

REVIEW ARTICLE

Bangladesh towards green growth: a review of environmental sustainability indicators

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Abstract

Pursuing green growth is crucial for Bangladesh to transition from an unsustainable economic trajectory to a more sustainable and inclusive one. Bangladesh is picked for this study because of impending and severe economic and environmental threats. This study intends to review the present scenario of various environmental sustainability-related indicators in Bangladesh, focusing on renewable energy consumption, freshwater resources, water productivity, CO₂ emissions, energy intensity, air pollution, and natural resource rents. The World Bank database has been utilized to obtain secondary time series data of Bangladesh spanning from 2000 to 2020. As a descriptive study, cross-sectional and observational research methods as well as descriptive statistics and figures are used to elucidate the secondary data. Data demonstrate that Bangladesh now generates 41.16% of its energy from renewables, despite considerable variability. Regardless of the variation in freshwater availability, averaging at 708.19 cubic meters per capita, efficient water productivity remains consistent, indicating a robust water management system. The country demonstrates a relatively low carbon footprint, emitting 0.35 metric tons of CO₂ per capita, alongside varying energy intensity levels, highlighting the need for enhanced efficiency measures. While pervasive PM_{2.5} air pollution poses a significant health risk, Bangladesh's reliance on natural resource rents underscores the importance of sustainable resource management practices for long-term economic stability. The observations of this study might assist in the formulation of policies of water management systems, air pollution control initiatives, and conservation of ecology to promote Bangladesh's long-term sustainability objectives and formulate policies.

Keywords: Green growth; Environmental sustainability; Low-carbon economy; Sustainable development; Bangladesh

Introduction

Green development with significant theoretical and practical repercussions is today's worldwide economic development movement for ensuring a sustainable environment. Nonetheless, there isn't a single, agreed-upon definition of "green development." Similar words like "green economy" and "green growth" are used in tandem with similar meanings in reports from numerous international organizations, with just small semantic changes. Nonetheless, they all focus on supporting economic development and the efficient use of natural capital and environmental resources.

They campaign for the prevention and reduction of waste pollution, along with the creation of opportunities to increase inclusive societal well-being by establishing a green economy, allowing for the transition to sustainable development (Kasztelan, 2017).

The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) first brought up the idea of "green growth" in 2005 to explore the possibility of implementing a new "low-carbon sustainable development model" for Asia's fast-developing nations. The idea is analogous to sustainable development, which is widely acknowledged in industrialized nations. Nonetheless, a lot of developing nations have seen environmental conservation as posh and worried that sustainable development would impede their ability to expand economically (United Nations, 1987).

Many developing nations are diversifying their production. So, their fixed natural resources and land are diminishing and as such pollution are becoming more prevalent (Udoh et al., 2023). The way the world economy is now developing is not sustainable and is predicated on the idea that burning fossil fuels would accelerate growth. Green growth, as opposed to sustainable development, is a long-term strategy for advancing economic expansion and development that aims to strike a balance between environmental risks and expansion (Popp et al., 2011). The management and protection of environmental resources is a component of the green growth approach. However, the value of such resources is often ignored.

Bangladesh among the South Asian countries has drawn special attention for various climatic issues. Bangladesh ranks sixth globally in terms of susceptibility to catastrophic weather patterns and climate change, as per the Global Climate Risk Index 2022. In Bangladesh, 185 weather-related incidents claimed over 700 lives between 1996 and 2015. Bangladesh suffers annual losses from average tropical storm damage of about \$1 billion. 13 million people may be impacted by inward displacement due to climate change by 2050, and the agriculture industry may lose a third of its GDP as a result. Floods can lower GDP by up to 9% if they are severe. Based on scientific projections, one of the largest mass migrations in Bangladesh may effect due to climate change in human history. Furthermore, it is anticipated that Bangladesh's energy consumption will continue to rise in the next decades. The country's overall energy consumption has increased recently due to a combination of factors including substantial industrialization, growing urbanization, and expanding populations (Raihan et al., 2022). Bangladesh is still dependent on fossil fuels to supply its energy needs, even though there has been a noticeable shift towards a more ecology-friendly energy system and there is a considerable opportunity for environmentally friendly energy sources. In 2020, a mere 28% of Bangladeshi energy originates from renewable sources, according to World Bank figures for 2023 as well. Nonetheless, by 2041, the government of Bangladesh has promised to get 40% of its electricity from renewable sources. Moreover, the findings of the study of Raihan (2023c) provide a dire picture, alerting decision-makers to the ways that national growth contributes to rising carbon emissions and the ways that foreign corporations operating there exacerbate the issue.

In 2009, Bangladesh became the first low-income nation to have a climate change strategy that included a significant focus on climate mitigation. Bangladesh has adopted the nationally determined contributions (NDC) papers as national policies, which outline precise climate obligations, as part of the Paris Agreement. According to Fisher (2013), Bangladesh has placed significant emphasis on climate mitigation within its climate policies in order to attain low-carbon development by actively pursuing interaction with climate change mitigation and economic growth. According to forecasts, Bangladesh has pledged at COP22 to reduce emissions by 21.8% throughout 2020 and 2030, as part of its Nationally Determined Contributions (NDCs). Bangladesh has the capacity to surpass these commitments through efficient execution, the creation and use of technical solutions, and collaboration within the region. In light of this, Bangladesh's hopes of realizing its NDC goals depend on changes it makes to its energy funding and policy (Raihan, 2023b).

According to the World Bank (2023), Bangladesh's economy has witnessed rapid growth, ranking second in South Asia and fifth internationally. With a population density among the highest globally, it is projected to reach 200 million people by the year 2050. The expansion in population was followed by urbanization and industrialization, which resulted in significant pressure on the quality of environmental and natural resources, such as water, soil, and air pollution. Ecological and public health, along with economic prosperity, have been jeopardized by this phenomenon. Consequently, Bangladesh is now engaged in a comprehensive examination of environmental and climatic concerns in conjunction with its economic development, demonstrating much excitement in embracing a green growth strategy. Bangladesh has made a vow to transition towards a green economy in its national plans and goals, despite its carbon emissions accounting for just over 0.1 percent of world carbon emissions (Bangladesh Planning Commission, 2020). This commitment is aimed at tackling difficulties connected to the environment. So, Bangladesh firmly believes that environmental degradation has a detrimental impact on the inclusive economic growth of the country. As part of this issue, Bangladesh has given priority to climate change and degradation of different environmental factors in their 7th and 8th five-year plan with an aspiration to achieve green growth and to calculate the green GDP as a long-term goal. So, to attain this goal Bangladesh needs to monitor and evaluate the green growth-related indicators. In this regard, some research questions can be raised; what are the present scenarios of green growth of Bangladesh especially the environmental sustainability related indicators? What successes does Bangladesh have so far, and what obstacles does it yet face in the pursuit of green growth?

However, numerous previous studies have been conducted considering the economic, social and environmental indicators as a whole to describe the green growth of different countries in the globe but very few on Bangladesh. This study addresses to fill a research vacuum in the existing literature on green growth in Bangladesh. Moreover, previous research has primarily focused on overall indicators of green growth, with no specific study on evaluating environmental factors. So, considering the foregoing as the novelty, this present study aims to narrate and investigate only the environmental indicators of green growth to show the current state of these indicators in Bangladesh. Recognizing the climate sensitivity of Bangladesh, the goal of this research is to review the present situation of environmental sustainability-related variables as well as the accomplishments and obstacles in its quest for green growth. Based on the observations, this research has also drawn several practical and policy implications.

Based on the study of Jha et al. (2018), this study considered CO₂ emissions, energy intensity level of primary energy, renewable energy consumption, PM_{2.5} air pollution, total natural resources rents, per capita renewable internal freshwater resources, and water productivity as the environmental indicators of green growth in Bangladesh. Consequently, any study on green growth in Bangladesh will show the path to formulate and design environment, climate, and green growth-related strategies and policies for Bangladesh.

The paper proceeds as follows. In section 2, presents a review of literatures on relevant topics of green growth both in domestic and international view point. Section 3 presents the research materials and methods. Results and discussion of main observations by comparing with previous studies are in section 4. Section 5 discusses the academic and practical implications based on the observations of the study. Section 6 put forth some policy recommendations. And, finally, section 7 concludes the study by mentioning further research avenues considering the limitations of this research.

Literature Review

To conduct this study various literatures have been studied regarding the concept and theoretical background of green growth, different indicators of green growth, and current state of the green economy of Bangladesh.

Theoretical Background of Green Growth

In the 1870s, Marx examined justice and fairness, as well as people's livelihood and general well-being, in his 'Classic Work Capital'. He believed that because laborers created money, they ought to be its owners as well. In addition to condemning the misuse of money and reducing the gap between the affluent and the less fortunate, he urged society to advance justice and fairness. The world has seen incredible economic growth since the dawn of the twenty-first century, especially in rising countries whose success stories have gained international recognition. However, disparity and discrepancy between the affluent and impoverished are still expanding, which suggests that the pace of development has not had a significant influence on people's societal well-being (Kamah et al., 2021). Consequently, it's vital to transition from conventional economic growth to growth that may decrease disparity and poverty to produce growth that is helpful to the poor. Nevertheless, global economic development has raised a limited supply of resources and eco-friendly challenges and moved the attention of nations from conventional economic growth toward green growth (Ulucak, 2020).

The idea of sustainable development was put up by the UN World Commission on Environment and Development, with the stated objective of "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1985). This notion of sustainable development deficiencies of flexibility since it is unclear how to balance the interactions between the natural environment and society when the economy is growing. The sustainable development mode known as inclusive green growth (IGG) aims to coordinate the economy, society, and environment comprehensively while also promoting the growth of the economy, equity in society, social well-being, triumph sharing, resource conservation, and ecological environment protection (Wu & Zhou, 2021). The phrase has gained a reputation as a stand-in for collaboration and development planning, and it is seen as a way to meet the objectives of sustainable development (Berkhout et al., 2018). In contrast to the theory of 'classical growth' which argues that "economic growth comes first," inclusive growth theory is better for social welfare, environmental protection, and equilibrium inclusivity. Furthermore, it is a widely acknowledged solution to the problems of poverty, injustice, and environmental damage.

Scholars in the domain of sustainable development targets have ongoing and conflicting perspectives in the literature. Certain researchers claim that economic expansion will facilitate inclusivity throughout society and foster environmentally sustainable development. Firstly, the economic expansion of an area would attract foreign direct investment, enhance the fiscal revenue of the government, and boost public infrastructure investment, while also fostering technical advancement. One potential advantage is that it may support the social care services sector by allocating fiscal resources to generate employment and promote gender-inclusive development (Kim et al., 2019; Nair et al., 2020). The "trickle-down" effect will offer new possibilities to poor individuals to enhance their income and well-being, foster justice, and achieve social inclusion. Furthermore, they hold the belief that economic growth has the potential to enhance the natural environment and foster a greater degree of sustainable development for global green growth simultaneously (Aşıcı, 2013). For instance, economic expansion has the potential to enhance worker productivity by improving the overall health status, addressing market inefficiencies, and promoting energy and environmental efficiency via the provision of subsidies. Furthermore, economic growth has the prospective to expedite the development of more environmentally friendly infrastructure or advancements in technology (Van Der Ploeg & Withagen, 2013).

Nonetheless, the new inclusive development paradigm known as the Amsterdam School of Governance posits that the objective of "inclusion" as a comprehensive framework is incompatible with the idea of constant economic progress. According to this perspective, social inclusion cannot be achieved without ecological inclusion, which refers to having access to the environment-friendly resources necessary for the well-being of humans. Additionally, relational inclusion—which means making choices that affect well-being and its basis—

is equally crucial. (Gupta et al., 2015; Gupta & Vegelin, 2016; Rammelt & Gupta, 2021). This comprehensive comprehension indicates that inclusive development is a notion that is closely linked, where "inclusive" is not only an adjective but rather signifies a transition of "development" after the growth phase (Rammelt & Gupta, 2021). Recently, scientists suggested the theory of "postgrowth", which strives to promote the welfare of human, and environmental health by equitably and consciously downscaling (degrowth) overconsumption, over-accumulation and expropriation, and social justice (Sandberg et al., 2019). According to this theory, GDP should not be the primary goal of development, and the growth paradigm has to be updated. Based on economic growth, it is vital to minimize the consumption of energy and encourage members of society to share the advantages of development jointly while safeguarding the environment (Hankammer et al., 2021). Hence, comprehensive development and degrowth concentrate on the link between economic conditions, society at large, and the environment (Gupta & Vegelin, 2016).

Beginning with the first Rio conference on environmental sustainability, the world has struggled to address several issues, including the pressing need to maintain economic growth and the escalating degradation of the environment. Considering these stressful challenges, the green growth idea emerged as a means to integrate and tackle these two problems. Green growth entails the promotion of economic progress by making use of ecological resources for the sake of mankind (The Washington Post, 2017). According to the OECD, green growth refers to the extent to which economic development is becoming more environmentally friendly by using natural resources more efficiently. Again, a sustainable and more ecologically friendly economy is being tracked by the green growth index. Green growth refers to the use of natural resources in a sustainable way to achieve economic development. The aim is to transition towards an economy that promotes the well-being of humans and mitigates disparities among individuals in the long term, while also avoiding the imposition of environmental hazards on future generations (OECD, 2020).

Concept of Green Development

Human cultures share the goal of progress, and maintaining the environment is essential to their existence and further growth (Barbier, 2014). As a result of the world's rapid economic development, there are now more and more severe environmental issues, including extreme weather events and frequent natural disasters brought on by climate change, excessive resource consumption that is causing forests, grasslands, land, and water resources to disappear or degrade, and an increase in pollution issues related to air, water, and soil pollution. History demonstrates the unwavering nature of advancement. In some nations, black development (BD) was the focus of the early industrial revolution. For instance, in China, the term "black development" describes the high levels of consumption, pollution, and emissions, coupled with inefficient industrialized economies (Hu, 2017, 2018; Xu, 2014). With this strategy for growth, people may accumulate as many resources as they choose to fulfill their own material needs. While implementing BD in certain sectors may help stakeholders in the near run, there is not much dispute that it has led to an increase in environmental issues. However, if this pattern is followed, non-green behaviors will eventually surface. Therefore, the issue is: Does development always mean environmental degradation? Green development (GD), which concurrently takes into account ecology, economics, resources, and the environment, emerged as a solution to the urgent environmental issues that follow economic and social growth (Li et al., 2019). According to He et al. (2019), the majority of scholars believe that green economy theories serve as the conceptual underpinning of GD. But concepts related to GD, green growth, sustainable development, social duty, production, and living have been more intertwined throughout time. It is thus a difficult effort to completely depict GD. Therefore, green development is a complex adaptive system (CAS) that is strongly entwined with the environment, and natural, social, and economic spheres. The ultimate goal of any progress is to benefit human civilization. Green development should thus

focus more on individuals. For instance, China's growth has advanced at an astounding rate over the last few decades, and its accomplishments are stupendous. However, this strategy is unsustainable since some of these successes have come at the price of the environment (Li et al., 2019).

Different Countries' Views on Green Growth

In 2008, the Republic of Korea became the pioneer nation to proclaim low-carbon green economic growth as the country's vision and strategy. Following this declaration, the government established an extensive institutional and legislative structure to put the vision and strategy into practice. The plan consists of fifty areas of activity, 10 policy orientations, and three primary policy goals. With the three strategies and ten policy direction sets of the 5-year plan for Green Growth serving as a framework, Statistics Korea chose 30 indicators in November 2011 to evaluate policy success and the degree of green growth implementation (UN Escap, 2013).

China is now the biggest and most rapidly growing emerging economy globally. The economic boom is accompanied by significant environmental damage, rendering the current growth style unsustainable. It is imperative to fundamentally alter the method of economic expansion and choose the path of sustainable and environmentally friendly growth. Based on this, how to eradicate the 'black footprint' in the process of fast economic expansion while attaining green growth is an important topic that is extensively concerned by China and most nations around the globe (Sun et al., 2020).

During the 2012 Rio+20 Summit, the idea of inclusive green development was first put out. The agenda of sustainable development goals of the UN in 2015 included suggestions for China's economic transition as well as additional clarification on inclusive green growth. "Inclusive green growth" is the principal objective of China's 12th 5-year plan to attain sustainable development. According to the 19th National Congress Report of China's communist party, China's economy has transitioned from a fast growth stage to a high-quality advancement stage. This indicates that to achieve economic and socially inclusive green growth, economic development of China should not only concentrate on raising total factor productivity in the future but also, on enhancing the effectiveness of green growth, advancing the green economy, and establishing and enhancing the green and low-carbon circular creation economic structure under the five development concepts (Sun et al., 2020).

National policies including explicit climate pledges were interpreted as nationally determined contributions (NDC) papers for the purposes of the Paris Agreement. Bangladesh and Nepal, two low-income nations that have made some beginning efforts toward resource conservation and climate mitigation while not being significant contributors to global greenhouse gas (GHG) emissions, were selected as case studies for an investigation into the greening of economic development. In 2009, Bangladesh became the first low-income nation to have a climate change strategy that included a significant mitigation component. Nepal's "climate change policy -2011" came after Bangladesh's "climate change strategy and action plan -2009." To attain low carbon development by pursuing synergies with climate adaptation and economic growth, Bangladesh and Nepal placed a strong emphasis on climate mitigation in their climate policies (Fisher, 2013).

Different Indicators of Green Growth

Much research has been attempted and established to assess inclusive green growth and discover its generating indicators. In 2016, the Green Growth Knowledge Platform (GGKP) employed resource efficiency, natural assets, decoupling, risk and resilience, economic possibilities and activities, and inclusivity as the primary

indicators (Green Growth Knowledge Platform, 2013). The World Economic Forum (WEF) used the following metrics in 2017: adjusted net savings, GDP's carbon intensity, public debt, dependent ratio, per capita employment rate of GDP, poverty rate, labor productivity, median family income, health-life expectancy, and wealth and income Ginis (World Economic Forum, 2017). In addition, studies conducted by the United Nations Economic and Social Commission for Asia and the Pacific, or UN ESCAP, used planetary limits, eco-efficiency, investment in natural capital, equitable distribution and access, and structural transformation as forming indicators in calculating inclusive green growth (UN Escap, 2013). The directional distance function and an output-oriented slack-based measure were used in a study by Sun et al. (2020) to calculate inclusive green growth conditions in China's cities. The study used labor, GDP, capital, wastewater, and energy as desirable outputs and emissions as undesirable outputs. Due to the indicators' incompleteness in including crucial variables to characterize inclusive green development, several of these studies contain several flaws (Jha et al., 2018).

Green growth may be measured using established frameworks and metrics. The OECD's 2017 collection of green growth indicators has contributed the most practically of all of them. Nonetheless, almost all of the performance assessment frameworks associated with green development consistently include fourteen metrics. Three selection criteria for indicators have been proposed by the OECD: measurability, analytical soundness, and policy relevance (Merino-Saum et al., 2018). It is noted that SMART indicators—specific, measurable, attainable, relevant, and time-bound—should be used in the context of studies. They have to be well defined, "measurable in both qualitative and quantitative ways, achievable with the resources at hand, pertinent to the problem, or responsive to adjustments within policy frameworks" (Schomaker, 1997).

Environmental Indicators of Green Growth

Indicators can be important in a variety of information brokerage patterns, from immersive and cooperative co-creation processes to one-way distribution. The process of producing indicators should be viewed as a component of knowledge brokerage, taking into account both value- and fact-based factors. The process of developing indicators should be able to unite disparate viewpoints and promote social learning among participants with various backgrounds and areas of interest. Future research might take an intriguing turn when combining the indicator-based approach with other methods of communication and engagement, such as visualizations (Bell et al., 2016). The indicators should be in line with locally relevant user demands to maximize their utility at the national or local level; yet, considering the national context might easily result in indicators that are not internationally compatible. The indicators need to be based on current and trustworthy data to meet the many expectations (Lyytimäki et al., 2018).

The group of environmental indicators that Ryszawska (2015) proposed in his study is based on the recommendations of the United Nations Environment Programme. These indicators cover four areas: management of ecosystems (forestland, water stress, land, and marine conservation area), energy productivity and efficiency (such as material productivity, water productivity, CO₂ productivity), and waste and chemical management (waste generation, collection, recycling, reuse, and management).

To assess green growth, the OECD provided a list of metrics approved by the Green Growth Knowledge Platform (2013). The following are the indicators they suggest: CO₂ productivity, energy intensity by sector, water productivity, resource productivity, intensities of waste creation and restoration ratios, material productivity (non-energy), renewable energy, replenished resources (fish inventory, woodland areas, and aquatic resources), environment-related technologies, nutrient flows and balances, all-purpose business r&d, natural resources, the risks and health effects of the environment include exposure to air pollution, non-renewable resources (such as fossil fuels and certain minerals), biodiversity and ecosystems (such as land cover

and land use), environmental goods and services, and environmental amenities and services (such as population access to clean drinking water). Also includes global financial influxes (funding through the carbon market), pricing and transfers (tax share in end-use prices), training and skill development, and, regulations and management approaches. Various types of patents, including environment-related, all-purpose, and patents of significance to green growth in the percentage of nation applications under the Patent Cooperation Treaty. According to the study of Hoogeveen et al. (2013), the European Environmental Agency uses a DPSIR model, which is their design, to measure environmental concerns. The model is based on a collection of indicators that are divided into five categories: The driving force indicators, or 'D'-symbols, characterize the general levels of output and consumption as well as the lifestyle changes that follow social and economic progress. The main forces at work are changes in the population and economic activity (transport and energy usage); 'P' stands for pressure indicators which show changes in the amount of emissions of air and water pollution from greenhouse gasses and other contaminants, as well as land and resources used. They show how the ecosystem is changing and how natural resources are depleting; 'S' for state indicators of biological, physical, and chemical interactions (e.g., trash concentration, temperature, diversity of environment) that offer a thorough assessment of the environment by describing both quantitatively and qualitatively; 'I' stands for impact indicators which explain the significance of environmental changes and the ensuing effects on human health and well-being (smog, acidity of the soil, heavy metals in food goods, etc.) the economy, and ecosystems; 'R' stands for reaction indicators, which are how the public and politicians try to stop, make up for, improve, or environmental adjustment (fuel-catalysts in cars, taxes, environmental surcharges, etc.).

Relation between Environmental Factors and Economic Growth

The significance of augmenting environmental quality to foster economic growth via the enhancement of societal well-being and sustainable development on environmental quality has garnered noteworthy interest from scholars in the last few years (Tefera, 2024). Research released in 2021 by Swiss Reinsurance Company Ltd (Swiss Re) suggests that by 2050, the effects of climate change might reduce global economic production by 11–14%, or up to \$23 trillion yearly. Rich countries like the United States would probably see a 7% decline in their economy, but certain underdeveloped nations would be devastated, losing over 20% or perhaps 40% of their economic production. Unfairly, the advantages of global warming have gone to high-income, high-emitting nations, while low-income, low-emitting countries have suffered the most. According to projections, greenhouse gas emissions cost the US economy over \$2 trillion between 1990 and 2014 (Raihan, 2023b). Adebajo and Shakiru (2022) found that there is a strong correlation between Jordan's economic development and air pollution factors using a multiple regression model. Furthermore, the EKC demonstrated that economic expansion significantly affects air pollution in a positive as well as negative manner. In the meanwhile, the Granger causality test demonstrates that Jordan's air pollution is causally related to economic development. The use of renewable energy and financial development had little effect on CO₂ emissions in the Middle East and North Africa (MENA) between 1980 and 2015, according to Charfeddine and Kahia's (2019) analysis of the two variables. Using time series data from 1990 to 2020, Raihan and Voumik's (2022) research investigated the dynamic impacts of financial development, the use of renewable energy, technical innovation, economic expansion, and urbanization on carbon dioxide (CO₂) emissions in India. Urbanization, economic expansion, and financial development all had a favorable and considerable impact on CO₂ emissions in India, according to the results of the ARDL long- and short-run investigation. On the other hand, the usage of renewable energy and technical innovation have both short- and long-term coefficients that are statistically significant and negative, indicating that increasing these variables would result in a decrease in CO₂ emissions.

Azam et al. (2022) examined data from the top five emitter countries from 1995 to 2017 and found a negative correlation between renewable energy and CO₂ emissions and a positive relationship between economic growth and CO₂ emissions using an advanced panel quantile regression model. Using time series data from 1990 to 2021, Raihan (2024) examined the effects of FDI and CO₂ emissions on Vietnam's economic development. The study's findings indicate that a 1% marginal increase in FDI and CO₂ emissions is linked to comparable long-term increases in GDP of 1.11 percent and 1.36 percent, respectively. Moreover, these increases result in a 0.61 percent and 0.29 percent rise in GDP in the near run.

Using temporal data spanning 1992–2013, Liu et al. (2017a) established a negative correlation between the BRICS nations' usage of renewable energy and CO₂ emissions. Furthermore, Liu et al. (2017b) found that economic growth and CO₂ emissions were positively correlated when utilizing period data spanning 1970–2013, however, there was a negative correlation in Thailand, the Philippines, Malaysia, Indonesia, and the Philippines between renewable energy usage and CO₂ emissions. Again, applying data from 1990 to 2018, Raihan and Tuspekova (2022) found a negative correlation between CO₂ emissions and the usage of renewable energy and a positive correlation between economic development and CO₂ emissions in Peru.

Therefore, it is evident from previous studies that environmental factors like CO₂ emissions, air pollution, renewable energy use, etc. have a long and immediate influence on the economic growth of different countries. Hence, theoretically, it can be said that these environmental factors also have an impact on green growth. It is noticeable that many previous studies have been conducted on the different countries in the world but rare on Bangladesh which is a novelty of this current study.

Empirical Studies on Green Growth

To ascertain the ecological and socio-economic effects of a green economy within the context of Bangladesh's pursuit of Sustainable Development Goals (SDGs), Hasan et al. (2023) conducted a study that sought to evaluate the relationship between economic expansion, longevity, higher education, technological advances, and gases like carbon dioxide (CO₂) emissions. The empirical findings indicated that there is a statistically positive significant correlation between the increase in CO₂ levels and the long-term growth of GDP, with a 3.66% increase observed. The primary conclusion drawn from this study is that the economic expansion in Bangladesh is being accompanied by detrimental consequences for the environment.

Another study by Raihan (2023a) looked at how Bangladesh's low-carbon economy was affected by technological innovation, green energy, economic expansion, urbanization, and labor force. The ecosystem and economy of Bangladesh have suffered greatly as a result of climate change. Nevertheless, the study's result revealed that a marginal increase of 1% in the adoption of green energy and advancements in technology would lead to a decrease of 0.21% and 0.18% in the carbon economy over an extended period. In contrast, a decrease of 0.15% and 0.10% was observed in the short term. The findings of the study indicate that economic enhancement, urbanization process, and workforce have negative effects on the low-carbon economy.

Xu et al. (2020) explored the connection between 111 Chinese cities' economic development and noise pollution between 1991 and 2017. The study's findings demonstrated an N-shaped negative association between noise pollution and China's economic development on a nationwide level. According to Carauta et al. (2021), water stress and global warming have a detrimental effect on Brazil's agricultural industry. Research by Datta et al. (2024) was done to find out how environmental conditions affected the cost of producing crops in Bangladesh. The findings demonstrated that although sound pollution and deforestation had no discernible effect on agricultural production costs, air and water pollution costs had a statistically significant beneficial influence on those costs. In 2023, Hien and Chi carried out research on the use of green innovation in agricultural growth. They put forward connections between social networks, green innovation, technology spillover (TS), and environmental consciousness. The results imply that TS and environmental awareness have

a major beneficial impact on green innovation. Davari et al. (2020) look at how indices of soil quality are affected by deforestation. The Savan watershed in Baneh, Kurdistan, west of Iran, is where the data set originates. Debow et al. (2023) used deep learning to anticipate and predict water quality. They used several variables, including pH, turbidity, temperature, dissolved oxygen, nitrate, and fecal coliform, to describe water quality.

In a follow-up research, Baniya et al. (2021) examined empirical data about the greening of economic development in Bangladesh and Nepal from 1985 to 2016 and projected forward to 2030 to explore the chances for achieving both environmental and economic objectives. As many as 6 green growth indicators are employed to assess their past performance, and “energy and material consumption” models are employed to project their 2030 levels of consumption.

Research measuring the regional inclusive green development of China was carried out in 2020 by Sun et al. A thorough directional distance function and a slacks-based measuring model was presented in this research to assess the inclusive green growth levels of 285 Chinese cities between 2003 and 2015. The determinants of inclusive green development are broken down using the Luenberger indicator, which also shows a tendency toward convergence. Once again, research using the OECD framework and a selection of 12 indicators was conducted to evaluate 30 nations, including South Korea, via cross-national comparisons of green development plans. Each of the global indicator's latest information is rated on a scale of 1 to 10 and then compared to the OECD nations' 10th percentile (Kim et al., 2014).

In 2018, the Asian Development Bank launched a study to introduce the inclusive green growth index (IGGI) which is a new way to measure the quality of growth that incorporates the 3 pillars of economic growth, social equity, and environmental sustainability using data from 2015 and covers a wider range of indicators than previous measures (Jha et al., 2018). To achieve both environmental sustainability and economic growth and development by 2030, empirical research using data from 123 industrialized and developing nations was conducted to investigate the elements that impact green growth. The empirical findings demonstrated that green growth is favorably impacted by economic development. Open commerce, however, is bad for green growth. According to the research, energy-related variables hurt green growth; however, renewable energy use has a considerable positive impact on environmentally friendly development (Tawiah et al., 2021).

According to the study of Jha et al. (2018), South Asian, Southeast Asian, and Pacific countries have a more equitable performance across the inclusive green growth index (IGGI) pillars compared to Central Asian and East Asian countries. Analysis of their study reveals that in 2015, a majority of 9 out of a sample of 24 countries from Asia region prioritized economic growth, while environmental sustainability was found to be the least prioritized aspect in 22 countries. Therefore, Bangladesh among the South Asian countries is selected as the focal point of this study due to its ranking as the sixth most susceptible nation.

To wrap up from the reviews of literature, it is evident that very few researches were initiated regarding the green growth of Bangladesh. Moreover, most of the research has been conducted on the overall indicators of green growth as a whole. No specific study has been found regarding the evaluation of environmental factors of green growth in Bangladesh which specifies the originality of this study. Consequently, this present study aims to bridge this gap and attempt to review and describe the environmental factors towards the journey of green growth in Bangladesh.

Materials and Methods

This current study has used a secondary time series dataset for Bangladesh. This study has chosen Bangladesh because of the presence of significant economic and environmental dangers along with the vulnerability to climate change that is imminent (Macgregor et al., 2016). Data on environmental sustainability-related indicators has been extracted from the database of World Development Indicators (WDI) of the World Bank

(World Bank, 2023). The time frame is from the year 2000 to 2020. For the selection of environmental indicators, this study follows and adopts the study of Jha et al. (2018). This study encompasses various aspects of environmental sustainability such as sustainable utilization of natural resources, the implications of climate change, water productivity, and air pollution. Nonetheless, land productivity biodiversity protection, waste management, and water quality are crucial components of environmental sustainability; but, due to data insufficiency, this present study does not address these issues. The specifics of the chosen indicators are shown in the table 1.

Table 1. Description, measurement, and impact direction of environmental sustainability-related indicators for Bangladesh

Indicator	Description	Measure ment unit	Impact Direction
CO2 emissions (metric tons per capita)	The emissions from the combustion of fossil fuels and the production of cement are known as CO2.	Metric tons	Inverse
Renewable energy consumption (% of total energy consumption)	Percentage of final energy used that comes from renewable sources.	Percent	Positive
Water productivity (GDP per cubic meter of total freshwater withdrawal)	Calculated as the yearly total freshwater extraction divided by the 2015 US\$ GDP in constant prices.	Ratio	Positive
Natural resources rent (% of GDP)	The GDP-to-rent ratio of natural gas, oil, coal (both hard and soft), minerals, and forests combined.	Ratio	Inverse
PM2.5 air pollution (% of total population)	Percentage of the population exposed to air pollution levels over the WHO's recommended air quality threshold for particulate matter (PM) at 2.5.	Percent	Inverse
Renewable internal freshwater resources per capita (cubic meters)	Per capita, the annual availability of renewable water is determined by dividing the total amount of renewable water in a nation by its population.	Cubic meters	Positive
The energy intensity level of primary energy (MJ/\$2017 PPP GDP)	It is calculated by taking the GDP, expressed in constant 2017 US dollars at purchasing power parity and dividing it by the total primary energy supply.	Ratio	Inverse

Source: Jha et al. (2018) and data extracted from <https://databank.worldbank.org/source/world-developmentindicators>

This research is descriptive in nature. The purpose of descriptive research is to characterize a phenomenon and its features. This style of inquiry is primarily focused on what rather than how or why something has occurred. It delivers a picture or overview of a given scenario without changing or modifying it (Nassaji, 2015). Since the present study is descriptive research, this study has employed cross-sectional and observational studies approaches in analyzing and interpreting the secondary data (Datta, 2024). Again, based on the study's goals, a comprehensive review of the literature is also included in this present study.

In addition, descriptive statistics and figures have been utilized to explain the data. Descriptive statistics provides a snapshot of the data distribution to understand the range, central tendency, and variability of the data. The "mean" represents the average value, the "maximum" and "minimum" values show the range of the data, and the "standard deviation" indicates the amount of variation or spread around the mean. Necessary analyses have been conducted by utilizing the software MS Excel 2010. Proofreading, grammatical formatting and paraphrasing has been done using the free version of "Grammarly" and "QuillBot" apps respectively.

Results and Discussion

Representation of the current scenario for environmental sustainability indicators in Bangladesh

Bangladesh's government has demonstrated its commitment to sustainable development by incorporating components of green growth into its national policies that are fostering the country's journey towards sustainable growth while conserving the environment. The present state of the environmental sustainability-related indicators in Bangladesh from the year 2000 to 2020 is illustrated by the following figures:

Figure 1 represents the proportion of renewable energy sources, such as solar, wind, hydroelectric, and biomass, in the total final energy consumption of Bangladesh. It's expressed as a percentage, indicating the sustainability of energy usage. Starting at 59.06% in 2000, it decreases steadily to 24.75% by 2020.

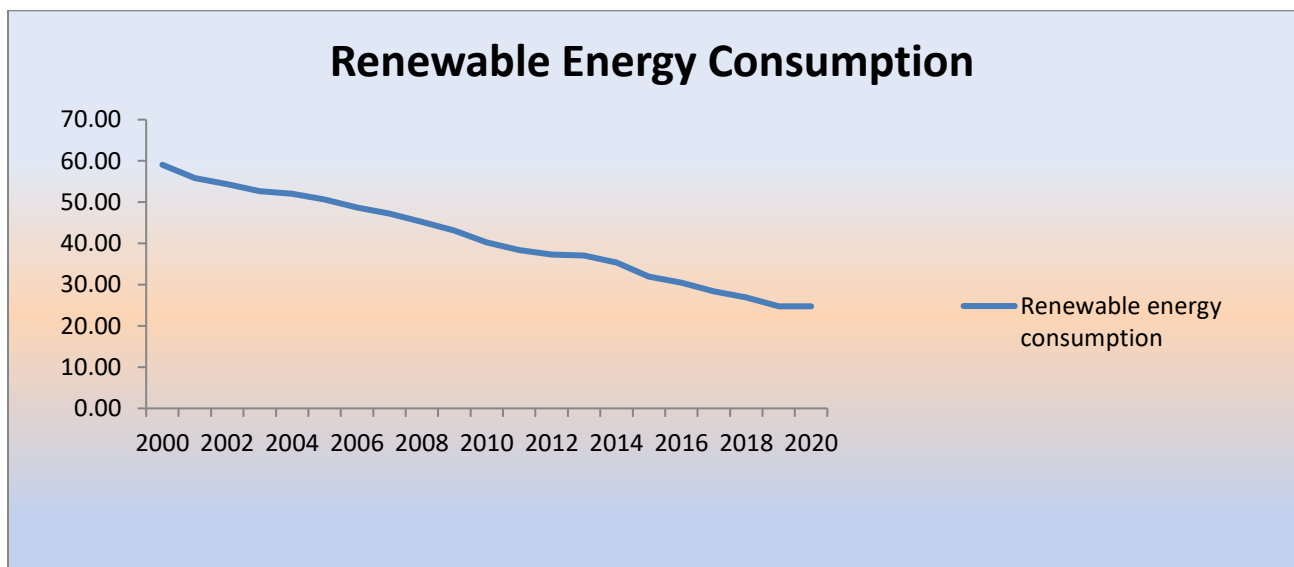


Figure 1. Renewable energy consumption (% of total final energy consumption) of Bangladesh from 2000 to 2020

Figure 2 indicates the indicator that measures the amount of renewable freshwater available per person within a particular region. It's calculated in cubic meters, indicating the volume of internal freshwater resources that can

be sustainably utilized per individual in Bangladesh. This remains relatively stable throughout the period, hovering around 650-800 cubic meters per person.

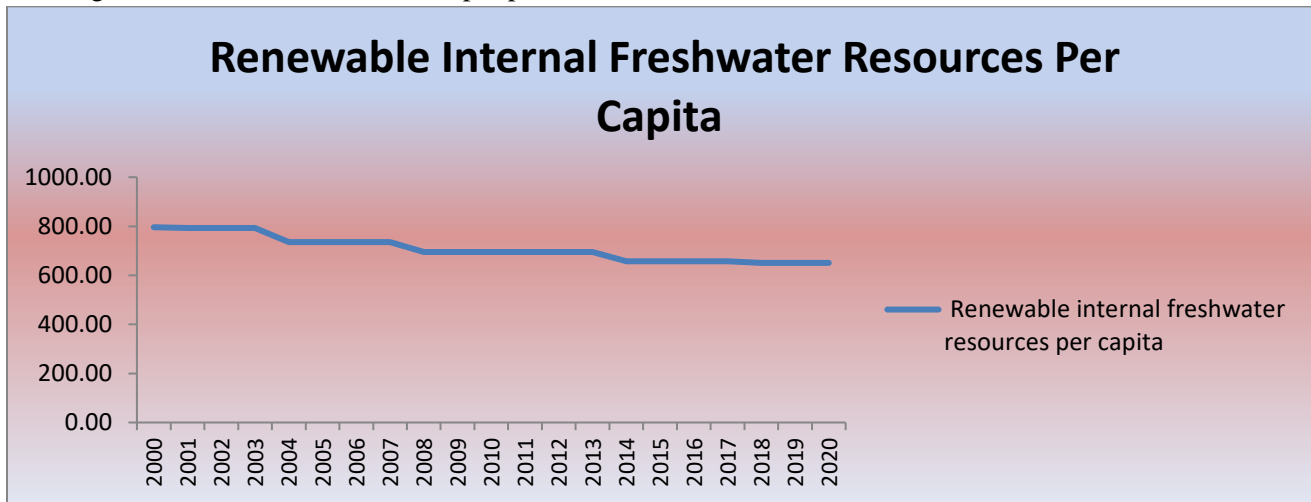


Figure 2. Renewable internal freshwater resources per capita (cubic meters) of Bangladesh from 2000 to 2020

Figure 3 shows the indicator of water productivity which signifies the economic output (GDP) generated per unit volume of freshwater withdrawn for various purposes like agriculture, industry, and domestic use. It's a measure of how efficiently water resources are being utilized to drive economic growth. It starts at 5.00 in 2000 and remains constant until 2004. From 2008 onwards, there was a gradual increase, reaching 6.66 in 2018 and maintaining that level till 2020.

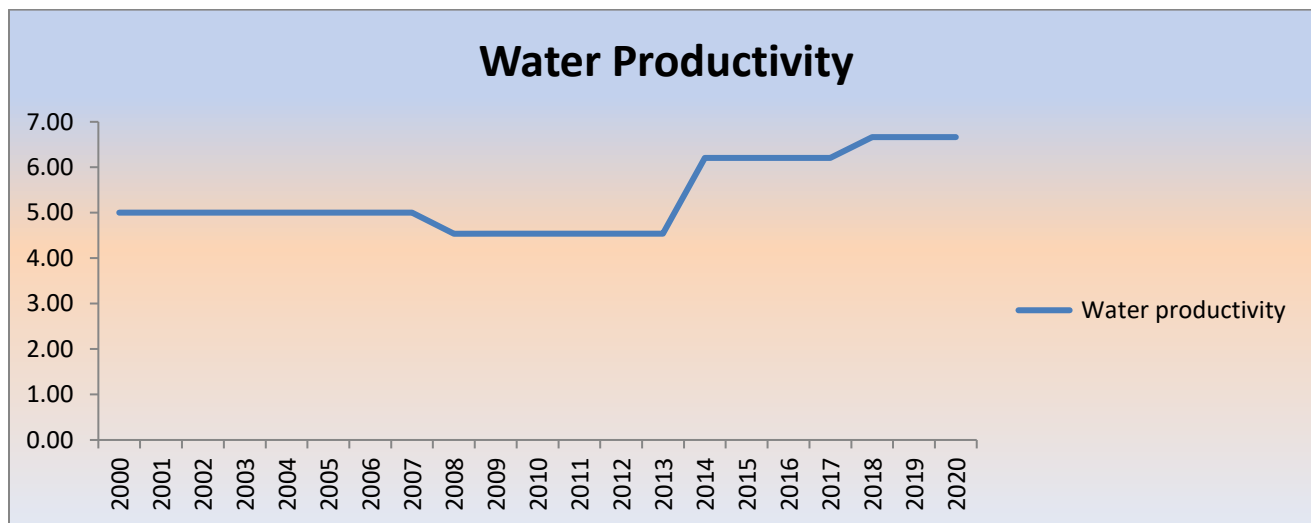


Figure 3. Water productivity (GDP per cubic meter of total freshwater withdrawal) of Bangladesh from 2000 to 2020

Figure 4 refers to the amount of carbon dioxide emitted per person, measured in metric tons. It's an indicator of how much carbon dioxide is being produced per individual. Starting from 0.17 metric tons per capita in 2000, CO2 emissions gradually increased over the years, reaching 0.56 metric tons per capita by 2020.

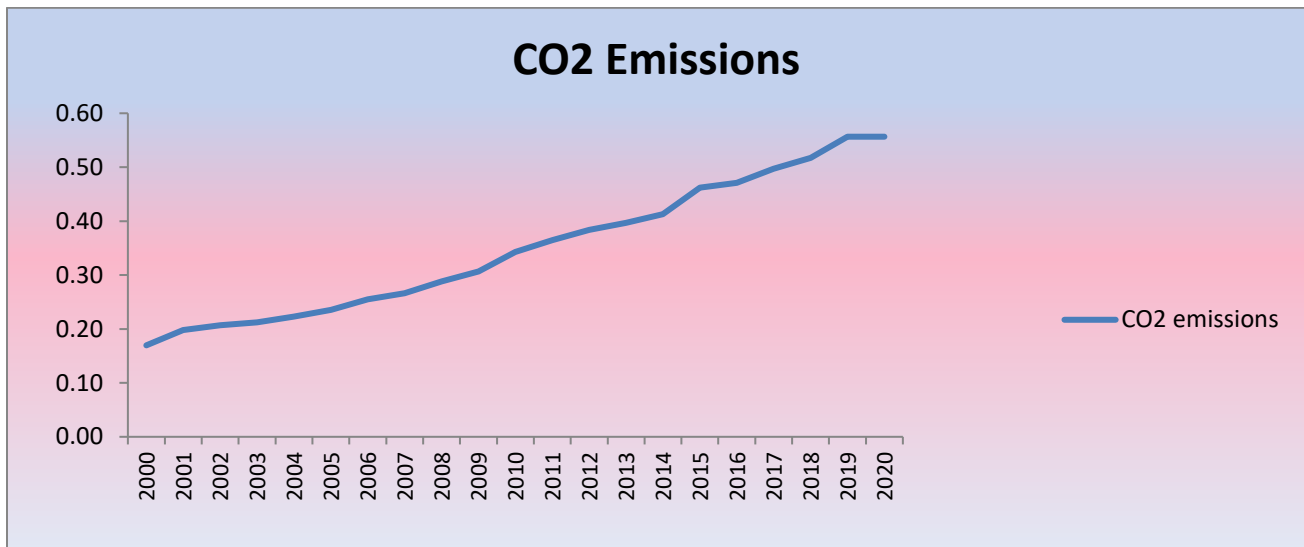


Figure 4. CO2 emissions (metric tons per capita) of Bangladesh from 2000 to 2020

Figure 5 illustrates the energy intensity level of primary energy refers to the quantity of energy needed to generate a unit of economic output. Here, it specifically relates to primary energy, which is energy that hasn't been converted or processed yet, like coal, oil, natural gas, and renewable sources. Data showed a declining trend starting at 3.14 in 2000 and decreasing to 2.36 by 2020.

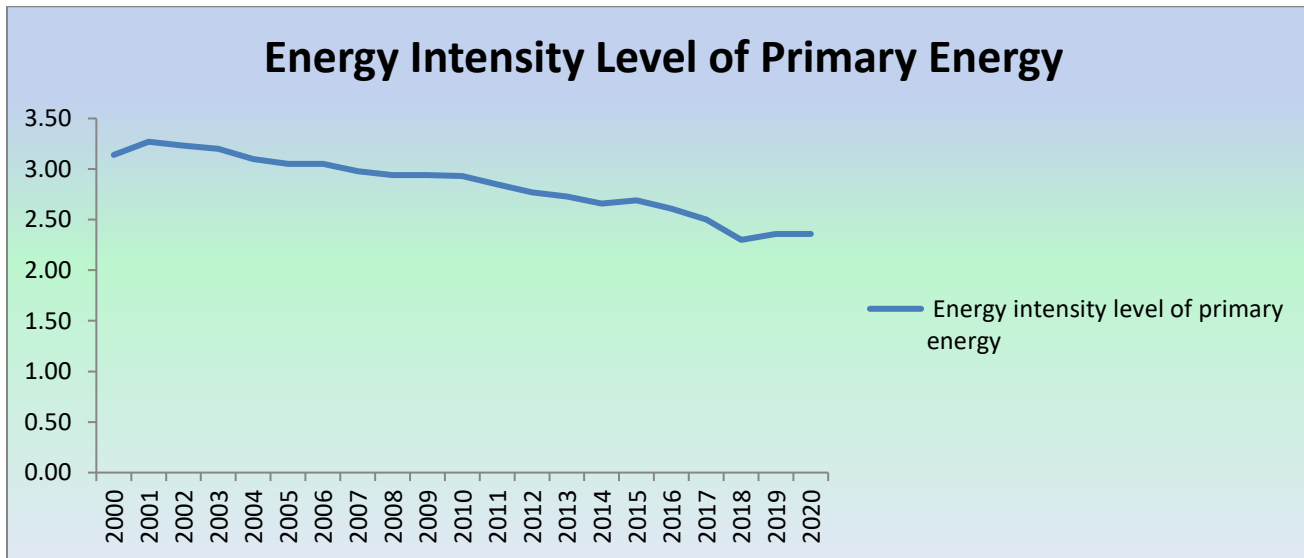


Figure 5. Energy intensity level of primary energy of Bangladesh from 2000 to 2020

Figure 6 shows the data representing the percentage of total air pollution made up of PM2.5 particles. A higher percentage indicates a larger contribution of these fine particles to overall air pollution. This remained consistently high throughout the period, with levels at 100.00% of total air pollution without any significant change over the years.

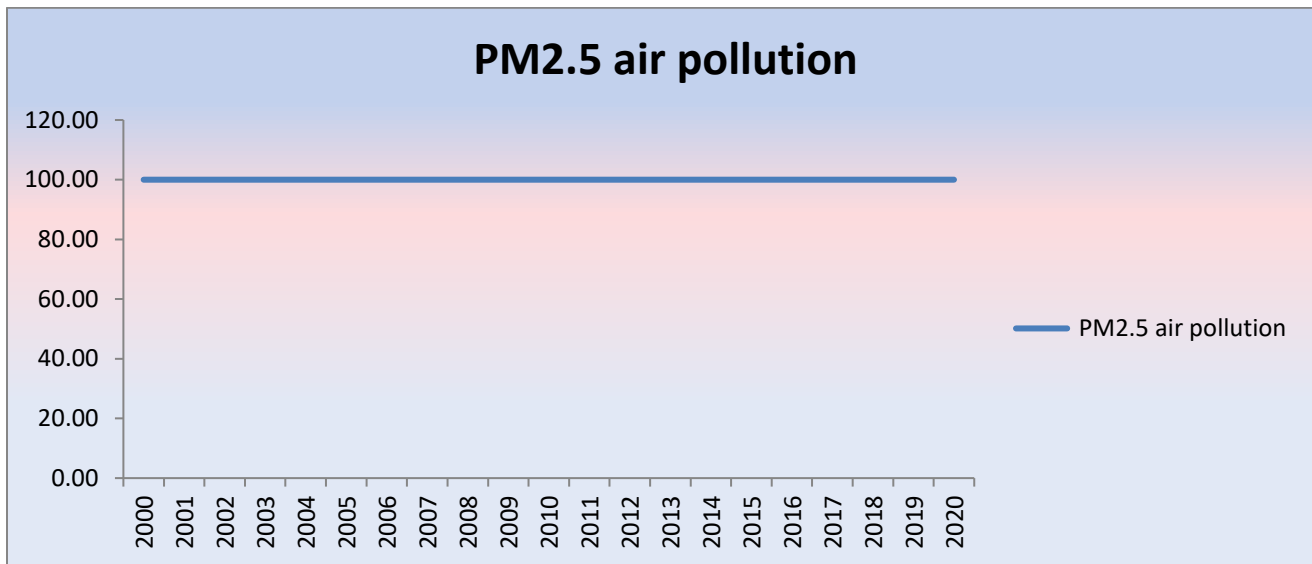


Figure 6. PM2.5 air pollution (% of total) of Bangladesh from 2000 to 2020

Figure 7 shows the term "natural resource rents," which is used to describe the revenue obtained from the exploitation and use of natural resources such as minerals, oil, and gas. This revenue is often expressed as a percentage of GDP. It indicates the contribution of natural resources to the overall economic output of a country. The data showed a fluctuation over the years, starting at 0.58% in 2000, and peaking at 1.64% in 2011, after declining to 0.32% by 2020.

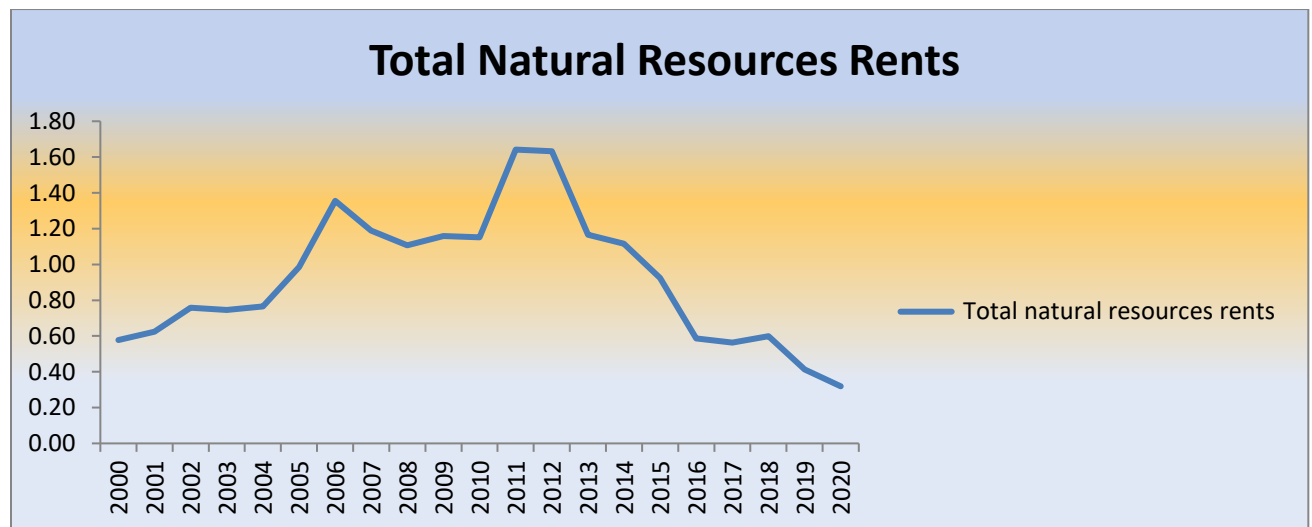


Figure 7. Total natural resources rents (% of GDP) of Bangladesh from 2000 to 2020

Descriptive Statistics

Table 2 presents the descriptive statistics for a set of environmental sustainability-related indicators used to measure the inclusive green growth of Bangladesh from the years 2000 to 2020. These indicators provide insightful information about various aspects of the country's environmental performance and its efforts to promote sustainable development.

Table 2. Descriptive statistics of the environmental sustainability-related indicators of green growth

Environmental Sustainability Indicators	N	Maximum	Minimum	Mean	Std. Deviation
Renewable energy consumption	21	59.06	24.75	41.16	10.82
Renewable internal freshwater resources	21	796.00	650.65	708.19	51.65
Water productivity	21	6.66	4.54	5.34	0.81
CO2 emissions	21	0.56	0.17	0.35	0.13
The energy intensity level of primary energy	21	3.27	2.30	2.84	0.30
PM2.5 air pollution	21	100.00	100.00	100.00	0.00
Natural resources rents	21	1.64	0.32	0.92	0.37

Source: Author’s calculation

The detailed evaluations of the statistics of these indicators are as follows:

The percentage of renewable energy consumption ranges from 24.75% to 59.06% of total energy consumption. On average, approximately 41.16% of the total energy consumption comes from renewable sources, with a moderate standard deviation of 10.82. This indicates slight variability in the adoption of renewable energy technologies, suggesting that Bangladesh has made substantial strides in promoting green and clean energy sources.

The renewable internal freshwater resources available per capita range from a minimum of 650.65 cubic meters to a maximum of 796.00 cubic meters. The mean value is 708.19 cubic meters, with a standard deviation of 51.65. This advocates significant variation in water availability across different regions or time periods, emphasizing the importance of sustainable water resource management to meet the population's needs.

Water productivity, measured by GDP per cubic meter of total freshwater withdrawal, ranges from 4.54 to 6.66. The average water productivity stands at 5.34, with a tiny variability of 0.81. This specifies consistency in the efficiency of water use in economic activities, with potentially positive implications for water security and sustainable economic growth.

The CO2 emissions per capita range from 0.17 to 0.56 metric tons. The mean value is 0.35 metric tons, with a small standard deviation of 0.13. This suggests a relatively low carbon footprint per capita, indicating Bangladesh's initiatives to fight climate change and cut greenhouse gas emissions.

The energy intensity level of primary energy sources varies between 2.30 and 3.27. On average, the energy intensity level is 2.84, with a standard deviation of 0.30. This shows how much energy is needed to generate one unit of economic output, and a lower value signifies more energy-efficient practices in the country.

The percentage of the population exposed to PM2.5 air pollution is reported as 100.00% for all regions. While this lack of variability in the data is unusual, it could indicate a pervasive air pollution problem affecting the entire population, calling for significant efforts to improve air quality and public health.

Natural resources rents, which represent the share of income derived from natural resources, range from 0.32% to 1.64% of GDP. On average, natural resources rents account for approximately 0.92% of GDP, with a standard deviation of 0.37. This indicates the income generated from the extraction and utilization of natural resources and can highlight the significance of sustainable management practices to ensure the preservation of valuable resources.

Summary Discussion

The descriptive statistics of the environmental sustainability-related indicators in Bangladesh provide valuable insights into the country's environmental performance and the progress made in promoting inclusive green growth. The data highlights areas of strength, such as the significant uptake of renewable energy sources, as well as areas that require attention, such as water resource management and air pollution control. Despite the low carbon footprint, Bangladesh poses potential challenges in carbon emissions due to increased industrialization and urbanization. These are also deteriorating the environmental quality of the country. However, from the observations of this study, it is concluded that Bangladesh being a developing nation has recently experienced severe stress due to the negative effects of climate change. Likewise, this statement is endorsed by Raihan (2023a) and Raihan et al. (2022) in their recent studies. To uphold the country's elevated ecological benchmarks, the government of Bangladesh and other relevant parties must make investments in renewable energy sources. In this regard, the results of this study support the conclusion of Murshed et al. (2021) in the context of the economy of Bangladesh. They concluded that the carbon footprint figures of Bangladesh are augmented by the combined usage of fossil fuels, natural gas, and energy. Additionally, there is evidence that economic expansion and global trade contribute to the escalation of carbon footprints. Whereas, from the outcome of the study of Sultana et al. (2022), it is argued that economic development endeavors in Bangladesh may be sustained and expanded with minimum ecological impact by implementing fundamental economic reforms and effective environmental stewardship.

Furthermore, the present study's observation regarding natural resources rent suggests that Bangladesh's economy relies to some extent on natural resources, indicating the importance of sustainable resource management to avoid depletion and ensure long-term economic stability. These findings also corroborate the results of the study by Hussain et al. (2020). Their findings demonstrated that when natural resource depletion grows, there is a corresponding increase in CO₂ emissions and energy consumption. Specifically, a 1% rise in natural resource depletion across the BRI nations in the sample would result in a 0.0286% increase in CO₂ emissions and a 0.0117% increase in energy consumption. Whereas, Rasheed and Liu's (2024) study examines the intricate relationship between China's emissions, energy consumption, and economic development. It uses the Environmental Kuznets Curve (EKC) paradigm to assess the dynamics between 1990 and 2022. Their research validates the EKC theory, indicating that focused actions may slow down environmental deterioration as China's economy grows.

The observations from the descriptive statistics of this study are also consistent with the study of Jha et al. (2018) where they stated that South Asia has many environmental issues to deal with. In this location, almost all people are exposed to hazardous concentrations of particulate matter with a diameter of 2.5 millimeters or less, making air pollution a widespread issue. In Bangladesh, India, and Sri Lanka, freshwater resources and water production are much lower than recommended for developing Asia. However, these statistics can serve as a basis for formulating targeted policies and initiatives to ensure a sustainable and environmentally conscious development path for Bangladesh.

Academic and Practical Implications

Academic Implications

The observations of this study have the potential to generate and broaden the understanding within the fields of green growth, renewable energy, climate change, and sustainable development. Furthermore, scholars and upcoming researchers can expand their investigations based on the constraints and potential avenues for future research of this work. Additionally, the results of this study can aid in the advancement of theories of green growth for any country.

Practical implications

Given that Bangladesh has prioritized development by the Sustainable Development Goals (SDG), the observations of this study certainly support SDG9, SDG11, and SDG12 which are connected to carbon dioxide emissions, air pollution, and natural resources rent respectively. This study can also assist in attaining the goal of SMART Bangladesh, Delta Plan 2100, Mujib Climate Prosperity Plan, and the Perspective Plan (PP) 2041. The result of this study highlights lucrative investment opportunities in renewable energy infrastructure development. Private investors and international development agencies can capitalize on Bangladesh's growing renewable energy market by financing projects such as solar, wind, hydroelectric, and other renewable energy projects aimed at expanding clean energy generation capacity. Moreover, this study can help formulate policies regarding water management strategies, air pollution control measures, and sustainable natural resource management practices to advance the sustainability agendas of Bangladesh's journey towards green growth.

Policy Recommendations

Bangladesh is a policy-rich nation where most regulations and guidelines are already in effect. This is mainly because of the colonial heritage of British rule and because development operations are heavily dependent on foreign finance. In addition to aiming to fulfill international commitments, Bangladesh's post-millennium environmental legislation also guarantees the country's fair and sustainable development, with many of them including elements of green growth (Macgregor et al., 2016). The results of this study offer valuable insights for policymakers to develop evidence-based policies and strategies aimed at promoting sustainability, enhancing environmental quality, and fostering socio-economic development in Bangladesh. By incorporating the following policy directives, the government of Bangladesh and its stakeholders can work towards achieving more resilient green growth in the future.

Renewable energy policy reform: Policymakers should prioritize the reformulation and implementation of renewable energy policies to further incentivize the adoption of clean energy technologies. This may include enhancing financial incentives, streamlining regulatory frameworks, and investing in renewable energy infrastructure development.

Water resource management strategies: Effective water resource management policies are critical for ensuring sustainable freshwater availability. Therefore, policy interventions aimed at improving water resource management should be prioritized to address regional disparities in water availability and ensure equitable access to clean water. This may involve implementing water conservation measures, promoting efficient irrigation practices, and investing in water infrastructure development.

Climate mitigation strategies: Addressing CO₂ emissions requires comprehensive climate mitigation strategies, including energy efficiency programs, transition to cleaner energy sources, and adoption of low-carbon technologies. Policymakers should prioritize measures to reduce carbon emissions across sectors while promoting sustainable economic growth.

Air quality improvement initiatives: Policymakers should develop comprehensive air quality improvement initiatives to mitigate the adverse effects of PM_{2.5} air pollution on public health. This may include implementing stricter emission standards, promoting clean energy technologies, and investing in pollution monitoring and control measures.

Natural resource governance: Sustainable natural resource management policies should be devised to minimize environmental degradation and ensure the sustainable utilization of natural resources. This may involve implementing resource taxation mechanisms, promoting eco-friendly extraction practices, and fostering community-based conservation initiatives.

Conclusion and Further Research Directions

The findings presented in this study provide valuable insights into Bangladesh's journey towards progress and challenges in achieving environmental and economic sustainability. Bangladesh has made significant progress in promoting renewable energy and maintaining water productivity, but still faces challenges like air pollution and energy intensity. Despite low CO₂ emissions per capita, the country's commitment to climate change mitigation is evident. Addressing PM_{2.5} air pollution and implementing sustainable resource management techniques is crucial for protecting natural resources and ensuring a stable economy.

While Bangladesh has shown a strong commitment to sustainable development and green growth, however, some critics argue that Bangladesh's focus on green growth and sustainable development is not comprehensive enough to address the country's pressing social and economic needs. They argue that while environmental concerns are important, they should not take precedence over issues such as poverty alleviation, unemployment, and access to basic services. Additionally, critics point out that Bangladesh's prioritization of green growth may hinder certain industries and sectors, affecting the overall economic growth and job creation. These opposing viewpoints highlight the ongoing debate surrounding the country's path towards green growth and sustainable development. To truly progress towards a greener and more sustainable future, the government must adopt a comprehensive approach that addresses to strike a balance between environmental concerns and socio-economic needs. Collaborative efforts between government, industry, and civil society are essential. The government should prioritize innovation, policy reforms, and community engagement. Moreover, Bangladesh needs to strengthen its environmental governance and enforce existing regulations effectively. By doing so, Bangladesh can pave the way for a more inclusive and impactful green growth strategy that considers the needs of its people while safeguarding the environment for future generations.

Several limitations to this study need further research. First off, although Bangladesh is the focus country of this study, other developing countries may find it more interesting. Results might become more broadly applicable in future studies if more developing countries are examined or if the sample size is expanded (Raihan, 2023a). This study's primary shortcoming is its failure to use mathematical methods and inferential statistics to make conclusions. Future researchers may explore advanced modeling techniques including artificial intelligence experiments and data analytics to enhance accuracy and reliability. Moreover, scholars can delve deeper into the factors influencing the adoption of renewable energy technologies and assess their socio-economic implications. Future research may integrate insights from various disciplines to develop holistic solutions. Additionally, comparative analyses with other countries facing similar sustainability challenges can yield valuable insights into effective policy interventions and best practices.

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Authors contribution: Rony Kumar Datta contributed to conceptualization, visualization, methodology, reviewing literature, extracting information, synthesize, and manuscript writing.

Data availability: Data used in this study are publicly available and accessible by anyone.

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