundwater use, and reduced cost of irrigation. Similarly, the National Agricultural Policy (2013) emphasized conservation and proper use of surface water by strengthening re-excavation of *khas* (government owned) ponds and water bodies, to enhance conservation and utilization of surface water and encourage groundwater recharge through watershed management, rainwater harvesting and the establishment of water reservoirs.
Figure 4.1 Percentage of cropped area under irrigation and surface water as share of total irrigation, Bangladesh, 1996-2015


However, the policy of increasing surface water irrigation in place of groundwater irrigation is not easy to implement. Groundwater is critical for agriculture in Bangladesh, due to a shortage of and inconsistencies in surface water supplies. Despite the policy commitment to move in the opposite direction, dependency on groundwater for irrigation is increasing. Currently, about 79 per cent of the total cultivated area is irrigated by groundwater, using 35,322 deep tube wells and 1,523,322 shallow tube wells (BADC 2013). The share of surface water irrigation coverage to total cropped area has been falling (Figure 4.1). However, this long-run downward trend has slowed down in recent years, as a direct result of continued government effort.

Further efforts by the government have included the development of the Water Act in 2013, for integrated development, management, extraction, distribution, usage, protection and conservation of water resources. In 2012, the government approved a 20-
year master plan for the Hoar Development Board (HDB) towards integrated planning and implementation through multi-organizational involvement and community participation. To protect rivers and water bodies from illegal encroachment, pollution, and unscrupulous exploitation a National River Protection Commission Act-2013 was passed. In line with the Seventh Five Year Plan (FY2016 – FY2020) for managing water resources a number of strategies are now being undertaken; including river dredging, excavation/re-excavation of natural canals, implementation of the Ganges barrage project with ancillary infrastructure, and river channelization. The next section describes case studies that were carried out by the IRRI, Bangladesh’s VDSA data with the aim of identifying land utilization patterns to determine how the aforementioned government policies are impacting at household level.

### 4.3 Land ownership and use pattern in survey areas

The villages covered in this study are located in diverse areas of Bangladesh. This thesis covers ten different agricultural zones throughout the country. Table 4.3 shows the study areas along with different districts and sub-districts and Figure 4.2 shows those districts of Bangladesh within which the eight villages were chosen. The villages differ ecologically and are geographically dispersed (Appendix-C). The productivity levels and infrastructural facilities varied extensively between the different parts of the country, those are examined in this study.
Table 4-3 Agroecology, size and infrastructure of study areas of Bangladesh

<table>
<thead>
<tr>
<th>Village</th>
<th>Upazila (sub-district)</th>
<th>District</th>
<th>Development infrastructure</th>
<th>Size of the village (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darikamari</td>
<td>Alamdanga</td>
<td>Chuadanga</td>
<td>Favourable</td>
<td>37.71</td>
</tr>
<tr>
<td>Khudiakhali</td>
<td>Shajahanpur</td>
<td>Bogura</td>
<td>Favourable</td>
<td>93.45</td>
</tr>
<tr>
<td>Bhabanipur</td>
<td>Sadar</td>
<td>Madaripur</td>
<td>Favourable</td>
<td>62.30</td>
</tr>
<tr>
<td>Begumpur</td>
<td>Uttar Matlab</td>
<td>Chandpur</td>
<td>Favourable</td>
<td>73.55</td>
</tr>
<tr>
<td>Rasun Shimulbari</td>
<td>Kaliganj</td>
<td>Jhenaidah</td>
<td>Unfavourable</td>
<td>40.37</td>
</tr>
<tr>
<td>Konapara</td>
<td>Amtail</td>
<td>Mymensingh</td>
<td>Unfavourable</td>
<td>90.28</td>
</tr>
<tr>
<td>Nishaiganj</td>
<td>Bhaluka</td>
<td>Mymensingh</td>
<td>Favourable</td>
<td>73.26</td>
</tr>
<tr>
<td>Patordia</td>
<td>Monohardi</td>
<td>Narsingdi</td>
<td>Favourable</td>
<td>48.52</td>
</tr>
</tbody>
</table>


In different study areas, farmers have very small land holdings (ranging from 0.25 in the village of Rasun Shimul village to 0.58 hectares in the village of Konapara). The land rental market (leasing and mortgaging) is very active, and access to land through rental markets has been an important approach to optimize the operational farming unit in different study areas. Farmers rent in, and at the same time rent out, land for crop production. The lease agreements also vary between cropsharing and a fixed rental basis. Except for the villages of Konapara and Rasun Shimul, villages in all other areas have a fixed rental leasing system. Moreover, land is mortgaged in and out, in all the regions of the country. There is no crop sharing rental practice in the village of Darikamari, and this is an exception. This stance can be justified by Rahman (2010a)’s finding who mentioned that transactions on the land rental markets tend to contribute towards equalizing the size distribution of the farm, by: (a) allowing access to land through renting-in by the marginal/landless farmers; and/or (b) promoting a type of equalization. One remarkable finding from this survey data, however, is that through the
practice of land rental arrangements, the total operated area did not increase remarkably. Thus, perhaps the main purpose of land marketing is not to overcome the constraints of small land holdings, but rather to adjust to more convenient farming. It is also probable that farmers tend to rent-in land in fertile areas to reap the benefits of higher productivity of crops, from soils with relatively high fertility status, as mentioned by Rahman (2010a). In some villages, including Konapara, Khudiakhali, Nishaiganj, and Patordia, the area operated by farmers is smaller than the total owned land size. This might be related to the tendency of households to rent out more land than they rent in. Moreover, it was found that farmers’ total holdings are composed of several parcels of land scattered over a wide area, characterized by varying size, quality and other factors.

Cropping patterns in study areas are related with coverage of irrigation facilities. In the study areas, the percentage of land which contains irrigation facilities varies between 64 per cent and 100 per cent of the farmed land, depending on location (Nishaiganj village is an exception, as in this village, rather than cropping, fish farming is dominant). However, when considering the actual coverage of irrigation as a percentage of the total cropped area, a different picture is revealed. In presence of irrigation facilities either through surface water or ground water irrigation facilities (Shallow Tube Well, Deep Tube Well or Low Lift Pump), only the dry season (boro rice and winter crops) is dependent on underground irrigation. The aus and aman seasons require less irrigation; as aman is mostly rain fed, and farmers are not providing supplemental irrigation in aus crops. Because of the availability of irrigation facilities, cropping areas are much higher than total operated areas, and this result in increased cropping intensity. The cropping intensity varies between 156 and 230 per cent across regions, with the highest percentage in the village of Darikamari. In terms of crop diversity, Khudiakhali village
of Bogra district has the most diversified cropping pattern, where in addition to rice, crops including wheat, jute, maize, vegetable, potato, pulses, mustard, sugarcane, and spices are produced. The lowest crop diversity is in the village of Nishaiganj, which only produces two rice crops in a year.

**Figure 4.2 Map of Bangladesh showing the study areas (by districts)**

Source: Author’s own design for locating study areas.
Table 4-4 Land utilization in different villages of Bangladesh in this study, 2011, in average hectare/household

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Darikamari</th>
<th>Khudiakhali</th>
<th>Bhabanipur</th>
<th>Begumpur</th>
<th>Rashun</th>
<th>Konapara</th>
<th>Nishaiganj</th>
<th>Patordia</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owned land</td>
<td>0.26</td>
<td>0.56</td>
<td>0.34</td>
<td>0.33</td>
<td>0.25</td>
<td>0.58</td>
<td>0.48</td>
<td>0.33</td>
<td>0.39</td>
</tr>
<tr>
<td>Leased in on crop share</td>
<td>0.01</td>
<td>0.00</td>
<td>0.01</td>
<td>0.04</td>
<td>0.02</td>
<td>0.06</td>
<td>0.01</td>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>Leased in on fixed rent</td>
<td>0.15</td>
<td>0.06</td>
<td>0.16</td>
<td>0.04</td>
<td>0.00</td>
<td>0.11</td>
<td>0.00</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Leased out on crop share</td>
<td>0.00</td>
<td>0.04</td>
<td>0.02</td>
<td>0.06</td>
<td>0.03</td>
<td>0.13</td>
<td>0.04</td>
<td>0.11</td>
<td>0.05</td>
</tr>
<tr>
<td>Leased out on fixed rent</td>
<td>0.01</td>
<td>0.10</td>
<td>0.07</td>
<td>0.02</td>
<td>0.00</td>
<td>0.28</td>
<td>0.00</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Mortgaged in</td>
<td>0.01</td>
<td>0.02</td>
<td>0.04</td>
<td>0.07</td>
<td>0.08</td>
<td>0.03</td>
<td>0.01</td>
<td>0.02</td>
<td>0.04</td>
</tr>
<tr>
<td>Mortgaged out</td>
<td>0.03</td>
<td>0.02</td>
<td>0.10</td>
<td>0.08</td>
<td>0.01</td>
<td>0.06</td>
<td>0.03</td>
<td>0.09</td>
<td>0.05</td>
</tr>
<tr>
<td>Operated area</td>
<td>0.39</td>
<td>0.49</td>
<td>0.36</td>
<td>0.34</td>
<td>0.31</td>
<td>0.47</td>
<td>0.26</td>
<td>0.26</td>
<td>0.36</td>
</tr>
<tr>
<td>Irrigation facility</td>
<td>99.82</td>
<td>99.84</td>
<td>96.14</td>
<td>96.12</td>
<td>99.52</td>
<td>98.57</td>
<td>64.20</td>
<td>100.00</td>
<td>94.28</td>
</tr>
<tr>
<td>Irrigation area coverage</td>
<td>0.39 (43.48)</td>
<td>0.49 (83.75)</td>
<td>0.34 (58.24)</td>
<td>0.32 (61.38)</td>
<td>0.31 (44.16)</td>
<td>0.47 (53.84)</td>
<td>0.17 (143.97)</td>
<td>0.26 (55.67)</td>
<td>0.34 (68.06)</td>
</tr>
<tr>
<td>Cropping intensity</td>
<td>230</td>
<td>120</td>
<td>165</td>
<td>156</td>
<td>225</td>
<td>185</td>
<td>45</td>
<td>176</td>
<td>162.75</td>
</tr>
<tr>
<td>Number of crops grown in a year</td>
<td>6</td>
<td>13</td>
<td>9</td>
<td>12</td>
<td>9</td>
<td>8</td>
<td>2</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Source: Calculated from Bhandari et al. (2013).
On the basis of data from the same survey, the respondent farmers are divided into three categories\(^1\). The largest group, in terms of the proportion of total farmers, is marginal farmers’ group (comprising 98.4 per cent of total respondents), followed by small farmers (1.6 per cent) and medium farmers (0.18 per cent). Overall, average farm landholding is 0.67 hectare per household. Within the households sampled, there are no large farmers at all. These results are consistent with the national data; among 15,183,183 farm holdings in Bangladesh, the breakdown was 51.8, 32.6, 14.1 and 1.5 per cent respectively for marginal, small, medium and large farm households.

**Table 4-5 Distribution of farm households by land holdings**

<table>
<thead>
<tr>
<th>Farm categories</th>
<th>Per cent of farmers (survey respondents)</th>
<th>National data</th>
<th>Average land size (hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal</td>
<td>98.23</td>
<td>51.75</td>
<td>0.10</td>
</tr>
<tr>
<td>Small</td>
<td>1.60</td>
<td>32.63</td>
<td>0.55</td>
</tr>
<tr>
<td>Medium</td>
<td>0.18</td>
<td>14.07</td>
<td>1.36</td>
</tr>
<tr>
<td>Large</td>
<td>-</td>
<td>1.54</td>
<td>-</td>
</tr>
<tr>
<td>All</td>
<td>100.00</td>
<td>100.00</td>
<td>0.67</td>
</tr>
</tbody>
</table>


This overall scenario reflects the fact that land availability, utilization, and farm size vary widely among different regions of the country. Also, the availability of rural irrigation infrastructure and other irrigation supporting technologies differs from village to village. The consequences for productivity will be analyzed later in Chapter 6, to better understand the situation.

---

\(^1\) According to Department of Agricultural Extension (DAE) of Bangladesh definition farmers are classified in four groups: having less than 0.4 hectares of land= marginal, having 0.4 to 1.01 hectares of land=small, having 1.01 to 3.03 hectares of land= medium, more than 3.03 hectares of land=large
4.3.1 Landholdings in Mymensingh district

Discussion on landholding pattern of this section is based on the primary survey data from Shutiakhali and Kashiarchar villages of Mymensingh district for this study. Within the sample households, there are no large farmers (Table 4.6). The largest group in term of proportion of farmers belonging is the group of marginal farmers (69 per cent) which is followed by small and medium farm 24 and 7 per cent respectively. The average size of land holding within marginal, small and medium farm group is 0.23, 0.57 and 1.56 hectares respectively. Overall, average farm landholding is 0.42 hectares.

### Table 4-6 Distribution of farm households by land holdings

<table>
<thead>
<tr>
<th>Farm categories</th>
<th>Per cent of farmers</th>
<th>Average land size (in hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal</td>
<td>69</td>
<td>0.23</td>
</tr>
<tr>
<td>Small</td>
<td>24</td>
<td>0.57</td>
</tr>
<tr>
<td>Medium</td>
<td>7</td>
<td>1.56</td>
</tr>
<tr>
<td>Large</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>All</td>
<td>100.00</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Source: Field survey 2016.

Thus, it is also evidenced from the primary data source that the number of large farmers is the lowest, and marginal farmer is the highest. This scenario is very common in rural Bangladesh.
4.4 Conclusion

The physical environment of crop production in Bangladesh depends critically on land and water. However, the country provides classic example of an extremely unfavourable land-per-person ratio. Overall incidence of landlessness is rising every year due to rapid population growth, loss of farmland to urban and settlement expansion, the impact of the law of inheritance, riverbank erosion and many more non-farm activities. In addition, inequality in the distribution of land resources is growing. The number of landless, small and marginal farmers is increasing at the expense of reduction in the number of medium and large farmers. Consequently, the access of the rural poor to land resources is becoming increasingly limited. Such an agrarian structure impedes the adoption of modern rice varieties in Bangladesh.

Land fragmentation is an influential predictor of technical inefficiency and loss of productivity. Despite many initiatives of the government on land reform, little has been achieved. There is much debate amongst researchers about the relative efficiency of different tenurial arrangements. For political economic reasons, there seems little hope of stabilising viable land size for livelihood resource by land redistribution. As land is limited, instead of land redistribution there is now a focus on increasing the productivity of this natural resource. However, such processes of land intensification expose the fragility of the environment, raising the critical issue of sustainability.

Given the massive land constraints in Bangladesh, horizontal crop production may be insufficient to feed an increasing population, and vertical expansion may be necessary. Appropriate technologies should also be implemented or, if necessary,
developed to restore already degraded land to protect the land against future degradation. As food security is a major concern of Bangladesh, necessary steps also need to be taken to protect agricultural land from shifting to non-agricultural use.

Land use pattern varies across different regions of Bangladesh. Though the country is small, it has diversified topographies, and is divided into 30 agroecological zones. Depending upon the available land and population size in each region, the land utilization patterns also vary substantially. Cropping patterns vary, as do cropping intensities. Based on household level data, this chapter has revealed the land use patterns and conditions across ten regions Bangladesh, representing ten different agro-ecological zones.

With respect to the issue of the country’s deepening groundwater table and declining aquifer levels, along with arsenic water contamination, there is an urgent need to improve water infrastructure for irrigation and drainage. Construction of irrigation pipelines, introducing Alternative Wetting and Drying (AWD) methods, repairing old deep tube wells, and infrastructure development are some of the options available when striving for sustainable use of irrigation water.
Chapter 5  Labour Use Patterns in Bangladesh Agriculture

5.1  Introduction

To gain insights into the functioning of the agricultural labour market in rural areas; this chapter discusses several related key features of the employment structure, including: the size of the labour force; the quality of human capital; the share of employed people in agriculture; wages; the mobility of labour; and demographic measures of the labour force. Initially, focus is given to the broad economy with macro level data. This is followed by discussion of household level labour data. The information is useful for the TFP growth analysis in Chapter 6.

5.2  Some distinctive features of agricultural labour

The agricultural workforce has a number of distinctive features. The term agricultural labour forces refer to the knowledge, experience and skills possessed by people involved in the processes of agricultural production. Compared with other sectors of the economy, in Bangladesh agriculture has:

- a high proportion of self-employed, family and casual workers;
- seasonality in labour work;
- a low incidence of higher secondary school qualifications;
- low employee wages.
Many of the above features arise from the dominance of family farming (87.76 per cent of farms are family owned and operated), providing flexibility in the use of labour in terms of hours worked and engagement in off-farm earnings (BBS 2008). Unexpectedly, although the adoption of modern agricultural technologies (High Yielding Varieties of rice) increases the incomes of poorer, near-landless households, does not tend to help them rise above the poverty line; highlighting the need for more effective equity-enhancing policy measures (Mendola 2007). The following subsections attempt to analyse the distinguishing features of agricultural employment, including facts and figures that are relevant to production practices.

5.2.1 Proportion of self-employed and family labour

The agriculture workforce in Bangladesh has a high proportion of self-employed (employers and owner account workers). Bangladesh is, a labour abundant country, with the majority of people living in rural areas (72.2 per cent) with farming occupations (91.6 per cent); therefore, the agriculture sector is mostly rural based and labour intensive (GOB 2017b). The rural population, endowed with labour (big farm family sizes) but few other productive assets, lacks formal employment opportunities. As a result, family members get engaged either in their land holdings for crop farming, or participate in the rural wage labour market. Thus, in a farming household, family labour is informal, unpaid and surplus in nature. In the fiscal year 2016-17, about 86 per cent of the labour force in Bangladesh works in the informal economy, and among those the agriculture sector alone employs around 48 per cent (GOB 2017b). Family labour in small scale agriculture is substantial, while the contribution of hired labour is small. Family labour is much more productive than hired labour, and there is a limited substitution between the two (Rahman 2005).
With the introduction of Green Revolution technologies, Bangladesh received significant employment gains (47 per cent higher than traditional varieties) (Barker and Cordova 1978; Hossain 1988). For instance, Alauddin and Tisdell (1995) found that labour employment and labour intensity (man-days per hectare) in food grain increased from 21 and 14 per cent from the late 1960s to 1990-91. Hossain (1988) found that farmers use about 47 per cent more labour per unit of land for cultivation of MVs than for traditional varieties, although per unit of output, labour requirements are about 35 per cent lower for modern varieties (MVs). Often this results in upward pressure on wage rates and increasing earnings from the same amount of labour. Compared with other sectors of the economy, agricultural production is spread over a longer time period and is subject to bursts of intensive activity, separated by quieter periods. The following sub-section particularizes the seasonal labour pattern in crop production.

5.2.2 Seasonal labour use

Seasonality in labour use is inherent in agriculture, due to the crucial dependence of the sector on climatological and biological factors (stages of plant growth). Required labourers per hectare of rice production (total, family and hired) are shown in Table 5.1. As presented in Table 5.1, the highest levels of labour are required during weeding and harvesting. As also presented, family labourers represent 25 per cent of the total labourers used during boro rice production. Rahman (1981) found that only during the sowing and harvesting seasons does there appear to be full employment. Once these seasons are over, the majority of agricultural workers become jobless or switch to other non-farm activities; especially in areas, where there is single cropping pattern. In some parts of Bangladesh, agricultural labourers are migratory, moving in search of jobs at the time of harvesting with associated harmful consequences including dislocation of
family life, disrupted education of children, and numerous other impacts. The problem is further aggravated because the vast majority of these labourers, being unskilled, do not have decent alternative income earning options.

Any discussion of the distribution of labour in agriculture needs to consider hours worked throughout the farming year. Time spent on farm work (number of hours) varies significantly between farming systems, seasons, crops, and even land types.

**Table 5-1 Total number of family labourers involved in producing rice in Bangladesh**

<table>
<thead>
<tr>
<th>Rice season</th>
<th>Seed-bed prep.</th>
<th>Plucking of seedling</th>
<th>Sowing/planting</th>
<th>Weeding</th>
<th>Harvesting</th>
<th>Threshing</th>
<th>Total</th>
<th>% of family labour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Family labour</td>
<td>Hired labour</td>
<td>Family labour</td>
<td>Hired labour</td>
<td>Family labour</td>
<td>Hired labour</td>
<td>Family labour</td>
<td>Hired labour</td>
</tr>
<tr>
<td>Boro</td>
<td>3.08</td>
<td>3.52</td>
<td>2.76</td>
<td>8.62</td>
<td>4.06</td>
<td>8.17</td>
<td>2.97</td>
<td>10.60</td>
</tr>
<tr>
<td>Aus</td>
<td>2.47</td>
<td>2.69</td>
<td>1.95</td>
<td>4.04</td>
<td>4.05</td>
<td>7.61</td>
<td>3.36</td>
<td>8.37</td>
</tr>
<tr>
<td>Aman</td>
<td>3.61</td>
<td>5.50</td>
<td>2.53</td>
<td>7.61</td>
<td>2.84</td>
<td>7.29</td>
<td>1.95</td>
<td>9.63</td>
</tr>
</tbody>
</table>

Source: GOB (2010b).

The following sub section deals with educational qualification of the labour force of Bangladesh with national level data.

### 5.2.3 Educational qualifications

Agricultural efficiencies and productivity have been found to be related to farmers’ education levels in various ways. Many researchers, including Hayami (1969, 1970) and Hayami and Ruttan (1970) in earlier years, followed by Nguyen (1979), and Kawagoe and Hayami (1983), have emphasised the influence of education and human capital on productivity growth. Similarly, Wiebe et al. (2003) mentioned that literacy is expected to improve a farmer’s ability to make use of information provided by extension services,
or to keep better track of the costs and returns of alternative inputs and marketing opportunities. Moreover, in order to explain the growth in productivity in the United States Griliches (1963) incorporated education as a measure of labour quality. Chang and Zepeda (2001) proposed that since better-educated farmers are more likely to adopt new technologies, human capital is a pre-condition for technology adoption and hence productivity growth. However, Pritchett (2001) argued that quality of education in developing countries may have remained so low that the years of schooling do not produce an increase in human capital.

In the Bangladesh context, Rahman and Salim (2012), Deb (1995), Hossain (1989), and Coelli et al. (2002) have found that the country’s low literacy rates work against agricultural efficiency changes and TFP growth. In this instance, Coelli et al. (2002) argued that higher education provides opportunities for moving away from less rewarding agriculture to more rewarding non-agriculture sectors of the economy. The findings of Jahan (1997) indicate that there is a positive relationship between agricultural efficiency, and farmers having schooled up to high school level, but a negative relationship between agricultural efficiency and farmers having education beyond high school level. On the basis of her research findings Jahan (1997) reported that:

“Although the role of education in improving farmers efficiency is widely accepted, for a developing country education up to [and not beyond] a certain limit is appropriate for improving efficiency.”

Agricultural workers typically have lower levels of educational and fewer qualifications. Most of the peasant community are illiterate and have become skilled in their occupations by learning skills from their relatives, friends and neighbours. In this
instance, the data presented in Table 5.2 show that for people 15 years and older who are employed and who have not completed any education, the largest proportion (44 per cent) is engaged as agricultural worker (GOB 2017a). Of the group, 22 per cent and 27 per cent have only reached primary and lower secondary education levels respectively. This scenario is completely reversed for higher education; i.e. for those who have undertaken higher secondary and tertiary level education, only 2 per cent and 0.7 per cent respectively are engaged in agriculture occupation. Many educated peasants who are doing agricultural work only do so for lack of alternatives, or because they are committed to work on their family farms.

Table 5-2 Employed populations aged 15 and above by educational attainment in Bangladesh, 2016-17

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Level of education completed (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Agriculture</td>
<td>44.01</td>
</tr>
</tbody>
</table>

Source: GOB (2017b).

When considering the proportion of the population employed in agriculture by sex, Table 5.3 shows that female participation in agricultural production has fallen significantly from 85 per cent in 1990 to 44 per cent in 2017. This may be due to the improved level of female education and associated tendency to switch from the agricultural sector to urban-based jobs. In the fiscal year 2016-17, female labour employed in the rural agricultural sector was about 44 per cent, while in urban areas the rate was 45 per cent (GOB 2017b). In urban areas, agriculture is relatively much less important; only 8 per cent of labour is engaged in urban agriculture (GOB 2017b).
Table 5-3 Distribution of agricultural labour by sex in Bangladesh, 1990-2017

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment in Agriculture, female (%)</td>
<td>84.9</td>
<td>76.9</td>
<td>68.10</td>
<td>53.50</td>
<td>44.14</td>
</tr>
</tbody>
</table>


At this point, discussion turns to the labour wage rate in Bangladesh during 2010 to 2015.

5.2.4 Labour wages

Agriculture has a high proportion of relatively low paid employees compared with other sectors of the economy. There are two types of wage payment systems in Bangladesh agriculture: the wage rate including food; and the wage rate without food. If wages are paid with the inclusion of food, then the nominal wage rate is lower in comparison to the without food wage. The data given in Table 5.4 show that there is considerable difference between the male and female wage rates. The ratio of female to male nominal wage rates was 71 per cent in FY2010, which increased marginally to 75 per cent in FY2015. Nominal agricultural labour wages increased more than three times over 2010 to 2015, from 178 Bangladeshi Taka per day of work in 2010 to 303 Bangladeshi Taka in 2015. Moreover, the agricultural rice wage had experienced an increasing trend within same period.
Table 5-4 Agricultural daily average wage rate by sex in Bangladesh, 2010-2015

<table>
<thead>
<tr>
<th>Years</th>
<th>Wage without food (in Bangladeshi Taka)</th>
<th>Wage with food (in Bangladeshi Taka)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>2010</td>
<td>178</td>
<td>126</td>
</tr>
<tr>
<td>2012</td>
<td>268</td>
<td>190</td>
</tr>
<tr>
<td>2014</td>
<td>291</td>
<td>221</td>
</tr>
</tbody>
</table>


During the Bangladesh government’s sixth five-year plan period average labour productivity in agriculture is estimated to have increased by over 3 per cent per year. This is an important result and provides the basis for sustained increases in real wages both, economy wide and in agriculture. In terms of purchasing power of wages over rice, agricultural wages surged from FY2010 to FY2014, with annual real increases of 14 per cent. In addition to farm income, there is prospect of expanding rural non-farm income in Bangladesh, which is important for the access of food security.

According to FPMU (2016, p.24) report about rural non-farm income is,

“About 19 per cent of farmers had farming as a subsidiary occupation and at the same time they used to earn income from other non-farm occupations. Among the rural non-farm activities (RNAs) included day labour, shop keeping, rickshaw/van pulling, boatmanship, tractor driving, blacksmith, mechanic work and other non-farm labour are found. The necessity of this non-farm work has arisen because the rural economy of Bangladesh has undergone extensive structural changes over recent decades. Analysis of HIES and Labour Force Survey (LFS) data show that the growth of employment in agriculture and RNA were 8 per cent and 26 per cent respectively during the 2006-2010 period. The share of agricultural income decreased from 50 per cent in 2000 to 48 per cent in 2010, while the share of RNA income increased from 50 per cent to 52 per cent during the period.”
Table 5-5 District-wise wage rate of agricultural labourers in Bangladesh in 2016
(in Bangladeshi Taka)

<table>
<thead>
<tr>
<th>Wage</th>
<th>Jhenaidaha (Rasun Shimul)</th>
<th>Chuadanga (Darikamari)</th>
<th>Bogura (Khudiakhali)</th>
<th>Chandpur (Begumpur)</th>
<th>Madaripur (Bhabanipur)</th>
<th>Mymensingh (Konapara and Nishaiganj)</th>
<th>Narsindhi (Patordia)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Without food</td>
<td>280</td>
<td>218</td>
<td>214</td>
<td>0</td>
<td>288</td>
<td>226</td>
<td>350</td>
</tr>
<tr>
<td>With food</td>
<td>260</td>
<td>206</td>
<td>230</td>
<td>0</td>
<td>270</td>
<td>230</td>
<td>320</td>
</tr>
</tbody>
</table>

The next section depicts the socio-economic condition of the International Rice Research Institute (IRRI), Bangladesh’s Village Dynamics in South Asia (VDSA)’s survey households. It will help to conceptualise their performance in terms of technical efficiency.

5.3 Socio-economic condition of farming households

In order to understand the socio-economic profile of the households of eight different villages, this section condenses relevant indicators. A summary of socio-economic characteristics of the International Rice Research Institute (IRRI), Bangladesh’s Village Dynamics in South Asia (VDSA) surveyed household is presented in Table 5.5. As shown in Table 5.5, a majority of household population belonging to the age group of 15-59 years (percentage ranges from 75 to 53 in different regions) and this range of population is found to be economically active. Rest of the economically inactive population belongs to the age groups of 0-14 and above 60 years; the later age group represents minority population in almost all study areas. The dominancy of 15-59 age group indicates that farmers stay in their jobs for long periods. Several factors may contribute to the skewed age profile of workers in the agriculture sector compared to other sectors of the economy, includes: (i) fewer young people entering farming; (ii) limited interest of young people in taking over the family farm; and (iii) the high proportion of households headed by males (the share ranges between 95 and 87 per cent across villages). Regarding education levels of farmers, one common feature in most of the villages is, farmers are mostly educated up to primary and secondary levels. Further,
there is an inverse relationship between higher education levels of household members and their likelihood of participating in farming.

Table 5.5 also reveals that among the households, percentage share of farmers having farming as their primary occupation across different regions/villages ranges between 31 and 72. For those farmers who do not have farming as a primary occupation, their spouses are often found to be engaged in farming activities. Both farm and non-farm incomes safe-guard the respondent households. Households rely predominantly on agriculture for income, and are poor with small landholdings. Off-farm income (for example from auto-driving, boat driving, petty business), in addition to complementing farm income and contributing towards food security and poverty alleviation, provides an important risk management tool by diversifying income sources. In terms of negative shocks that affect agriculture, such as floods, cyclones, droughts; families rely on off-farm income to maintain their livelihoods.
Table 5-6 Selected socio-economic characteristics of the sampled farm households of Bangladesh, 2011

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Darikamari</th>
<th>Khudiakhali</th>
<th>Bhabanipur</th>
<th>Begumpur</th>
<th>Rasun Shimul</th>
<th>Konapara</th>
<th>Nishaiganj</th>
<th>Dakhin Kabirkathi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population by age group (in per cent)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-14</td>
<td>20</td>
<td>18</td>
<td>24</td>
<td>15</td>
<td>33</td>
<td>24</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>15-59</td>
<td>69</td>
<td>71</td>
<td>68</td>
<td>75</td>
<td>56</td>
<td>61</td>
<td>64</td>
<td>54</td>
</tr>
<tr>
<td>60+</td>
<td>10</td>
<td>11</td>
<td>8</td>
<td>10</td>
<td>11</td>
<td>14</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td><strong>Sex of household head (in per cent)</strong></td>
<td>87</td>
<td>95</td>
<td>79</td>
<td>85</td>
<td>90</td>
<td>93</td>
<td>90</td>
<td>87</td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>5</td>
<td>21</td>
<td>15</td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Education status of population (in per cent)</strong></td>
<td>13</td>
<td>12</td>
<td>10</td>
<td>2</td>
<td>21</td>
<td>22</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Illiterate</td>
<td>13</td>
<td>3</td>
<td>11</td>
<td>4</td>
<td>1</td>
<td>14</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Can sign only</td>
<td>20</td>
<td>17</td>
<td>20</td>
<td>28</td>
<td>21</td>
<td>27</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>Primary</td>
<td>39</td>
<td>48</td>
<td>38</td>
<td>52</td>
<td>43</td>
<td>32</td>
<td>42</td>
<td>50</td>
</tr>
<tr>
<td>Technical</td>
<td>-</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Higher secondary</td>
<td>11</td>
<td>1</td>
<td>9</td>
<td>11</td>
<td>1</td>
<td>2</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Graduate</td>
<td>4</td>
<td>7</td>
<td>12</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Farming as the main occupation (in per cent)</td>
<td>31</td>
<td>67</td>
<td>58</td>
<td>71</td>
<td>37</td>
<td>55</td>
<td>38</td>
<td>72</td>
</tr>
</tbody>
</table>

Source: Bhandari et al. (2013).
Distribution of labour hours, presented in Table 5.6, reveals that farmers require a considerable number of hours of labour for farming activities, including for pre-tilling and clearing of land, tilling, irrigation, applying fertilizers and pesticides, transplanting/broadcasting, weeding, harvesting, threshing, drying grains and storage. Different activities require different numbers of labour hours and farmers also use different kinds of labour for different activities, choosing between family males, hired males, family females, hired females, and regular farm servants.

As Bangladesh has limited capital-intensive mechanised agricultural practice, the country needs large number of labour for various crop cultivation activities. Human labour, required to carry out different farming activities in the study areas, is presented in Table 5.6. The data show that the highest labour is required for harvesting, followed by weeding, transplanting and, threshing. Labour requirement also varies among regions; in this study, the highest labour requirements occurred in the village of Khudiakhali, requiring 670.49 labour hours for crop cultivation per year. The lowest levels of labour required for crop cultivation in this study were in Nishaiganj village, requiring 158 labour hours.
Table 5-7 Required labour hours for crop production in different study areas of Bangladesh in number of hours

<table>
<thead>
<tr>
<th>Village</th>
<th>Pre-tilling clearing of land</th>
<th>Tilling</th>
<th>Irrigation</th>
<th>Applying fertilizer and pesticide</th>
<th>Transplanting/broadcasting</th>
<th>Weeding</th>
<th>Harvesting</th>
<th>Threshing</th>
<th>Harvesting and threshing</th>
<th>Drying</th>
<th>Storing</th>
<th>Others</th>
<th>Making shelf</th>
<th>Total labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darikamari</td>
<td>21.04</td>
<td>0.00</td>
<td>4.25</td>
<td>53.32</td>
<td>81.43</td>
<td>67.34</td>
<td>146.84</td>
<td>22.50</td>
<td>164.32</td>
<td>0.00</td>
<td>35.34</td>
<td>-</td>
<td>-</td>
<td>596.38</td>
</tr>
<tr>
<td>Khudiakhali</td>
<td>33.42</td>
<td>5.44</td>
<td>44.22</td>
<td>11.06</td>
<td>67.94</td>
<td>132.95</td>
<td>148.12</td>
<td>61.74</td>
<td>69.00</td>
<td>31.43</td>
<td>17.17</td>
<td>0.00</td>
<td>48.00</td>
<td>670.49</td>
</tr>
<tr>
<td>Bhabanipur</td>
<td>14.98</td>
<td>2.45</td>
<td>0.47</td>
<td>9.18</td>
<td>81.48</td>
<td>80.03</td>
<td>62.98</td>
<td>19.19</td>
<td>64.36</td>
<td>20.76</td>
<td>7.68</td>
<td>98.00</td>
<td>17.00</td>
<td>478.56</td>
</tr>
<tr>
<td>Begumpur</td>
<td>15.19</td>
<td>0.00</td>
<td>2.56</td>
<td>11.78</td>
<td>70.77</td>
<td>149.24</td>
<td>27.29</td>
<td>16.95</td>
<td>131.82</td>
<td>39.29</td>
<td>7.02</td>
<td>45.00</td>
<td>0.00</td>
<td>516.91</td>
</tr>
<tr>
<td>Rasun Shimul</td>
<td>0.00</td>
<td>0.44</td>
<td>3.85</td>
<td>9.11</td>
<td>75.02</td>
<td>103.93</td>
<td>70.00</td>
<td>34.00</td>
<td>80.92</td>
<td>17.19</td>
<td>7.54</td>
<td>-</td>
<td>-</td>
<td>402.00</td>
</tr>
<tr>
<td>Konapara</td>
<td>34.66</td>
<td>0.00</td>
<td>10.42</td>
<td>10.85</td>
<td>135.14</td>
<td>51.38</td>
<td>56.50</td>
<td>24.90</td>
<td>170.36</td>
<td>25.33</td>
<td>10.27</td>
<td>13.18</td>
<td>16.00</td>
<td>558.99</td>
</tr>
<tr>
<td>Nishaiganj</td>
<td>7.20</td>
<td>0.00</td>
<td>6.80</td>
<td>2.80</td>
<td>27.20</td>
<td>12.80</td>
<td>32.00</td>
<td>12.00</td>
<td>37.00</td>
<td>18.40</td>
<td>2.20</td>
<td>-</td>
<td>-</td>
<td>158.4</td>
</tr>
<tr>
<td>Patordia</td>
<td>18.96</td>
<td>0.90</td>
<td>3.16</td>
<td>2.23</td>
<td>89.89</td>
<td>38.46</td>
<td>16.50</td>
<td>12.00</td>
<td>101.92</td>
<td>19.43</td>
<td>3.81</td>
<td>-</td>
<td>-</td>
<td>307.26</td>
</tr>
</tbody>
</table>

5.3.1 Household portfolio of two villages of Mymensingh district

This section deals with the primary respondents’ socioeconomic conditions including age, education, occupation, and gender of household head. Table 5.7 describes the socioeconomic portfolio of the households of two villages of Mymensingh district. About 99 per cent respondent households are male headed and 1 per cent is female headed. The female respondent was widow and manages her property herself.

Table 5-8 Selected socio-economic characteristics of the sample farm households of Bangladesh

<table>
<thead>
<tr>
<th>Variables with category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of the HH head</td>
<td></td>
</tr>
<tr>
<td>≤ 30 years</td>
<td>17</td>
</tr>
<tr>
<td>31-45 years</td>
<td>43</td>
</tr>
<tr>
<td>46-55 years</td>
<td>26</td>
</tr>
<tr>
<td>56 and above</td>
<td>14</td>
</tr>
<tr>
<td>Sex of HH head</td>
<td></td>
</tr>
<tr>
<td>Male headed household</td>
<td>99</td>
</tr>
<tr>
<td>Female headed household</td>
<td>1</td>
</tr>
<tr>
<td>Primary (1-4 class)</td>
<td>15</td>
</tr>
<tr>
<td>Middle (5-7 class)</td>
<td>25</td>
</tr>
<tr>
<td>High school (8-10 class)</td>
<td>18</td>
</tr>
<tr>
<td>Intermediate level (11-12)</td>
<td>6</td>
</tr>
<tr>
<td>Diploma</td>
<td>1</td>
</tr>
<tr>
<td>Degree</td>
<td>2</td>
</tr>
<tr>
<td>Illiterate (cannot read and write)</td>
<td>12</td>
</tr>
<tr>
<td>Literate (able to read and write without formal education)</td>
<td>21</td>
</tr>
<tr>
<td>Farming as main occupation</td>
<td>40</td>
</tr>
<tr>
<td>Farming as subsidiary occupation</td>
<td>8</td>
</tr>
</tbody>
</table>

The overall age of household heads ranges between 22 and 82 years, and a majority (43 per cent) of them belong to the age group of 31-45 years. Average age of the household heads is around 44.21 years. About 67 per cent household head have formal education. Table 5.7 also reveals that there is less participation of higher educated households in farming. Among the households, about 85 per cent farmers had farming as their primary occupation, and out of them, 29.7 per cent do not have any subsidiary occupation. In addition to non-farming jobs, 22 per cent farmers took farming as a subsidiary occupation. Some mentionable non-farming occupations are auto driving, boat driving, power tiller driving, retail business, wage labour, seasonal jobs are mentionable here. The following section attempts to depict the government extension service in terms of overall country performance (national) and farmers’ level experience.

5.4 Agricultural extension

The focus of the section of this chapter is on outreach activities, specifically agricultural extension services, and farmers’ experience in getting extension service from different sources. Technology includes not just tools and cultivation systems, but also involves how farmers are benefited in the production process. The availability of skilled labour is an important determinant of agricultural productivity growth. The importance of education, training and extension services lies in the fact that these initiatives have a significant impact on the adoption of new technologies, which in turn, affect the allocation of resources and productivity (Chang and Zepeda 2001). As farm systems become more complex, farmers need more advanced skills to better manage risks, and to identify and apply new technologies and management practices (Gray, Oss-Emer, and Sheng 2014).
Agricultural extension services include transferring knowledge to farmers, advising and educating them in their decision making, enabling farmers to clarify their own goals and possibilities, and stimulating desirable agricultural development (Jaim and Akter 2012; Jaim 2015). From a regional perspective, these efforts are vital as far as transferring information to farmers, and educating them about how to make better decisions is concerned. Extension service in Bangladesh is largely run by the public-sector ministries, though the country has developed pluralistic extension system. The Department of Agricultural Extension (DAE) within the Ministry of Agriculture (MoA) is the biggest agency involved; with a network of around 14,092 extension workers (Sub-Assistant Agriculture Officers) and 3,064 officers (FPMU 2016).

In addition to government agencies, other groups those provide extension and associated advisory services include: agricultural universities, large NGOs (such as BRAC, CARE Bangladesh, and World Vision), private companies, commercial traders, and input suppliers. For the instance of input supplier, private seed companies offer advice on varietal selection, pest and nutrient management. In an example of public-private partnership, the Bangladesh Agricultural Research Institute (a public sector research organization) provides its technology support to farmers, in collaboration with Grameen Krishi Foundation (GKF, a private organization), which provides financial support and other input; the two organizations have been working together since 1995 in North-West Bangladesh to introduce modern technologies into the regional cultivation systems (Uddin et al. 2001).
The training of farmer is an important mechanism to transfer technologies to end users. In recognition of this, Agricultural Training Institute (ATI)s have been established throughout the country, to provide training to field extension staff (Sub-Assistant Agricultural Officers- SAAOs). The SAAOs then are assigned to provide training to farmers, mainly on crop production technology and farming systems. The number of farmers, trained by the Department of Agricultural Extension (DAE), during 2007-08 to 2014-15, is presented in Figure 5.2. This figure shows that a considerable number of farmers are trained by the DAE every year. Figure also reveals that this number has increased significantly (by 26 per cent) between 2014-15 and 2013-14. This increase is likely due to the increase in informal training provided through the “Farmers’ information and advice Centre” (FPMU 2016). In addition, the Bangladesh Rice Research Institute (BRRI) has so far trained more than 90,000 personnel on rice production technologies; among these, 3 per cent are rice scientists, 34 per cent are extension personnel of the DAE and NGOs, and the remaining 63 per cent are rice farmers (BRRI 2016).

**Figure 5.1 Number of farmers trained by DAE on sustainable agricultural practice, Bangladesh, 2007/08-2014/15**

![Graph showing the number of farmers trained by DAE]

Source: Data from FPMU (2016).
It is necessary to have clear idea about how farmers in the field are benefitted from
government extension department and other sources of knowledge on agricultural
technologies. The following sub-section analyses the performance of different source of
information in farmers’ perspective.

5.4.1 Sources of technological information received by farmers

This sub-section of the chapter uses International Rice Research Institute (IRRI),
Bangladesh’s Village Dynamics in South Asia (VDSA) data to investigate how farmers
ranked the convenience of the various sources of information about agricultural
technologies. Farmers obtain their information and advice about farm technologies,
including use of chemical fertilizers, seed selection and storage, horticultural crops and
pesticides from a range of different sources. Table 5.8 shows village wise sources of
information obtained by the sample farmers.

The surveys revealed that farmers first preference as an information source is “relatives,
friends and neighbors” as this source dominates in ranking (as shown in Table 5.8). Most often, farmers adopt crop production technologies following the advice of other
neighboring farmers, friends and relatives. Farmers appear to feel free to share
technology readily among their community, and any successful outcomes of the
adoption of a particular technology by one farmer are then visible to neighboring
farmers. Input suppliers are found to be the second most preferred source of information
to farmers, after “relatives, friends and neighbors”. It is evident that in addition to input
marketing, the input dealers and seed companies also provide information about variety
selection, seed selection and processing, pesticide use and other related technologies.
Input dealers not only deal with local varieties of crops, but also market imported seed, fertilizer and machineries. Therefore, their coverage and knowledge of technology is usually much broader than that of government department staff. However, in some cases, reliance of input suppliers presents the risk that farmers will adopt foreign technology directly into their fields, without inspections at the government level. Moreover, television and radio, as electronic media, are the other sources of information on agricultural production. Farmers ranked this source as fourth preference.

Field level extension staff (SAAO) from the government were ranked further down, after electronic media. Although the ranking of government department support for agricultural extension services is not high in the study area, support may still be satisfactory, considering the limitations of manpower and other financial resources faced by many departments of government. Alongside government departments and input dealers, NGOs are also effective at disseminating technologies; the survey data found that NGOs are important sources of information (ranked as third) for farmers within the study areas. Another trusted category of informal information provider is village administrative leaders (i.e. the local Chairman), who respondents ranked as the sixth most preferred source. Other sources of information used by farmers include community bulletin board, Upazila (Sub-district) government agricultural officers, and national and local newspapers.
Table 5-9 Access to sources of information of the sample households of Bangladesh, in ranking

<table>
<thead>
<tr>
<th>Sources of information</th>
<th>Darikamari</th>
<th>Khudiakhali</th>
<th>Bhabanipur</th>
<th>Begumpur</th>
<th>Rasun</th>
<th>Shimul</th>
<th>Nishaiganj</th>
<th>Konapara</th>
<th>Patordia</th>
<th>Overall rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block supervisor/union agri. Officer</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Community bulletin board</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Input supplier</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>National newspaper</td>
<td>7</td>
<td>3</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>NGOs</td>
<td>6</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relatives, friends and neighbours</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Electronic media (Television/ Radio)</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Training and agriculture fair</td>
<td>11</td>
<td>10</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Upazila Agricultural Officer</td>
<td>10</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Village leader</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Local newspaper</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>11</td>
</tr>
</tbody>
</table>


*Ranking is done on the basis of farmer’s convenience in getting access to information. The lowest rank indicates the best option.
In addition to the above discussion, based on secondary household survey data, the primary data (qualitative information) from two villages of Mymensingh district reveals that farmers hardly get direct benefit from government extension service in their village level. A total of 5 respondent confirmed that they received formal training on agricultural production technologies. Farmers however relies more on informal sources of technological knowledge. About 65 per cent farmers mentioned that they rely on knowledge and information from neighbours and friends.

5.5 Conclusion

This chapter has discussed the nature of the agricultural labour force in Bangladesh. This analysis serves as a foundation for an analysis of agricultural total factor productivity, in later chapters. Bangladesh is a country that is abandoning labour, yet agricultural labour remains dominant in rural areas. Peasant communities use both family supplied labour and limited hired labour for their production. As more modern technology is adopted, more labour is required for crop production. Therefore, Green Revolution technology has opened the door to providing greater employment in the agriculture sector than before. However, labour use patterns remain heavily seasonal in nature; maximum labour is required during harvesting season, at which time hired labour is required to ensure a timely harvest.

Increasingly, a large proportion of females are engaged in agricultural production. However, male labour still dominates; both in rural agricultural economic activities. In terms of literacy, it is found that most farmers have little. Further, there seems to be a tendency for educated members of the farming population to leave agriculture and
search for off-farm jobs leaving the sector to illiterate farmers in rural villages. In addition to their agricultural occupation, many farmers also have non-farm occupations in order to maintain their coping capacity in the face of economic vulnerabilities. Government policy also supports non-farm employment opportunities, especially via the expansion of rural transport infrastructure, electricity supply, and telecommunication facilities. As well, this study supports claims that the expansion of technical and vocational training facilities along with the provision of credit on easy terms is facilitating the expansion of non-farm activities in rural areas.

The survey revealed a range of other labour use patterns among the country’s farmers, including demographic patterns and information about training and extension services related to new technologies. Demographic data from households in the study areas showed that the age group 19-59 is mostly active and skilled manpower and more likely is involved in agricultural occupations. Male headed households are still dominating peasant society in the study areas. Farming as their primary occupation varies region to region and the percentage varies from 31 to 72. The government of Bangladesh has developed initiatives to develop the farmers’ skills, by providing technical training through the Department of Agricultural Extension. The survey data show that considerable numbers of farmers receive training each year. Further, the survey information has shed light on the farmers’ experiences with extension services that provide information about new technologies, revealing that farmers obtain new information and knowledge about seeds, fertilizers, pesticides and selection of crop varieties selection knowledge from a wide range of sources, but still rely preferentially on local village sources, over sources of information provided by state agencies.
Chapter 6  Household Crop Productivity  
Growth in Bangladesh

6.1  Introduction

The central aim of this chapter is to empirically quantify the impact of TFP growth on sustainable food production of eight different regions of Bangladesh. In doing so, it may help to shed light to three important questions: (i) What is the contribution of TFP to the agricultural output of these selected small householders? (ii) Are there any variations in the TFP growth level of these different regions? If so, what is driving these variations? (iii) What government policy initiatives can be taken to improve TFP performance across regions? The chapter is organized as follows. It begins with a brief overview of the literature conducted on TFP growth accounting on Bangladesh over the last 40 years or so. This is then followed by the construction of a growth accounting framework to empirically quantify TFP growth of different selected regions in Bangladesh. Finally, the results are discussed with references to relevant theories and policy implications.

6.2  A brief overview of empirical studies on agricultural TFP growth

A brief review of literature on empirical studies of TFP growth in agricultural sector at cross-country and national/regional level other than Bangladesh has been discussed in Chapter 2. The same is done for Bangladesh in this section. Table 6.1 gives a summary of the various methods used for estimating TFP growth of Bangladesh covering the period 1948 – 2013.
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Commodity</th>
<th>Objective</th>
<th>Period</th>
<th>Data sources</th>
<th>Methodology used</th>
<th>Annual growth (%) of TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hossain (1974)</td>
<td>Agriculture</td>
<td>Measuring both TFP and Partial Factor Productivity (land and labour)</td>
<td>1960-70, 1971-81</td>
<td>BBS and other secondary sources</td>
<td>Theil-Tornqvist (T-T) index</td>
<td>0.29</td>
</tr>
<tr>
<td>Anderson and Pray (1985)</td>
<td>Crop sector</td>
<td>TFP growth with Total output and conventional input</td>
<td>1960-70, 1971-81</td>
<td>BBS and other secondary sources</td>
<td>Theil-Tornqvist (T-T) index</td>
<td>0.97</td>
</tr>
<tr>
<td>Rosegrant and Evenson (1992)</td>
<td>Crop sector</td>
<td>Measuring TFP growth</td>
<td>1957-87, 1965-75</td>
<td>Not given</td>
<td>T-T index</td>
<td>0.78</td>
</tr>
<tr>
<td>Delgado (1998)</td>
<td>Crop Sector</td>
<td>Green revolution and economic development with respect of TFP growth</td>
<td>1948-93, 1969-81</td>
<td>BBS, World Bank, Christensen and Jorgenson index and Theil-Tornqvist (T-T) index</td>
<td>1.56, 1.85, 0.84, 0.72</td>
<td>0.32</td>
</tr>
<tr>
<td>Dey and Evanson (1991)</td>
<td>crops</td>
<td>predate structural reforms</td>
<td>1952-71, 1973-89</td>
<td>BBS and other secondary sources</td>
<td>T-T index</td>
<td>0.72, 0.96, 0.98, 1.15, 0.93, 0.83, 1.96, 3.92</td>
</tr>
<tr>
<td></td>
<td>rice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Author(s)</td>
<td>Commodity</td>
<td>Objective</td>
<td>Period</td>
<td>Data sources</td>
<td>Methodology used</td>
<td>Annual growth (%) of TFP</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>-----------------</td>
<td>----------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td></td>
<td>Livestock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>Crops and livestock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.3</td>
</tr>
<tr>
<td>Coelli and Rao (2005)</td>
<td>Crop and livestock</td>
<td>Estimate convergence and divergence in productivity in agriculture</td>
<td>1980-2000</td>
<td>FAOSTATA</td>
<td>Data envelopment analysis (DEA) to derive Malmquist index</td>
<td>1.024</td>
</tr>
<tr>
<td></td>
<td></td>
<td>within global framework</td>
<td></td>
<td></td>
<td></td>
<td>(in Bangladesh)</td>
</tr>
<tr>
<td>Rahman (2007)</td>
<td>crops (16 regions)</td>
<td>Regional productivity and convergence</td>
<td>1964-75, 1975-84, 1985-92</td>
<td>Data from Uttam Deb's Ph.D. thesis</td>
<td>Malmquist index (non-parametric approach)</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.60</td>
</tr>
<tr>
<td>Rahman and Parkinson (2007)</td>
<td>Rice</td>
<td>Productivity and soil fertility relationship</td>
<td>1996</td>
<td>Primary data from 3 districts (agro-ecological zones)</td>
<td>the translog profit function</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Technical efficiency change= 0.996, Technical change= 1.011)</td>
</tr>
<tr>
<td>Wadud and White (2000)</td>
<td>Rice</td>
<td>To measure farm household efficiency</td>
<td>1997</td>
<td>150 farmers from 2 Villages (primary sources)</td>
<td>Translog stochastic frontier production model (SFA) and DEA</td>
<td>NA</td>
</tr>
<tr>
<td>Hossain et al. (2012)</td>
<td>Rice</td>
<td>TFP and efficiency measurement</td>
<td>1990-2008</td>
<td>BBS and other secondary sources</td>
<td>SFA and DEA</td>
<td>2.30</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Commodity</td>
<td>Objective</td>
<td>Period</td>
<td>Data sources</td>
<td>Methodology used</td>
<td>Annual growth (%) of TFP</td>
</tr>
<tr>
<td>----------</td>
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</tr>
<tr>
<td>Continued Table 6.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rahman and Salim (2013)</td>
<td>Crops</td>
<td>Estimate 60 years productivity change and sources of growth</td>
<td>1948-2008</td>
<td>BBS and other secondary sources (17 region)</td>
<td>Färe–Primont index of TFP</td>
<td>0.57</td>
</tr>
<tr>
<td>Alam et al. (2014)</td>
<td>Rice</td>
<td>Impact of market reform and productivity growth</td>
<td>1987, 2000, 2004</td>
<td>IRRI, IFPRI data (26 Districts)</td>
<td>Stochastic production frontier approach</td>
<td>0, 46.64 (cumulative), 27.26 (cumulative)</td>
</tr>
<tr>
<td>Murdoch Commission Report (2015)</td>
<td>Agriculture sector</td>
<td></td>
<td>2005, 2006, 2007, 2008, 2009, 2010, 2011, 10-year Average</td>
<td></td>
<td></td>
<td>0.018, 0.036, 0.051, 0.054, 0.018, 0.007, -0.012, 0.0227</td>
</tr>
</tbody>
</table>

Source: Authors’ compilations.
Table 6.1 shows significant variations in TFP growth among the various studies conducted on Bangladesh, over the period 1948-2011. Some possible reasons causing these variations could be due to the coverage of the period, the methods that are used in the estimations, or perhaps both. For instance, taking four decades (1948-81) of crop sector data into consideration, Pray and Ahmed (1991) reported an annual average TFP growth of 0.32 per cent per annum. Dey and Evanson (1991) found an average TFP growth rate of 0.96 per cent per year for the period 1973-89. Applying a stochastic production frontier approach Coelli et al. (2003) reported a decline in TFP growth at an average rate of 0.23 per cent per year. Covering the longer period (from 1948 to 2008-six decades), Rahman and Salim (2013) estimated average TFP growth to be at the level of 0.57 per cent per year. The overall finding in Table 6.1 shows that the TFP growth level in agriculture to be very low.

Considering all aspects of findings from literature review, a number of research gaps are identified:

(i) None of the TFP growth studies focused exclusively on food security and sustainability;

(ii) None of the studies mentioned in Table 6.1 uses a more direct approach pioneered by Solow (1956, 1957) to measure TFP growth on the agricultural sector. As such, it is highly appropriate (perhaps long overdue) to further the literature on sustainable food production with other alternative approaches, like the Solow (1956) growth accounting framework. It is also useful and meaningful to conduct research using original methodological framework (Taylor, 2007). After all, Solow (1956) was awarded the Nobel Prize in 1987 for his growth accounting model;
(iii) Studies on regional variations in TFP performance are very rare and determining regional variations would shed additional light on sustainable crop production;

(iv) Studies on TFP growth accounting are not up to date and the latest time period covered is up to 2011. As such, an update is long overdue.

Based on the above research gaps, the Solow (1956, 1957) growth accounting framework will be utilized to calculate TFP growth for the various areas in Bangladesh.

A detail of the Solow (1956, 1957) growth accounting methodology to conduct empirically analysis is discussed in the following sections.

6.3 The Solow growth accounting specifications

As summarized in Table 6.1, there are different approaches used by various authors (Hossain 1974; Anderson and Pray 1985; Rosegrant and Evenson 1992; Pray and Ahmed 1991; Dey and Evanson 1991; Jahan 1997; Hossain et al. 2012; Fuglie 2012; Rahman and Salim 2013; Alam et al. 2014; and Murdoch Commission 2015) to estimate TFP growth. Table 6.1 shows that both parametric and non-parametric methods were used to estimate TFP growth in Bangladesh. Some studies used both, parametric and non-parametric approach, for comparing and cross-checking the results. For this instance, Wadud and White (2000) and Hossain et al. (2012) used both, the translog
stochastic frontier production (SFP) model as a parametric approach\textsuperscript{11}, and the data envelopment analysis (DEA) method as a non-parametric approach\textsuperscript{12}.

Index number approach is very common in estimating agricultural TFP growth analysis of Bangladesh. Various types of index number is applied by researchers in different studies. For instance, (shown in Table 6.1), Rahman and Salim (2013) used Fa"re–Print index to estimate 60 years productivity change and sources of growth in Bangladesh agriculture. Besides, most commonly used index number (eight out of 24 reviewed studies, shown in Table 6.1) is the Tornqvist-Theil index. For case in point, Pray and Ahmed 1991; cited in Rahman and Salim (2013), Jahan (1997), and Kamruzzaman et al. (2006) used the T-T index. Another index is the Malmquist index. Although the Malmquist index, as a non-parametric approach is widely used in different country comparison (as found in Chapter 2), it is only used by Rahman (2007) to estimate Bangladesh’s agricultural TFP growth.

In this study, the Solow (1956, 1957) growth accounting approach is employed. The justification for do so has already been discussed in Chapter 2. Briefly, the Solow (1956, 1957) growth accounting model predicts that without TFP growth, output growth would cease as a result of diminishing returns to factor inputs, such capital \((K)\) and labour \((L)\). When the production process finally arrives at its steady-state growth path (see Figure 2.6, in Chapter 2, p. 41), output per worker is primarily determined by the rate of TFP growth. Furthermore, authors such as Denison (1962), and Jorgenson and Griliches (1967) had wrote about the mechanical rigour of the Solow (1956, 1957) model, making it ideal for the analysis found in this chapter. In fact, the early 1990s saw an expansion in the growth

\textsuperscript{11} Parametric approaches require the estimation of the parameters of cost or production functions, and commonly employ the stochastic frontier approach.

\textsuperscript{12} Nonparametric approaches are represented by growth accounting techniques and index numbers.
literature in employing the TFP approach to explain the divergence in per capita income between the developed and developing economies, and the East Asian growth “miracle” (Taylor 2007). This expansion resulted in the development of the new or endogenous growth paradigm seeking to shed further light on TFP growth (Taylor 2007).

In addition, despite a variety of approaches, as indicated in Table 6.1, the estimation of TFP growth shares a common feature in that it is built with the traditional constant returns to scale production function whereby technological progress is assumed to be Hicks neutral and exogenous.

Many scholars, (such as, Antle 1983, Nehru and Dhareshwar 1994, Evenson and McKinsey 1991, and Rosegrant and Evenson 1992; cited in Zepeda 2001), incorporated factors of production such as labour, farming experiences, fertilizers, input availability and management of land, water and other biological factors in estimating agricultural TFP growth. Accordingly, this study includes information on operation-wise input-output data for each plot by crop/season during a calendar year. Monetary values of all Output ($Y$), Capital ($K$) and Labour ($L$) are adjusted to real prices using 2009 as base year.

Hence, TFP growth is quantified on basis of following production relationship:

\[ Y_t = A_t + K_t^\alpha + L_t^{1-\alpha} \]  \hspace{1cm} (6.1)

Where, $Y$ is output (a qualitative discussion of output is found in Section 3.4 of Chapter 3), $K$ is capital stock (a qualitative discussion of capital input is provided in Section 3.5 of Chapter 3, and land rent as a capital cost is discussed in Chapter 4), $L$ is labour (a qualitative analysis of labour force is provided in Chapter 5), and $A$ indicates
productivity or TFP. \( \alpha \), is a parameter with a value between 0 and 1, equal to capital’s share of the value of output.

Output \( (Y) \) and inputs \( (K \text{ and } L) \) can be converted in a common “wheat unit”\(^{13} \) (Hayami and Ruttan 1985; Block 1994, 1995), or a monetary unit. Monetary values are the most widely used method of aggregation of both inputs and outputs, in that monetary values can be summed together in a meaningful way and prices reflect the relative value of the items being aggregated (Zepeda 2001). For instance, studies of Food and Agriculture Organization (FAO) of the United Nations (UN) on international agricultural productivity pattern by Trueblood and Coggins (1997) and Craig, Pardey, and Roseboom (1997) used international dollars. In measuring agricultural productivity growth, Hussain (1976) also converted agricultural production into monetary values. Accordingly, this research used monetary value (in Bangladeshi Taka) of all inputs and outputs.

Output \( (Y) \) is the value of real output, including main product, and by-product. This is because, in many crops, in addition to main products, by-products, generally being fodder and fuel; also have value. Main products usually are quantities (Kilograms) of farming household’s annual production of grains, crops, vegetables and fruits, which then are converted into monetary values. Unit price (in Bangladeshi Taka), received by producer households for their produces, are recorded to compute returns from each crop. In a same way, by-products, are recorded in quantity; and are converted to monetary value. In the case of the crop failure output are recorded as zero.

\(^{13}\) The wheat units approach was developed by Hayami and Ruttan (1985) and is based on the ratio of each individual commodity price to the price of wheat in India, the United States and Japan.
In this analysis, labour \((L)\) consists of hired, owner operator, and family labor. Labour hours spent on almost all farming activities; including pre-tilling clearing of land, tilling, irrigation, applying fertilizers and pesticides, transplanting, broadcasting, weeding, harvesting, threshing, harvesting and threshing, drying grains and storing; are considered in this study. All labour hours are then converted to monetary value (in Bangladeshi Taka), by multiplying labour hour and wages (as mentioned by the respondent).

The capital stock variable \((K)\) is constructed by summing all the costs incurred during the production of agricultural output and divided by a set price level:

\[
\int_{i=1}^{t} I_i / P_i 
\]

Where, \(I\) denotes gross investment in material inputs (as discussed below), \(t\) represents the age of the oldest vintage in capital stock, \(i\) denotes the current capital stock, and \(P\) is the price level, which in this case 2009 is taken as the base year.

Capital variable \((K)\) covers all costs (in Bangladeshi Taka) incurred by the household for crop production. Type and quantity of material inputs (seed, fertilizers, pesticides, weedicides, and micronutrients are some of those), and their unit prices are taken into consideration, to calculate the capital cost. Hence, the prices are recorded as mentioned by farmers for computing cost for capital input. Quantity in kilogram and price in Bangladeshi Taka are recorded in the survey. If the household used seedlings of sugarcane, chilies, onion; then the number is recorded instead of seed in kilograms quantity and price of all fertilizer are recorded (Urea, USG, DAP, TSP, MP, Gypsum,
Zink, Mix fertilizer). In addition to mentioned inputs, land rent is also included into the capital cost. Regardless of ownership, total rent of farmed land for each crop is recorded in the survey. Hence, if the land is owned, then rent is considered as opportunity cost, otherwise whatever rent is paid by the tenant, is considered as capital cost. Monetary values of Output \((Y)\), Capital \((K)\) and Labour \((L)\) are adjusted to real prices using 2009 as base year.

Taking logs and differentiating with respect to time, output growth can be derived from equation (6.1):

\[
y_t = a_t + \alpha k_t + (1-\alpha) l_t
\]  

(6.3)

Where, \(y_t, k_t\) and \(l_t\) represent the rate of change to output, capital and labour with respect to time respectively. Technological progress \((a_t)\), captured by TFP, is a summation of capital and labour productivity. Once an estimate of \(a_t\), \(\hat{a}_t\) is provided, then TFP can be estimated using the following equation:

\[
\hat{a}_t = y_t - \alpha k_t - (1-\alpha) l_t
\]  

(6.4)

Prior to the estimation of TFP growth (using equation 6.4), it is important that an appropriate capital share to output (\(\alpha\)) value be derived. This is because TFP estimation is sensitive to various \(\alpha\) values. In a comprehensive analysis, Taylor (2007) stated the sensitivity of TFP estimates to the value of \(\alpha\). In his case study of Malaysia (1963-1998), Taylor (2007) concluded that the lower the value of \(\alpha\), the higher is the estimate of TFP growth. Moreover, Chen (1997) mentioned that an inappropriate choice of \(\alpha\) would explain why many studies reported a small TFP value in East Asia. Several authors (Sarel 1994; Collins and Bosworth 1996; Harberger 1996; and Chen 1997)
reported that TFP is highly sensitive to the sampling period, the size of $\alpha$, and the overall rate of output growth during the survey period. Dowling and Summers (1998) also pointed out that TFP estimation is highly sensitive to the size of $\alpha$. Most of the studies of TFP growth in the East Asian economies tend to focus on parameter estimation of the size of $\alpha$, resulting enormous effort being devoted to the achievement of a spurious accuracy which in the first place is problematic due to difficulties in the construction of capital stock (Robinson 1962; Hunt 1979; cited in Taylor 2007). Past studies on TFP reveal that the value of $\alpha$ employed for different countries ranged from 0.29 to 0.69. These different $\alpha$ values are presented in Table 6.2.

**Table 6-2 Different $\alpha$ values for different countries**

<table>
<thead>
<tr>
<th>OECD countries 1947-73</th>
<th>Canada</th>
<th>0.44</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>0.39</td>
<td>Italy 0.39</td>
</tr>
<tr>
<td>Japan</td>
<td>0.39</td>
<td>Netherland 0.45</td>
</tr>
<tr>
<td>UK</td>
<td>0.38</td>
<td>US 0.40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>G-7 Countries, 1960-90</th>
<th>France</th>
<th>0.42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>0.40</td>
<td>Italy 0.38</td>
</tr>
<tr>
<td>Japan</td>
<td>0.42</td>
<td>UK 0.39</td>
</tr>
<tr>
<td>US</td>
<td>0.41</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Latin American Countries, 1940-80</th>
<th>Brazil</th>
<th>0.45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>0.52</td>
<td>Colombia 0.63</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.69</td>
<td>Peru 0.66</td>
</tr>
<tr>
<td>Venezuela</td>
<td>0.55</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>East Asian Countries, 1966-90</th>
<th>Singapore</th>
<th>0.53</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>Korea</td>
<td>0.32</td>
<td>Taiwan 0.29</td>
</tr>
</tbody>
</table>

| Average $\alpha$ value            | 0.45 |

In examining the trend of TFP growth in 39 Chinese industrial branches during the 1980-85 period, McGuckin et al. (1992) found TFP growth results as sensitive to $\alpha$ values. Hall and Jones (1999) and Fuentes and Morales (2011) estimated TFP growth using the capital-output ratio. In addition, using the capital-output ratio of 0.33, Baier, Dwyer, and Tamura (2006) found that TFP accounts for 21 per cent of output growth.

Based on the assumptions that factor inputs, such as capital ($K$) and labour ($L$) are paid their marginal products, and that there are constant returns to scale to the production function, $\alpha$, which is the capital share of output ($Y$), can be derived from:

$$\frac{Y}{K} = A k^{\alpha - 1} \tag{6.5}$$

Second differentiation of equation 6.5 yields the marginal products of capital:

$$\frac{\partial Y}{\partial K} = A \alpha K^{\alpha - 1} L^{-(\alpha - 1)} = A \alpha (K/L)^{\alpha - 1} = A \alpha k^{\alpha - 1} \tag{6.6}$$

If each input is assumed to be paid by the amount of its marginal product, the relative share of total product accruing to capital will be:

$$\frac{K(\frac{\partial Y}{\partial K})}{Y} = \frac{KA \alpha k^{\alpha - 1}}{LAk^\alpha} = \alpha \tag{6.7}$$

The following section describes data sources for TFP growth analysis in this chapter.
6.4 Data sources

Comparable and consistent data are needed to make cross-country or cross region comparisons over time in TFP growth analysis. The Food and Agriculture Organization Statistics (known as FAOSTAT), under the World Agricultural Information Centre (WAICENT) is one of the most comprehensive agricultural databases, that is commonly used in estimating agricultural TFP growth (Zepeda 2001). In addition, recent developments in measuring changes in productive efficiency over time focuses on the use of farm level panel data (Khumbhakar, Heshmati and Hjalmarsson 1999; Henderson 2003; cited in Songqing Jin 2010), because panel data sets (i.e., a combination of time-series and cross-section data) permit a richer specification of technical change, and contains more information about a particular farm than a single cross-section farm data. Therefore, in estimating micro-level crop productivity, this study intends to use farm-level panel data.

The data sources found in Table 6.1 shows that, with exception Wadud and White (2000), Alam et al. (2014), Rahman and Parkinson (2007), del Ninno and Liu (2010), and Rahman (2007); all other studies used macro level, and secondary data (for example, BBS, FAOSTAT, IFPRI, MOF, MOA are among others). Among primary data users, Wadud and White (2000) used two village data (without justifying area selection criteria), and Rahman and Parkinson (2007) used purposively three rice dominating agro-ecological zones (covering regions-wet, dry, wet and developed) of Bangladesh. Moreover, Alam et al. (2014) used International Rice Research Institute (IRRI) and International Food Policy Research Institute (IFPRI) household level rice production data, which they claimed unique and rarely available household panel data.
for a long time period. In estimating farm efficiency, del Ninno, and Liu (2010)’s study is based on 960 rice farm households, those are spread over 64 villages. Overall observation reveals that there are few studies, using primary data. Difficulties and the lack of resources in collecting long term household panel data might be the reason why there are so few studies conducted on the agricultural production in Bangladesh using primary data.

TFP growth analysis of this chapter is divided into two parts. The first part deals with secondary data, and the second part uses a combination of primary and secondary data for empirical estimation. The following (first part) sub-section describes the secondary source data.

### 6.4.1 Secondary data sources

The data for the analysis are drawn from a longitudinal survey from 2009 to 2014 with the support of International Rice Research Institute (IRRI), Bangladesh’s Village Dynamics in South Asia (VDSA) data covering 6 major ecological zones (of 8 villages) for the period of 2009-2014. The logic of taking these databases in this study is these surveys are nationally representative\(^\text{14}\). In terms of ecology some areas are found to be favourable and some are unfavorable (ecosystems like flood prone, drought prone and costal). In order to get balanced panel data for a cohort of farm households, from the huge database of VDSA, only those farm households are chosen (a total of 159 respondents) for this study, who were interviewed in all the six consecutive years (2009-2014) of survey (shown in Table 6.3).

\(^{14}\) As, VDSA data is being used by government and donors to plan and direct funding, for example in Bangladesh’s 7th Five-Year Plan, the major programs of the International Rice Research Institute (IRRI) in Bangladesh and those of the Bill & Melinda Gates Foundation (IRRI, Bangladesh 2015).
Table 6-3 Secondary Data source for the study, 2009-2014

<table>
<thead>
<tr>
<th>Village</th>
<th>Agroecological zone (AEZ)</th>
<th>Agroecology</th>
<th>Number of respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darikamari</td>
<td>Level Barind Tract (AEZ 25)</td>
<td>Unfavourable-drought (low organic matter and limited nutrients)</td>
<td>21</td>
</tr>
<tr>
<td>Khudiakhali</td>
<td>High Ganges River Floodplain (AEZ 11)</td>
<td>Favourable (low soil fertility)</td>
<td>20</td>
</tr>
<tr>
<td>Bhabanipur</td>
<td>Middle Maghna River Floodplain (AEZ 16)</td>
<td>Favourable (medium fertility level)</td>
<td>21</td>
</tr>
<tr>
<td>Begumpur</td>
<td>Old Maghna Estuarine Floodplain (AEZ 19)</td>
<td>Unfavourable-drought (medium fertility)</td>
<td>22</td>
</tr>
<tr>
<td>Rasun Shimulbari</td>
<td>Active Tista Floodplain (AEZ 2)</td>
<td>Unfavourable-flood prone (low to medium fertility)</td>
<td>25</td>
</tr>
<tr>
<td>Konapara</td>
<td>Old Brahmaputra Floodplain (AEZ 9)</td>
<td>Unfavourable-drought (low fertility)</td>
<td>25</td>
</tr>
<tr>
<td>Nishaiganj</td>
<td>Madhupur Tract (AEZ 28)</td>
<td>Unfavourable-flood prone (low fertility)</td>
<td>5</td>
</tr>
<tr>
<td>Patordia</td>
<td>Madhupur Tract (AEZ 28)</td>
<td>Favourable</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>159</td>
</tr>
</tbody>
</table>


In addition to above mentioned secondary data, the following section describes primary data sources for the second part of TFP analysis.

6.4.2 Primary data source

The second part of analysis draws upon quantitative data collected from interviews on the farmers conducted by the researcher. Before going to the field, an extensive review of relevant literature was done to conceptualise the research questions pertaining to the output ($Y$), capital ($K$) and labour ($L$) variables. The research fieldwork was carried out in December 2015 for a period of two months. At the initial stage of the field work, a
series of informal discussion with academics, experts, and policy makers, national and international consultants was carried out. The assumptions, research questionnaire (for farmer interviews) were developed and sharped prior to going for field work. In the later stage, interviews were conducted by the researcher herself in two villages of Mymensingh district.

A survey was conducted for the crop year 2015 in Mymensingh district. Multipurpose sampling technique was applied to select respondents for the study. Firstly, considering the available secondary data sources in hand for current research, Mymensingh district of Bangladesh was selected purposively, as this study area is familiar to the researcher. A number of researches were carried out earlier by the researcher, and consequently she is accustomed with the agricultural practice in this area. After selection of District, Mymensingh Sadar upazila (sub-district) was purposively selected due to the convenience of communication from Bangladesh Agricultural University campus. Under this sub-district, two villages, Shutiakhali and Kashiarchar, were randomly selected for this study. The criteria of selecting sample household were: (i) households, whose occupation is crop production; (ii) households, located in diverse locations to ensure that the sample would be spatially representative. From those two villages, a total of 100 sample households were selected for the survey.

A draft structured of the interviews, containing both open-ended and closed-ended questions were developed, and those were shared with academicians and researchers. Open-ended questions were developed to address the household’s experience and opinion regarding accessibility to technological knowledge and production inputs. On the other hand, closed-ended questions were designed firstly, to collect information about the household’s demography and different socio-economic characteristics
(education, income, land holdings are some of those); and secondly, to collect information about farming activities. It received the formal approval of the Australian Human Ethics (AHE). Arm with the questionnaires (Appendix E), the researcher herself visited different households of the selected area and took their oral consent for taking information on their crop cultivation for 2015 year. The interview schedule had three broad sections: first section was designed to gather information about the household’s demography and different socio-economic characteristics such as age, education, land holding, relationship with different organizations; second section dealt with information on farming activities; third section of the questionnaire was developed to address the household’s interaction and experiences with government services regarding production and technologies. The reference period of the survey was January-March 2016 (at the middle stage of the research).

Considering the year 2009 to 2014, total observation is 30 (same household repeatedly interviewed each of the 6 years) from IRRI, Bangladesh data. In total, specifically for the study of Mymensingh district, it was 280 (180+100) observation all along seven years of data (2009 to 2015). It is necessary to mention here that households those were interviewed during 2009-2014 by IRRI, Bangladesh consecutively, the survey for this study (primary data) did not specifically cover those because of budget and time constraint. Two reasons of doing so are: i) to understand the productivity scenario with upgraded data (adding one more year, 2015) for one of the same agro-ecology of Bangladesh, and ii) to have a deeper understanding by personally being present in the field. A summary statistics of the variables used to calculate TFP growth is presented in Appendix J. Moreover, a details socio-economic condition of all the surveyed sample is elaborated in Section 5.3 of Chapter 5.
On the basis of above mentioned background, the next section attempts to empirically estimate average annual TFP growth in eight different villages of Bangladesh.

6.5 TFP growth estimation and results- part one

The determination of TFP would, in the first instance, require the coefficients of $\alpha$ and $1-\alpha$. By substituting these estimated coefficients together with the logarithms of growth of output $Y$, capital $K$, and labour $L$, TFP growth for Bangladesh agricultural output can be estimated using equation (6.4).

The area-wise and average decomposition of the TFP growth are also presented in Table 6.4. The results of TFP growth of this study are mixed. During the period 2009-2014, the annual average TFP growth of the crop sector is found to be at the level of 0.24 per cent. While this result cannot be compared directly with those in previous studies due to differences in areas of analysis, data used, and period examined, this result is consistent with previous studies such as those found in Table 6.1. The results (found in Table 6.4) of different villages suggest that the higher the value of $\alpha$, lower the TFP growth, reinforcing the proposition put forward by Taylor (2008) and others (Chen 1997; Dowling and Summers 1998; McGuckin et al. 1992), in that TFP growth is sensitive to different $\alpha$ values. Besides, the empirical results of TFP growth in diverse regions of Bangladesh show considerable variations (Table 6.4 and Figure 6.1), which is consistent with findings of earlier studies (as discussed in earlier Section 6.2). During the same period, in the villages Bhabanipur (an average TFP growth of 0.12 per cent per year, Begumpur (an average TFP growth of 0.31 per cent per year), Rasun Shimul (average
TFP growth of 0.30 per cent per year), Konapara (average TFP growth of 0.19 per cent per year), Nishaiganj (average TFP growth of 0.29 per cent per year), and Patordia (average TFP growth of 0.22 per cent per year), positive TFP growth are found.
<table>
<thead>
<tr>
<th>Villages</th>
<th>2009/10</th>
<th>2010/11</th>
<th></th>
<th>2011/12</th>
<th></th>
<th>2012/13</th>
<th></th>
<th>2013/14</th>
<th></th>
<th>Average</th>
<th></th>
<th>Value of α (TFP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\dot{y})</td>
<td>(\dot{k})</td>
<td>(\dot{l})</td>
<td>(\dot{y})</td>
<td>(\dot{k})</td>
<td>(\dot{l})</td>
<td>(\dot{y})</td>
<td>(\dot{k})</td>
<td>(\dot{l})</td>
<td>(\dot{y})</td>
<td>(\dot{k})</td>
<td>(\dot{l})</td>
</tr>
<tr>
<td>Darikamari</td>
<td>0.065</td>
<td>0.042</td>
<td>-2.074</td>
<td>-0.014</td>
<td>0.008</td>
<td>0.004</td>
<td>0.006</td>
<td>0.017</td>
<td>0.006</td>
<td>0.008</td>
<td>0.005</td>
<td>0.015</td>
</tr>
<tr>
<td>Khudiakhali</td>
<td>-0.003</td>
<td>0.013</td>
<td>-2.026</td>
<td>-0.006</td>
<td>0.043</td>
<td>0.019</td>
<td>0.071</td>
<td>0.015</td>
<td>0.010</td>
<td>-0.061</td>
<td>0.001</td>
<td>-0.008</td>
</tr>
<tr>
<td>Bhabanipur</td>
<td>0.057</td>
<td>0.055</td>
<td>-2.095</td>
<td>-0.018</td>
<td>-0.003</td>
<td>0.000</td>
<td>0.005</td>
<td>0.006</td>
<td>0.003</td>
<td>0.013</td>
<td>-0.003</td>
<td>0.004</td>
</tr>
<tr>
<td>Begumpur</td>
<td>0.048</td>
<td>0.065</td>
<td>-2.104</td>
<td>-0.024</td>
<td>0.014</td>
<td>0.012</td>
<td>0.011</td>
<td>-0.022</td>
<td>-0.018</td>
<td>0.014</td>
<td>0.016</td>
<td>0.021</td>
</tr>
<tr>
<td>Rasun Shimul</td>
<td>0.068</td>
<td>0.040</td>
<td>-2.083</td>
<td>-0.014</td>
<td>0.027</td>
<td>0.020</td>
<td>-0.013</td>
<td>0.001</td>
<td>-0.003</td>
<td>0.027</td>
<td>-0.005</td>
<td>0.007</td>
</tr>
<tr>
<td>Konapara</td>
<td>0.080</td>
<td>0.064</td>
<td>-2.103</td>
<td>-0.016</td>
<td>0.021</td>
<td>0.010</td>
<td>0.026</td>
<td>0.009</td>
<td>0.004</td>
<td>-0.009</td>
<td>-0.009</td>
<td>-0.008</td>
</tr>
<tr>
<td>Nishaiganj</td>
<td>0.068</td>
<td>0.041</td>
<td>-2.081</td>
<td>-0.036</td>
<td>0.004</td>
<td>0.008</td>
<td>-0.027</td>
<td>0.007</td>
<td>-0.034</td>
<td>0.066</td>
<td>-0.006</td>
<td>0.012</td>
</tr>
<tr>
<td>Patordia</td>
<td>0.066</td>
<td>0.061</td>
<td>-2.081</td>
<td>-0.039</td>
<td>0.002</td>
<td>-0.005</td>
<td>0.003</td>
<td>-0.002</td>
<td>0.010</td>
<td>0.037</td>
<td>0.014</td>
<td>-0.004</td>
</tr>
<tr>
<td>Average</td>
<td>0.056</td>
<td>0.048</td>
<td>-2.081</td>
<td>-0.021</td>
<td>0.015</td>
<td>0.009</td>
<td>0.010</td>
<td>0.004</td>
<td>-0.003</td>
<td>0.012</td>
<td>0.002</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Source: Authors analysis of IRRI, Bangladesh (2009-2014) data.

Hence, \(\alpha\) value calculation is shown in Appendix H, page XXI.
The overall findings suggest that agricultural output growths in all those villages are TFP driven. Based on the Solow (1956, 1957) growth accounting framework, this type of growth is sustainable until the point in time when the capital and labour ratio arrived at the point of the steady-state as discussed in Chapter 2. Food insecurity is unlikely to be threatened at this state of production in those study areas.

Variation in average TFP growth rate per annum among different regions is evinced in a number of earlier studies; and those identified a number of probable causes in this regard. For example, using national level secondary data of 16 regions of Bangladesh, covering period 1970 to 1985, Alauddin and Tisdell (1991) identified variation in irrigation infrastructure, land ownership and land tenurial arrangement among different districts as causes of variation in TFP growth performance. Moreover, Alauddin and Hossain (2001) identified differences in the pattern of modern input use, as a major cause of regional variations of productivity growth in Bangladesh. Studies of Coelli, Rahman, and Thirtle (2003) and Rahman (2007) found highly variable TFP growth performances over time (during 1961-1992), and across regions (16 different regions); hence the TFP performance is found led by regions with high level of Green Revolution technology diffusion. Thus, it reveals that there are a number of identified probable causes behind regional variation in TFP growth performance.

In a same way, it can be argued that there might be a number of possible causes for variation in TFP growth performance among different villages of this study. Discussion of this chapter turns now to a closer reconsideration of the TFP growth regarding the location-mix of rural production practice.
6.6 Revisiting salient aspects of variation in TFP growth

The study areas cover eight villages; those are located in six different agroecological zones (in two cases, two villages are common in one AEZ) of Bangladesh (mentioned earlier in Table 6.3). Village Khudiakhali, situated in the High Ganges River Floodplain (AEZ 11) zone, has a favourable agroecology. Therefore, the favourable agroclimatic condition along with available technology may have helped it to achieve the highest average TFP growth among the other villages. Moreover, village Patordia, which is located in a favourable ecosystem, productivity growth is also found to be technology driven (due to a positive average annual TFP growth). However, despite having favourable agroecology, village Darikamari, experienced the lowest average annual TFP growth in this study.

By contrast, village Begumpur, located in the Middle Meghna Flood prone (AEZ 16) zone, with an unfavourable agroecology, has the second highest average annual TFP growth performance. Similarly, the village of Konapara also performs well in terms of average annual TFP growth, despite being located in an unfavorable drought agroecology. It could be that farm householders of those villages are able to overcome the constraint of unfavourable agroecology with technology (as proxy by annual average TFP growth) and other related factors (will be discussed later). Thus, the annual average TFP growth results are not only responsive to the agroecological conditions but to other factors as well.
Referring back to Table 4.4, page 128 (also earlier discussion in Chapter 4), the cropping intensity of the study areas varies between 45 and 230 per cent. It is well-known that high cropping intensity is a sound indicator for high productivity in agricultural production. If this is to be the case, there should be a positive relationship between TFP growth and cropping intensity. However, not all the villages studied show this positive relationship. For instance, the highest cropping intensity is found in village Darikamari, and the lowest is in village Nishaiganj. The average annual TFP growth is found to be the lowest in the former (average 0.14 per cent per year) village as compared to all the other villages in this study, suggesting a weak link between cropping intensity and average annual TFP growth. Yet the positive relationship between cropping intensity and productivity (TFP growth) seems to hold in the village Rasun Shimul. The cropping intensity is 225 per cent in village Rasun Shimul, and the TFP performance is impressive (average 0.30 per cent per year, the second highest). Apart from the aforementioned three villages, cropping intensity of all the other villages is more or less high, a very common scenario of Bangladesh. Having 165 per cent and 176 per cent of cropping intensity in village Bhabanipur, and Patordia respectively, TFP growth during the study period is showing positive signs, averaging 0.12 per cent per year and 0.22 per cent per year correspondingly. As the cropping intensities of eight different villages are high or satisfactory and the TFP growths are positive, it is conceivable to argue that there could be a positive relation between TFP performance and cropping intensity.

The use of irrigation in crop production is an important indicator of technology adoption, as it reflects cropping patterns, and cropping intensity. Irrigation technology in villages is also presented earlier in Table 4.4, page 128, in Chapter 4. Irrigation as a percentage of cropped area ranges between 43 (in village Darikamari) and 144
village Nishaiganj) per cent. As mentioned earlier, in the latter village, the unusually high percentage of irrigation coverage is due to fish farming (with higher irrigation demand), which is more exclusively practiced than crop production. Thus, this high irrigation coverage does not matter for crop production in the concerned village. Irrigated crop production scores the highest in the village of Khudiakhali (average 84 per cent per year), which has the highest average annual TFP growth performance also. A similar situation is observed in village Begumpur, where the second highest irrigated crop production (61 per cent), average annual TFP growth is also the second high in ranking. In all other villages, irrigation coverage in crop production shows moderate rates (ranging between 44 and 61 per cent). Therefore, to some extent, a positive relationship seems to appear between irrigation coverage and average annual TFP growth.

**Figure 6.1 Village wise annual TFP growth in percentage (2009-14)**

![Figure 6.1 Village wise annual TFP growth in percentage (2009-14)](image)

Source: Author’s own calculation of IRRI, Bangladesh (2009-2014).
In addition to irrigation, adoption of high yielding crop varieties and hybrid technology are good indicators of technology advancement. In almost all villages, in addition to local varieties, high yielding crop varieties are cultivated. However, in terms of hybrid technology, not all villages are ready enough to adopt; for example, in villages Nishaiganj and Darikamari, hybrid seed technology are not adopted yet. However, in terms of high yielding varieties, the question is still remains whether farmers are getting and adopting the suitable high yielding variety for their region (for example drought tolerant, submergence tolerant rice variety).

Crop diversity varies between villages. Among all study villages, in village Nishaiganj only two crops (the lowest in number) are grown in a year, whereas 15 (the highest in number) crops are grown in village Khudiakhali. As mentioned earlier, average annual TFP growth in village Khudiakhali is the highest. In the village of Darikamari, only six crops are grown in a year, and average annual TFP performance of this village is the lowest. In five other villages, on an average, eight to nine crops are grown round a year, with moderate levels of TFP growth. Therefore, it could be postulated that, crop diversity could be a positive driver for higher TFP growth.

Agricultural land size can have a significant impact on the average annual TFP growth. Household owned land varies between 0.25 (in village Rasun Simul) and 0.58 (in village Konapara) hectares (discussed earlier in Table 4.4 of Chapter 4). Farmers have large land holdings in their own in the village of Khudiakhali, where average annual TFP growth are the highest. With smaller areas of owned land, in villages Patordia (0.33 hectare/household), Darikamari (0.26 hectare/household) and Bhabanipur (0.34 hectare/household), lower average annual TFP growth performance are found. Thus, the analysis suggests that there is a positive correlation between land size and ownership,
and average annual TFP performance. A further investigation is required to check whether householders could manage their total operated area by rental arrangements (renting in and out, mortgaged in and out) and thereby enjoy better TFP growth.

Total operated area, after land rental arrangement, stands at, and varies between 0.26 (in villages Patordia and Nishaiganj), and 0.49 (in village Khudiakhali) hectares per household. Recalling data of Table 4.4, page 128, of Chapter 4 shows that in village Patordia, Nishaiganj, Konapara and Khudiakhali, after land rental arrangement, per household cropped area became less than owned land. For instance, in villages Konapara and Khudiakhali, through rental arrangement, operated area decreased from 0.58 to 0.47 hectares/household; and from 0.56 to 0.49 hectares/household respectively. The estimated average annual TFP growths are found in those two villages at 0.30 and 0.38 (highest) per cent per year respectively.

On the other hand, in village Rasun Shimul, Darikamari, Begumpur, and Bhabanipur; the scenario of operated land area is completely opposite. For instance, in village Begumpur, after rental arrangement, operated area is increased (from 0.33 to 0.34 hectares/household) and estimated TFP growth is also found at a high level (average 0.34 per cent per year). Thus, operated area, after land rental arrangement, does not show any significant influence on TFP growth. Therefore, land rental arrangement for settling operated/cropped area is not a significant strategy for better technological performance.

In an earlier presented Table 5.8 in Chapter 5, page 152, shows that agricultural extension agents from government department are not a popular option for source of information to the farmers in the different villages (overall preference score in terms of ranking is 5 out of 11). As such, the Government needs to pay attention in
strengthening field-level extension services, either through public sector service, or by promoting private extension system. Moreover, respective government regional level extension departments need to design respective extension strategy considering the topography of soil and socioeconomic condition of respective area. Although, it is difficult (also not the nature of this study) to trace directly the impact of the capacity of the government department in the villages to TFP growth performance, however, it is possible to trace such impact indirectly through improvement made to the transmission of useful and meaningful knowledge on agricultural production to the farmers. Transmitting useful and meaningful agricultural production techniques successfully to the farmers could in turn improve agricultural production. The capacity of the farmers to be able to absorb new farming techniques, in turn, hinges on their education levels.

Education level in almost all villages is quite satisfactory. Data shows from Table 5.5 that literacy rate among respondents of study areas varies between 62 per cent (in village Konapara) and 92 per cent (in village Begumpur). Having high level of literacy, in villages of Begumpur (average 92 per cent per annum), Khudiakhali (82 per cent), Rasun Shimul (average 78 per cent per annum), and Nishaiganj (average 78 per cent per year); average annual TFP growth are found to be positive. Thus, it seems, there is a positive relationship between high literacy rate and TFP growth performance. Literate farmers are able to adopt new farming technology, and also to contribute through “assimilations” of modern farming techniques (as discussed in Chapter 2). Regarding age factor, irrespective of villages, male and female population between age group 15-59 are dominant, who are active in terms of income earning for their families (evidenced from Table 5.5). Due to limited variation in age and sex groups among
villages, it is not easy to identify probable relationship of these two factors with annual average TFP growth.

Considering all factors as discussed earlier, there are reasons to believe that household owned land, irrigation facilities, cropping intensity, crop diversity, and literacy rate could impact positively on average annual TFP growth.

6.7 TFP growth estimation- part 2

The analysis of part of the chapter is based on primary data covering the period 2015, and secondary data covering the period 2009 to 2014. Irrespective of villages, data of Mymensingh district is taken into consideration. Following the same accounting method found in Part 1, this analysis for part 2 begins the estimates with working out the relative share of capital ($\alpha$) and labour ($1-\alpha$) to total agricultural output ($Y$). This is shown in Table 6.5.

6.7.1 Empirical results and discussion

Following the same method and same data covering up to the 2014 period and incorporating the update from the primary survey data of the 2015 period, the average annual TFP growth for the Mymensingh district (covering average of villages Konapara and Nishaiganj) was calculated. The average annual TFP growth is found to be 0.46 per cent. It shows a positive change and sign suggesting a productive agricultural practice ensuring food sustainable security for this district.
Table 6-5 Estimated value of labour, capital, output and TFP growth in Mymensingh district (in per cent per year), 2009-2015

<table>
<thead>
<tr>
<th>District</th>
<th>2009/10</th>
<th>2010/11</th>
<th>2011/12</th>
<th>2012/13</th>
<th>2013/14</th>
<th>2014/15</th>
<th>Average</th>
<th>Average α</th>
<th>TFP growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mymensingh</td>
<td>0.067</td>
<td>0.051</td>
<td>-2.081</td>
<td>-0.037</td>
<td>0.003</td>
<td>0.002</td>
<td>-0.012</td>
<td>0.052</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Source: Analysis of IRRI, Bangladesh (2009-2014) and field survey data for the year 2015.

Note: α value calculation is shown in Appendix H, page XV.
6.8 Revisiting TFP growth related salient aspects of Mymensingh district

Discussion of this section is based on primary data and the personal observations of the researcher. In both the primary source villages, Shutiakhalil and Kashiarchar, of Mymensingh district, roads and transport facilities are quite satisfactory. It is found to be very convenient to go to distant markets with readily available relatively cheap automobile services. Those services are cheap to utilize. Even in village Kashiarchar, located close to the Bangladesh Agricultural University (BAU) campus, householders did not complain about the transportation inconveniences. Regular motorised boats are available to transport agricultural inputs and outputs. However, they face problems transporting heavy machinery, and that might be the reason behind less mechanization in farming in that village. However, in terms of infrastructural facilities, both villages are adequately served.

Agroecologically, those two primary data source villages are located in the Old Brahmaputra Floodplain (AEZ 9) zone with unfavourable drought agroecology. Earlier it was found that Mymensingh district achieved a 0.34 per cent TFP growth per annum (average of earlier estimation of TFP growth for villages of, Konapara and Nishaiganj) for the period of 2009 to 2014. Average TFP growth for the period of 2009 to 2015 is found to be 0.46 per cent per annum. Despite drought, soil is fertile in this region, and the TFP growth result shows technological progress of this district is driving crop output in a sustainable manner.
Irrigation facilities, to some extent, are completely mechanised in the study areas. Few farms were found to be dependent on surface irrigation from the river, and adjacent water reservoirs. Regarding ground water irrigation, farmers rent irrigation facilities from the concerned service providers on a fixed term basis. However, farmers were not familiar with the Alternative Waiting and Drying (AWD) or similar type water saving sustainable irrigation practices. Perhaps, the expansion of the irrigation system to the drought prone area of the Mymensingh district could help to further improve the average annual TFP growth of this district.

Like other parts of the country, in the study areas most farms are small and medium in size (earlier discussed in Table 4.6, page 130 of Chapter 4) and scattered all over the district. Like the villages discussed in Part 1, farmers of this study area practice land rental arrangements to make convenient sizes for farming. However, whatever strategies they follow, farm size remain below the optimum for applying mechanized techniques, and not a viable livelihood option; this is a common scenario in rural Bangladesh. Farmers reported inadequacy of labour at the peak season of cropping as a great problem, and expressed a desire for mechanization. They urged for smaller machines, instead of big machinery, suited for their farming operation on smaller crop plots. Therefore, government needs to prioritize research and investment in the development and popularisation of small machines that meet local farm demand. In relation to this, government policy support needs to be strengthened the capacity of local agricultural machinery workshops.
Farming is not the sole occupation for 60 per cent of farmers. In addition to crop production, the remaining (40 per cent) has non-farming occupations for their livelihood. Relying only on crop production for their livelihood is not a viable option. However, most farmers prefer to continue farming as it warrants a valuable contribution to meeting family food demand.

Almost all farmers in the study area are aware of the importance of using the latest production technology. Mostly (in 65 per cent cases) they get knowledge about technological management from their neighbours and friends who have better access to technological information. As the study area is located nearby to the BAU campus, many of the villagers work as casual labourers in different experimental farms of the university. A few are employed as permanent employees, and have good interaction with relevant technical staff, and the outreach facilities of the university. Thus, the location is convenient in facilitating the spread of technological information. However, about 69 per cent of farmers were not happy with the government extension services. About 8 per cent of the respondents confirmed that they received technical training on seed production from the Department of Extension (DAE), and 11 per cent farmers had obtained training from the research projects of BAU. The respondents mostly prefer Farmers Field School (FFS, that was identified through interactive discussion in the survey) type training from the extension service providers, that enables them to acquire the necessary knowledge and skills by more participation and interaction. Moreover, contract farming and field demonstration plots are also a convenient extension strategy. Farmers were not however, generally aware of sustainable farming techniques, such as conservation (minimum tillage), and the use of organic fertilizer.
Recent rises in temperature and extreme weather events have posed challenges for farmers. They are mostly interested in short duration crops to cope with the threat of flash floods, tornedoes and cyclones. Farmers of the study villages, for a long time use to produce the same BRRI dhan (Bangladesh Rice Research Institute developed rice variety) 28 and 29 varieties. Although scientists are discouraging the cultivation of the same varieties year after year, as there is threat of losing biodiversity, farmers are not practicing it due to unawareness. Also, due to the higher cost of irrigation, 80 per cent of the respondents desired less water demanding crop varieties. Therefore, respective government departments and research stations need to take these issues into consideration in designing research policy.

6.9 Conclusion

This study is a first step towards research on crop producing householders of regional Bangladesh. This research approach applies regional-level data and provides new empirical evidence regarding the productivity (as captured by TFP growth) of the agricultural sector in Bangladesh over the period from 2009 to 2015. In doing so, the literature on sustainable food production driven by productivity growth is extended further. This chapter found that there are variations in average annual TFP growth among villages of different agoeological zones of Bangladesh. Although some possible reasons to account for the variations are provided in this chapter, they covered only a small constituent of what is best though to be driving agricultural output in Bangladesh. Hopefully, the findings and suggestions of this chapter will provide some additional basis for rich future studies.
By utilizing primary source data, this chapter updates and contributes to the existing pool of agricultural TFP growth estimation in Bangladesh. It helps to deepen the understanding on the socio-economic and agroecological condition of rural farmers in respect of technology adoption. The overall findings suggest that agricultural output growths in all those study villages are TFP driven. Based on the Solow (1956, 1957) growth accounting framework, the estimated agricultural TFP growth suggests that food production practices in different study areas are sustainable until the point in time when the capital and labour ratio arrived at the point of the steady-state as discussed in Chapter 2. Food insecurity of food producing householders is unlikely to be threatened at this state of production in those study areas. A summary of research findings and policy implications are further discussed in Chapter 7.
Chapter 7  Summary, Policy Recommendation, and Conclusions

7.1  Introduction

The central aim of this thesis is to investigate the effects of TFP growth on the foodgrain producing sector in Bangladesh, taking particular note of the changing policy environment over the period. This thesis has estimated the impacts or relationships between productivity and long-run sustainable output growth, using the growth accounting framework pioneered by Solow (1956, 1957). In examining the process of technological change this study has employed a blend of secondary and primary farm-level evidence for different regions of the country. This concluding chapter firstly revisits the objectives of this thesis. Then the chapter summarizes the main findings of the study, then outlines policy implications, and finally provides directions for further research.

7.2  Summary of key themes

Food security is a major global concern. The number of undernourished people is alarming, and in most areas, they are overwhelmingly dependent on agriculture for their food and livelihoods. The severity of food insecurity varies widely across regions and countries, related in large part to population size. One means of addressing this issue is to increase the food supply locally (domestic) by improving agricultural productivity. While the demand side of food security can be met by increasing agricultural...
productivity, food supply is facing tightened constraints on natural resources and increasing climate variability and can be ameliorated by sustainable agricultural production practices. Considering the aforementioned facts for a particular region - South-Asia and a particular country – Bangladesh – the situation was further investigated in this thesis.

The agriculture sector of Bangladesh has experienced a significant change since independence in 1971. Technological advancements, along with government policy initiatives, contributed significantly to this achievement (as discussed in Chapter 3). However, Bangladesh faces formidable challenges to feed a growing population (Alauddin and Hossain 2001). With about 2.19 per cent of the world population on 0.029 per cent of the world’s land area, the country has severe population pressures on land and other natural resources (Kumar, Mittal, and Hossain 2008; Rahman 2007). The agriculture sector has to produce food for 163.65 million people from merely 8.75 million hectares of agricultural land (59 per cent arable land). The topography and soils, water and land resources critically influence the complex physical and environment surrounding Bangladesh agriculture (Alauddin and Hossain 2001). Increased crop production intensification far beyond the current level is the only option to increase the effective supply of food for the severely land constrained Bangladesh. Technological progress, including greater use of chemical fertilizers and pesticides, has contributed to the crop output growth. However, intensification of agricultural production puts resources under considerable strain (Jahan 1997) and poses a threat to sustainability. In this situation, further technological progress can, therefore, play an important role in addressing the challenges of feeding the huge population, given tightening constraints on natural resources and increasing climate variability.
Successive Bangladesh development plans have aimed to achieve food self-sufficiency, which is a prerequisite for a country which has a subsistence nature food production system and for which the food production sector is a large part of the national economy (Talukder 2005). Over the years, through technological progress the supply of cereal food items has kept pace with rising aggregate demand. However, the direction of technological progress has led to the crop sector of Bangladesh becoming a virtual rice monoculture, at the expense of non-cereal crops; the most important manifestation of the process is production intensification that has resulted in lower import intensity of food. As well, due to increasing climatic variability the country faces considerable variations in foodgrain production and fluctuations in production performance, and therefore still requires considerable quantities of food imports. Consequently, in an effort to maintain food availability, the import intensity of food grains has strained the country’s balance of payments.

Land ownership is of central importance to the social, political, and economic life of rural householders in Bangladesh. The process of growing landlessness and near-landlessness has not only marginalised rural peasantry but also made the poor increasingly dependent on wage employment for their subsistence (Alauddin and Hossain 2001). Thus the access of the rural poor to land resources is becoming increasingly limited (Alauddin and Tisdell 1991) and the number of landless, small and marginal farmers has dramatically increased. It is beyond the capacity of the crop producing sector to absorb the bulk of landless farmers (Rahman 1998).
The land reform policies of Bangladesh, that were initiated during the 1970s primarily emphasised the redistributive aspects of rural land management. During the 1980s, policy initiatives were formulated mainly to safeguard the interests of sharecroppers. Both these policy initiatives, ignoring the issues of land record keeping, registration, and land administration procedures, were not fully successful. Since 2000 there has been much talk among researchers about effective national land policy through embracing productivity and equitable land distribution. Consequently, the National Land Use Policy 2001 was formulated to reform the system of land administration and related laws; preserve and optimize the use of agricultural land; make suitable government-owned land available for development projects; reduce soil degradation; and establish a data bank for various categories of land. However, there is, as yet, no visible impact of the policy initiative on the living standards of the rural population.

Empirical research by Rahman (2010a) showed that redistribution of land from large farms to marginal and landless farmers would leave each landless household with only 0.21 ha of land, which is unviable as a livelihood resource. Due to this, Alam et al. (2014) suggested undertaking land reform measures aimed at increasing farm size by land consolidation. Rahman and Rahman (2009) and Alam et al. (2014) recommend addressing the structural causes of land fragmentation, through modification of the law of inheritance and regulations. In this research, it can be argued that government policy support is required to maintain an effective land rental market which can be a convenient option for optimizing farm size.
National level research and development efforts, complemented by efficient extension services, can help with the generation and diffusion of technology. Thus, both agricultural research systems and extension services are crucial for agricultural development. Gains in agricultural productivity result from technological progress, which critically depends on research. Resource allocation to these two sectors is almost never sufficient in developing countries, like Bangladesh. Moreover, there is evidence of a lack of communication and coordination among government departments. Bangladesh needs to enhance its research capability to generate technologies consistent with socio-cultural endowments and agro-ecological conditions (Alauddin and Hossain 2001). Inadequate linkages between research and extension hinder increased efficiency in farm production. Despite tremendous progress in commodity based agricultural research, an effective location specific research approach needs to be prioritized in the face of diversified agroecologies across regions. Further, there is wide variation in physical, social and economic variables influencing the farming system. A thorough understanding of those critical environments will help in developing appropriate technologies. The government of Bangladesh urgently needs to strengthen location specific on-farm based research.

7.3 Empirical estimation and major findings

Solow (1956) emphasized the importance of technological progress in the production of output. Accordingly, production approach that is based on using more inputs will never be sustainable in the long run, as this type of production approach is subjected to the constraint of diminishing returns. To avoid this constraint, it requires effective technological advancement. TFP is used widely as a proxy for technological progress, because it provides a broad indication of how efficiently farmers combine all market inputs
to produce total output. This approach can be applied to any specific sector of the economy, and agriculture is no exception. In the agriculture sector, however, the use of Solow (1956)’s TFP measure is very limited due to data unavailability or unsuitability. This study used household data for medium-term (7 years) to provide a unique measure of productivity growth for Bangladesh agriculture. The contribution of this study to the existing research field is not only in terms of empirical estimation of crop productivity (in terms of TFP) growth of applying a unique method, but also for relating TFP growth as a proxy indicator of household food security. Until now, no study had systematically addressed the issue of agricultural productivity as a determinant of domestic food availability and accessibility in ensuring sustainable food security of Bangladesh. The current research adds to the growing literature which examines crop productivity for sustainable food security.

From the empirical estimation, different levels of TFP growth have been found in different study areas. Overall findings suggest that output growth in all those villages is technology (with positive TFP growth) driven, and sustainable in terms of food security, based on the Solow (1956)’s growth accounting framework until the point in time when the capital and labour ratio arrives at the steady-state. Food insecurity is unlikely to be threatened at this state of production in those study areas of Bangladesh.

7.4 Policy implications

Higher TFP growth in agriculture is desirable, as it is a fundamental precondition to sustain the sector. Moreover, the potential role of agriculture in enhancing food security cannot be materialized without concerted and purposeful policy action that is aligned
with the TFP growth of Bangladeshi agriculture. These issues point to the needs for programs and policies that boost agricultural productivity.

Achieving the goal of having similar TFP growth level across the regions may be difficult, in a large part, due to the inescapable nature, and environmental differences across regions. Moreover, the rate of technology adoption is not the same in different regions of the country. Therefore, to some extent, agricultural research and development (R&D) policy might not completely served in bridging the gaps in TFP levels, but may still achieve converging TFP growth rates across regions by influencing the public and non-local nature of agricultural technological change and innovations. Allocation of public agricultural R&D funds requires prioritizing research programs that have general (non-region specific) applications. In addition, a part of funds needs be reserved for the specific needs of lagging, or marginal agriculture regions.

Regional variability in TFP performance is observed in the current study, which implies this is partially due to variations of agro climatic condition across the regions. Therefore, location specific technological innovation is desired. For this purpose, saline tolerant, submergence tolerant, drought tolerant, and short duration crop variety development is required. Moreover, government needs to prioritize on-farm research, rather than commodity-based research to develop suitable cropping patterns in a specific location. In addition to technology development, a strategic technology dissemination policy initiative is obligatory. Effective monitoring of the agricultural extension services is also required. It can be argued that policy focus on improvement in location specific extension services, introduction of incentives to encourage young, able, and educated individuals with basic education to go into farming, and the introduction of robust training program for farmers on the usage of modern technology.
Due to variations of market facilities, access to technological inputs (seed, fertilizer, equipment is some of those) varies across regions. There is a need to develop an effective supply chain for agricultural inputs. Although the government appoints authorized dealers to deliver seed, and fertilizer to villages, greater monitoring is needed to ensure the best input marketing service. As an immediate strategy, to save the farmers from exploitation by the market participants, the marketing and distribution must be properly organized to derive maximum benefits from the subsidy policy currently in place. Government needs to increase the supply of inputs not only for rice cultivation but also for the agriculture sector as a whole.

Policy needs to facilitate farmers to achieve efficient farm size by creating in an effective land rental market to maintain convenient farm size for crop production. Research innovation needs to be focused more on small scale farming units so that it suits the common farming structure of farm householders. For example, innovation of small and handy machinery for seeding, weeding, spraying, harvesting, and other agricultural operations.

A facilitating environment is required for sustainable intensification of natural resources. In addition to development of super high yielding varieties (better than modern high yielding varieties), it requires resource conserving, and environment protecting technologies. Popularizing and awareness building about Integrated Pest Management (IPM) technology, Leaf Colour Chart (LCC) technology, conservation (minimum tillage) technology, alternate waiting and drying (AWD) irrigation technology, can be some of those efforts.
Together all the policy efforts will help in facilitating TFP growth over time, which ultimately supports to maintain household level sustainable food availability and accessibility. This has substantial impacts on agricultural policy making as well as implementation mechanisms for food policy of Bangladesh.

7.4.1 The implications of the Study: beyond Bangladesh

This thesis attempted to understand empirically the implication of crop productivity growth on food security in Bangladesh. Not surprisingly, although this thesis draws on the Bangladesh case, it does not mean that the findings do not have implications that extend beyond this case study. It is likely that this thesis has implications particularly for many South-Asian countries, where many countries are struggling to maintain sustainable food security with severely resource constraints. The implications can be summarized as follows:

Despite risk of generalization, many of the in countries in Asia and Africa, which are resource constrained, are poor and food insecure. In order to explore the problems of food security mechanisms of those nations, the existing literature mainly focuses on policy and agricultural production issues. By going underneath the surface, this study has shown how empirical economic performance can demonstrate the status of sustainable food security status of regional levels of Bangladesh. Thus, the analytical framework of the present study could also be useful for examining the situation of food insecurity in other food-insecure countries in other regions of the world.
7.5 Limitation and directions for additional research

This thesis has attempted to empirically examine the role of technological progress on food security in Bangladesh using the Solow growth accounting approach. However, there was some limitation in the study. Based on the findings and limitations of this study, there are five areas which could be proposed for further research: (i) covering the agriculture sector as a whole; (ii) assessing food security in a holistic way; (iii) national level food security analysis; (iv) direct assessment of household food security; and (v) quality of household data. Following discussions addresses limitations and proposals for further research in this field.

Firstly, in order to understand the role of sustainable food production practices using appropriate agricultural technologies in Bangladesh, this thesis exclusively delved into the crop sub-sector, excluding fisheries and the livestock sub-sector. All sub-sectors have crucial roles in ensuring food self-sufficiency, so the present study could be extended to covering all sub-sectors.

Secondly, food security is a multidimensional issue. In order to understand the role of crop productivity growth on food security, this research only covered food availability, accessibility, and sustainability. Even in availability dimension, leaving out food imports and food aid, only domestic food production was focused. Hence, this study acknowledges that in order to understand fully the issue of food security in Bangladesh, additional insights may be gained from examining the other dimensions of food security (utilization, stability and vulnerability), and their various determinants. With the given framework of this research, other dimensions of food security can be examined in future research.
Thirdly, using only household level analysis, such as that conducted in this thesis, is unavoidably a limitation of this study. Additionally, an arduous understanding of the TFP growth of the agricultural sector obliges focus on national level analysis for cross-checking the contribution of TFP growth in maintaining national food security of Bangladesh. To this end, further researches are needed to examine the macro level analysis. Such complementary studies are particularly important for food and agricultural policy development under the Sustainable Development Goal- 2 of the United Nations. Furthermore, this research draws on international literature on food productivity growth in the adversely affected regions of the world, particularly the food security and TFP growth literature.

Fourthly, this study undertook household level crop productivity (TFP) growth analysis; with interpretations made on a regional performance basis. Inevitably, this approach raises another limitation of the present study. Specifically, in this study, crop productivity growth is taken as an indirect indicator of food security; a more complete understanding of food security will benefit from using a direct approach. Therefore, a rigorous understanding of the role of the crop productivity growth in achieving food security, demands additional focus on other directly related issues; such as household food consumption pattern, nutrition status, and gender dimension issue.

Finally, productivity analysis on a developing country, like Bangladesh, was very challenging. Because, in Bangladesh, farmers do not keep record in black and white and rely on their memory which is a significant hindrance to access towards gathering complete information on annual crop production. More intensive and long run data collection will help to recover such limitation of future research.
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Appendix A Location of Bangladesh
Appendix B  List of Agro-Ecological Zones of Bangladesh
## Appendix C  Area and map of study areas (secondary data sources)

<table>
<thead>
<tr>
<th>Study area</th>
<th>Map</th>
</tr>
</thead>
</table>
| District: Kushtia  
Upazila: Alamdanga  
Village: Khudiakhali |     |
| District: Bogura  
Upazila: Shahjahanpur  
Village: Darikamari |     |
| District: Comilla  
Upazila: Barura  
Village: Dakshin Bhabanipur |     |
| District: Chandpur  
Upazila: Uttar Matlab  
Village: Begumpur |     |
### Study area

<table>
<thead>
<tr>
<th>Study area</th>
<th>Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>District: Kurigram</td>
<td></td>
</tr>
<tr>
<td>Upazila: Fulbari</td>
<td></td>
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<tr>
<td>Village: Rasun</td>
<td></td>
</tr>
<tr>
<td>Shimulbari</td>
<td></td>
</tr>
<tr>
<td>District: Mymensingh</td>
<td></td>
</tr>
<tr>
<td>Upazila: Haluahgat</td>
<td></td>
</tr>
<tr>
<td>Village: Konapara</td>
<td></td>
</tr>
<tr>
<td>District: Mymensingh</td>
<td></td>
</tr>
<tr>
<td>Upazila: Bjaluka</td>
<td></td>
</tr>
<tr>
<td>Village: Nishaiganj</td>
<td></td>
</tr>
<tr>
<td>District: Narsingdi</td>
<td></td>
</tr>
<tr>
<td>Upazila: Monohardi</td>
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<tr>
<td>Village: Patordia</td>
<td></td>
</tr>
</tbody>
</table>

Source: Bhandari et al. (2013).
Appendix D  Cropping pattern of Bangladesh

Source: GOB 2015b.
Appendix E Literature survey on TFP growth

During empirical accounting or estimation, technological progress in the Solow (1956) model can be captured by TFP. Briefly, output growth can either be driven by increasing factor inputs (capital and labour), or by increasing the productivity of both (total) capital and labour (hence, TFP, as a proxy for technological progress). In other words, it is possible to increase a country’s GDP growth rates either by employing more capital and labour, or by using capital and labour more efficiently. The production approach that is based on employing more capital and labour will not be sustainable in the long run as this type of production approach is subject to the constraint of diminishing returns.

Growth in TFP is sometimes also referred to as the Solow (1956)’s residual. Most often, the Solow (1956) residual has been referred to as innovation, efficiency, technological progress, or economies of scale (Cornwall 1987). Intuitively, TFP (being a broad, all-inclusive definition of technology) growth figures provide a rough measure of the economy’s capacity to escape the constraint of diminishing returns. As such, it can be a useful tool for monitoring the state of the economy. A positive TFP growth suggests that growth is productivity or technology driven, and this type of growth is sustainable in the long run. In reverse, a minimum or negative TFP growth suggests an accumulation (capital and labour) process, and therefore is not sustainable. In this case, it requires incentives to increase activities those are associated with advancement of technology such as, human capital accumulation, research and development (R&D), or the expansion of the education system in a manner, suggested by the new or endogenous growth theorists (Aghion, P., and Howitt, P. 1992; Crafts 1997; Grossman and Helpman 1990, 1994; Romer 1987, 1993, 1994).
The Solow growth model has been extremely popular in examining the growth process of the developed countries, but the same cannot be said for the developing world. Although from time to time, books and academic journal articles using the neoclassical growth accounting approach did surface to explain economic growth in East Asia, the numbers have remained small, and often skewed towards a small group country, primarily Taiwan, Japan and Hong Kong. It was only in the mid-1990s that interests in quantifying the impact of technological progress on the growth of East Asia began to intensify. Spurred on by the publication of the World Bank (1993)’s “The East Asian Miracle”, economists began to take the growth performance on this part of the world more seriously. Why did it take economists so long to gain an interest in quantifying the impact of technological progress on the East Asian growth performance? Perhaps it made little sense in carrying out empirical studies to find what was thought to be the obvious, in that the “development gap” is simply a “technological gap”. If this small group of initially economically and technologically backward countries were able to converge to the per capita income of the developed nations, it was only because they were able to narrow the “technological gap” and hence close the “development gap”.

Prior to the publications of two influential works by Kim and Lao (1994) and Young (1992, 1994), it was often thought that technological progress (productivity growth) had played a big part in driving the rapid growth of the East-Asian economies. When Young (1992) presented his findings to the European Economic Association in 1993, his conclusion, that output growth in this part of the world was an accumulation process, was not well received. It is not hard to see this as a visitor to, for instance, Singapore will see a modern and sophisticated city-state with infrastructures that rival many European cities.
Young (1994) published a follow-up paper that carefully scrutinized the data. The findings of the reworked version were similar to the previous findings in that productivity growth played very little role in the East Asian growth miracle. Moreover, Yuan (1983) reported virtually no TFP growth for the average of 28 manufacturing industries in Singapore between 1970 and 1974; in fact TFP growth was negative for 17 of them. A subsequent study conducted by Young (1995) supported his 1994 findings of significantly lower TFP growth in Singapore. Young (1995)’s finding of lower TFP growth are consistent with studies conducted by Yuan (1983, 1985) and Kim and Lau (1994). It was Nobel Laurate Paul Krugman (1994)’s interpretation of two influential works by Kim and Lao (1994), Young (1992, 1994), and Yuan (1983) findings that caused a big stir in this part of the world. The myth of Asia’s miracle particularly upset senior leaders of the small city state, especially with the analogy “Lee Kuan Yew’s Singapore is an economic twin of the growth of Stalin’s Soviet Union (p.66), and the miracle turns out to have been based on perspiration rather than inspiration: Singapore owe through a mobilization of resources that would have done Stalin period (pp. 65-66).

Within the same theme, in another study Krugman (1997, p. 27) added:

“If there is one thing that believers in an Asian system admire, it is the way Asian governments promote specific industries and technologies; this is supposed to explain their economies’ soaring efficiency. But if you conclude that it is mainly perspiration-that efficiency is not soaring-then the brilliance of Asian industrial policies becomes a lot less obvious. The other unwelcome implication of the perspiration theory was that the pace of Asia’s growth was likely to slow. You can get a lot of economic growth by increasing labor force participation, giving everyone a basic education and tripling the investment share of GDP (gross domestic product), but these are one-time unrepeatable changes.
The biggest lesson from Asia's [recent] troubles is not about economics, it is about government. When Asian economies delivered nothing but good news; it was possible to convince yourself that the alleged planners of these knew what they were doing. Now the truth is revealed, they do not have a clue.”

Quibria (2002) mentioned that for much of the past 30 years, growth in East Asia derived largely from high rates of capital accumulation, which also served as the vehicle for technological change, and from the increasing influx of young, educated workers. After all, this school of thought indicated that the East Asian high growth achievement could not sustain in the long run as diminishing returns to production inputs will set in and the growth potential of these economies will be limited.

The findings and conclusions drawn from the studies conducted by Kim and Lao (1994), Young (1992, 1994), Krugman (1994), and World Bank (1993) have led to the interpretations and the reinterpretations of the relationship between TFP and long run output growth, resulting in the development of competing views: the accumulationists and the assimilationists, in the interpretation of results generated from TFP as shown in the following table.
A Accumulation and assimilation of factor inputs

<table>
<thead>
<tr>
<th>Accumulation Theories</th>
<th>Assimilation Theories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement - rate of factor accumulation</td>
<td>Measurement - rate of total factor productivity</td>
</tr>
<tr>
<td>Rapid economic development is caused by high investment</td>
<td>Rapid economic development is linked to entrepreneurship, innovation and learning. New</td>
</tr>
<tr>
<td>rates, whereby the bulk of the share of increased output</td>
<td>technologies from advanced nations also have to be adopted. Although investments in human</td>
</tr>
<tr>
<td>per worker is explained by increases in physical and human</td>
<td>and physical capital are pre-requisites, they are not sufficient.</td>
</tr>
<tr>
<td>and physical capital are pre-requisites, they are not</td>
<td></td>
</tr>
<tr>
<td>sufficient.</td>
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<tr>
<td>Little attention is paid to firms as their behaviour is</td>
<td>Entrepreneurial firms and their ability to learn rapidly are critical factors behind</td>
</tr>
<tr>
<td>basically determined by the external environment.</td>
<td>the success of South Korea, Singapore, Taiwan and China.</td>
</tr>
<tr>
<td>Accumulation of human capital is treated as an increase</td>
<td>Sharply rising educational attainment means that well-educated managers, engineers and</td>
</tr>
<tr>
<td>in the quality or effectiveness of labour.</td>
<td>workers have comparative advantage in terms of new opportunities and effective learning</td>
</tr>
<tr>
<td></td>
<td>of new production techniques. Accumulation of human capital is an important factor for</td>
</tr>
<tr>
<td></td>
<td>successful entrepreneurship.</td>
</tr>
<tr>
<td>Economies in which the stocks of physical and human</td>
<td>In order to compete effectively in world markets, firms require not only government</td>
</tr>
<tr>
<td>capital are rising rapidly are expected to show a steep</td>
<td>support but must also acquire factors such as the necessary learning, entrepreneurship</td>
</tr>
<tr>
<td>rise manufacturing exports. There would also be a shift</td>
<td>and innovation. Exports stimulate learning sectors in two ways: (1) Being forced to</td>
</tr>
<tr>
<td>in comparative advantage towards sectors that employ these</td>
<td>compete in world markets will make managers and Engineers of firms pay close attention</td>
</tr>
<tr>
<td>inputs intensively. Therefore, there is nothing commendable</td>
<td>to best practice; and (2) The increase in exports is usually with US and Japanese firms</td>
</tr>
<tr>
<td>about a surge in manufacturing exports.</td>
<td>which provide assistance in order to achieve their demanded high standards.</td>
</tr>
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</table>

Several authors (Dahlman and Westphal 1981; Dahlman et al. 1987; Hobby 1994a, 1994b, 1994c, 1995; Romer 1993a, 1993b; Pack 1993; Pack and Page 1994a, 1994b, Nelson and Pack 1996; cited in Felipe 1999), argued that the essential component of the recipe followed by the East Asian countries was the acquisition and mastery of foreign technology, and the capacity to put ideas into practice. Several authors such as Kaldor (1960), Salter (1962) and Singh (1998) argued that the decomposition of growth in output is difficult because technical progress is embodied in new capital. Accordingly, the effects of technical progress cannot be separated from the expansion of capital inputs. Technological progress can only take place through the introduction of new machines i.e. through an increase in capital inputs. In fact, this type of rationale had been put forward in the 1960s by Kaldor. According to Kaldor (cited in Taylor, 2007, p.32),

“In a world in which technology is embodied in capital equipment and where both the improvement of knowledge and production of new capital goods are continuous, it is impossible to isolate the productivity growth which is due to capital accumulation as such from the productivity growth which is due to improvements in technical knowledge. There is no such thing as a “set of blueprints” which reflect a “given state of knowledge” – the knowledge required for making of, say, the Concorde only evolved in the process of designing or developing the aero plane; the costs of obtaining the necessary new knowledge is causally indistinguishable from the other elements of investment.”

According to Taylor (2007), even replacement investment is associated with technical progress. This is because, when a machine is being replaced by a new one the latter is likely to be technologically more advanced and not simply a new copy of the old one. On this basis, decreasing returns are unlikely to occur because the higher the rate of investment, the greater would be the turnover of machines and the greater would be the
technical progress. This in turn would lead to greater ‘learning by doing’ activities, thereby increasing technological progress (Arrow 1962).

Despite conflicting views between different disciplines in interpreting the determinants of long-run economic growth, there seems to be a consensus among them that technological progress (TFP) is the underlying factor for long-run growth. This short survey of the Solow (1956, 1957) growth model reinforced the importance of technological progress in driving higher aggregate output. The mechanics of the growth analysis demonstrated that the only way in which to escape the constraint of diminishing returns to factor inputs is through higher productivity growth of both labour and capital in a sustainable manner. Although the original Solow (1956, 1957) is used for estimating the overall economic progress, it can easily be applied in a specific sector of the economy. For example, Yuan (1983, 1985) utilized the Solow (1956, 1957) aggregate growth accounting analysis to quantify the impact of technological progress (TFP growth) on 28 manufacturing industries in Singapore.
Appendix F Questionnaire for sample survey (Primary data)

Is verbal consent taken?

1. Household code:

Village (an administrative unit of the union):

Union (administrative unit under Upazila):

Upazila (administrative unit under district):

District (an administrative unit of the country):

2 a. Family particulars

<table>
<thead>
<tr>
<th>Relation with family head</th>
<th>Age</th>
<th>Sex</th>
<th>Marital status</th>
<th>Education level</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
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</table>

b.

<table>
<thead>
<tr>
<th>Relation with family head</th>
<th>Primary occupation</th>
<th>Secondary occupation</th>
<th>Other part time job</th>
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</tbody>
</table>

3. Land owned in acre/decimal

<table>
<thead>
<tr>
<th>Homestead</th>
<th>Cultivable</th>
<th>Rented in</th>
<th>Rented out</th>
<th>Landless</th>
</tr>
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<tbody>
<tr>
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</tr>
</tbody>
</table>
4. Crop produced

a.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Present ton/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aus High Yielding Variety (HYV)</td>
<td></td>
</tr>
<tr>
<td>Boro HYV</td>
<td></td>
</tr>
<tr>
<td>Aman HYV</td>
<td></td>
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<tr>
<td>Wheat HYV</td>
<td></td>
</tr>
<tr>
<td>Gram</td>
<td></td>
</tr>
<tr>
<td>Masur (lentil)</td>
<td></td>
</tr>
<tr>
<td>Moong (lentil)</td>
<td></td>
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<tr>
<td>Jute</td>
<td></td>
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<tr>
<td>Potato</td>
<td></td>
</tr>
<tr>
<td>Tobacco</td>
<td></td>
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<tr>
<td>Cotton</td>
<td></td>
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<tr>
<td>Other specify</td>
<td></td>
</tr>
</tbody>
</table>

b.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Seed in Kg</th>
<th>Fertilizer in Kg</th>
<th>Irrigation (rent/day)</th>
<th>Labour (man days/acre/decimal)</th>
<th>Pesticide used (gm/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>urea</td>
<td>TSP</td>
<td>LLP</td>
<td>DTW</td>
</tr>
<tr>
<td>Aus HYV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boro HYV</td>
<td></td>
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<tr>
<td>Aman HYV</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Wheat HYV</td>
<td></td>
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<tr>
<td>Gram</td>
<td></td>
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<tr>
<td>Masurai (lentil)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Moong (lentil)</td>
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<tr>
<td>Other pulses</td>
<td></td>
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<tr>
<td>Jute</td>
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<tr>
<td>Potato</td>
<td></td>
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<tr>
<td>Other specify</td>
<td></td>
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</tbody>
</table>

5. Irrigation use

<table>
<thead>
<tr>
<th>Mode of Irrigation</th>
<th>Land covered (acre/decimal)</th>
<th>Price paid for water use (acre/decimal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharecropper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DTW (deep tube well)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLP (low lift pump)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STW (shallow tube well)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landowner</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DTW (deep tube well)  
LLP (low lift pump)  
STW (shallow tube well)  
Traditional  
Canal

6. Use of other machinery

<table>
<thead>
<tr>
<th>Machine</th>
<th>Use of irrigated land</th>
<th>Use of non-irrigated land</th>
<th>Rent/crop paid to use the irrigation machine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present unit/acre</td>
<td>Present unit/acre</td>
<td>Bangladeshi Taka/kg</td>
</tr>
<tr>
<td>Power tiller</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other named</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Approximate cost and return of major crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Production per ton/acre</th>
<th>Cost per ton</th>
<th>Return per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HYV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aman</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HYV</td>
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<td></td>
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<tr>
<td>Local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boro</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HYV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HYV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jute</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others named</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Do you own irrigation equipment

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

a. what equipment do you have  
   DTW  LLP  STW  

b. When you bought this

c. How much you paid

d. Operating cost Bangladeshi Taka.  
   Electricity  
   Diesel  
   Labor  
   Other specify

e. Repairing cost Bangladeshi Taka.:
9. Have any member of household migrate to some other places

Yes  No

If yes, for what purpose/reason

Job  business  wage labor  other

10. Has irrigation/HYV increase employment for both male and female

Yes  No

11. Do your income increase than before, if yes how?

Yes  No

By agri production/off farm income/female participation in wage employment/NGO activities

12. Approximate monthly/seasonal income TK………………………………………………

13. What causes them to be more impoverished?

14. Do you know about the following agricultural policies of the government?

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Awareness</th>
<th>Are you benefiting from the policy? If not, then how it can be improved?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extension services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input market facilities</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

15. Do you have an idea about output processing, marketing policies of the government?

<table>
<thead>
<tr>
<th>Production</th>
<th>Awareness</th>
<th>Comment/experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-harvest management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport facilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profit earning</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix G  Questionnaire of IRRI, Bangladesh (Secondary data)

VILLAGE DYNAMICS STUDIES IN SOUTH ASIA (VDSA)

IRRI-BANGLADESH

CULTIVATION SCHEDULE (VDS -Y) 2009-14

Village___________________ Union ________________ Upazila: ______________
District: ______________ HH No._________
HH Code: ______________ __________________________________
Main/Subplot Code: _____ Plot Name: ________________
Cropped area: ______________ Irrigation area: ______________
Season*: ______________ Ownership**: ______________ Yearly Rental value
(Bangladeshi Taka/Decimal): __________

* Seasons: 1=Boro; 2=Robi; 3=Aus; 4=aman; 5=annual
** Ownership: Own land=1, Leased in on crop share=2, Leased in on fixed rent/crop=3,
Leased out on rent/ crop share=4, leased out on fixed rent=5, Mortgaged in =6, Mortgaged
out=7.

Table A Crop production details

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Description</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Variety Name</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td>Variety Type a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>% Area/ratio b</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

a.  1 = Local, 2 = Improved/HYV, 3 =Hybrid, BT =4, Mix of local and improved=5, and
Others --------------------------6,
b.  based on the area occupied by each crop.
Table B Land ownership details

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Plot name</th>
<th>Change in status</th>
<th>Plot code</th>
<th>Ownership</th>
<th>Who owns this plot</th>
<th>Unit Acres</th>
<th>Total area</th>
<th>Irrigable land</th>
<th>Distance from house</th>
<th>Source of irrigation</th>
<th>Distance from well</th>
<th>Tank. pond</th>
<th>Soil type</th>
<th>Soil depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
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<td>08</td>
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</tbody>
</table>

Note: In ownership status note down the details of leased/shared/owned.

* Own land=1, Leased in on crop share=2, Leased in on fixed rent/crop=3, Leased out on rent/ crop share=4, leased out on fixed rent=5, Mortgaged in =6, Mortgaged out=7.

* Source of irrigation: Open dug well=1, Borewell=2, Irrigation canal=3. Tank/pond=4, Submergible pump=5, Rivers=6, Lift pump=7, Local irrigation system=8, others (specify) =.........9, STW=10, DTW=11, LLP=12.
<table>
<thead>
<tr>
<th>Round no</th>
<th>Date of operation</th>
<th>Name of operation</th>
<th>Human labor</th>
<th>Material input use***</th>
<th>Output (main and by product)‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Labor code¹</td>
<td>Total hours</td>
<td>Total cash and kind wages</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *** Material inputs such as manures, fertilizers, pesticides, and seed are recorded by name. Material inputs and machinery use (Codes): 1= Tractor, 2= Power Tiller, 3= Combined harvester, 4= Sprayer, 5= Seed drill, 6= BBF Marker, 7= Duster, 8= Electric motor, 9= Submersible pump, 10= Tropicultor, 11= Manual thresher, 12= Power thresher, 13= Seed, 14= Chemical fertilizer; 15= Organic manure; 16= Pesticide, 17= Herbicide; 18= Diesel pump, 19= Diesel, 20= others …………… (Specify) 21= Materials of shelf (Bamboo, Jute etc.) 22= Urea; 23= USG; 24= DAP; 25= TSP; 26= MP; 27= Gypsum; 28= Zink; 29= Mix fertilizer, 30= others (specify) …………………………………….
Name of operation: 1=Pre-tilling clearing of land; 2=Tilling; 3=Irrigation; 4=Applying fertilizers and pesticides; 5=Transplanting/broadcasting; 6=Weeding; 7=Harvesting; 8=Threshing; 9=Harvesting and Threshing; 10=Drying grains; 11=Storing; 12=Others (specify) ………………….13= Making shelf (Bamboo, Jute etc.)

Main production, Seed, Fertilizers (Kg/Mound) By-products, FYM, Tank silt in (Qt), Pesticides (Lt/Kg) and Tractor, Sprayers, Dusters, Pump sets, Thresher (Hr),

Type of Labor (Codes): 1= Family Male, 2= Hired Male, 3= Exchange Male, 4= Family Female, 5= Hired Female, 6= Exchange Female, 7= Family Child, 8= Hired Child, 9= Exchange Child, 10= Own Bullocks, 11= Hired Bullocks, 12= Exchange Bullocks, 13= Regular farm servant, 14= Others ………………

1=Quintal, 2=Maund, 3=Kg, 4=Lt, 5=Number, 6=Bangladeshi Taka.

1=Own, 2=Purchased, 3=Loan/credit, 4=Hired, 5=others including gift or exchanged

Table D What are the most important sources of information does the household generally receive (Government programmes, agriculture and other related information)?

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Information</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Relatives, friends and neighbours</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Community bulletin board</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Community or local news papers</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>National news papers</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Radia</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Television</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Group or association</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Community leaders</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Upazila Agriculture Officer</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Block Supervisor</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>NGO</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Field days</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Training and krishi mela</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Input supplier</td>
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</tr>
</tbody>
</table>
## Appendix H Calculation of α from 2009 to 2014 (different study areas of Bangladesh)

<table>
<thead>
<tr>
<th>Villages</th>
<th>2009/10</th>
<th>2010/11</th>
<th>2011/12</th>
<th>2012/13</th>
<th>2013/14</th>
<th>Average</th>
<th>Average α (in per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>k</td>
<td>ẏ</td>
<td>k</td>
<td>ẏ</td>
<td>k</td>
<td>ẏ</td>
<td>k</td>
</tr>
<tr>
<td>Darikamari</td>
<td>0.042</td>
<td>0.065</td>
<td>0.008</td>
<td>-0.014</td>
<td>0.017</td>
<td>0.006</td>
<td>0.005</td>
</tr>
<tr>
<td>Khudiakhali</td>
<td>0.013</td>
<td>-0.003</td>
<td>0.043</td>
<td>-0.006</td>
<td>0.015</td>
<td>0.071</td>
<td>0.000</td>
</tr>
<tr>
<td>Bhobanipur</td>
<td>0.055</td>
<td>0.057</td>
<td>-0.003</td>
<td>-0.018</td>
<td>0.006</td>
<td>0.005</td>
<td>-0.003</td>
</tr>
<tr>
<td>Begumpur</td>
<td>0.065</td>
<td>0.048</td>
<td>0.014</td>
<td>-0.024</td>
<td>-0.022</td>
<td>0.011</td>
<td>0.016</td>
</tr>
<tr>
<td>Rasun Shimul</td>
<td>0.040</td>
<td>0.068</td>
<td>0.027</td>
<td>-0.014</td>
<td>0.000</td>
<td>-0.013</td>
<td>-0.005</td>
</tr>
<tr>
<td>Konapara</td>
<td>0.064</td>
<td>0.080</td>
<td>0.021</td>
<td>-0.016</td>
<td>0.009</td>
<td>0.026</td>
<td>-0.009</td>
</tr>
<tr>
<td>Nishaiganj</td>
<td>0.041</td>
<td>0.068</td>
<td>0.004</td>
<td>-0.036</td>
<td>0.007</td>
<td>-0.027</td>
<td>-0.006</td>
</tr>
<tr>
<td>Patordia</td>
<td>0.061</td>
<td>0.066</td>
<td>0.002</td>
<td>-0.039</td>
<td>-0.002</td>
<td>0.003</td>
<td>0.014</td>
</tr>
<tr>
<td>Average</td>
<td>0.048</td>
<td>0.056</td>
<td>0.015</td>
<td>-0.021</td>
<td>0.004</td>
<td>0.010</td>
<td>0.002</td>
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</tbody>
</table>
Appendix I Calculation of coefficient α from 2009 to 2015 (Mymensingh district, Bangladesh)

<table>
<thead>
<tr>
<th>District</th>
<th>2009/10</th>
<th>2010/11</th>
<th>2011/12</th>
<th>2012/13</th>
<th>2013/14</th>
<th>2014/15</th>
<th>Average</th>
<th>Average α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mymensingh</td>
<td>0.051</td>
<td>0.067</td>
<td>0.003</td>
<td>-0.037</td>
<td>0.002</td>
<td>-0.012</td>
<td>0.004</td>
<td>0.052</td>
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</table>
### Appendix – J Summary statistics of variables

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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Darikamari</td>
<td>Crop production</td>
<td>57848.35</td>
<td>115633.09</td>
<td>93756.95</td>
<td>104169.47</td>
<td>152623.15</td>
<td>73857.69</td>
<td>132407.5</td>
<td>272158.5</td>
<td>242811.5</td>
<td>398056.0</td>
<td>605610.0</td>
<td>315030.0</td>
</tr>
<tr>
<td></td>
<td>Crop by production</td>
<td>1945.23</td>
<td>6456.04</td>
<td>9604.52</td>
<td>6939.89</td>
<td>8914.04</td>
<td>6010.95</td>
<td>4850.00</td>
<td>7683.5</td>
<td>20280.0</td>
<td>14430.0</td>
<td>28580.0</td>
<td>2785.00</td>
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<tr>
<td></td>
<td>Capital cost</td>
<td>24818.31</td>
<td>31028.26</td>
<td>41724.38</td>
<td>49895.30</td>
<td>54739.25</td>
<td>31055.60</td>
<td>61663.52</td>
<td>122842.0</td>
<td>92853.0</td>
<td>167657.9</td>
<td>227401.2</td>
<td>26721.66</td>
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<tr>
<td></td>
<td>Labour hour</td>
<td>767.95</td>
<td>679.46</td>
<td>1109.69</td>
<td>1202.37</td>
<td>1275.73</td>
<td>679.46</td>
<td>1622.50</td>
<td>2875.50</td>
<td>2550.75</td>
<td>3773.75</td>
<td>5031.50</td>
<td>2875.70</td>
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<tr>
<td>Khudiakahi</td>
<td>Crop production</td>
<td>92106.25</td>
<td>83616.55</td>
<td>74344.10</td>
<td>170830.60</td>
<td>166891.50</td>
<td>75963.20</td>
<td>947760.0</td>
<td>365150.0</td>
<td>188380.0</td>
<td>545650.0</td>
<td>431980.0</td>
<td>499080.0</td>
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<tr>
<td></td>
<td>Crop by production</td>
<td>2192.00</td>
<td>7463.47</td>
<td>7104.00</td>
<td>5966.84</td>
<td>5599.44</td>
<td>3526.50</td>
<td>8700.00</td>
<td>12400.0</td>
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<td>28370.17</td>
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<td>175473.0</td>
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<td>6639.66</td>
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<td>3676.79</td>
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<td>22584.44</td>
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<td>75705.73</td>
<td>55383.32</td>
<td>91275.03</td>
<td>93448.04</td>
<td>55676.44</td>
<td>1785865.0</td>
<td>585000.0</td>
<td>287560.0</td>
<td>395570.0</td>
<td>205056.0</td>
<td>371275.0</td>
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<td>75705.73</td>
<td>55383.32</td>
<td>91275.03</td>
<td>93448.04</td>
<td>55676.44</td>
<td>1785865.0</td>
<td>585000.0</td>
<td>287560.0</td>
<td>395570.0</td>
<td>205056.0</td>
<td>371275.0</td>
<td>1537.00</td>
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Crop by production

8556
(3910.00)

11219.18
(10913.50)

4439.13
(5286.43)

4435.38
(4581.65)

8284.35
(8524.02)

5791.00
(7055.22)

4695.00
(0.00)

3000.00
(0.00)

31880
(0.00)

20870.00
(100.00)

6560.00
(0.00)

5680.00
(35.00)

Capital cost

13485.48
(9279.45)

24682.02
(18659.31)

30546.98
(21844.14)

33475.84
(22056.06)

30422.04
(23238.79)

9951.48
(7513.59)

36420.00
(1598.00)

81688.00
(1406.00)

89870.00
(1695.50)

91052.50
(3076.00)

103606.00
(2520.00)

30843.00
(700.00)

Labour hour

539.64
(401.92)

1202.60
(965.90)

1109.88
(847.89)

1169.26
(792.07)

1034.84
(884.96)

450.34
(435.11)

1747.00
(59.00)

4454.00
(50.00)

3553.00
(53.00)

3552.00
(351.00)

3977.00
(102.00)

1972.00
(46.00)

26428.00
(3444.59)

55475.50
(15686.24)

35068.00
(11373.51)

25360.00
(13102.83)

34194.50
(14890.57)

6203.50
(3100.96)

32100.00
(21400.00)

75185.00
(30660.00)

49160.00
(17160.00)

40590.00
(6330.00)

50105.00
(8040.00)

9800.00
(2362.50)

3996.00
(867.49)

5899.00
(1995.10)

6320.00
(2061.94)

5680.00
(3479.74)

6390.00
(3493.91)

2036.00
(759.72)

5400.00
(3120.00)

8950.00
(2950.00)

9050.00
(3050.00)

11000.00
(1100.00)

10600.00
(1050.00)

3000.00
(1100.00)

7874.60
(1436.11)

11327.50
(2511.81)

11728.20
(3995.26)

12471.10
(5611.72)

11165.20
(5091.60)

2847.40
(886.92)

10017.00
(5860.00)

14438.00
(6903.00)

17254.00
(5755.00)

18800.00
(3970.00)

17723.00
(2918.00)

3631.00
(1408.00)

334.40
(61.28)

658.10
(173.49)

623.30
(142.99)

420.60
(191.24)

408.00
(208.59)

115.80
(34.04)

420.00
(274.00)

919.50
(396.00)

761.00
(372.00)

625.00
(123.00)

692.00
(84.00)

151.00
(64.00)

29131.00
(14141.05)
1689.50
(778.10)
7039.63
(3426.92)
436.05
(179.77)

53820.35
(26659.36)
7163.60
(4233.93)
12062.13
(6124.77)
863.88
(420.66)

34901.63
(19553.32)
4955.00
(3125.74)
12249.19
(6801.28)
807.45
(440.94)

33446.28
(20857.49)
7507.50
(4516.48)
12012.10
(7260.37)
772.04
(473.43)

45153.25
(26150.81)
9639.00
(5375.62)
13706.53
(8308.62)
736.30
(423.48)

16237.13
(9835.57)
2822.50
(1740.72)
3710.43
(2421.38)
302.38
(177.02)

56080.00
(7150.00)
3020.00
(340.00)
13363.00
(1514.00)
668.00
(111.00)

117502.00
(14620.00)
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(1500.00)
23159.00
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1752.50
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(206.50)

72158.00
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16820.00
(1600.00)
26990.50
(2935.00)
1632.00
(181.50)

95450.00
(5720.00)
18930.00
(1800.00)
31074.25
(1280.50)
1545.50
(126.00)

33430.00
(2330.00)
6700.00
(300.00)
9168.00
(678.00)
722.00
(69.50)

40468.95
(30179.44)

81167.20
(58155.30)

66979.60
(52296.84)

61174.82
(55712.21)

76789.45
(68646.79)

25632.80
(20545.71)

134020.00
(8040.00

235750.00
(17250.00)

211110.00
(5940.00)

272855.00
(2100.00)

322325.00
(10360.00)

79500.00
(2250.00)

Crop by production

2071.20
(1434.35)

6792.40
(6147.61)

8416.32
(6317.44)

4070.28
(2617.99)

5510.80
(4670.32)

1576.80
(1321.09)

6110.00
(450.00)

24440.00
(600.00)

24435.00
(145.00)

12267.00
(200.00)

21795.00
(700.00)

4880.00
(150.00)

Capital cost

13133.77
(8513.67)

19117.16
(13012.56)

24835.21
(17146.75)

24904.48
(16329.62)

24343.32
(16980.65)

6160.15
(5077.68)

36364.30
(3449.00)

52769.00
(2619.00)

69949.75
(2728.00)

59315.00
(5946.50)

70923.50
(4237.50)

21530.00
(617.00)

Labour hour

604.76
(405.43)

1201.53
(890.55)

1236.65
(927.40)

911.67
(651.19)

950.84
(865.74)

318.82
(242.37)

1716.55
(162.00)

4037.00
(225.00)

3923.50
(291.00)

2885.00
(305.50)

4262.00
(129.00)

822.00
(30.50)

Nishaiganj

Crop production
Crop by production
Capital cost
Labour hour
Pathordia

Crop production
Crop by production
Capital cost
Labour hour

Rasun Shimul
Crop production

XXIV

