Chapter 1

BANGLADESH AGRICULTURAL SUSTAINABILITY: ECONOMIC, ENVIRONMENTAL AND SOCIAL ISSUES

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ABSTRACT

This chapter examines the potential for agricultural sustainability in Bangladesh mainly by analyzing economic, environmental and social issues at the macro-level. The economic issues were examined by assessing the contribution of the agricultural sector to Gross Domestic Product (GDP), trends in cereal yield, employment of the labor force in agriculture and domestic food price index covering a 38–year period (1980–2017). The environmental issues were examined by assessing the use of chemical fertilizers, pesticides, irrigation, cropping intensity and CO_2 emission from agriculture over time (1990–2015). The social context of agricultural sustainability were analyzed by examining attributes such as encroachment of arable land for urbanization and other industrial uses, unavailability of arable land, trends in increase in import of food grains and variability in food production. Results revealed that all of these issues adversely affected future agricultural productivity, thereby casting doubt on the sustainability of agriculture in Bangladesh. Despite having increasing trend in cereal yield since 1980s, the contribution of agriculture sector to the GDP was found to be decreasing over time. Also the proportion of working age population engaged in agriculture sector was declining over the last forty years. Furthermore, variability in food production and increasing domestic food price index affected food stability. Bangladeshi farmers are losing valuable arable land at a rate of

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0.3% p.a., which may have influenced increase in cropping intensity at a rate of 0.6% p.a. since 1980's. Increasing trend in low-cost food grain import reflects changing preference of the consumers. The use of chemical fertilizer is increasing at a rate of 2.5 kg/ha p.a., which may be a principal factor in increasing CO_2 emissions from agriculture at a rate of 1.1% p.a. since 1990's. Among the selected indicator variables, a high uncertainty for sustainability in agriculture was found from falling agricultural value added to the GDP and use of chemical pesticides, while moderate uncertainty for sustainability was found for other indicator. The environment friendly agricultural practice can play a vital role in achieving agricultural sustainability in the long–run. Policy reforms are required with respect to subsidies in agriculture and the use of farm chemicals in order to improve agricultural productivity and limit adverse environmental impacts from agriculture.

Keywords: agricultural sustainability, trend analysis, economic, environmental and social indicators, Bangladesh economy.

1. INTRODUCTION

Sustainability in agriculture is primarily concerned with sustainable growth in productivity over time. Bangladesh, as an agriculture-based developing country, has improved production of cereals over the last 50 years. Because of the technological changes in agriculture, the annual yield of major cereals increased from 1.68 t/ha to 4.62 t/ha during this period (Faostat 2014). Notably, the rice yield increased from 1.70 t/ha to 4.62 t/ha over the past 50 years (Faostat 2014), hence supporting the growing demand for food for the growing population. Also, considerable amount of vegetables are now cultivated and produced in Bangladesh. An increase in annual production of fresh vegetables was also seen from its level in 1961. The vegetable yield increased from 4.88 t/ha to 7.36 t/ha over the past 50 years, which contributed towards provision of supplementary fiber, vitamins, minerals and nutrients particularly for the middle income and poor households (Faostat 2014).

Despite having increasing trends in both yield and quantity of agricultural production, Bangladesh is facing challenges to sustain the increasing rate of growth of agricultural production for the long term (Kesavan and Swaminathan 2008; Mondal 2010). In a broad sense, agricultural sustainability encompasses diverse economic, environmental and social attributes which varies across different countries and regions (Zhen and Routray 2003; Ozturk 2017). In addition to manmade capital, the level of agricultural production also depends on the services and inputs from environmental and natural resources. The intensive cultivation practices create negative impacts on the environmental constituents such as land, water and air (Pretty et al. 2003). These environmental constituents are the natural capitals, which are considered vital for agricultural production. Negative impacts on such inputs affect both future production and production efficiency (Sabiha et al. 2017). The cost of such negative impacts is, therefore, likely to be substantial. It is worthwhile to use agricultural inputs and production technologies in an environmentally friendly and economically efficient way. This would hold the growing trends of important agricultural attributes for the long-run, thereby, ensuring sustainability. In this respect, it is important to identify indicators, which are growing unsustainably over the past years (Zhen and Routray 2003). This would help taking policy initiatives for corrective measures by giving primary focus on those identified issues.

Given this fact, the principal aim of this paper is to analyze the potential for agricultural sustainability in Bangladesh. This is based on a comprehensive review of published literature and databases covering economic, environmental and social aspects of Bangladesh agriculture. The specific aims of this paper are to: (i) investigate historical data on production, yield, inputs, employment, environmental pollution, food security condition, and import of major crops; (ii)estimate annual compound growth rates of selected economic, environmental and social attributes; (iii) visualize historical performance of selected indicators using three-years moving average trend lines; (iv) estimate 5 years and 10 years forecast values of those selected attributes of agricultural sustainability; and (v) measure sustainability potential index (SPI) of respective attributes by evaluating deviations between the 10-year forecasted and current year values (i.e., 2027 and 2017, respectively).

The rest of the paper is structured as follows. Section 2 presents a brief review on the concept of agricultural sustainability, structural stability and the status of ecological attributes of Bangladesh agriculture to serve as the background to assess potential of agricultural sustainability. Sections 3 and 4 present methodology and the data respectively. Section 5 presents the results and Section 6 provides conclusions and draws policy implications.

2. Literature Review

2.1. Agricultural Sustainability: A Conceptual Overview

Previous studies pointed out various aspects of sustainable agriculture to explain the concept of agricultural sustainability. One of the most widely accepted views of sustainable agriculture is explained in the report of the American Society of Agronomy (ASA 1989). According to this report, agriculture that ensures the natural resource base, human food and fiber, economic viability, improved living standards along with other social aspects is referred to as sustainable. This idea highlights three important and interrelated aspects of sustainable agriculture. These aspects can be distinguished as environmental, economic and social aspects. In agriculture, the environmental sustainability concerns with the maintenance of the natural capital (the stock of an environmentally provided asset) both as a source of inputs and as a repository for wastes (Goodland 1995). The economic and social sustainability consider maintaining increased rate of growth of agro-economic indicators and improvement in socio-agricultural factors, respectively.

The definition of measuring agricultural sustainability is difficult to express in a single context. Generally, a normative definition of sustainability addresses the measurement of the economic, ecological/environmental and social aspects of agriculture, while the temporal analysis moves within the short- and long-term aspects of agriculture (von Wirén-Lehr 2001; Rasul and Thapa 2004). In this respect, Pretty (1995) denoted that it is desirable to analyze sustainability issues in empirical research by selecting specific normative parameters or criteria and investigating whether those trends are stable, increasing or declining. For instance, intensive agricultural practices that cause land degradation, beneficial pest extinction, water depletion, and deforestation can be considered unsustainable for future agricultural production and maintaining natural resource base. Evidence of such environmental impacts can be used to represent the status of environmental sustainability in agriculture. Technically, such trends can be done by analyzing data on historical performance of relevant impact-indicators (Pretty 1995).

The selections of impact-indicators and aspects that can be considered as appropriate criteria of sustainability have always been important issues in agro-economic research (Roy and Chan 2012; Sabiha et al. 2016). Researchers consider the status and trends of specific economic, environmental and social indicators to evaluate the potential for sustainability in agriculture (Allen et al. 1991; Rasul and Thapa 2003). For instance, share of agriculture's value added to the nations GDP, quantity of inputs used, amount of crop produced were considered as economic aspects. While the application of chemical fertilizers, pesticides use, irrigation intensity and cropping intensity are examples of environmental aspects (Rahman and Thapa 1999). Major social attributes might include food security issues, urbanization, shrinking arable land area, land fragmentation, switching consumer's preference for imported agricultural produces, etc. Therefore, it is important to select several agro-ecological, agro-economic and socio-agricultural parameters that are consistent with sustainability analysis in agriculture. In this respect, it is also necessary to examine the structural stability as well as the ecological and climatic condition upon which country's agriculture primarily depends.

2.2. Structural Stability in Bangladesh Agriculture

The structural stability in agriculture can be considered as the foundation of sustainability potential. The potential for sustainability can be higher if all of its major structural components are in a favorable setup (Mondal 2010). One of the important components of agricultural structure is the distribution of farm households. The percentage of rural farm households with respect to the percentage of total households followed a decreasing trend in three successive census years, i.e., 72.7 per cent in 1984, 66.2 per cent in 1996 and 56.7 per cent in 2008. Rapid urbanization and switching employment to the non-agricultural sector are the two important reasons behind this scenario.

Land fragmentation is considered as another structural component that affects agricultural profitability and production efficiency. The land fragmentation results in unavailability of arable land decrease in yield and a rise in intensive use of environmental resources as inputs. Agricultural lands are getting fragmented by the division of large farms holdings into discrete parcels such as medium and small farm units (King and Burton 1982). Compared to the large and medium farm units, the percentage of small farm units increased in every successive agriculture census years during the period of 1983 to 2008. Land fragmentation affects land ownership status, which disrupts social and economic sustainability in agriculture (King and Burton 1982).

Land ownership can be considered as an important structural component of agriculture. The increasing trend in the number of landless farm holders apparently causes difficulties in attaining sustainability goals. The transfer of land ownership causes the farm size to gradually become smaller. Changes in farm land ownership and the replacement of experienced farmers with new farmers increase the risk of a significant amount of unrealized profits in crop production. The transfer of farm land ownership also causes the transfer of agricultural land to non-agricultural purposes. In the census year of 1996, the proportion of owner farm households to the total farm households was recorded as 67 per cent, whereas it fell to 65 per cent in the next census year 2008. In addition, a 3 to 5 per cent increase in the number of tenant farm holdings was also found in these two census years (BBS 2008). Both tendencies of ownership transfer by selling farm land or other non-selling transfers are frequent in Bangladesh. The sustainable rate of agricultural production is considerably conditional on farms that are operated by owner farmers (Sabiha et al. 2016). Therefore, the previous census years' data on these major structural components show that structural stability in Bangladesh agriculture does not adequately provide the base for sustainability.

2.3. Ecological Soundness in Bangladesh Agriculture

The ecological soundness of country's overall environment partially depends on the ecological soundness in agriculture. Agricultural activity directly uses major elements of the ecology such as natural resources, and therefore plays a vital role in maintaining ecological sustainability. On the contrary, the ecological soundness is one of the foremost requirements of agricultural production to grow sustainably (Saysel et al. 2002).

One of the most accepted measures of ecological sustainability is the ecological footprint. The ecological footprint measures the biologically productive land that is required to sustain a country's population at the current consumption levels. The countries whose footprints exceed their own arable land area are consuming at unsustainable levels. According to the Report on the Environmental Sustainability Index (2005), Bangladesh's ecological footprint was estimated as 0.05 ha (ESI 2005). This estimate implies that the biologically productive land (e.g., agriculture, forestry, fishery, etc.) that is required per person is 0.05 ha. The ecological footprint score, i.e., 0.05, equaled the per capita agricultural land score in 2005 (World Bank 2013; ESI 2005). In 2011, the per capita arable land fell to 0.04 because of population growth and increased consumption and intensive agricultural practice (World Bank 2013). This decrease had a certain impact on the ecological footprint. A smaller footprint implies lower amount of biologically productive land is available, which indicates considerable potential for ecological instability.

Intensive agricultural practice that continues the use of farm chemicals can also cause ecological instability by eutrophication. In Bangladesh, one of the measures of eutrophication, i.e., the dissolved oxygen concentration accounts for 6.70 mg per liter of water; whereas the world's highest measure of this eutrophication is 13.76 mg (ESI 2005). Since, the highest value implies the lowest eutrophication; Bangladesh is still half way behind the world's highest level for dissolved oxygen concentration, which indicates considerable risks for ecological stability.

The farm or industrial chemicals and its resulting eutrophication can have impacts on the health of aquatic resources such as fresh water unavailability and reduction in farm output or both. The average level of harmful nitrate and phosphate content in water sources have been found above the drinking and irrigation limits set by irrigation water quality standards (water quality standards for drinking and irrigation by Bangladesh gazette notification in 1997, Ministry of Environment and Forest GOB) (BADC 2012). Consequently, approximately 23 per cent of the national territory suffers from severe water stress, which affects the availability of water for environmental services, agriculture and human well-being (ESI 2005). To ensure a sustaining ground water level and the pollution-free surface water sources, limiting this kind of pollution is essential.

On-ground agriculture (crop cultivation, forestry, etc.) and under-water agriculture (fishery, other aquatic vegetables) both depend on a frequent and sustainable water supply. As a riverine country, Bangladesh has potential in its fisheries and aquaculture beside crop agriculture. A sustainable fishery culture is also a concern because, in Bangladesh, the overfishing index accounts for 6 out of 7 (theoretical maximum) (ESI 2005). Overfishing puts pressure on the ecosystem and threatens biodiversity. The national bio-diversity index is 0.54 out of 1 in Bangladesh (ESI 2005). To reach even near the acceptable threshold level 1, Bangladesh has a long way to go.

Table 1. Ecological indicators and their status in Bangladesh

Indicators	Value	Unit	Threshold value and explanation	Vulnerable to Sustainability

Ecological Footprint	0.50	Hectares of biologically productive land required per capita	If less than the per capita arable land, then ecology is threatened.	***
National Bio-diversity index	0.54	Score between 0 and 1	Large values correspond to high levels of species abundance, and small values reflect low levels of species abundance.	**
Dissolved oxygen concentration	6.70	Mg per liter of water	Low levels correspond to high eutrophication: the world's lowest level is 0 and highest is 13.76.	**
Phosphorus concentration	0.29	Mg per liter of water	High levels correspond to high levels of eutrophication: the world's highest level is 0.67 and lowest is 0.	**
Productivity of Overfishing	6.00	Scores from 1-7	A high score corresponds to a greater degree of overfishing.	***
Hydropower and renewable energy production	1.85	Percentage of total energy consumption	A lesser proportion corresponds to a high reliance on an environmentally damaging source such as fossil fuels.	***
Environmental Hazard Exposure Index	1.31	An index of population-weighted exposure to high levels of environmentally related natural hazards	The theoretically possible range is from 0-4, and the world range is from 0-2.5.	***

Note: Severely vulnerable (***), Moderately vulnerable (**), Vulnerable (*).
Source: ESI (2005); World Bank (2013).

In Bangladesh, the major source of energy for irrigation is environmentally damaging energy sources such as fossil fuels (e.g., diesel operated motor engines). On an average, only 1.85 percent of the total energy consumption comes from hydroelectric and other renewable sources (ESI 2005). Lower proportion of hydroelectric and other renewable energy sources implies higher reliance on fossil fuels and nuclear energy, which implies higher potential for environmental damage.

2.4. Climate Change

Bangladesh is one of the most vulnerable countries to climate change (Brouwer *et. al*. 2007). ESI (2005), reports that the 'environmental hazard exposure index' is 1.31 in Bangladesh, while the world maximum of this index is 2.5 (Table 1). This index is a measure of vulnerability to natural disasters, which identifies its exposure (how often and how severe the natural hazards are) and the sensitivity (how strong the linkages are to social systems), as well as the resilience to its impacts. Therefore, the score of 1.31 indicates that it is challenging to manage frequent natural hazards, minimize their impact on society and address social sensitivity linkages (Brouwer et al. 2007). Evidently, the Global Climate Risk Index (GCRI) 2010 assessed this country as the most vulnerable country to extreme climate events.

Table 2. Climate change indicators in Bangladesh

Sectors	Extreme Temperature	Coastal Flood Inundation	Salinity Intrusion	Drought	River Flood	Flash Flood	Cyclone and Storm Surges	Erosion and Total Accretion
Crop	***	**	***	***	*	**	***	---
Fishery	**	*	*	**	**	*	*	---
Livestock	**	**	***	---	---	*	***	---
Infrastructure	*	**	---	---	**	*	*	***
Industry	**	***	**	---	**	*	*	
Biodiversity	**	***	***	---	**	---	---	*
Health	***	*	***	---	**	---	**	---
Human Settlement	---	---	---	---	---	---	***	***
Energy	**	*	---	---	*	---	*	---

Note: Severe vulnerability (***); Moderately vulnerable (**); Vulnerable (*); Not vulnerable (--).
Source: MOEF (2005).

Climate change and its impact on agricultural sustainability is one of the major concerns currently in the agronomic research. This concern is because agricultural production primarily depends on the climate (Sarker *et. al.* 2012). Crop cultivation and its healthy growth are mainly conditional on climatic potentials such as rainfall, temperature, humidity, drought, flooding and the weather. Moreover, climate change may amplify the observed dynamics and trends, such as fewer but more intense rainfall events during the monsoon season, which will affect crop growth. Among all other sectors identified the MOEF (2005), crop agriculture is the most vulnerable to climate change. Crop agriculture has the potential for severe vulnerability in terms of extreme temperature, salinity, droughts, cyclones, and storms and a moderate vulnerability from coastal flood inundation and flash floods (Table 2). As for instance, an increased level of loss in HYV rice yield was found in the past several years because of climate change (BBS 2011). Compared with

2006, the amount of this damage doubled in 2007 and followed an increasing trend later from 2008 to 2012.

The overall condition of structural instability, unsound ecology and climate change vulnerability can provide a fragile foundation to support agricultural productivity and its sustainability.

3. METHODOLOGY

3.1. Estimation of Growth Rate and Forecast Values

Historical data on agricultural attributes play a vital role in analyzing the potential for sustainability. In particular, this can be useful to estimate both previous trends and future projections of selected attributes. Trends of past performance and future tendency of different attributes allow generating systematic and relevant information about agricultural operations and production efficiencies. Also graph of the moving average trend lines helps visualizing historical trends of a given attribute with ease. Along with the moving average trend line, the rate-of-growth estimates can provide with useful information, thereby enabling a structured approach towards decision-making. Technically, a time series growth analysis and forecasting analysis give overall trend charts from which the researchers and policymakers can get an idea about the past and future performance of a given indicator at a glance.

Given the importance of historical performance analysis, statistical trends were calculated by estimating growth curves of indicator variables applying semi-logarithmic trend function: $\ln Y = \alpha + \beta T$, where Y is the target variable, T is time, and β is the growth rate (Rahman 2010). The moving average analysis is based on the average value of the variable over a specific number of preceding periods. A moving average provides trend information that a simple average of all historical data would mask. The three-years moving average value was calculated using the following formula: $F_{t+1} = \frac{1}{N}\sum_{j=1}^{N} A_{t-j+1}$ where, N is the number of prior periods to include in the moving average; A_j is the actual value at time j; F_j is the resulted value at time j.

A common goal of time series analysis is extrapolating past behavior into the future. Therefore, forecast function was calculated as a future value by using existing values. The forecasted value is a y-value (target variable) for a given x-value (time). The known values are existing x-values and y-values, and the new value is predicted by using linear regression. Forecasted values are used to predict future requirement of agricultural inputs (e.g., fertilizers, pesticides), requirement of natural capital/environmental resources (e.g., land, water), consumer’s preference trends of particular crops, arable land availability etc.

The equation for forecast is $a + bx$, where: $a = \bar{y} - b\bar{x}$ and $b = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sum(x-\bar{x})^2}$, where $\bar{x}$ and $\bar{y}$ are the sample means.

3.2. Sustainability Potential Index (SPI)

The sustainability potential index (SPI) is measured by using statistical deviations. Deviation is a measure of difference between the observed value of a variable and some other reference value. The magnitude of the deviation indicates the size of the difference while the sign of the deviation (positive or negative), shows the direction of that difference. The sign of deviation is positive if the observed value exceeds the reference value and is negative otherwise. These concepts are applicable for data at the interval and ratio levels of measurement. Deviations can be non-dimensionalized in two ways: (i) scaling by dispersion, i.e., by using statistical measures of dispersion and (ii) scaling by location, i.e., by calculating a percent deviation, which is defined as the observed value minus reference value divided by the reference value multiplied by 100 (Doane and Seward 2005).

The SPI was calculated by applying the measurement of scale by location. For a given indicator, the SPI is defined as a percentage of deviations of the recent year's value from the forecasted value the: $SPI = (\frac{T_f - T_r}{T_r})/100$ where, T_f and T_r are 10 year forecasted value of year 2027 and value for year 2017 respectively. An attribute that poses larger deviations and grows with an opposite direction implies higher uncertainty for sustainability. While moderate deviations that grows with an opposite direction, imply lower uncertainty for sustainability. Annotations of the SPI categories and their definitions are explained in Table 3.

Table 3. Categories and annotations of the sustainability potential index (SPI)

Desired sign of growth rate parameters	Positive with large deviations (above 50 percent)	Positive with moderate deviations (below 50 percent)	Negative with large deviations (above 50 percent)	Negative with moderate deviations (below 50 percent)
Positive	High potential for sustainability (HPS)	Moderate potential for sustainability (MPS)	High uncertainty for sustainability (HUS)	Moderate uncertainty for sustainability (MUS)
Negative	High uncertainty for sustainability (HUS)	Moderate uncertainty for sustainability (MUS)	High potential for sustainability (HPS)	Moderate potential for sustainability (MPS)

4. DATA

Table 4 shows descriptive statistics of selected indicators of agricultural sustainability. Indicators that are classified as economic issues of agricultural sustainability are: share of agriculture in GDP at constant price (%), cereal yield (t/ha), labor force in agriculture (% of total labor force), and domestic food price index. The environmental issues were explained using indicators such as: use of chemical fertilizers (thousand t), area under irrigation (million ha), cropping intensity, emission from agriculture CO2 eq. (thousand Giga-grams) and pesticide use (t of active ingredients). Social issues of agricultural sustainability were discussed using relevant socio-agricultural indicators. For example, arable land (% of total land area), land cover as urbanization (i.e., artificial surface including urban and associated areas) (thousand ha), food grain import (thousand t) and food production variability (‘000 USD per capita).

Table 4. Data description of selected indicators

Indicator names	Data year range	Mean	Max	Min	Stdev.
Share of Agriculture in GDPat Constant price (%) (GDP_{AG})	1981-2017	22.64	33.1	11.18	7.16
Cereal Yield (mt/Hectare) (CY)	1977-2014	2.97	4.62	1.87	0.849
Labor Force in Agriculture (% of Total) (LF_{AG})	1984-2016	58.79	66.38	40.8	7.92
Domestic Food Price Index (DFP)	2000-2014	8.17	8.5	7.91	0.185
se of Chemical Fertilizers (Thousand MT) (CF)	1994-2016	3474.7	4791.22	2217.8	677.96
Area Under Irrigation (Million Hectare) (IA)	1980-2017	3.86	5.512	1.56	1.368
Cropping Intensity (CI)	1982-2017	174.21	194	150.35	12.13
Emission From Agriculture CO_2 eq. (Thousand Giga-grams) (CO_2 EM)	1991-2014	67.33	76.15	59.32	5.51
Pesticide use (tonnes of active ingredients) (PU)	1990-2014	11159.16	34068.3	1266	9433.57
Arable Land (% of Total Land Area) (AL)	1977-2014	74.04	80.23	69.9	3.23
Land cover(Artificial surface including urban and associated areas) Thousand Hectare (URB)	1992-2015	34.67	83.15	15.92	20.71
Food Production Variability (Per capita Thousand $) (FPV)	1990-2014	3.48	5.5	1.1	1.16
Food Grain Import	1980-2013	2512.58	4952.44	773.41	1060.17

(Thousand MT) (FGI)						

Source: FAOSTAT (2014); World Bank (2013); BER (Annual Issues).

5. RESULT

5.1. Economic Issues

Table 5 shows annual growth rates of selected economic indicators of agricultural sustainability. Also, values of 5-year and 10-year forecast of those indicators are presented in Table 5. The SPI of GDP_{AG} shows that the growth rate of agriculture's value added to the nation's GDP is negative. A wide deviation is forecasted for the next 10 years. This trend implies high uncertainty for economic sustainability in agriculture (HUS). Unlike the positive annual growth rate in cereal yield, labor force and domestic food price index are following variable trends i.e., unfavorable for economic sustainability in agriculture. The SPI remarks for these agro-economic issues fall under the category of 'moderate uncertainty for sustainability (MUS)' (Table 3). Three-years moving average trend lines visualize historical tendencies of these selected economic attributes (Figures 1, 2, 3 and 4).

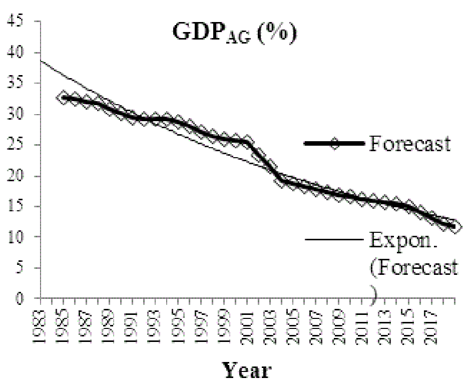


Figure 1.

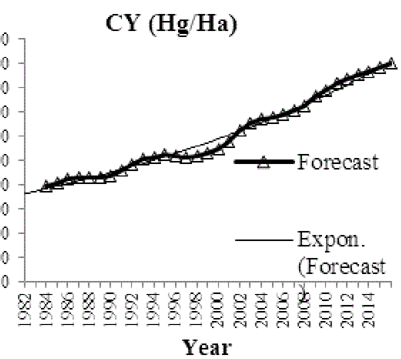
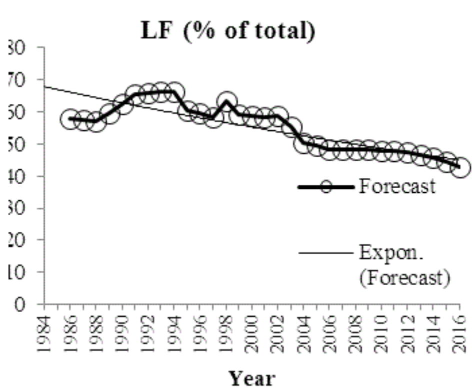


Figure 2.



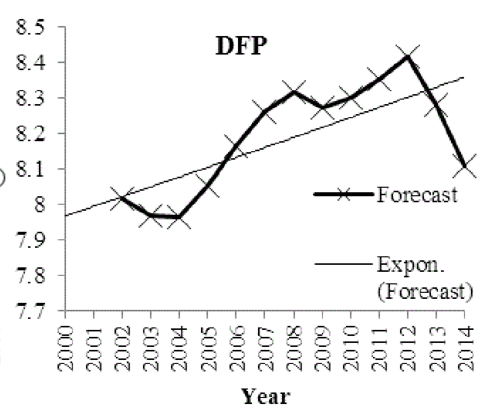


Figure 3. Figure 4.

Table 5. Growth rates, forecast values and SPI of economic indicator variables

Indicator names	Growth (Annual rate)	Recent year* value (2017)	5 Years forecast (Year 2022)	10 Years forecast (Year 2027)	SPI Value	SPI Remark
GDP_{AG}(%)	-0.031	11.18	7.41	4.14	-63.0	HUS
CY (Hg/Ha)	0.026	46671.59	49252.22	54263.21	16.2	MPS
LF_{AG} (% of total)	-0.024	40.8	39.65	35.67	-12.6	MUS
DFP (Index)	0.002	7.99	8.4	8.51	6.5	MUS

Note: HUS and MUS imply high and moderate uncertainty for sustainability respectively; MPS implies moderate potential for sustainability. * Recent year means 2017 (we use actual value where it is available for 2017 and forecasted value for 2017 upon unavailability in literature).Source: Authors calculation.

Although having a rising trend in cereal yield and a falling trend in GDP_{AG} indicate that the agriculture sector is not satisfactorily viable for economic growth. Percentage of agricultural labor force also followed a declining trend over the period 1984 to 2016. Limited scope for employment creation in agriculture, social and economic challenges in doing agribusiness, tendency for migration into urban areas, employees' preference for working in industrial sector for higher wage might be considered as some of the major reasons of such falling trend (Puga and Venables 1996).

Declining labor force participation and a consequent fall in economic activity in agriculture might inflate prices of agricultural products. Consequently, an increasing trend in domestic food price index was found over the last 15 years, which projects subsequent increases in following 10 years (Table 5). Also, IRRI (2013) found an indiscriminate pattern of food grain prices in different market-phases. As for instance, rice has been one of the major food grains that contribute substantially to the total food grain production in Bangladesh. Historical data on Bangladesh's rice statistics shows that the farm harvest price has always remained at a half point below the wholesale and retail prices over the last thirty years (IRRI 2013). Such distortions in price levels of major food grains and other cereals would disrupt economic sustainability in Bangladesh agriculture.

5.2. Environmental Issues

Table 6 shows growth rates of selected environmental indicator variables along with 5-years and 10-years forecast points and the SPI indices. SPIs of the selected environmental indicators project moderate uncertainty for agricultural sustainability (MUS) while it showed high uncertainty for sustainability (HUS) for 'use of farm pesticide' with 120 percent deviations in next 10 years. In Bangladesh, farmers used chemical pesticides at an increasing rate, i.e., at a rate of 14.3% p.a. If such trend persists, the use of pesticides in agriculture may be more than double in next 10 years. Bangladeshi farmers apply chemical pesticides at a high rate, firstly, as a precaution i.e., in advance. Secondly, while facing the pest attack problems, they rarely follow instructions on applying the recommended dose and often fail to choose the correct types of pesticides. Farmers' awareness on pest attack problem and its environment-friendly management techniques is likely to be unsatisfactory for realizing environmental sustainability in Bangladesh agriculture (Wilson and Tisdell 2001; Dasgupta et al. 2007; Robinson et al. 2007).

Farming practices such as extensive irrigation and chemical fertilizers application also affect the quality of natural resources e.g., soil, water and air. Percentage of area brought under irrigation is rising at a rate of 3.5% p.a. since 1980s, which indicates considerable extraction of both groundwater and surface water sources. Application of chemical fertilizers increased at a rate of 2.5% p.a. over the period 1992 to 2016. This increasing trend in use of farm chemicals partly explains why CO_2 emission from agriculture was rising at a rate of 1.1% p.a. in Bangladesh in last 15 years. The CO_2 emission from agriculture contributes pollution of atmospheric constituents (air) along with soil and water sources. The chemical-intensive and irrigation-based farming practices leave the soil exposed and aggravate land degradation (Lal 2000). Also, FAO (2015) considers that the pollution of soil can be greatly influenced by agriculture and deforestation. Bangladesh is ranked 3rd among South Asian countries for the extent of soil degradation. The Global Assessment of Human-Induced Soil Degradation (GLASOD) identifies 5.0 degrees of land degradation and finds Bangladesh has a degree of 2.61 (FAO 2015). The GLASOD explains countries, such as Bangladesh, might experience a drastic reduction in agricultural productivity and must restore the original biotic functions that have been largely destroyed.

Table 6.Growth rates, forecast values and SPI of environmental indicator variables

Indicator names	Growth (Annual rate)	Recent year* value (2017)	5 Years forecast (Year 2022)	10 Years Forecast (Year 2027)	SPI Value	SPI Remark
CF(Thousand MT)	0.025	4738.4	4982.6	5360.37	13.1	MUS
IA (Million hectare)	0.035	5.512	6.69	7.28	32.1	MUS
CI	0.006	194	199.64	204.98	5.7	MUS
CO2 EM (Thousand Giga-grams)	0.011	78.51	82.142	86.112	9.68	MUS
PU(Tons of active ingredients)	0.143	15833.62	29696.06	34833.96	120.0	HUS

Note: HUS and MUS imply high and moderate uncertainty for sustainability respectively; MPS implies moderate potential for sustainability. * Recent year means 2017 (we use actual value where it is available for 2017 and forecasted value for 2017 upon unavailability in literature). Source: Authors calculation.

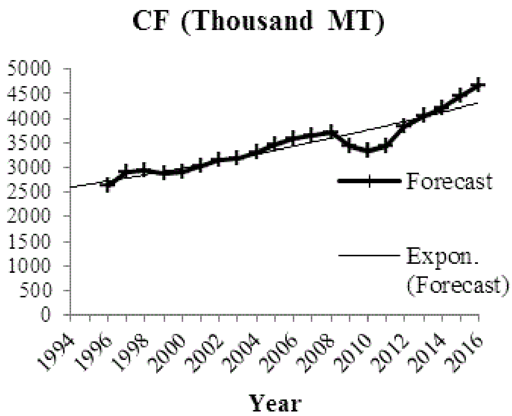


Figure 5.

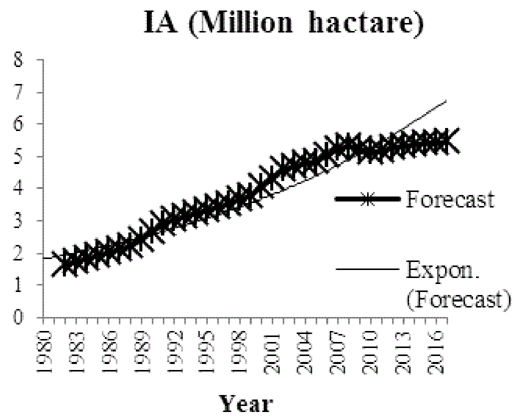


Figure 6.

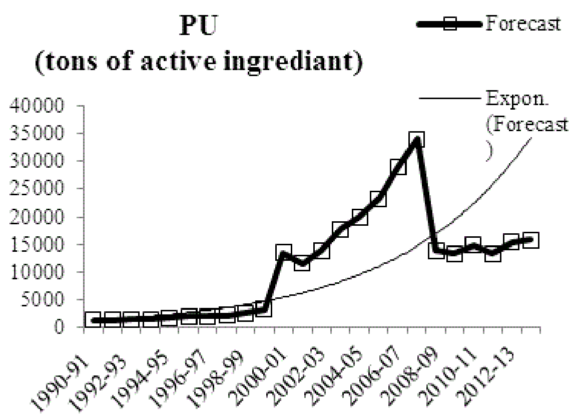


Figure 7.

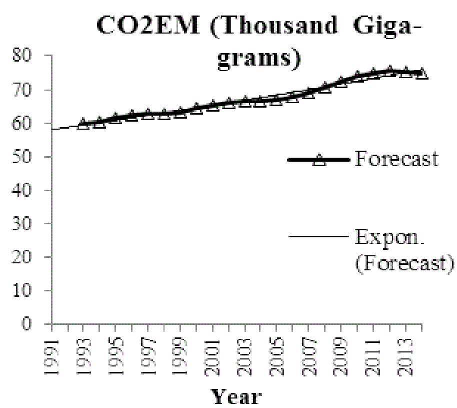


Figure 8.

5.3. Social Issues

Table 7 shows major social attributes of agricultural sustainability. All of these selected socio-agricultural variables were found as moderately uncertain for sustainability (MUS). For instance, arable land as a percentage of total land area in Bangladesh was decreasing at a rate of 0.3% p.a. over the years from 1977 to 2014. Bangladeshi farmers are losing valuable arable lands as a result of rapid urbanization, which creates agro-ecological zoning problems, inflates land rental values, and affects production efficiency and productivity (Cohen 2006). The area of land encroached for urbanization and non-agricultural purpose increased at a higher rate, at a rate of 7.7% p.a., therefore casting uncertainty for agricultural production. This results in an increase in land lease cost. The land lease cost for the major crop (i.e., rice cultivation) was BDT 3,698 per acre in 2008, which has increased to BDT 5,500 per acre in 2010 (BBS 2010).

Table 7.Growth rates, forecast values and SPI of social indicator variables

Indicator names	Growth (Annual rate)	Recent year* value (2017)	5 Years forecast (Year 2022)	10 Years forecast (Year 2027)	SPI Value	SPI Remark
AL (% of total land area)	-0.003	68.62	67.67	66.30	-3.37	MUS
URB(Thousand Hectare)	0.077	83.15	84.98	101.45	22.0	MUS
FGI (Thousand MT)	0.028	4083.60	4273.43	4732.87	15.9	MUS
FPV (Per capita thousand $)	0.004	3.66	3.76	3.75	6.3	MUS

Note: HUS and MUS imply high and moderate uncertainty for sustainability respectively; MPS implies moderate potential for sustainability. * Recent year means 2017 (we use actual value where it is available for 2017 and forecasted value for 2017 upon unavailability in literature.Source: Authors calculation.

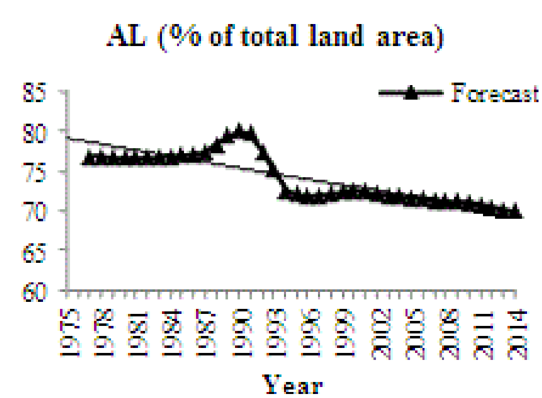


Figure 9.

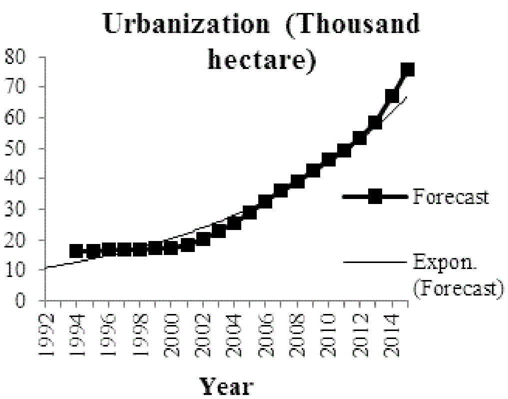


Figure 10.

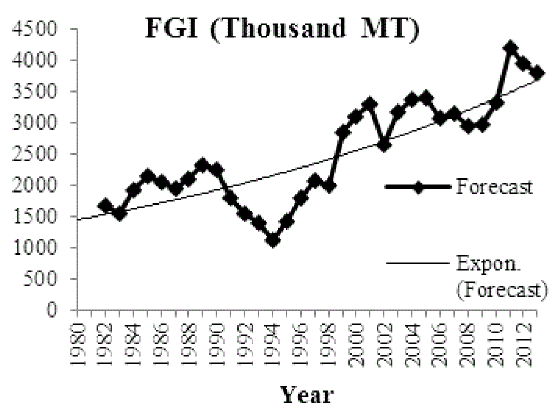


Figure 11.

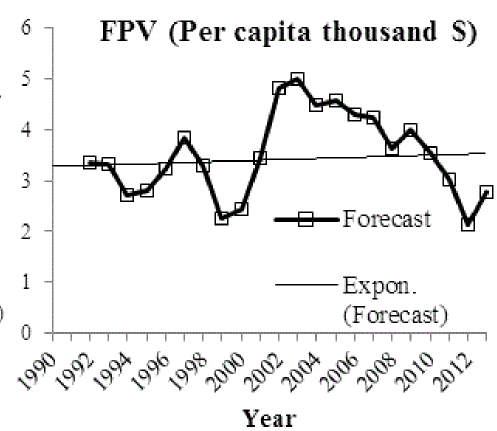


Figure 12.

An increasing growth rate of food grain (rice, wheat and maize) import was also found at a rate of 2.8% p.a. over the period 1980-2013. This study furthermore forecasted that the quantity of food grain import is going to reach from 4.08 to 4.73 million t over the next 10 years. Such increasing trend indicates nation's gradual dependency on imported food grains. This might be due to the growing demand for imported variety of rice, wheat and maize, which exhibits switched preference of the consumers for those particular food grains. Such pattern of consumers' preference might result in farmers' voluntary discontinuation of cultivating specific crops or vegetables that are being imported. Production decisions are often directly influenced by consumers' preference for a particular crop (Allen et al. 1991). When demand for imported grain increases due to either better quality or relatively lower price of imported crops, the domestic production of that particular grain subsequently declines. Domestic farmers' incomes might fall and agriculture loan incurred to expand production might not be repaid and, therefore, major socio-economic interruptions in agricultural sustainability might occur. A decline in production of domestic food grain affects food production variability (Pretty et al. 2003). In Bangladesh, the per capita food production variability has been following a fluctuating trend (Figure 12) and the annual growth rate was only 0.4% p.a. over the period 1990-2014. Such trend anticipates uncertainties for food security condition and hence the SPI evaluated this indicator as having moderate uncertainty for sustainability (MUS).

Overall, trends in economic, environmental and social issues of Bangladesh agriculture affect the sustainability condition considerably. In particular, chemical-based intensive farming practice directly influences environmental issues while growing trends of population density primarily hinder social issues (Sabiha 2016). The farm chemical degrades the quality of natural resource and the population pressure results scarcity in natural capital/agricultural inputs. Limited availability of agricultural inputs influences major economic issues and causes uncertainty in agricultural sustainability.

CONCLUSION AND POLICY RECOMMENDATIONS

The principal aim of this paper was to analyze the potential for Bangladesh agricultural sustainability. The agriculture is defined as sustainable if it is economically viable, environmentally sound, and socially non-exploitative. Therefore, the analysis encompassed three major issues in evaluating sustainability. These are: agro-economic, agri-environmental and socio-agricultural issues, which are evaluated by examining selected indicators for each issue. In particular, analysis was conducted to evaluate how these selected indicators have been performing since last three decades using growth function. Also future projections of these indicators were estimated using statistical forecast function to predict the potential and/or uncertainty for agricultural sustainability in the next decade. A sustainability potential index (SPI) is also calculated for each selected indicator as the percentage of deviation of the recent year value from the forecasted value. Higher and moderate uncertainties for agricultural sustainability are defined by the SPI value above/equal to 50 percent and below 50 percent respectively (when it is trending against hypothesized sign of direction toward sustainability).

Results reveal that environmental attributes pose considerable uncertainty for agricultural sustainability compared to social and economic attributes (Table 8). Pollution and degradation of environmental resources from pesticides and chemical fertilizers, extensive water extraction for irrigation, increase in cropping intensity, CO2 emission from agriculture cause uncertainty for sustaining agricultural growth. Rapid urbanization and gradual decline in arable land, fluctuating per capita food production variability and switching consumers' preference for imported food grains were also found as some of the major social issues affecting the likelihood of agricultural sustainability. Economic issues such as declining trends in percentage of working age population in agriculture, increasing trend in domestic food price index and negative growth rate in agricultural value added to the GDP (GDPAG) were observed in this study, which shows uncertainty for economic viability of agriculture. In particular, the SPI of the GDPAG and pesticide use (PU) was identified as two economic and environmental indicators, respectively, that pose high uncertainty for agricultural sustainability (HUS). Rest of the selected social, economic and environmental indicators were found as moderately uncertain for agricultural sustainability (MUS).

Table 8. Comparing the SPI of economic, environmental and social issues

Issues	Indicators	SPI remarks	Relative grade point
Economic issues	GDP_{AG}(%)	HUS	40
	CY (Hg/Ha)	MPS	
	LF_{AG} (% of total)	MUS	
	DFP (Index)	MUS	
Environmental issues	CF (Thousand MT)	MUS	60
	IA (Million hectare)	MUS	
	CI	MUS	
	CO_2 EM (Thousand Giga-grams)	MUS	
	PU (Tons of active ingredients)	HUS	
Social issues	AL (% of total land area)	MUS	50
	URB (Thousand Hectare)	MUS	
	FGI (Thousand MT)	MUS	
	FPV (Per capita thousand $)	MUS	

Note: Relative grade point of different issues are calculated as apercentage of total SPI remarks valuesfor a given issue by assigning values MUS = 1, MPS =-1, HUS = 2, and HPS = -2. Higher grade point implies higher uncertainty in agricultural sustainability.

The following policy recommendations can be drawn from these findings. First, implementation of pesticide regulation is required. The pesticide regulation is a measure of whether countries allow, restrict, or ban the 'dirty dozen' Persistent Organic Pollutants (POPs), that are 12 highly toxic chemicals commonly used in agriculture, under the Stockholm Convention. At present, Bangladesh scores 21 award points of pesticides regulation out of maximum award points of 25 (EPI 2014). This implies some of the POPs are still being used in Bangladesh. Implementation of the pesticide regulations can be done through frequent monitoring and field inspections. Also investments are required in organizing demonstrative instruction on pesticide/chemical fertilizers application procedure and extension services for improving farmers' awareness on pollution from farm chemicals (Rahman 2003). Second, access to and availability of basic agricultural inputs should be ensured, particularly for small and marginal farmers cultivating in remote areas, through investments in infrastructure and price ceiling policies for basic inputs. Third, policies for restrictions on importation of food grains and vegetables varieties are needed, which are cultivated well in domestic regions. Fourth, investment in agricultural research and development is required to put quality-control regulation in effect. This would work for switching-back consumers' preference for imported food grain. Fifth, land fragmentation is required to be restricted by reforming land ownership policies such as imposition of higher registration fee, particularly in case of farm lands. In Bangladesh land fragmentation is one of the most significant determinants that negatively influence productivity growth (Rahman and Rahman 2009; Rahman and Salim 2013).

The aforementioned policy recommendations are expected to foster the interactions between three important issues of agricultural sustainability. Implementation of pesticide and farm chemical regulations is expected to ensure environmental soundness, while agricultural subsidy and extension services would expand agriculture as an economic activity and therefore, facilitate its economic viability. An economically viable agriculture that is environmentally sound can be better off for socio-agricultural policies measures to be in effect.

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