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Special Issue S2: “Global Warming and Climate Change: Part 1”

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CONTENTS

Editorial Note

There has been much hue and cry across the world that "earth is dying" and we have to "save the planet," trying to influence the policies on climate change. But most unfortunately, neither the developed nor the developing countries are really sincere to tackle the planet's worst and most critical issue. Accordingly, the earth has been facing the chronic problems of rising temperature, increasing sea level, earthquakes, tsunamis, and other natural disasters. These problems have become regular features. The issue of global warming and climate change has created unprecedented challenges for nations to face and to find out solutions to these burning issues. Numerous negotiations have been taking place across the world (including the last Paris Agreement), but unfortunately, nothing concrete has come up so far, and as a result, the issues are remaining as a myth. For example, the Paris accord has been taking place for climate change policies, but on the implementation horizon, nothing has happened. The worst is the disassociation of the United States from the accord. All this speak volumes about the concern, attitude, responsiveness, and sincerity of nations toward the issue of global warming and climate change.

Keeping in mind the abovementioned issues and their significance to humanity, we need to ask academicians, professionals, and policy makers to examine the issues in depth and explore possible practical solutions. This journal, Management and Economics Research Journal (MERJ), has come forward to publish a special issue on global warming and climate change in two volumes, the most burning issue of the 21st century for everyone irrespective of developed, developing, large, or small economies. The purpose of the special issue is to motivate researchers to deliberate on climate change and come up with substantial contribution on the relevant emerging issues.

The special issue in hand (in two volumes) deals with the different issues of the topic and the contributors have authored research papers on the different aspects of global warming and climate change. The present volume (I) contains nine well-written and documented papers. Here is a brief summary of these papers, contributed by eminent authors from across the world. These papers provide a critical and an in-depth analysis on the different aspects of the topic.

Does Climate Change Have Real Negative Impact on Economic Growth in Poor Countries? Evidence from Côte d'Ivoire (Ivory Coast), authored by Felix Fofana N'Zué, discusses how to determine the impact of climate change on Côte d'Ivoire's economic performance via per capita gross domestic product (GDP) growth, change in agricultural value-added contribution, and change in the country's cereal yield. The author is of the view that climate change has not significantly impacted the economic performance of the country. However, precipitation has been found to have positively and significantly influenced the country's cereal yield and agricultural value-added contribution to GDP at large, and thus there is no need to worry more than it is necessary.

The paper **Climate Change and Agriculture in India: Studying Long-Term Patterns in Temperature, Rainfall, and Agricultural Output**, contributed by Bhanumurthy and Lalit Kumar, provides an estimate of the impact of climate change on agricultural GDP in India. Climate change is now an established reality and the unusual weather patterns being observed in various parts of the world in the last 30 years are unequivocally due to variations in temperature and rainfall. The authors are of the firm view that agriculture sector in India has been adversely affected by rise in mean annual minimum temperature and shown a positive correlation with the changes in monsoon rainfall and mean annual temperature.

The paper titled **Climate Change Fiasco: What Multilateral Arrangements Have to Offer?**, written by Nida Rahman and Munir Hassan, opines that multilateral arrangements have been a talking thing for decades now. As the globalization process unleashed nations' potential to converge on matters of concern, there has been a spiraling movement in agreements and arrangements. Climate change is the buzzword in multilateral arrangements now. In the recent past, startling alterations in the planet's environment have brought the attention of countries, both developed and developing, to take a call of action.

The paper titled **Environmental Policy in Brazil after the 2016 Coup: An Analysis of Government Expenditure**, contributed by Maria de Fatima Silva do Carmo Previdelli and Luiz Eduardo Simões de Souza, presents the association of federal public expenditures with the environmental issues by using regression analysis. The coup government launched in 2016 has abandoned any environmental policy, is interested in

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dissolving the institutional framework established after 20 years of Brazil's participation in the global debate on the environment, and does not even supervise and protect the country's natural resources, in an attitude characteristic of a state of exception.

The paper titled **Will Africa Be able to Keep Its Promises to Reduce Greenhouse Gases? A Review of African Countries' Commitments at COP 21**, authored by ZieBallo and Fabrice EsséOchou, describes the different types of commitments made by Africans in their National Determined Contributions (NDCs) and tries to explain whether or not it will be possible for them to fulfill their commitments. Countries with conditional commitments subject to external financing are likely to fulfill their commitments that are stronger. Only countries with unconditioned commitments are more realistic in not relying on external assistance, which is becoming more and more hypothetical.

Another contribution titled **Has Climate Change Even Impacted the Valuation of Companies? An Evidence from Gujarat Fluorochemicals Ltd in India**, written by Anjala Kalsie and Ishwarya Nagpal, shows that climate change is undeniably the major challenge of our times and poses a global threat to civilization. The study discovers that climate change in the form of increased carbon credits has positively impacted the financial valuation of Gujarat Fluorochemicals Limited (GFL). The findings suggest that an increase of approximately 44% in the valuation of GFL is owing to the revenue from the sale of carbon credits as per the Kyoto Protocol.

The paper **Climate Change Issues in BRICS Countries**, by Mohd Nayyer Rahman and Abdul M. Turay, highlights that climate change has emerged as one of the topics where more is discussed and very less implemented. People wait for the actions to be taken by the government/multilateral organizations but seldom do they capture the developments going on. Several initiatives have been taken by individual countries as well as countries forming groups/conglomerates to tackle the challenges of climate change. This is true for Brazil, Russia, India, China, and South Africa (BRICS) as well. BRICS countries share the idea of climate protection but are skeptical of the policies passed by the developed countries. BRICS as a forum of developing countries challenging the status quo of climate change policies has emerged to formulate its own climate change policies and initiatives in the light of BRICS discussions.

Green Energy as a Driver for Green Economy and Organizations' Sustainability, authored by Maria José Sousa, gives a critical review of the green innovations directed explicitly to the green energy challenges faced by organizations and the world economies. The research question is this: What are the main dimensions of a model to implement a green innovation process focus on green energy in organizations? The paper further seeks to make a valid contribution to definitions of Green Innovations and for operationalizing the green innovation in organizations.

Lessons Learnt from the Killer Floods in Kerala: Time for Retrospection, written by Raveesh Agarwal, observes that the climate of the earth has undergone drastic changes over periods of time. Natural factors and anthropogenic factors both contributed to climate change. The paper identifies the reasons of the disaster in Kerala and the lessons learnt from it. Due to climate change and natural disasters, their impact on water, air, agriculture, infrastructure, health, education, biodiversity, forest, and socioeconomic sectors are bound to increase. Nobody can stop natural disasters but we can take certain steps to lower their intensity. It is very much important to learn from the lessons so that the effect of such type of events can be minimized.

I am of the firm opinion that these papers will be interesting to the readers. The second volume (under print) in coming months may also provide in-depth knowledge about the most critical topic of global warming and climate change. I am sure that both volumes would be an asset for academicians, professionals, and policy makers. The special issue is of "light and fruit bearing" in nature and contents.

ACKNOWLEDGMENTS:

I am very much grateful to the contributors who have given me enormous cooperation in transforming the critical issue in reality. I had planned only one volume (Part 1). But because of the tremendous support I got from the authors worldwide, I have decided to publish the special issue in two volumes (Parts 1 and 2). I am also very much thankful to the reviewers who have come forward voluntarily and reviewed the papers in the shortest possible time. Further, I am highly obliged to Mr. T. Begg, Managing Editor of Management and Economics Research Journal (MERJ), United States, who was kind enough and also has generously agreed

upon to publish the special issue in two parts. Without his help, both the parts would not have seen the light of the day.

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Climate Change and Agriculture in India: Studying Long-Term Patterns in Temperature, Rainfall, and Agricultural Output

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Abstract

This paper provides an estimate of the impact of climate change on agricultural gross domestic product in India. Climate change is now an established reality, and the unusual weather patterns being observed in various parts of the world in the last 30 years is unequivocally due to variations in temperature and rainfall. The long-term trend pattern of the temperature and rainfall in India is studied, which clearly shows a distinct rise in mean temperature and declining trend rainfall after 1980. ARIMA analysis is used to generate the predictive values for temperature and rainfall, which are then used as explanatory variables along with nonclimatic variables to estimate the impact on agricultural output using an augmented Cobb-Douglas production function. The paper clearly establishes a clear and positive correlation between climate change and loss of agricultural output. The trend pattern of long-term productivity growth factor in agriculture is also showing a declining trend, which is due to unfavorable climatic and nonclimatic factors. Climatic parameters like El Niño and sea surface temperature have emerged as key determinants of monsoon rainfall in India. The agriculture sector in India has been adversely affected by rise in mean annual minimum temperature and shown a positive correlation with the changes in monsoon rainfall and mean annual temperature.

Keywords: Climate change; Greenhouse gases; Annual average temperature; Monsoon rainfall; El Niño; Sea surface temperature; Crop productivity.

1. INTRODUCTION

1.1. Agriculture and Climate Change in India

Climate is defined as "average weather," in terms of variability of temperature and precipitation over a period of 30 years, as defined by the World Meteorological Organization. Global surface temperature has increased by 0.8°C between 1900 and 2000, and a further warming of the earth by 2-4°C by the end of this century is expected as per the report (IPCC, 2001). The global mean temperature in 2006 was 14.5°C. This was the second warmest year in the last 125 years. Of the last 15 years, 11 have been the warmest. The three consecutive years from 2014 to 2016 were the warmest recorded in the last 100 years.

India is a country of 1.3 billion people who constitute almost one-sixth of the world's population. The average population density is around 326 persons per square kilometer, which varies widely across the country. The population is projected to rise to 1.8 billion by 2050 and will then start to decline. Over 25% live below the poverty line and subsist with less than $2 a day. Per capita income is less than $2000 per year, and agriculture is the main occupation, employing about 60% of the workforce. Agriculture is sustained by annual rainfall of around 1100 mm out of which 80% occurs in summer monsoon months. Agriculture accounts for nearly 15% of the gross domestic product (GDP), and more than 60% of agricultural production is rain fed, having no assured means of irrigation. Recent trends in agriculture production suggest that the effect of climate change is very pronounced and highly visible on crop production and productivity (Kapur, Khosla and Mehta, 2009). Even without the impact of climate change, the yields of major crops like rice and wheat had stagnated and were showing a declining trend due to environmental degradation and soil fatigue (Gadgil and Gadgil, 2006). Crop production has been showing a strong correlation with the variability of

Table 1. El Niño Years by Classification.

Moderate years	1963, 1986, 1987, 1991, 2002, 2009
High years	1965, 1972, 1997, 2014, 2015

Source: Skymet Weather Services, 2016.

temperature and precipitation (Singh *et al.*, 2009). In the drought years 2002, 2007, 2008, and 2009, the monsoon rainfall was highly deficit in terms of spatial distribution and overall volume. Rainfall deficiency during 2002 was 22%, which adversely affected the productivity of kharif and rabi crops across India (Lal, 2011; Agarwal, 2009). Total rice production in India in 2002 was 17.40% lower than in the previous year. Wheat production declined by 2.15% at 70.26 million tons in 2002 as compared with 71.81 million tons in 2001. In 2009, which was another severe drought year, annual GDP declined from 5 to 6% (Aggarwal, 2003). The total area under crop production fell from 635 lakh hectares in 2008 to 563 lakh hectares in 2009. Paddy/rice was severely affected, and its production declined by about 15%. The total area under rice production was 289 lakh hectares in 2009 as against 358 lakh hectares in 2008 (Gupta, Sen, and Srinivasan, 2012).

1.2. El Niño Southern Oscillation (ENSO) and Indian Agriculture

The El Niño Southern Oscillation (ENSO) phenomenon that originates in the tropical Pacific is the strongest natural inter annual climate anomaly having widespread effects on the global climate system. El Niño is a warming of the eastern Pacific Ocean that occurs mainly along the Equator, and it indicates that sea waters are warmer than normal (Wainer and Webster, 1996). During an El Niño event, the waters of the eastern Pacific warm up by over 4°C than normal. The Oceanic Niño Index (ONI) measures the intensity of El Niño: zero indicates average conditions, positive numbers above +0.5 indicate warmer conditions, and negative numbers indicate colder conditions or La Niña conditions. Anything above +0.5 is considered El Niño conditions, and anything above 1.0 is a strong El Niño, which is capable of affecting rainfall across Asia and America. The strongest recorded El Niño was the ONI index value of 2.3 in 1997-1998 (Kripalani and Kulkarni, 1997; Monsoon Monograph, IMD, Volume I and II, 2012).

Table 1 shows that of 26 El Niño events since 1900, around 50% have been followed by a neutral year and 40% by La Niñ. Two successive El Niño years are rare but have occurred earlier. In cases when El Niño gets prolonged, the performance of monsoon rains suffers in India and leads to drought-like conditions in most part of the country (Lal, Cubasch, Santer, 1994). The severe El Niño event of 1997-1998 caused worldwide havoc and created adverse climatic conditions that killed an estimated 24,000 people with around $60 billion in damage on a global scale. Climate change combines with the effects of El Niño, as warmer temperatures lead to more water vapor being held in the atmosphere. This leads to higher El Niño–induced floods and droughts on a much wider scale than normal (Duncan, Dash, and Atkinson, 2013).

During the warm El Niño phase, the total food grain production in India decreased in 12 out of 13 years by about 2-15%. The relationship between the ENSO index (ONI values) and the kharif season food grain production variation is about $r = -0.54$. This clearly demonstrates that there exist a significantly negative relationship between the kharif production and existence of El Niño. The average fall in rice production during a warm El Niño year has been to the tune of 3.5 million tons, which translates to about 7% of the total rice production. The El Niño years in 2002 and 2009 recorded a 10-15% drop in agricultural production and created drought conditions in most parts of India (Gupta, Sen, and Srinivasan, 2012).

2. LITERATURE REVIEW

2.1. Global Case Studies

There have been a number of studies that have been conducted at the national and regional level to estimate the impact of climate change on agricultural output. The findings and results from nearly all studies unequivocally suggest that there is a clear and positive link between rise in temperature and falling crop output. The first major work done at the global level was by Stern (2007), which comprehensively dealt with the rise in greenhouse gases at the global level and the consequent increase in temperature. The report uses the Integrated Assessment Models (IAM) to estimate that an investment of 1% of GDP per year at the global level is required to avoid the disastrous effects of climate change. Cost of inaction will lead to loss of global GDP by almost 4-8% for very poor countries dependent on agriculture. The Stern Review equates climate change with nonreversible market failure and cost of inaction to be in the range of around 2-4% of global GDP. Chebil and Frija (2016), have measured the economic impact of climate change on the wheat crop in Tunisia, Africa, using the Ricardian approach. The overall impact assessment shows that rise in temperature and a fall in rainfall will cause a fall in gross revenue margin by 4% in subhumid areas and by 24% in arid zones. The net results states that climate change has significant nonlinear impacts on net revenue per hectare of wheat production in Tunisia. According to Steven Van Passel, Massetti, and Mendelsohn (2012), the impact of climate change on European agriculture is causing output to fall by 5-9% per degree Celsius rise in temperature. In the case of modest changes in climatic variable, the loss is about 8% of the farm revenue by 2050. Increases in temperature beyond 4°C will lead to losses of over 28% by 2100. Yousefi, Khalilian, and Hajiyan in 2011 estimated the role of water as a factor of production and intermediate consumption in the climate change situation in Iran. They showed that in case of little climate change and low water scarcity, the GDP will be reduced only by 0.8% but that in a high-impact case, the GDP will fall by 8.4%. Agricultural productions will decline by 4-8.4% under different scenarios. A study at the global level by Asbjørn Torvanger *et al*. in 2005 indicated that climate change is likely to affect agricultural productivity significantly. They estimate that there is a positive impact on yield of 18% from increased temperature. Increase in rainfall will lead to a decline by 20% in crops like barley, oats, and wheat. Naylor *et al*. (2007) estimated the impact of rising incidences of climate change and extreme events to record and estimate the impact on agriculture and economic growth. They estimated that in Indonesia a 1°C increase in the sea surface temperature in the Central Pacific leads to a 1.2 million ton decline in rice production.

Juana *et al*. (2013), analyzed the impact of climate change on households' welfare via its impact on water resources in South Africa. Their study simulates the impact of 10, 20, and 30% reductions in water availability on sectoral output, value added, and household welfare, respectively. The results indicate that total sectoral output declines by 4.3, 7.58, and 16.39% with 10, 20, and 30% respective reductions in sectoral water availability. Agricultural output declines by 8.43, 12.37, and 15.96% when sectoral water use reduces by 10, 20, and 30%, respectively. Kurukulasuriya *et al*. (2006), have estimated the economic impact of climate change on African agriculture. Net farm revenues are expected to fall with warm temperature for dry land crops (temperature elasticity of −1.9). Increase in temperature causes dry land (unirrigated) crop revenue to fall by $27 per hectare per 1°C increase in temperature and irrigated crop revenue increases by almost $30 per hectare per 1°C rise in temperature.

2.2. Indian Case Studies

Birthal *et al*. (2014), have analyzed changes in climate variables like temperature and rainfall in India during the period 1969-2005 and have estimated the impact on crop yields. They show that with significant changes in temperature and rainfall due to climate change, the rice yield will fall by 15% and wheat yield by 22%. For the state of Andhra Pradesh, Singh *et al*. (2014), used Ricardian analysis to analyze the economic impact of climate change on agriculture in Andhra Pradesh, India. They came to the conclusion that there is highly significant nonlinear impact of temperature change and rainfall variability on rice productivity yield and on net income. A 1°C rise in temperature will reduce the net income of the farmers by $2 per hectare in select districts. Kumar and Sharma (2013), investigated the impact of climate sensitivity on crop-wise productivity by utilizing panel data for the time period 1980-2009, by the Cobb-Douglas production function model. They show that climatic factors have a negative and statistically significant impact on per unit land production of wheat, barley, sorghum, maize, and other crops. Increase in maximum temperature by 1% reduces rice productivity 2.6%. For the crucial granary state of Punjab, Hundal and Prabhjyot-Kaur (2007), the research estimated that in the last 30 years, the minimum temperatures have decreased by 0.02°C/year or increased by 0.07°C/year, maximum temperatures have decreased by 0.005-0.06°C/year, and rainfall has increased by 2.5-16.8 mm/year. An increase in temperature by 1.0°C will reduce the yield of rice and wheat by 3 and 10%, respectively. They also estimated that if maximum temperature decreased by 0.25-1.0°C and minimum temperature increased by 1.0-3.0°C, the yield of rice and wheat would decrease by 0.8 and 3.0%, respectively. At the pan India level, Khan *et al*. (2009), estimated the impact of climate change on Indian agriculture. They concluded that there is linear decline in wheat productivity with the rise in mean minimum temperature.

For every 1°C increase in mean temperature, wheat yield decreased by 430 kg/ha. For increase of 2°C temperature, the study estimated 10-15% fall in crop yield in different regions, while a 4°C rise led to 20-30% reduction in crop output.

3. LONG-TERM RAINFALL TRENDS AND PATTERNS IN INDIA

The Indian summer monsoon is a major source of precipitation and provides more than 80% of the total annual rainfall received in the country. The effect of monsoon rainfall depends upon spatial and geographical dimensions. Western and central India receive around 90% of their annual precipitation during the summer monsoon while south and north-eastern India receive 60-80% of their annual precipitation during this period (Monsoon Monograph, IMD, Volume 1, 2012). The highly predictable and dependable pattern of monsoonal precipitation and stability from 1900 to 1970 with small variations has been broken in the last 30 years (Wahl and Morrill, 2010). While the overall trend is stationary, there exist wide variations in annual rainfall, which have started increasing after the 1950s. Areas in the north-east peninsula, north-east India, and north-west peninsular India show a decreasing trend in the monsoon average annual rainfall and an increasing deviation from the normal (Jain and Kumar, 2012). The extreme rainfall events have shown a dramatic increase, which is the major cause for floods and droughts in the recent past. An increasing trend is clearly visible in monsoon rainfall over the west coast, central peninsula, and north-west India (Ghosh *et al.*, 2012; Rajeevan, Bhate, and Jaswal, 2008).

The data in Table 2 shows that while overall the average rainfall has not shown any clear trend over the last 100 years up to 2012, a clear downward trend of annual rainfall can be seen after the 1950s, where the average rainfall has fallen to 876.73 mm/year from 898 mm for the whole period. The average rainfall for the period 1901-1950 was 909.96 mm/year. This shows that the annual average rainfall has fallen by almost 4% per year with increasing variation from year to year. The increasing variations of the monsoon's intensity, timing, and duration have led to famines and floods in the last decades (Table 3) (Guhathakurta and Rajeevan, 2007).

Spatial distribution of monsoon over India is uneven, and its standard deviation is about 8% for north-east India and 30-40% over the semiarid and arid parts of India. The coefficient of variation of monsoon rainfall for the whole of India is at 10%. The last 30 years of climatic variability of monsoon rainfall for India as a whole is about 3% of the normal average. The number of deficit monsoon years has increased between 1960 and 2015, and since 1988 there has been only one excess monsoon year. The rainfall has been mainly on the negative side since 1980 (Goswami *et al.*, 2006).

Table 2. Descriptive Statistics of Annual Monsoon Rainfall (mm) in India.

Time period	Minimum rainfall	Maximum rainfall	Average mean rainfall	Standard deviation
1901-2012	697.40	1124.20	898.04	92.84
1981-2012	698.20	1094.10	876.73	83.04

Source: Created by authors (IMD, 2012).

Table 3. Years Showing Drought and Flooding Years.

Flood years (i.e., rainfall anomaly/deviation exceeding +10% above the long-term average)	Drought years (i.e., rainfall anomaly/deviation by −10% below the long-term average)
1874, 1878, 1892, 1893, 1894, 1916, 1917, 1933, 1942, 1947, 1956, 1959, 1961, 1975, 1983, 1988, 1994, 2010 (total 18 years)	1873, 1877, 1899, 1901, 1904, 1905, 1911, 1918, 1920, 1928, 1941, 1951, 1965, 1966, 1968, 1972, 1974, 1979, 1982, 1985, 1986, 1987, 2002, 2004, 2009, 2014, 2015 (total 27 years)

Source: Monsoon Monograph, IMD, Volume 1, 2012.

Table 4. Trend of Deviation from Normal (mm/season) in South-West Monsoon Rainfall in Four Regions.

	Trend for 50 years		Trends for 112 years
	1901-1950	**1951-2012**	**1901-2012**
All India	2.78	−1.01	−0.9
West India	0.89	−1.00	0.03
Central India	3.19	−0.59	0.12
East India	6.79	−3.01	−1.99
Peninsular India	0.21	−0.29	0.39

Source: Monsoon Monograph, IMD, Volume 1, 2012.

The Indian monsoon has recorded wide variations on the intra-seasonal, inter-annual, and inter-decadal time frames. The rainfall has shown an increasing trend in the period 1901-1930 and 1931-1960 while recording a downward trend in the two periods of 1961-1990 and 1991-2012. The linear trend analysis of past extrapolated data clearly points to negative deviations (−4.0%) from the long-term average in the period 2010-2020 (Ghosh, Luniya, and Gupta, 2009). The decade 1951-1960 had the highest rainfall deviation of +5.8% from the long-term average. The last decade of 2001-2010 has shown below-normal rainfall with a departure of 4.9% from the long-term average. There is a significant increasing trend of annual rainfall during 1901-1950 and a decreasing trend during 1951-2012 (Table 4).

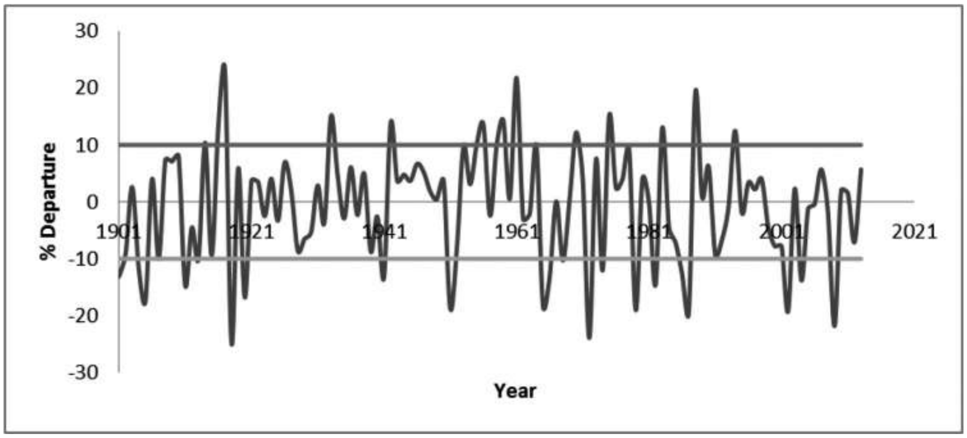
Doubling of CO_2 would lead to a 5-10% increase in Indian monsoon rainfall but decrease in the number of rainy days that would imply higher intensities and extreme rainfall over fewer periods of time. The number of extreme events with more than 100 mm rainfall in a day is reported to have increased by 10% per decade in the last 30 years (Monsoon Monograph, IMD, Volume 1, 2012). In the recent study "A New Metric for Indian Monsoon Rainfall Extremes" by Jun, Munasinghe, and Rind (2015), the authors found that from 1930 to 2013, the probability of extremely high and extremely low rainfall increases by two and four times, respectively. The probability of extreme rainfall events in recent years are statistically correlated with El Niño/ENSO (Southern Oscillation), especially when they are in the same phase with the Pacific decadal oscillation and Indian Ocean dipole in the ENSO year (Kripalani and Kulkarni, 1997).

The monsoon anomaly that measures the deviation of rainfall from its long-term average of 898 mm is a better measure of rainfall behavior in the recent past. If the rainfall is more than 10% over its average, then it is considered to be beneficial (Kumar *et al.*, 2010). If the rainfall is more than 10% below its average, then it leads to water shortages and creates drought-like conditions. The record suggests a close positive relationship between the presence of El Niño and deficient rainfall with a correlation coefficient of +0.55. The Indian Summer Monsoon Rainfall (ISMR) is said to be normal if the annual average rainfall percentage departure is within ±10% of the long-term mean. In India the statistical definition of drought is if the rainfall departure is by more than −10%.

Figure 1 shows the trend in annual monsoon rainfall from the normal over the last 100 years. An excess monsoon year is one where the rainfall departure is more than +10%. During the period, 1875-2015, there were 23 drought years (1877, 1899, 1901, 1904, 1905, 1911, 1918, 1920, 1941, 1951, 1965, 1966, 1968, 1972, 1974, 1979, 1982, 1986, 1987, 2002, 2004, 2009, 2014 and 2015) and 19 excess monsoon years (1875, 1878, 1892, 1893, 1894, 1914, 1916, 1917, 1933, 1942, 1955, 1956, 1959, 1961, 1970, 1975, 1983, 1988 and 2010).

As shown in Table 5, after 1980, there were seven years of deficient rainfall, indicating an increasing trend and climate change impact. Also there have been only three years of excess rainfall after 1980. Goswami *et al.* (2006) have shown significant increasing trends in the frequency and the magnitude of extreme rain events (heavy rainfalls, typhoons, hurricanes, etc.) and a significant decreasing trend in the frequency of moderate events for the period 1951-2000.

Figure 1. Percentage Departure of Annual Rainfall from Average (1901-2012).



Source: Created by authors (http://imdpune.gov.in/)

Table 5. Surplus and Deficient Categories of Monthly Rainfall Per Year after 1980.

Month	No. of deficit months	No. of surplus months
June	2	3
July	2	4
August	5	2
September	6	4
All India level (June-Sept.)	7	3

Source: Created by authors (http://imdpune.gov.in/).

4. METHOD(S)

4.1. Data Set Availability

The data for key climate change parameters of temperature and rainfall were taken for the time period 1900-2012. Minimum and maximum temperature and precipitation data from 1901 to 2012 were taken from the Indian Meteorological Department (IMD), Pune, and the rainfall data for India was taken from http://www.tropmet.res.in and http://www.Indiastat.com. Agricultural Data, crop-wise total production, area sown, irrigated area, and cropping intensity were taken from the Directorate of Economics and Statistics Ministry of Agriculture (Government of India) and http://www.Indiastat.com. Various reports of Planning Commission of India and Annual Economic Surveys of Government of India were also utilized for generating the data set for this paper.

4.2. Measurement Framework and Methodology

The conceptual framework of the paper starts with an initial analysis and information on the climate change and its impact on the agricultural sector. The main climatic variable that affects the cropping pattern in India is the annual monsoon rainfall. This along with the annual mean and minimum temperature are the other key climatic variables that have demonstrated a definitive and clear impact on the environment and GDP at the global level. The rainfall data is collected and analyzed from 1902 onward for which the record is available. In the case of the Indian subcontinent, the main determinants of rainfall activity are the formation of low-pressure areas, sea surface temperature, and the occurrence of El Niño phenomena. A structural equation is constructed with the actual rainfall from 1952 as the dependent variable and the formation of low-pressure areas, sea surface temperature, and the occurrence of El Niño phenomena (ONI index) are taken as the independent explanatory variable. The predicted value so obtained from the structural equation is used as an independent variable in estimating the impact of climate change on agricultural output.

The paper uses Autoregressive Integrated Moving Average (ARIMA) analysis to get the predicted values of annual mean and minimum temperature. The ARIMA approach combines two different processes into one equation: an autoregressive process (AR) that expresses a dependent variable as a function of past values of the dependent variable and a moving average process (MA) that expresses a dependent variable as a function of past values of the error term. The given time series data can be made stationary by differentiating the series one or more times. This is known as ARIMA (*p*, *d*, *q*) where *d* denotes the number of times differentiation has to be done to make it stationary. The conversion is similar to integration in mathematics, and hence, the letter *I* in ARIMA stands for integrated.

To test for stationarity of the time series, the Dickey-Fuller test is used, which examines the presence of a unit root in the variable. In the unit root test, we regress the first difference of the log of the variable on the trend variable and a one period lagged value of the exchange rate. We have used an augmented Dickey-Fuller equation in this paper to check for the correlation of the error term. This makes the residuals purely random. The augmented Dickey-Fuller equation is given below:

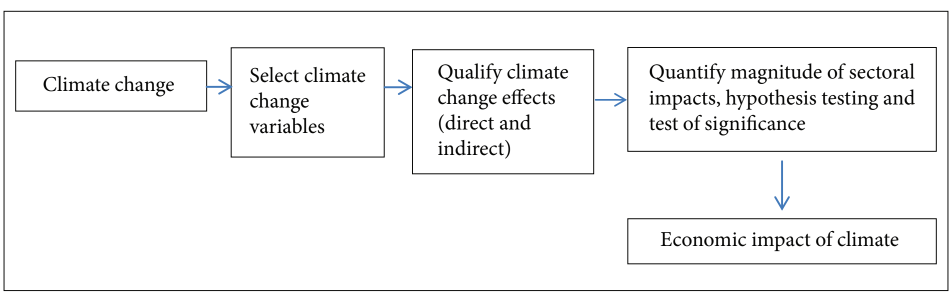
$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 T + \Sigma_{j=1}^{m} \delta_j \Delta y_{t-j} + u_t$$

where y_t is the natural logarithm of the data, y_{t-1} is a lagged value, T is a time trend, and Δy_{t-1} are lagged first differences of order *p*; e_t is a pure white noise error term, and *m* is the maximum length of the lagged independent variable. The null hypothesis is to put α_1, which is the coefficient of y_{t-1} equal to 1 against a trend stationary root of $\alpha_1 < 1$ for stationarity and unit root.

The three climatic variables analyzed and used in this paper are mean minimum annual temperature, mean annual temperature, and annual monsoon rainfall to study the impact of climate change on agriculture. The nonclimatic factors include gross domestic capital formation in agriculture in India, total irrigated area in India, and total nonirrigated area in India. These six variables are used as the explanatory variables in an augmented Cobb-Douglas production function to estimate the impact of climate change on the agricultural sector in India.

The measurement framework of the paper is given as under (Figure 2):

Figure 2. Climate change-Cause-Effects-Evaluation Methodology.



Source: Created by authors.

4.3. Research Methodology for the Paper

The methodology followed for this paper is explained in the four steps given below:

Step1. Analysis of independent variables in the present paper

The six independent (explanatory) variables along with value of agriculture output (AGDP) in the paper are analyzed, and the compound aggregate growth rate of the variables is calculated to find out the trend over time. This helps us understand clearly the underlying factors responsible for change in AGDP of India. The following log-linear or growth model is used for the analysis:

$$X_t = e^{a + bt} \quad (1)$$

Where X_t is the independent variable and t is the time variable, and estimating by taking log on both sides of Equation 1, we get:

$$lnX_t = a + bt + u_t \tag{2}$$

The coefficient b in Equation 2 gives the instantaneous rate of growth over the period. Since $b = \ln(1+r)$. Thus r = antilog (b) - 1 gives the compound aggregate rate of growth over the period.

Step 2. Creating the structural equation of the study

The model developed here takes variation in El Niño, which is represented by the ONI index, sea surface temperature represented by SST, and number of low-pressure areas in a given year by LPA. The autoregressive AR(1) and moving average MA(1) predicted values of the rainfall data are used to determine the final predicted value of rainfall. The logic of using MA (1) and AR (1) in the structural equation is because ARIMA (1, 1, 1) is used for short-term forecasting and is the best fit by the Akaike Information Criterion (AIC) method. The values of rainfall obtained from the structural equation will then be used in determining the impact of climatic variable on crop production and agricultural GDP. The other climatic variables are annual minimum temperature and annual mean temperature. The final functional model of rainfall determination model by the three climatic factors is as under:

Rainfall = F {ONI index, Sea Surface Temperature (SST), No. of Low-Pressure Areas (LPA), AR (1) Annual Rainfall, MA (1) Annual Rainfall},

which is finally expressed as the estimating equation:

$$\text{Rainfall} = \alpha + \beta_1 \text{ ONI Index} + \beta_2 \text{ SST} + \beta_3 \text{ LPA} + \beta_4 \text{ AR (1) Rainfall} + \beta_5 \text{ MA (1) Annual Rainfall} + u_t \tag{3}$$

Step 3. Using ARIMA model to forecast the predicted values of the other two climatic variables, namely, mean annual temperature and mean annual minimum temperature.

ARIMA modeling helps in understanding the impact of climatic factors on the rainfall pattern in India. This provides valuable information for economic forecasters and policy makers to plan for and cope with irregular movement in rainfall activity, which disrupts the economic cycle of India.

In this study we have used basic autoregressive process, where the dependent variable Y_t (three climatic variables) are a function of the past values of themselves as given below:

$$Y_t = f(Y_{t-1,} Y_{t-2,} \ldots . Y_{t-p}) \tag{4}$$

This is expressed in the estimating equation as:

$$Y_{t=0} = b_1 Y_{t-1} + b_2 Y_{t-2} + \ldots + b_p Y_{t-p} + u_t \tag{5}$$

where Y_t is the variable being forecasted and as there are p different lagged values of Y in this equation, it is referred to as a "pth order" or AR(p) autoregressive process (p is the number of past values used). Here u_t is the white noise error term. The value of p is determined empirically by AIC, used commonly in time series analysis.

Step 4. Using augmented Cobb-Douglas production to assess the overall impact of climatic and nonclimatic factors on agricultural output

To assess the overall impact of climatic and nonclimatic factors on the economy of India, the following augmented Cobb-Douglas production has been used in this study. Using an augmented Cobb-Douglas production function allows for climatic and nonclimatic factors of production to be analyzed in a single equation. The nonclimatic factors include capital and irrigated area, allowing for a consolidated relationship between the output (AGDP) and inputs to be studied. In the augmented Cobb-Douglas production function, the constant term represents the existence of the unexplained part (residual) or total factor productivity (TFP). The functional form of the equation is written as follows:

Table 6. Description of the Independent Variables.

S. No.	Variable	Description	Expected sign of the coefficient of the variable
1.	Mean annual minimum temperature (MMT)	The mean annual minimum temperature (MMT) is expected to adversely affect the crop output as per all the studies done on climate change impact. This predicted variable is taken from the ARIMA (1, 1, 2) analysis.	(-), the crop output is expected to decrease as MMT increases.
2.	Mean annual temperature (MT)	The mean annual temperature (MT) has shown a rising trend, and its affect will be negative in the long run but maybe positive in the short run due to fertilization and photosynthesis effect. This predicted variable is taken from the ARIMA (1, 1, 2) analysis.	(-), the crop output is expected to decrease as MT increases.
3.	Mean monsoon rainfall (R)	The (R) variable is taken from the predicted values obtained from the structural equation. The rainfall has shown a linear decreasing trend in the last 30 years, and the number of deficit years of rainfall has increased due to El Niño effect.	(-), agriculture output is expected to fall as rainfall decreases. But the ground situation is not clear due to rise in surface and groundwater irrigated area in total crop production.
4.	Gross domestic capital formation in agriculture in India (GDCF)	GDCF represents capital formation in the agricultural sector.	(+), agricultural sector output will rise as capital formation increases.
5.	Total irrigated area (TIR)	This variable represents the total area irrigated by surface and groundwater resources with the latter share rising in the total irrigated area.	(+), as area under irrigation increases, the output is expected to rise.
6.	Non-irrigated area (NTIR)	(NTIR) represents the area left in rain-fed conditions whose productivity is less than that of irrigated areas.	(-), as the nonirrigated area declines, the output is expected to rise.

Source: Created by authors.

Value of agriculture output of India (AGDP) = F {(Mean minimum temperature (MMT), Mean annual temperature (MT), Predicted monsoon rainfall from the structural equation (R), Gross domestic capital formation in agriculture in India (GDCF), Total irrigated area (TIR), Total Non-irrigated area (NTR)}

The augmented Cobb-Douglas production function is given below:

$$ADGP_t = e^{a + b_0 t}\, MMT_t^{b1}\, MT_t^{b2}\, R_t^{b3}\, GDCF_t^{b4}\, TIR_t^{b5}\, NTIR_t^{b6} \quad (6)$$

Taking log on both the side and adding error term:

$$\ln(AGDP)_t = \alpha + b_0 T + b_1 MMT_t + b_2 MT_t + b_3 R_t + b_4 GDCF_t + b_5 TIR_t + b_6 NTIR_t + u_t \quad (7)$$

Table 6 describes the six independent variables and the expected signs the coefficients of these variables are expected to generate in the augmented Cobb-Douglas equation.

4.4. Hypothesis for the Paper

Null Hypothesis, H_o: There is no impact of climate change variable on agriculture output in India.

1. H_o: There is no impact of climate change variables—that is, mean minimum annual temperature on agriculture output in India.
2. H_o: There is no impact of climate change variables—that is, mean annual temperature on agriculture output in India.
3. H_o: There is no impact of climate change variables—that is, annual monsoon rainfall on agriculture output in India.

Alternative Hypothesis, H_a: Climate change variables have a noticeable effect on agriculture sector in India.

5. RESULTS AND DISCUSSION

5.1. Result of the Structural Equation

The regression analysis in Table 7 reveals the relationship between annual average monsoon rainfall as a dependent variable and the three independent variables, which is broadly in line with the existing literature.

Table 7. Regression Result of Impact of Different Climatic Factors on Rainfall in India.

Coefficient	Constant	ONI index	SST	LPA	AR (1) Rainfall	MA (1) Rainfall
Result (Coefficient)	10,789.6	−35.76	−27.80	0.09	28.54	−38.78
t	0.48	−1.82	−2.28	0.02	0.34	−0.35
P>|*t*|	0.63	0.074**	0.026**	0.983	0.739	0.726

Source: Estimated by authors, and *, **, and *** indicate the 10, 5, and 1% significance level of regression coefficient for respective variables in the table.

Number of observations = 63; F (5, 57) = 2.96; Prob > F = 0.0191; R-squared = 0.2062; Adj R-squared = 0.1366

Table 8 shows the actual rainfall, rainfall predicted by ARIMA, and rainfall predicted by the structural equation in the study. The trend in actual rainfall and the trend in rainfall predicted by the structural equation show a clear and similar pattern over the last 100 years.

5.2. ARIMA Analysis of Climatic Variables

This study has used the ARIMA model to forecast the predicted values of the two climatic variables in our study. ARIMA modeling helps in understanding the impact of climatic factors on the rainfall pattern in India. ARIMA analysis of temperature data has been done to obtain the forecast for the next five-year period. For mean annual temperature, ARIMA (1, 1, 2) (Table 11, 12, 13), and for minimum mean annual temperature, ARIMA (1, 1, 2) (Table 14), are used in the paper. For annual monsoon Rainfall, ARIMA (1, 1, 1) is used (Table 9, 10). The goodness of the best available models is evaluated using AIC. The model having the least value of AIC is chosen in our study. Figures 3, 4, and 5 shows the graph of actual and projected values of the three climatic variables derived from ARIMA analysis.

5.3. Climatic Variable: Mean Annual Temperature

ARIMA (1, 1, 2), Time variable: Year 1901-2017, 1 unit-1 year
ARIMA regression result

Table 8. Monsoon Rainfall Pattern from 1950 to 2012: Actual, Predicted by ARIMA and Predicted by Structural Equation.

A	Actual Monsoon Rainfall
B	Predicted by ARIMA
C	Predicted by Structural equation (Rainfall hat)

Year	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
A	923.2	749.2	827.8	983.4	914.4	962	987.8	898.1	1012.9	1036.7
B	953.16	951.21	941.26	921.29	916.27	921.95	923.13	929.09	932.94	933.44
C	972.8439	895.3463	927.1014	913.3149	924.1011	959.9375	944.8895	853.111	888.522	905.9666

Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
A	930	1078.2	893.6	912.2	1031.4	738.3	779.8	884.1	791.6	888.3
B	944.24	951.52	954.93	962.9	955.47	955.11	953.16	928.97	915.2	908.06
C	878.2642	913.2903	885.9561	877.5426	921.2914	830.4758	874.0258	926.1235	891.2747	884.22
Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
A	998.7	885.7	697.4	956.1	798.8	1011.4	901.5	911.3	965.2	724.8
B	897.95	901.33	908.96	899.03	884.93	887.65	885.42	896.64	897.85	901.82
C	867.7988	944.7482	869.2604	945.0037	946.1258	987.2428	915.5814	895.4127	910.0359	865.8112

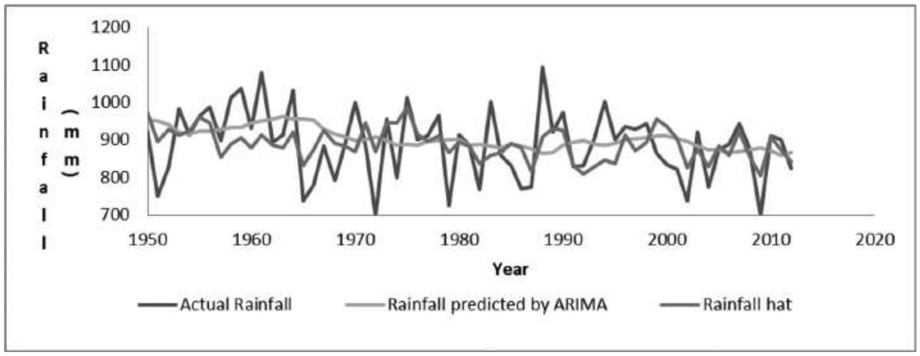
Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
A	912.1	887.1	767.4	1001.5	859.8	832.5	769.9	774.6	1094.1	920
B	900.36	886.62	888.97	884.31	879.52	889.01	884.64	876.12	863.66	865.58
C	892.6669	883.9714	836.9392	859.4416	866.3093	889.7929	879.7509	817.7399	908.5881	929.5605

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
A	972.3	828.3	831.7	905.7	1001.2	900.3	935.1	927.3	943.1	863.1
B	886.72	893.03	897.26	889.27	885.42	891.84	901.4	902.86	906.7	910.05
C	924.5195	832.3671	810.3644	827.9494	846.367	835.9285	913.9494	871.7083	894.2363	955.9778

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
A	833.7	821.9	737.3	919.5	774.2	874.3	889.3	943	877.7	698.2
B	911.17	904.44	895.64	883.64	873.25	873.42	865.54	867.43	872.41	878.66
C	935.5569	903.4689	826.1039	872.522	827.8513	884.2751	859.6882	922.3141	857.0317	803.9727

Source: Created by authors.

Figure 3. All Predicted Rainfall Values by ARIMA and Rainfall Structural Equation.



Source: Created by authors.

Table 9. Model Result.

Model	Observation	II (null)	II (model)	df	AIC	BIC
	111	-	7.060	5	−4.120	9.427

Source: Created by authors.

Table 10. Augmented Dickey-Fuller Test Result.

	Test Statistics	1% critical value	5% critical value	10% critical value
$Z(t)$	−5.020	−3.506	−2.889	−2.579

Source: Created by authors.
MacKinnon approximate p-value for $Z(t)$ = 0.0000.

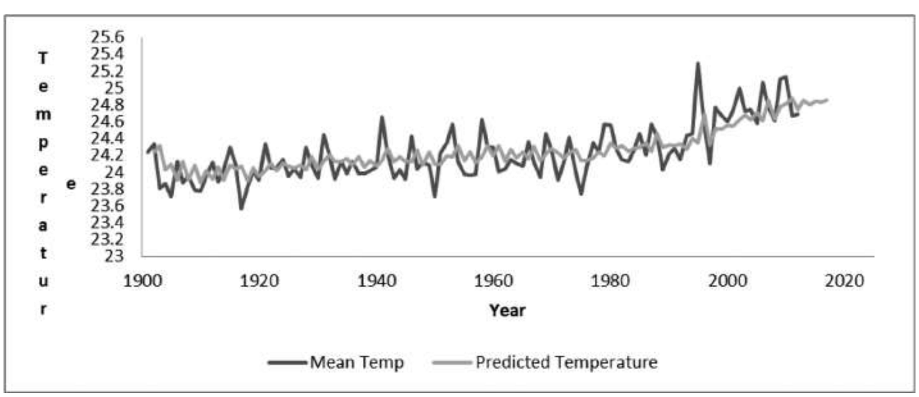
5.4. Forecasting of Mean Annual Temperature Based on ARIMA Model

Table 11. Forecast Values of Mean Annual Temperature.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Actual	24.61	25.11	25.13	24.66	24.69	-	-	-	-	-
Projected	24.63	24.78	24.81	24.87	24.74	24.85	24.80	24.84	24.83	24.85

Source: Created by authors.

Figure 4. Graph Showing Actual and Projected Mean Annual Temperature.



Source: Created by authors.

Table 12. Model Result.

Model	Observation	II (null)	II (model)	df	AIC	BIC
	111	-	0.5843	5	8.8303	22.37

Source: Created by authors.

Table 13. Augmented Dickey-Fuller Test.

	Test statistics	1% critical value	5% critical value	10% critical value
$Z(t)$	−6.454	−3.506	−2.889	−2.579

Source: Created by authors.
MacKinnon approximate p-value for $Z(t) = 0.000$.

5.5. Climatic Variable: Minimum Mean Annual Temperature

ARIMA (1, 1, 2), Time variable: Year 1901-2012, 1 unit-1 year
ARIMA regression result

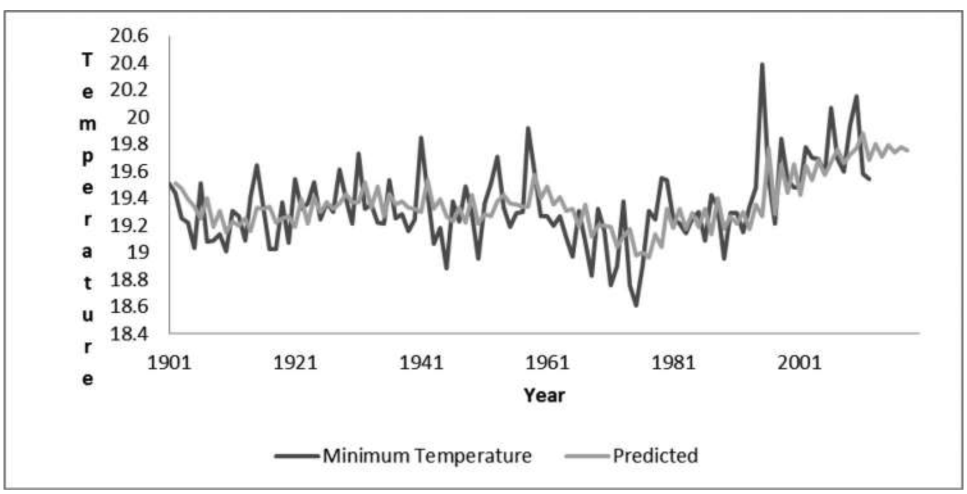
5.6. Forecasting of Minimum Annual Temperatures Based on ARIMA Model

Table 14. Forecast Values of Minimum Annual Temperatures.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Actual	19.6	19.94	20.15	19.58	19.54	-	-	-	-	-
Projected	19.66	19.72	19.77	19.88	19.68	19.8	19.71	19.79	19.74	19.78

Source: Created by authors.

Figure 5. Graph Showing Actual and Projected Mean Minimum Annual Temperature.



Source: Created by authors.

5.7. Analysis of the Independent Variables

An independent analysis of the dependent and independent variables has been done in this study to see the overall trend behavior from 1950 to 2012. A simple log-linear log model is taken up for the analysis because it provides the predictive values and the growth rate for the complete period.

The results from the above analysis of the independent and explanatory variables are presented in Table 15 to study the relative trends in these factors after 1950. The climatic factors are in tune with the general global trend and show positive growth rates. The negative impact of these climatic variables could have been avoided had GDCF and irrigated areas growth rates been more positive and robust.

Table 15 shows that the aggregate growth rate is positive for the two main climatic variables with respect to temperature. Both the mean and the minimum annual average temperature are positive, which shows the accumulation of greenhouse gases in the atmosphere. As expected, the irrigated area is growing at the compound rate of 2% per annum, and the nonirrigated area is falling by 0.6% per annum. The AGDP is increasing by almost 10% per annum compounding, which shows the declining share of agriculture in total GDP of India. Agriculture share has fallen from 40% in 1950s to less than 14% in 2015. The growth rate of GDCF in agriculture is only about 3.7% per annum, which is the root cause of low productivity and output growth in India. The trend in monsoon rainfall is about −0.1% per annum, which is not significant, but the trend has accelerated after 1980.

5.8. Value of agriculture output (AGDP): Impact of Climatic and Nonclimatic Variables

To assess the overall impact of climatic and nonclimatic factors on the economy of India, the augmented Cobb-Douglas Production was used in this paper. The results are given in Table 16.

Table 15. Aggregate Analysis of the Independent Variables for the Period 1950-2012.

Independent variables	Average annual mean minimum temperature	Annual average mean temperature	Irrigated area	Nonirrigated area	Mean monsoon rainfall	Gross domestic capital formation in agriculture (GDCF)	Value of agriculture output (AGDP)
Compound rate of growth	0.0317%	0.039%	2.07%	−0.635%	−0.1%	3.68%	10.04%

Source: Created by authors.

Table 16. Impact of Climatic and Nonclimatic Factors on Agricultural GDP (AGDP).

Coefficient	Constant	Year	Mean minimum temperature	Mean annual temperature	Annual monsoon rainfall	GDCF	Irrigated area in agriculture	Non- irrigated area in agriculture
Result (coefficient)	−5.67	0.00033	−1.73	2.62	0.24	0.045	0.1412	0.843
Std. err.	1.85	0.00048	0.94	1.43	0.066	0.043	0.22	0.17
t	−2.97	0.68	−1.85	1.83	3.61	1.05	0.66	4.84
P>|*t*|	0.004***	0.501	0.07**	0.073**	0.001***	0.296	0.509	0.00***

Source: Estimated by authors, and *, **, and *** indicate the 1, 5, and 10% significance level of regression coefficient for respective variables in the table.
Dependent variable = AGDP.

Number of obs. = 62; F (7, 54) = 13.96; Prob > F = 0.0000; R-squared = 0.6440; Adj R-squared = 0.5979

Table 16 displays the result of the augmented Cobb-Douglas production function Here, agriculture output in the total GDP of the country (AGDP) is the dependent variable. The constant/intercept term in the augmented production function is the mean/average of all the variables omitted from the above equation. In a double log production function, this represents Total Factor Productivity Growth (TFPG), which is significant and negative. TFP is the measure of the combined contribution of nonconventional inputs in agriculture, such as improvements in input quality, market access, economies of scale, and technology. The TFP was low at the beginning of 1950, and it was positive for some time in the period (1970-1990). This was mainly due to the introduction of high-yielding varieties seeds (HYV) in the green revolution. But all empirical studies points to a declining and negative TFP in Indian agriculture since the 1990s. The initial level of TFP in this study is negative and its value is −5.06. Taking antilog (−5.06), we get the value 0.003448, which is the net TFP in our study. This is the overall TFP for the period 1950-2012, which is low but significant. The TFP growth whose coefficient is 0.00033 is equal to 0.03 of 1% per annum for the last 60 years. This is positive but not significant, but this is expected, and the result is better than a lot of other studies on TFP in Indian agriculture. This, however, proves that after the initial level of negative TFP in 1950, the TFP growth has been positive but low, which is also corroborated by many other empirical studies.

The null hypothesis no. 1 says that there is no impact of mean minimum annual temperature on AGDP in India. The coefficient for the variable is negative and statistically significant as expected. Hence, we reject the null hypothesis, and the result in Table 16 indicates that 1°C rise in mean minimum annual temperature has resulted in loss of AGDP by 1.73%.

The null hypothesis no. 2 says that there is no impact of mean annual temperature on AGDP in India. The coefficient for the variable is positive and statistically significant as expected. Hence, we reject the null hypothesis, and the result in Table 16 indicates that 1°C rise in mean annual temperature has resulted in gain of AGDP by 2.62%.

The null hypothesis no. 3 says that there is no impact of annual monsoon rainfall on AGDP in India. The coefficient for the variable is positive though small in absolute terms and statistically significant, as expected. Hence, we reject the null hypothesis, and the result in Table 16 indicates that 1 mm decrease in annual rainfall has resulted in a small gain of AGDP by 0.24%. This indicates the fact that annual rainfall has not declined significantly and that the economy is learning to cope with hydrological stress by using water more efficiently. The decline of rainfall seen in the north-western states of Punjab and Haryana is compensated by a rise in rainfall in the eastern states of India.

The yield per hectare has reached a plateau and has started to decline in well-irrigated areas of Punjab and Haryana. No new technological breakthrough has happened in the last 20 years, which is also magnified by the falling investment in agriculture sector. The persistent increase in annual mean minimum temperature is a negative factor for agricultural growth. The coefficient is negative and significant (5%) and estimates that for every 1% increase in annual mean minimum temperature, the AGDP falls by 1.73%. The persistent increase in annual mean temperature is a positive factor for agricultural growth in India due to fertilization affect. This squares with the vast theoretical literature including the Stern report, which also predicts that initially the higher temperature will cause the agriculture output to rise but then fall gradually. The coefficient is positive and significant (5%) and estimates that for every 1% increase in annual mean temperature, the AGDP will increase by 2.62%. The annual monsoon rainfall coefficient is positive and also significant (1%) though the coefficient is small. For every 1 mm of excess rainfall over the annual average of 890 mm leads to a positive contribution to agriculture output. Every 1% increase in rainfall leads to 0.24% increase in output. This is particularly true because large parts of India are still dependent upon monsoon rainfall and almost 70% of the area is nonirrigated.

The contribution of nonirrigated area to agriculture output is significant and positive. For every 1% increase in nonirrigated area, the agriculture output increases by 0.84%. The coefficient of irrigated area is not significant. There are two main sources of growth of output in India—namely, agricultural extensification and intensification. This was mainly due to the inelastic nature of land available. Agricultural intensification in India essentially implies increasing the use of inputs per hectare and also bringing previously uncultivated land into cultivation. Cropping intensity has increased from 111% in 1950 to 192% in 2012. Extensification is the process of introducing production into land areas that were previously unused or used for less intensive purposes. Extensification has often involved exploiting marginal lands with resultant degradation and/or desertification. Empirically, the output from extensification is less than intensification. AGDP growth can be segregated into three parts: contribution of factor inputs, productivity change (TFP), and unaccounted factors that include changes in climatic variables.

The nonirrigated area has been falling in absolute numbers, and the positive sign of partial effect on AGDP implies that as the amount of area falls, the marginal productivity on that land will increase. In this study, the nonirrigated area has been falling in absolute terms. Production is based on land in agriculture, which implies that any society would first put productive land to use and then "extend" production to less productive land. Therefore, the first margin is the intensive margin, and the second margin is the extensive margin. Thus, it implies that total agriculture output should increase. If nonirrigated area is falling, then production in extensive margin is falling, which implies that marginal productivity is increasing. Intensive margin agriculture has been grossly overutilized and exploited to the maximum. Thus, the coefficient in our study for nonirrigated areas is positive and significant at 0.84. The coefficient for irrigated land is not significant though positive, which implies that the irrigated land has been overexploited, and no more output growth is possible. All evidence points to falling yields of rice and wheat in the best-irrigated lands of Punjab and Haryana. The limits of development of irrigation potential have been reached under falling water scarcity and climate change.

The coefficient of gross domestic capital formation in the agricultural sector though is positive but not significant. This is because public investment as a percentage of GDP has declined over the years. Instead, the share of subsidy for the agricultural sector has increased, whose output elasticity is close to zero or negative. The ratio of capital formation in agriculture GDP has stagnated at a level below 3% and been around 2.70% for the last 20 years. It is the nominal increase in private sector capital formation that is showing a small increase but is clearly unable to compensate for the decline of the former. In 2014-2015 the share of private sector capital formation was 80-85% of the total capital formation in the agriculture sector. This compares favorably with the figure of 42% in the 1980s. The advent of green revolution has encouraged farmers to incorporate new technology and mechanization, which is responsible for the small positive growth rate.

6. CONCLUSION

Climate change is proving to be the biggest challenge facing the earth today, and it has not spared any region from its negative effects. All the available climatic indicators suggest that things are not going to get better. The adverse impact of climate change impact in India is no different from the global trend and events like El Niño and environmental degradation have amplified the negative effects of climate change. The number of extreme rainfall events has increased, and there is clearly a decreasing trend observed since the 1980s, which is accompanied by high annual variation in the quantity and distribution of rainfall. The decreasing trend in monsoonal rainfall is adversely impacting small and marginal farmers. The result from this paper points to a gradual decline of TFP, which is significant for the overall productivity of the farm sector. The persistent increase in annual mean minimum temperature is a negative factor for agricultural growth. For every 1% increase in annual mean minimum temperature, the AGDP falls by 1.73%. The persistent increase in annual mean temperature is a positive factor for agricultural growth in India due to fertilization affect. The coefficient of annual mean temperature is positive and significant (5%) and estimates that for every 1% increase in annual mean temperature, the AGDP will increase by 2.62% (Our findings are fully supported by a study on relationship between temperature and plant growth and development by Hatfield and Prueger, 2015). The annual monsoon rainfall coefficient is positive and also significant (1%) though the coefficient is small. For every 1 mm of excess rainfall over the annual average of 890 mm leads to a positive contribution to agriculture output. Every 1% increase in rainfall leads to 0.24% increase in output.

6.1. Policy Recommendations to Combat Climate Change

Adaptation and mitigation strategies: Successful and effective response and adaptation to imminent climate change requires long-term investments in new policy initiatives and paradigms that incorporate climate change adaptation and mitigation strategies into development planning at the national level. For example, the Ministry of Agriculture can document all the indigenous practices of rain-fed farmers and quantify age-old practices of varied styles of agriculture in the different agro-ecological regions of the country. A robust and dynamic research plan has to be developed that would include diverse crop varieties, especially in rice and wheat. A planned and coordinated effort by states is that which is taken as a result of deliberate policy decisions. Adaptation leads to building national and local adaptive capacity and delivers specific regulatory mechanisms. The main focus of adaptation is to reduce vulnerability and increase the resilience of the dynamic system and return it to the equilibrium. There are many important adaptation and mitigation measures that have the capability to ameliorate the negative effects of climate change. Rainwater harvesting and storage is one of the most important components of the adaptation approach to combat desertification and climate change. Properly designed rainwater harvesting leads to stoppage of soil loss, which in turn contributes to reduced carbon losses and nutrients. This along with soil carbon sequestration helps in sequestering and capturing carbon in agriculture cropping systems, particularly in high rainfall regions. Proper usage of essential micronutrients and their management at the farmer level is one of the direct approaches with massive potential to alleviate the adverse effects of climate change. Proper nutrient management leads to increase in crop yields, covers the essential micronutrients deficit in crops for proper growth, and reduces requirements of chemical fertilizers leading to CO_2 sequestration and 20-30% increase in nitrogen-use efficiency. Conservative and ecosystem-friendly agriculture, also called zero tillage method, has the potential to reduce the demand for water in the rice-wheat cropping system of the Indo-Gangetic plains. It increases soil organic carbon, reducing energy intensity of the rice crop, and improves water and nutrient-use efficiency. Agroforestry systems within the present system of cultivation provide a shield against climate change, reduce atmospheric levels of GHGs, and provide an additional source of income. Agroforestry both sequesters carbon, which can be up to 10 tons/ha/year in short rotation eucalyptus, poplar plantations. Finally, diversification of agriculture away from water-intensive crops like rice and sugarcane to fruits, vegetables, and floriculture can help fight climate change. These are the new cash and high-value crops in the rapidly changing profile of Indian agriculture. The demand for fruits and vegetables has increased due to change in consumer taste and increase in per capita income. The average prices of fruits and vegetables have increased, and they have grown at an annual compound growth rate of 3.8 and 6.7 percent during the last 20 years. This high demand is complemented by high-income elasticity for fruits and vegetables. The higher price and increased profitability has led to an increase in the area under fruits and vegetables, and traditional areas under rice-wheat cultivation are shifting to cash crops.

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Climate Change Issues in BRICS Countries

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Abstract

Climate change has emerged as one of the discussions where more is discussed and very less is implemented. People wait for actions to be taken by the government or multilateral organizations but seldom do they capture the developments going on. Several initiatives have been taken by individual countries as well as countries forming groups or conglomerates to tackle the challenges of climate change. This is true for BRICS as well. BRICS countries share the idea of climate protection but are sceptical of the policies passed by developed countries. BRICS as a forum of developing countries challenging the status quo of climate change policies has emerged to formulate its own climate change policies and initiatives in the light of BRICS discussions. The present study is aimed to capture the BRICS climate change policies and initiatives with a descriptive approach.

Keywords: BRICS; Climate change; Carbon emissions.

1. INTRODUCTION

The history of economic thought can be divided into two streams as we see it from the present. Studying past as past and studying past from present are two different approaches. While the former is general, the latter is specific. When this is applied to economic thought that has culminated in the 21st century, two diametrically opposite approaches appear. One is mainstream economics, and the other is nonconformist economics, popularly known as heterodox economics (though not so popular). The neoclassical notion of “scarcity of resource” has been questioned by heterodox economists, and their understanding of resources is different. On the question of ownership of natural resources of a country, the two approaches have different answers. While mainstream economics makes an attempt to deal in a manner of opportunity cost or efficiency problem, heterodox economics deals more with social problems associated with distribution of resources. The two diametrically opposite stands are similar to the climate change policies formulated by developed countries on one hand and developing countries on the other hand. BRICS was highlighted by O’Neil (2001), and on the basis of his report, a formal meeting of BRIC was held in 2009, and South Africa joined in 2010 to complete the group for the acronym BRICS. The objective of BRICS apart from economic association was to challenge the international economic environment dominated by developed countries, at times ignoring the notions of developing and underdeveloped countries. Climate is both dynamic and static. Dynamic in the sense that changes do occur on the basis of anthropogenic causes and static due to fundamental climate attributes that cannot be altered. However, the usage of the term “climate change” has a specific connotation for the 20th and 21st century. It refers to a negative scenario where climate patterns are altering over a long period of time with the causal evidence of carbon emissions. The study is focused on discussing BRICS climate change issues and the trends in carbon emissions.

2. CONCEPTUAL FRAMEWORK

In the study several key words are used—namely, climate change, policies, initiatives, and BRICS. We take up each key term one by one in order to expound its meaning and definition. Climate change according to

Cambridge dictionary is "changes in the world's weather, in particular the fact that it is believed to be getting warmer as a result of human activity increasing the level of carbon dioxide in the atmosphere" [Def. 1]. In the present era of globalization, multilateral talks on climate change, "carbon emissions" has become the near synonym of climate change. Though this may not define all forms of causes of climate change, it is the most important one in affecting the climate change. Thus, in our study the term "climate change" specifically focuses on carbon emissions as an anthropogenic activity. Other multilateral organizations define climate change more specifically and differently. For example the Intergovernmental Panel on Climate Change defines it as follows: "Climate change refers to a change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use." The Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change in a more subtle manner as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes. In the present literature of climate change, seven theories are prominently coded for our further discussion in the study.

2.1. Theory 1 (CCT1): Anthropogenic Global Warming

This theory states that human causes are the primary ones in altering climate over decades through carbon emissions. These carbon emissions are due to humanity's efforts under industrialization or lifestyle choices as well as due to deforestation to expand urbanisation.

2.2. Theory 2 (CCT2): Bio-Thermostat

This theory states that rising temperatures and levels of carbon dioxide (CO_2) in the atmosphere create a spillover of biological and chemical effects, which then have a cooling effect, like a natural thermostat.

2.3. Theory 3 (CCT3): Cloud Formation and Albedo

This theory states that changes in the formation of albedo and clouds create negative feedback that cancel out all or nearly all the warming effects of higher levels of CO_2 causing serious climate change.

2.4. Theory 4 (CCT4): Human Forcings

This theory states that mankind's greatest influence on climate is not its greenhouse gas emissions, but its transformation of Earth's surface by clearing forests, irrigating deserts, and building cities.

2.5. Theory 5 (CCT5): Ocean Currents

This theory states that global temperature variations over the past century and a half and particularly in the past 30 years were due to the slowdown of the ocean's thermohaline circulation (THC).

2.6. Theory 6 (CCT6): Planetary Motion

This theory states that natural gravitational and magnetic oscillations of the solar system induced by the planet's movement through space drive climate change.

2.7. Theory 7 (CCT7): Solar Variability

This theory states that changes in the coronal ejections and magnetic fields of the sun cause changes in cloud formation, ocean currents, and wind cause the climate to change.

According to *Oxford* dictionary, policy means "a course or principle of action adopted or proposed by an organization or individual" [Def. 1]. For fulfilling the objective of this study, we will look toward climate change issues by BRICS countries in this respect. Initiatives pertaining to climate change will also be considered from the point of view of BRICS countries. The difference between initiatives and policy is formal and informal. In the light of such a distinction, it would be fitting to study BRICS climate change issues.

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3. REVIEW OF LITERATURE

Climate change has remained an area of natural scientists since time immemorial, but recently social scientists have jumped in to discuss carbon emission in government policy and in initiatives taken by myriad platforms. We are going to cite a few of those relevant studies from the point of view of social sciences and not natural sciences. We will move from a general to specific review of studies in this section. Recent study on the climate policy design in terms of emissions and solar radiation has suggested evaluating in terms of social cost and environmental changes. The impact of asymmetry on mitigation and solar radiation management has been found significant, and asymmetries play an important role in influencing incentives for cooperation and unilateral actions (Manoussi and Xepapadeas, 2017). Climate change in a political system of governance depends on national level public bureaucracies in order to formulate and implement effective and efficient measures. The aggregation of numerous climate change policies plays a decisive role in the implementation of climate policy. Studying these paradigms in the light of power theories has shown that climate initiatives and policies by national bureaucracies gives them power. The study was conducted in Bangladesh (Rahman and Giessen, 2017). On the issue of disproportionate policy reactions in the case of climate change policies, it was identified that governments react to climate change by formulating policies in order to manage blames. The government may involve itself in a blame game between policy makers and policy implementers (Howlett and Kemmerling, 2017). The world has collectively brought the discourse of global warming and recent study foci on the ratification plan. In Singapore, substantial measures have been taken for reducing global warming, and in the case study, the online policy documents by 11 organizations were used to identify policy levers as theoretical constructs of climate change policies (Ng, Lwin, and Pang, 2017). Research on BRICS with respect to climate change mitigation in the Forestry Sector has revealed new results. BRICS has demonstrated specific endeavors in this sector indicating its leading role in climate mitigation. Extended cooperation and knowledge sharing may bring additional gains in reducing carbon emissions from forests and developing tools for Safeguards Information Systems (SIS) (Bhan *et al.*, 2017). It has been identified that BRICS climate change policies are contextual and constitute the basis for future climate change negotiations. The geopolitical positioning of BRICS in the global economic order is also a key factor when it comes to climate change initiatives. The empirical study of media coverage of the IPCC reports shows a promising position of BRICS in climate change (Yagodin *et al.*, 2017). One of the studies examined time series behavior of CO_2 emissions in BRICS in a long approach with structural breaks and nonlinear trends. The results show that the CO_2 emissions are integrated of order one for BRICS countries indicating that there are permanent effects of shock for CO_2 emissions (Gil-Alana, Cunado, and Gupta, 2017). A study conducted on CO_2 emissions for BRICS for the sample period 1980-2011 suggested differences within BRICS countries. Due to the heterogeneity of emissions in BRICS, it is divided into groups, one consisting of Brazil and Russia and another consisting of China, India, and South Africa. It was concluded that environmental consequences of growing emissions should be studied on a case-by-case basis (Azevedo, Sartori, and Campos, 2018).

4. BRICS CLIMATE CHANGE POLICIES

Climate change policies for BRICS can be divided into two parts on the basis of chronology. Those that were followed by BRICS countries individually before the inception of BRICS and those that are the outcome of BRICS summits with respect to climate change. The theory of BRICS climate change policies demands to ignore the former and to consider latter as a collaborative effort. Much of the talk on climate change by BRICS has been on theoretical grounds ignoring the official statements and ratifications. The point is to include only those issues in BRICS climate change policies that are reflected in the BRICS summits official documents or oral releases. The reason being individual countries in BRICS take separate climate actions, but when they come together, it is only then that they form policies that can be said to be of BRICS countries. We take the approach of discussing climate change policies as discussed and expounded in different summits.

4.1. Before First Summit

Before the first summit of BRICS, there were few informal meetings between the countries on several issues, but no declarative statements were issued. Therefore, no official stand of the countries was clear or specific. In July 9, 2008, a meeting of BRICS representatives was held at Hokkaido, Japan, without any formal agreement.

4.2. First BRICS Summit

The first BRICS summit was held on July 16, 2009, at Yekaterinburg, Russia. A very popular joint statement was issued pertaining to Global Food Safety, an issue of concern to the world but particularly important to developing countries. In the first summit, an indication was given by BRICS countries that they are ready for constructive dialogue on climate change. BRICS countries identified principle of common but differentiated responsibility. The phrase "common but differentiated responsibility" gave a balanced approach to the climate change policies of BRICS, which would not conform to developed countries' dictates on climate policies but would reflect the issues of developing and underdeveloped countries. BRICS were also clear to take measures that were in symmetry with the socioeconomic development tasks of BRICS countries. Apart from this statement, no other specific information was released.

4.3. Second BRICS Summit

The second BRICS summit was held on April 15 at Brasilia, Brazil. The global players of G7 and G10 were already having an eye on BRICS due to its mention of climate change in the first summit. Climate change was discussed in the Declaration Statement of the Second Summit in points 17 and 22 of the statement. While point 17 dealt with agriculture, point 22 emphatically dealt with climate change. BRICS countries decided to curtail the food security issues due to climate change. Point 17 specifically talked about the climate change initiatives jointly to be taken by BRICS countries. BRICS countries identified climate change to be a serious threat and acknowledged the need for global action. BRICS countries committed themselves to promote the Sixteenth Conference of the Parties to the United Nations Framework Convention on Climate Change and the Sixth Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol, in Mexico. The phrase "common but differentiated responsibility" was reiterated. BRICS countries indicated their displeasure toward the Mexico meeting by demanding it to be more inclusive, transparent, and fair.

4.4. Third BRICS Summit

The third BRICS summit was held on April 14, 2011, at Sanya, Hainan, China. In this summit declaration, the wordings on climate change became more specific and clearly directed at reforming the existing system dominated by developed countries. Development and use of renewable sources of energy was appreciated, and BRICS initiatives on information exchange regarding renewable energy sources were presented to the global audience. Climate change as a global threat was repeated in the statement and South Africa's hosting of UNFCCC COP17/CMP7 was appreciated. A support for Cancun Agreement was extended toward the international community. It was specified that BRICS would intensify cooperation on the Durban conference.

4.5. Fourth BRICS Summit

The Fourth BRICS summit was held on March 29, 2012, at New Delhi. A Delhi action plan was made adjacent to the BRICS declaration. From referring to the last three summit declarations, it is now clear that the discussion on climate change in BRICS is getting bolstered, and BRICS are starting to say more about climate change. BRICS identified the increasing relevance of climate change discussion just before the UN Conference on Sustainable Development (Rio+20) and the Conference of Parties to the Convention on Biological Diversity being hosted in Brazil and India. The mention of the Eighth WTO Ministerial Conference was also found in the declarative statement. The phrase "common but differentiated responsibility" was reiterated. A promise for the use of clean and renewable energy sources was made with the clear contention that fossil fuels dominate the energy mix. BRICS demanded extended international cooperation in the development of safe nuclear energy.

4.6. Fifth BRICS Summit

The fifth BRICS summit was held on March 27, 2013, at Durban, South Africa. Again in line with what was said in the previous summit, BRICS acknowledged climate change as one of the greatest threat and challenge toward achieving sustainable development. BRICS called for reaching a successful conclusion by 2015 on COP17/CMP8.

4.7. Sixth BRICS Summit

The Sixth BRICS summit was held on July 15, 2014, at Fortaleza, Brazil. This summit was important due to the discussions that included post-2015 Development Agenda. Point 52 of the Declaration Statement focused on climate change policies taken up by BRICS countries. BRICS reiterated its stand to comply with the UNFCC adoptions and also invited the rest of the world for the same. The support for Kyoto Protocol was highlighted and its importance discussed.

4.8. Seventh BRICS Summit

The seventh BRICS summit was held at Ufa, Russia, on July 9, 2015. Point 53 of the Ufa declaration focused on the promotion of agricultural technologies so that provision for food is available to vulnerable communities. Support for 2015 as the International Year of Soils was extended to UN General Assembly. Protection of soil resources as the need of the hour was integrated with climate change policies. BRICS clarified that climate change policies can only be effective when formulated in a global context under UNFCCC. Transfer of knowledge and technologies are also important to address climate change.

4.9. Eighth BRICS Summit

The Eighth BRICS summit was held at Goa, India, on October 16, 2016. In this summit one of the key features was that importance of nuclear energy was highlighted by the BRICS. It was clearly stated in the Official Declaration that some BRICS countries will require the usage of nuclear energy in order to meet 2015 Paris Climate Change agreement. BRICS extended their support for natural gas usage as a clean fuel to promote sustainable development and to reduce greenhouse emissions.

4.10. Ninth BRICS Summit

The ninth BRICS summit was held on September 4, 2017, at Xiamen, China. Further promotion of green development and low-carbon economy was bolstered in the BRICS talk. The call to invite all countries to adopt UNFCCC principles was reiterated. BRICS urged developed countries to provide financial, technological, and capacity-building support to developing countries to enhance their capability in the adoption of climate change policies.

5. BRICS ENERGY CONSUMPTION AND CARBON EMISSIONS

BRICS policies on climate change and claims made in the official declaration need to be identified in the backdrop of energy consumption and carbon emissions data. It is indeed strange that few of the statements in the declarations appear to be contradictory in the light of the data set. We move to identify five core indicators of climate change in order to draw an inference for BRICS performance and adherence to climate change policies. Table 1 shows the list of indicators along with the targeted inference.

On the basis of Table 1, we would be building the discussion for BRICS countries. The first indicator is primary energy consumption expressed in million tonnes of oil equivalent (Figure 1). Trend study of PECO is important, as it has been reiterated by BRICS countries to achieve sustainable development and climate change benefits by reducing the overall fuel consumption. Second indicator is the fuel classification of primary energy consumption, which highlights the comparison of usage between fossils and clean energy sources. The third indicator, natural gas production, is selected as it has been said by BRICS countries to promote natural gas and its usage. Whether these are just words or deeds, has to be evaluated. The fourth and fifth indicator is CO_2 emissions in a different perspective and is selected to identify whether carbon emissions have reduced in BRICS countries or not. All the data of BRICS is compared with OECD, non-OECD, and EU countries, wherever available.

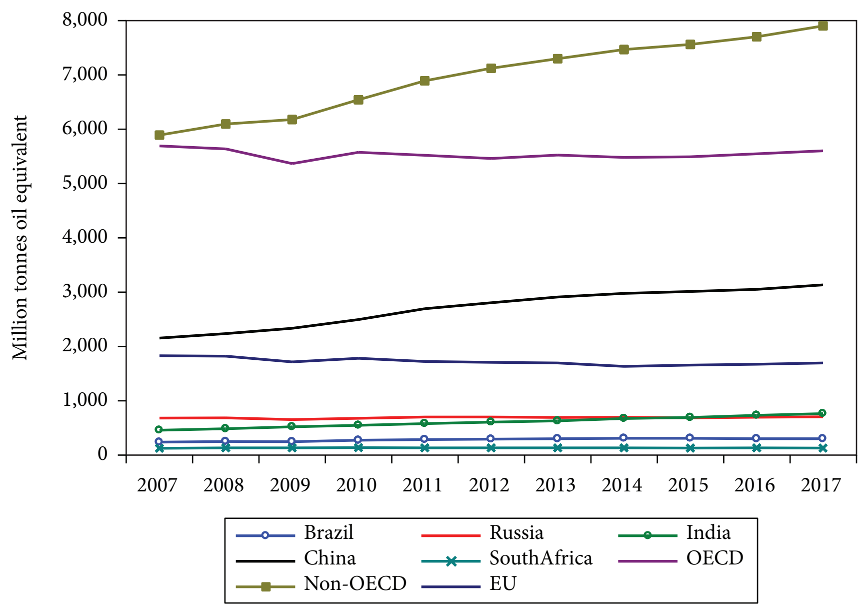
From Figure 2, we can compare the consumption of BRICS and other entities for 11 years' sample data (2007-2017). The mean value of the consumption of Brazil is 274.12 mtoe (million tonnes oil equivalent), and there is an overall increasing trend. Last three years growth rates are –0.89% (2015), –2.04% (2016), and 0.48% (2017), respectively. It shows that Brazil has in the last three years reduced the overall consumption of energy except for 2017. The mean value for the consumption of Russia is 680.64 mtoe, and the mean value for India is 600 mtoe. For India, the overall trend is increasing, while for Russia there is a mixed trend. For

Table 1. Key Indicators for BRICS.

Indicator	Measure	Code	Inference to be drawn
Primary energy consumption	million tonnes oil equivalent	PECO	Whether consumption has been reduced for achieving sustainable development and reducing carbon emissions indirectly.
Primary consumption by fuel classification	million tonnes oil equivalent	PECF	What is the status of fossils in comparison to other clean and green forms of fuel?
Natural gas production (billion cubic meters)	billion cubic meters	NGPO	What is the status of one of the clean sources for which BRICS declared support and there exists no restriction of any sort?
CO_2 emissions (metric tons per capita)	metric tons per capita	CEPC	Have BRICS policies on climate change been successful in reducing per capita carbon emissions?
CO_2 emissions (kg per PPP $ of GDP)	kg per PPP $ of GDP	EGDP	Have BRICS policies on climate change been successful in reducing carbon emissions with GDP as the base?

Source: Prepared by the researcher.

Figure 1. Primary Energy Consumption.



Source: Prepared by the researcher from British Petroleum Statistical Review of World Energy, 2018.

both countries, the growth rate for 2016 and 2017 is positive. China has an overall trend of increasing consumption with a mean value of 2705 mtoe that is highest among all BRICS countries. It is even more than the rest of the BRICS countries. The growth rate in 2016 was 1.3%, and in 2017, it was 2.7%.

Table 2 highlights the primary consumption by fuel type and shows fossils and clean energy sources. An analysis of the table shows that since 2016, usage of clean energy sources has increased in BRICS countries and the same trend has continued for OECD countries, non-OECD countries, and European Union member countries.

Table 2. Primary Consumption by Fuel Classification (million tonnes oil equivalent).

Country	Oil	Natural gas	Coal	Nuclear energy	Hydroelectricity	Renewable	Total
2016							
Brazil	135.7	32.4	15.9	3.6	86.2	19.1	293
Russia	152.5	361.3	89.2	44.5	41.8	0.3	689.6
India	217.1	43.7	405.6	8.6	29	18.3	722.3
China	587.2	180.1	1889.1	48.3	261	81.7	3047.2
South Africa	28.7	4	84.7	3.6	0.2	1.8	123
OECD	2190.6	1427.3	897.6	445.9	318.3	270.1	5549.8
Non-OECD	2366.7	1645.9	2808.4	145.4	594.9	147.3	7708.7
EU	635.5	385.9	239.5	190.1	79.2	136.3	1666.4
2017							
Brazil	135.6	33	16.5	3.6	83.6	22.2	294.4
Russia	153	365.2	92.3	46	41.5	0.3	698.3
India	222.1	46.6	424	8.5	30.7	21.8	753.7
China	608.4	206.7	1892.6	56.2	261.5	106.7	3132.2
South Africa	28.8	3.9	82.2	3.6	0.2	2	120.6
OECD	2206.8	1442.5	893.4	442.6	314.8	304.9	5605
Non-OECD	2415.1	1713.5	2838	153.8	603.9	181.9	7906.1
EU	645.4	401.4	234.3	187.9	67.8	152.3	1689.2

Source: British Petroleum Statistical Review of World Energy, 2018.

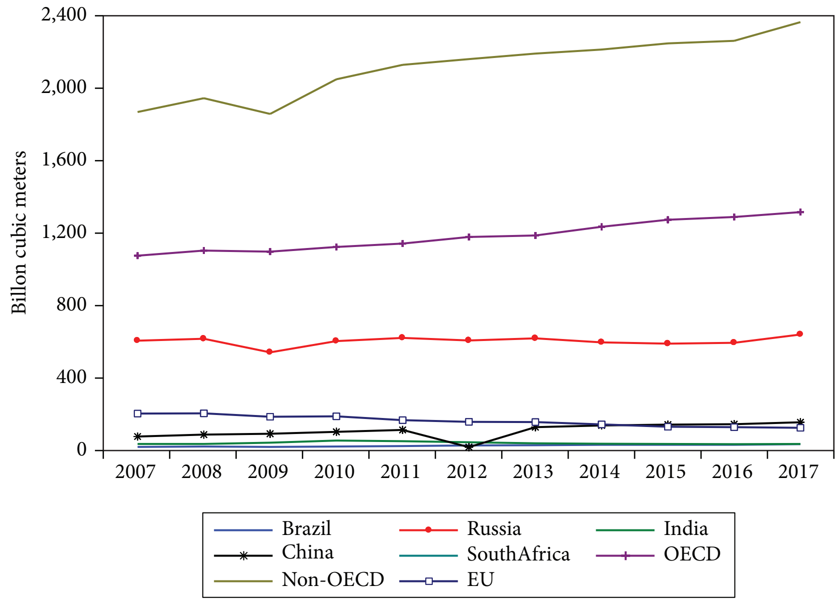
The inference drawn from Table 2 is that BRICS countries are performing well in terms of using clean energy sources such as renewables, nuclear, and so on, but they need to catch up with the growth rate of OECD and EU member countries. As has been reiterated, natural gas has been in the limelight due to the BRICS declaration.

As per Figure 2, Brazil has shown a mean value of 19.46 bcm (billion cubic meters), and the mean value of Russia is 598.3 bcm. For India and China, the mean values are 33.76 and 102.4 bcm, respectively. The data for South Africa is not available, but as per general information, it is negligible. Thus, out of BRICS except South Africa, all countries are using natural gas and are producing it. From Figure 2, it is clear that there is an increasing trend in the natural gas production of BRICS nations with a slight variation. This is a good indication in favor of climate change policies.

The other two indicators of climate change policies are based on carbon emissions with different expressions. The first is measured and expressed as per capita and the other as a ratio of GDP. CO_2 emissions (from now on carbon emissions) as per capita indicates per person carbon emission. Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. Figure 3 shows carbon emissions per capita. Carbon emissions for all the countries and groups are increasing from 1990 to 2014 according to World Bank statistics.

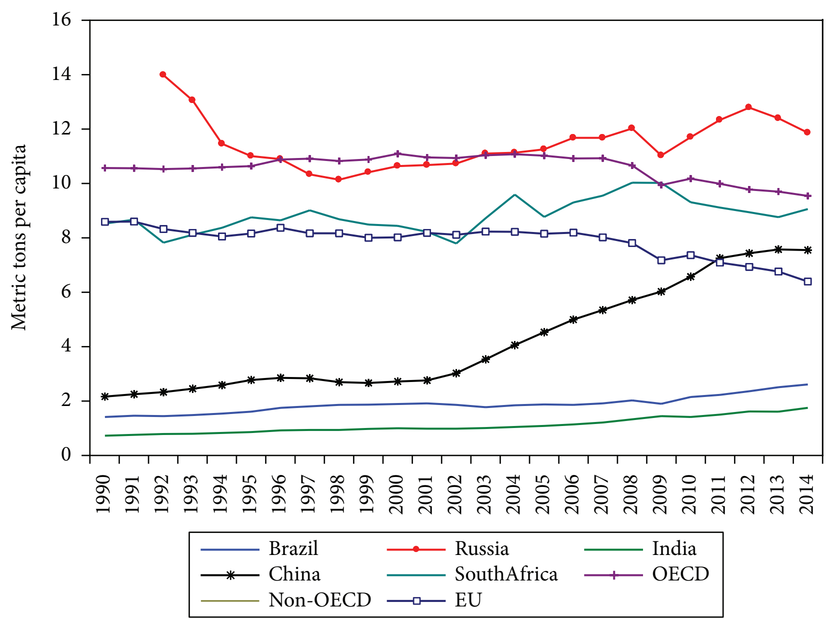
The mean value of carbon emission for Brazil is 1.86 mtpc (metric tons per capita), and for Russia it is 11.48 mtpc. For India the mean value is 1.08, and for China it is 4.1 mtpc. South Africa has a mean

Figure 2. Natural Gas Production (billion cubic meters).



Source: Prepared by the researcher from British Petroleum Statistical Review of World Energy, 2018.

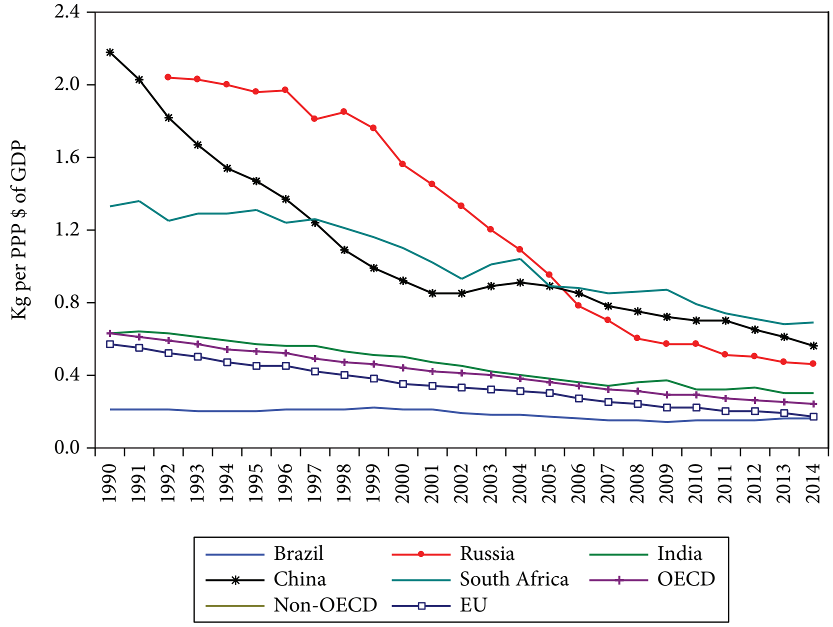
Figure 3. CO_2 Emissions (metric tons per capita).



Source: Prepared by the researcher from World Bank Database.

value of 8.1 mtpc. In totality, the mean value for BRICS countries in terms of per capita carbon emissions is 20.61 mtpc. If we compare it with the mean value of OECD (10.57 mtpc), the mean value of BRICS is more than OECD, indicating that carbon emissions are more in BRICS. The mean value for EU members is 7.87 mtpc, which is also less than BRICS countries. This has remained a challenge for the BRICS countries, and there is great need for BRICS nations to introspect.

Figure 4. CO_2 Emissions (kg per PPP $ of GDP).



Source: Prepared by the researcher from World Bank Database.

Carbon emissions when expressed as PPP of GDP can show the emissions from the economic perspective. Countries all over the world and signatories of Paris agreement have started taking measures to reduce carbon emissions. They understand that reducing in terms of GDP ratio is a better indicator than per capita carbon emission. From Figure 4, the mean value for Brazil is 0.18 ppgd (kg per PPP $ of GDP), and for Russia it is 1.22 ppgd. For India the mean value is 0.45 ppgd, and for China it is 1.08 ppgd. The value for South Africa stands at 1.03 ppgd. On the other hand, the mean value for OECD is 0.41 ppgd, and for EU members it is 0.35 ppgd. The mean value for BRICS is 3.04 ppgd. When BRICS is compared with OECD and EU, both OECD and EU have lesser carbon emission as a ratio of GDP. This indicates the BRICS policies may be in the right direction, but still there is a need for better results.

Trends in Figure 4 show that all countries and groups gives a promising figure for reducing carbon emissions.

6. CONCLUSION

The study has made an attempt to capture the descriptive issues regarding BRICS climate change. The study argues that BRICS has formulated policies for reducing carbon emissions and has adopted several key agreements on climate change. Among BRICS, China is leading the trend in carbon emissions, but it has also reduced emissions when expressed in terms of GDP ratio. BRICS has failed to outperform OECD, non-OECD, and EU member countries in terms of climate change and sustainable development climate goals though BRICS summits have focused on and reiterated the same objective. The nine BRICS summits have bolstered the commitment of BRICS countries toward climate change policies.

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Has Climate Change Even Impacted the Valuation of Companies? An Evidence from Gujarat Fluorochemicals Ltd. in India

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Abstract

Climate change is undeniably the major challenge of our times and poses a global threat to civilization. The present study attempts to analyze the shift in the environmental changes in the Indian chemical industry and to evaluate such an impact on the financial valuation and performance of the companies by investigating the case of one of the major players in the fluorochemical industry in India, Gujarat Fluorochemicals Ltd. (GFL). Employing Discounted Cash Flow Analysis, the study discovers that climate change in the form of increased carbon credits has positively impacted the financial valuation of GFL. The findings suggest that an increase of approximately 44% in the valuation of the GFL is owing to the revenue from the sale of the carbon credits as per the Kyoto Protocol.

Keywords: Carbon credit; Montreal Protocol; Kyoto Protocol; Greenhouse gases; CFCs; HCFCs; Valuation.

1. INTRODUCTION

Climate change is undoubtedly the major challenge of our times and poses an unwanted as well as a negative risk to the entire civilization. It is a serious global threat and calls for an urgent global response. This global urgency is also manifested in one of the UN's Sustainable Development Goals: "Take urgent action to combat climate change and its impacts." Even the World Economic Forum's Global Risks Report (2017) claims that out of the five major risks faced by our planet in 2017, in terms of potential impact, four risks are climate-related. Climate change is also the sole reason that brought 195 countries of the world together in an unprecedented agreement in Paris in December 2015. The objective of the Paris Agreement is to condense greenhouse gas (GHG) emissions to such an extent where global warming can remain under 2°C and preferably at 1.5°C (Rogelj et al., 2016). This dual characteristic of the climate crisis, which on one hand is poised to disrupt "business as usual" and on the other hand holds a promise of ushering in an age of collaboration and disruptive innovation, is also perhaps the prevalent opportunity of our times. The recalibration of the global economic compass toward a cleaner, greener, and low-carbon future has produced new paradigms that redefine the metric of economic growth and development. Emphasis has shifted from mere productivity to efficiency, profitability to sustainability, and from expanding footholds to minimizing carbon footprints.

Climate change issue underpins almost all facets of the economy and its effects are already being witnessed around the world. With the introduction of the Montreal Protocol and Kyoto Protocol, now every country in the world is trying to limit the carbon emissions so that the GHGs would be restricted in the environment. Although climate change is known to pose a range of risks, the *Global Opportunity Report 2017* identified cost-efficient adaptation to climate change as one of the best opportunities for business. It has indeed created innovative business opportunities for companies, mainly carbon credit generation and its trading, and they are regarded as the most financially tangible. A mechanism has been introduced, where excess carbon, which has not been used, could be traded in the global market called carbon market. India is the prominent country in the world holding second rank in carbon emission reduction earnings subsequent to China. India accounted for approximately 15% of total certified emission reduction (CER) issued under the United Nations Framework Convention on Climate Change (UNFCCC), while more than 55% of total CERs

Table 1. Current and Expected Trends in Performance of Carbon Credit Trading.

	India	China
Clean Development Mechanism (CDM) projects registered	886	2,198
CERs (average annually)	79,718	2,20,112
CERs (till 2020)	51,92,17,554	352,56,78,490
CERs (till 2030)	58,51,95,402	581,29,25,040

Source: Authors' compilation from various reports.

were generated by China as of 2012. Gujarat became the leading state in the nation, amounting to Rs.127, 021,481 CERs issued till 2012, which constitute nearly 18% of the total CERs in India. The existing and probable trends in carbon credit trading in India and China are depicted in Table 1.

The chemical industry is one of the most diversified industries, and it covers more than 80,000 commercial products. It is a critical element of the manufacturing industry and is highly fragmented in the downstream sector. Globally, the chemical industry was estimated at $4.3 trillion in 2015 and is projected to grow at 5.5% every year till 2020, compelled by the demand from end-use industries. China is the largest contributor, with 34% share, followed by the European Union (17%) and North America (16%), to the global chemical industry. The Indian chemical industry is estimated to be valued at $147 billion in 2015 and contributes 3% to the global chemical industry. India ranks 14th in exports and 8th in imports of chemicals (excluding pharmaceutical products) worldwide. The fluorochemical companies of India have gained a lot with the incoming cash flows by selling the carbon credits. This has changed the trends and scenario in the industry. The financial parameters of the companies have been impacted in a positive way. As the government has come up with a phaseout plan of the hydrochlorofluorocarbons (HCFCs), companies in this industry have diversified their business and moved into different verticals. Hence, there has been a profound impact on the valuation of the companies also. The inflow of the cash from the carbon credits has been proved to be effective for the companies in this industry.

Hence, there arises a need to analyze the shift in the environmental changes in the industry and to evaluate such an impact on the valuation and financial performance of the companies in the chemical industry. This paper contributes to the existing body of knowledge by investigating the case of one of the major players in the fluorochemical industry in India, Gujarat Fluorochemicals Ltd. (GFL), and hence presents evidence in the field of applied finance. This paper is set out as follows: Section 2 provides the motivation and the underlying rationale of the current study, followed by the methodology adopted for the analysis in Section 3. Section 4 offers an understanding of the Montreal Protocol and Kyoto Protocol adopted in the light of the climate change as part of the sustainable development goals. Section 5 provides a brief overview of the fluorochemical industry in India and the world. Section 6 presents an overview of Gujarat Fluorochemicals Ltd., followed by its detailed quantitative analysis in Section 7 and the implications of the carbon credit revenues on the financial valuation of the company in Section 8. Section 9 finally concludes the paper.

2. OBJECTIVES OF THE STUDY

The objective of the paper is to perform an analysis of the fluorochemical industries that had windfall gains from selling the carbon credits (from 2008 to 2014, under the Kyoto Protocol) and the impact of carbon credit revenues on the valuation as well as financial performance of the company, GFL.

The major objectives of the study include the following:

- Understanding the Kyoto Protocol as well as the Montreal Protocol and the impact of these protocols in the fluorochemicals industry
- Analyzing the fluorochemicals industry in India
- Identifying the utilization of the carbon credit revenues by GFL and its impact on the financial performance
- Analyzing the change in the valuation of the company: GFL, considering the carbon credit revenue obtained through the sale of carbon credits

3. METHOD(S)

The study is secondary in nature. For the purpose of this study, the relevant statistical data have been collected from various secondary sources—published and unpublished authenticated data sources such as GFL's annual reports, UNFCCC reports, CDM website, MCX, Energy outlook reports, various climate-centric reports by World Economic Forum, World Bank, KPMG, ICAI, etc. The research design opted is primarily descriptive along with supporting financial modeling. As the major objective of the paper is to identify the impact on the valuation of the company due to the carbon credit income emanating from climate change, for the purpose of valuation, Discounted Cash Flow (DCF) Analysis, as has been explained in the Damodaran's book on valuation (2016), has been used.

Before that, an understanding of the Montreal Protocol and the Kyoto Protocol and the implications of these protocols in the fluorochemical industry as a whole was explored via numerous reports.

4. MONTREAL PROTOCOL AND KYOTO PROTOCOL

4.1. Montreal Protocol

The Montreal Protocol on Substances That Deplete the Ozone Layer, a protocol to the Vienna Convention for the Protection of the Ozone Layer, is a landmark international treaty exclusively designed to protect the stratospheric ozone layer by gradually eliminating the production and consumption of a number of substances considered to be responsible for ozone depletion, referred to as ozone-depleting substances (ODSs). The treaty was opened for signature in 1987, and came into effect on January 1, 1989, superseded by a first meeting in Helsinki, May 1989. Ever since, it has gone through some amendments: in 1990 (London), 1991 (Nairobi), 1992 (Copenhagen), 1993 (Bangkok), 1995 (Vienna), 1997 (Montreal), 1999 (Beijing), and 2016.

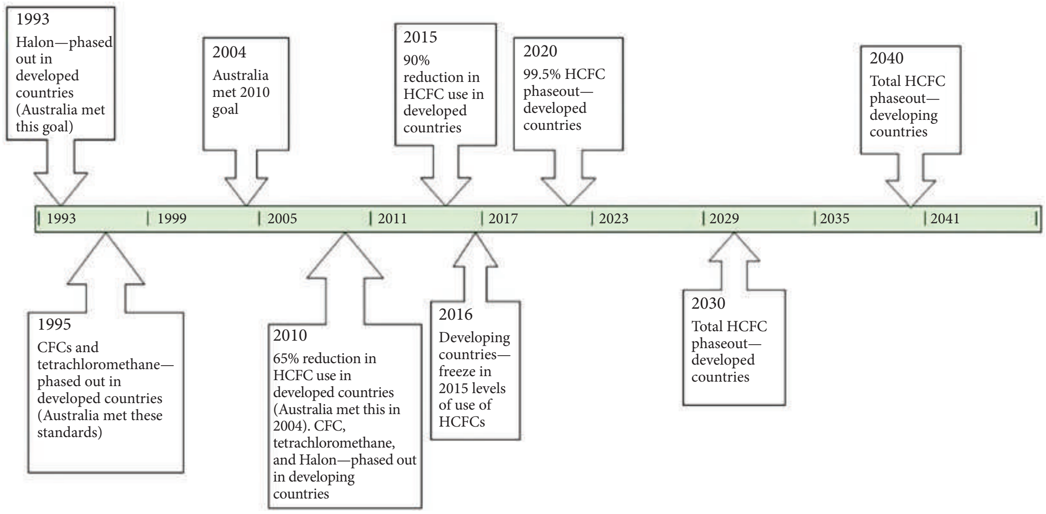
The Montreal Protocol phases down the consumption and production of the several ODS in a stepwise approach, with distinctive timetables for developed and developing countries (referred to as "Article 5 countries"). The initial aim of the Montreal protocol was to shrink the production and consumption of chlorofluorocarbons (CFCs) and halons to 50% of the 1986 level by 1999. However, the developed countries were successful in phasing out halons by 1994 and other ODS such as CFCs, carbon tetrachloride, and methyl chloroform by 1996. They also succeeded in phasing out methyl bromide by 2005. On the contrary, developing countries were able to phase out CFCs, halons, carbon tetrachloride, and methyl chloroform by 2010. Their deadline for methyl bromide phaseout was 2015. In 2010, the treaty set out to emphasize on the HCFCs, which are mainly used in cooling, refrigeration, and production of foam products. Figure 1 represents a timeline of goals that the treaty wishes to attain.

At present, CFCs are already completely phased out and the timeline has been set to wipe out HCFCs both in developed as well as developing countries. The phaseout of HCFCs has been in progress and an overall phaseout would be completed by 2020 in case of the developed countries whereas by 2040 in the context of developing countries (Figure 2). If the agreements under the Montreal protocol are adhered to in the austere sense, it is estimated that the ozone layer will be on the path to recovery by 2050. Table 2 lists down the phaseout schedule of ODS specifically for India in accordance with the Montreal Protocol.

The Montreal Protocol is extensively contemplated as one of the world's most effective multilateral environmental agreements, having phased out 97% of nearly 100 ODSs, thereby restoring the ozone layer. As various ODSs are also potent GHGs, their phaseout under the protocol has bestowed an often unobserved advantage for climate mitigation: Phasing out these 100 chemicals indeed has rendered powerful climate protection, circumventing the equivalent of projected 9.5 billion tonnes of CO_2 emissions per annum—roughly five times more than the emissions reductions of the Kyoto Protocol's first commitment period (2008–2012). It has been entitled by the Economist[1] to be the number one in policies that has performed best to check the alarming rates of global warming, ahead of hydropower, nuclear power, and renewables. Well-timed action under the Montreal Protocol can avoid 100–200 billion tonnes of CO_2-equivalent emissions by 2050, restrict intensification of hydrofluorocarbons (HFCs), and prevent up to 0.5°C of global warming

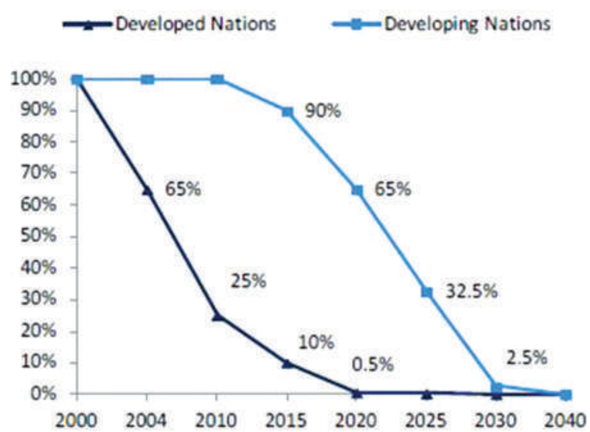
[1]https://www.economist.com/briefing/2014/09/20/the-deepest-cuts

Figure 1. Timeline of Montreal Protocol's Goals.



Source: Authors' adaption from UNEP reports.

Figure 2. HCFCs Consumption Reduction Schedule.



Source: US Environmental Protection Agency, HDFC Securities Institutional Research.

Table 2. Phaseout Schedule of ODS in India.

Ozone-depleting substances	Total phaseout by
CFCs	2010
Halons	2010
Hydrobromofluorocarbons (HBFCs)	1996
Carbon tetrachloride (CTC)	2010
Methyl chloroform	2015
Methyl bromide	2015
HCFCs	2040

Source: Authors' own compilation.

by 2100 (Xu et al., 2013 and Zaelke and Borgford-Parnell, 2014), with supplementary climate advantages of equivalent progresses in energy efficiency of air conditioners and other appliances (Roberts, 2017).

Due to its prevalent adoption and enactment, the Montreal Protocol has been acclaimed as an example of outstanding international cooperation with Kofi Annan cited as saying that "perhaps the single most successful international agreement to date has been the Montreal Protocol". It is to date the sole UN treaty that has been ratified by every single country on Earth, that is, all 197 UN Member States.

4.2. Kyoto Protocol

The Kyoto Protocol to the UNFCCC is an amendment to the international treaty on climate change, committing its parties to reduce GHGs and tackle the issue of global warming by putting in place internationally binding emission reduction targets.[2] The adoption of the Kyoto Protocol took place at the third conference of the Parties to the UNFCCC (COP3) in Kyoto, Japan, in 1997 and came into effect in February 2005. The comprehensive rules for the enactment of the Protocol were adopted at COP7 in Marrakesh, Morocco, in 2001, and are popularly known as the "Marrakesh Accords." Comprehending that developed countries are predominantly accountable for the existing excessive levels of GHG emissions in the atmosphere as an outcome of more than 150 years of historical industrial activity, the Protocol lays a heavier responsibility on developed countries under the principle of "common but differentiated responsibilities." It divides the countries into two categories: (a) Annex I parties: developed countries, who have accepted GHGs emissions reduction obligations, (b) Non-Annex I parties: developing countries, who have no GHG emissions reduction obligations, but may participate in Clean Development Mechanism (CDM).

Under the Protocol, 37 industrialized countries (referred to as 'Annex 1' countries) committed to reducing four GHGs viz. carbon dioxide, nitrous oxide, methane, sulfur hexafluoride, and two categories of gases such as HFCs and perfluorocarbons generated by them, and each member country gave a universal commitment. During the first commitment period ranging from 2008 to 2012, Annex 1 countries and the European Community committed to lessen their combined GHG emissions by an average of 5.2% against the 1990 levels. During the second commitment period, the parties pledged to reduce collective GHG emissions by not less than 18 percent below 1990 levels in the eight-year period from 2013 to 2020; nonetheless, the set of Parties in the second commitment period is distinct from the first. The sole objective is the normalization and restoration of GHG concentrations in the atmosphere at such a level that can impede hazardous anthropogenic meddling with the climate system.

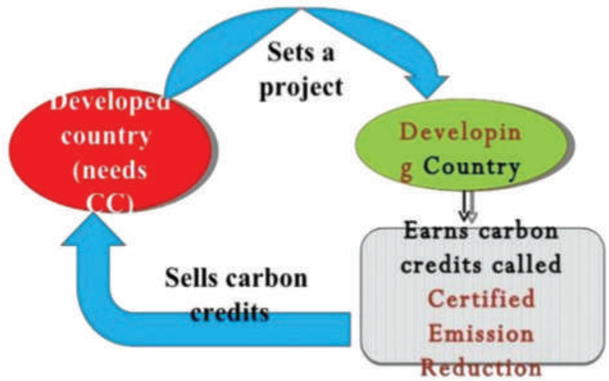
The five prime features of the Kyoto Protocol include[3]:

i. Commitments to shrink GHGs that are legally binding for Annex I countries, as well as general commitments for all member countries.
ii. Implementation to fulfill the Protocol's goals, to formulate guidelines and measures that mitigate GHGs, growing absorption of these gases (for instance via geo-sequestration and bio-sequestration) and utilize various mechanisms available, such as joint implementation, CDM and emissions trading.
iii. Curtailing the effects on developing countries by instituting an adaptation fund for climate change.
iv. Proper accounting, reporting, and review to warrant the integrity of the Protocol.
v. Compliance by bringing about a compliance committee to put in force commitment to the Protocol.

There are certain "flexibility" mechanisms that have been introduced by the Kyoto Protocol such as *emissions trading, clean development mechanism, and joint implementation* (Grubb, Vrolijk, and Brack, 1997) that will allow the parties to meet their GHG obligations. For instance, this could be performed by buying the GHG credits (carbon credits) from the countries that have them in excess. The countries having excess carbon credits could sell them to those who are in deficit. Consequently, carbon has become a commodity, which similar to other commodities is traded in the open market, called carbon market. As carbon dioxide is the most widely produced GHG and all other GHG gases are recorded in terms of carbon dioxide

[2]https://unfccc.int/process/the-kyoto-protocol
[3]http://www.yourarticlelibrary.com/environment/major-international-protocols-earth-summit-kyoto-protocol-and-montreal-protocol/27392

Figure 3. Working of Clean Development Mechanism.



Source: Authors' adaption from online sources.

equivalents, the emission trading is known as the carbon market. A brief of main Kyoto protocol mechanisms include the following steps:

(1) Compensating for emissions by augmenting the number of a nation's carbon sinks. The forests, which act as carbon sinks, grab carbon dioxide from the atmosphere. Countries are permitted to build carbon sinks on appropriate sites outside of their own territory.
(2) Emissions trading—trading of emission allowances between nations. The emissions trading mechanism provides countries the opportunity to shrink emissions where it is most cost-effective and efficient to do so.
(3) Clean Development Mechanism—stimulates the channelization of environment-friendly foreign investments from industrialized nations in developing nations. The developing countries are therefore assisted in achieving sustainable development and in contributing to the ultimate objective of the Convention (Figure 3).
(4) Joint implementation—permits developed economies to sponsor foreign research to reduce emission levels in countries of economic transition. In exchange for the developed nation's investment, the host country offers the investor with emission reduction units, also called as carbon credits. The developed countries can subsequently utilize their carbon credits toward fulfilling their emission-reduction requirements under the Kyoto Protocol.

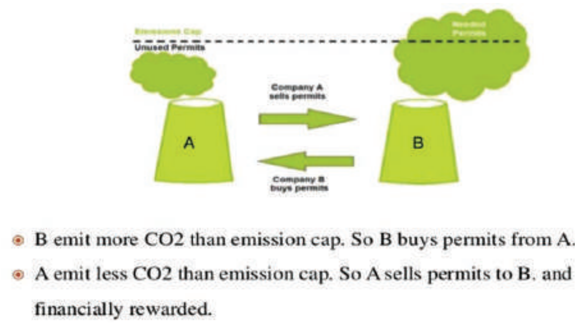
4.2.1. Carbon Credits

Carbon credits (often called a carbon offset) are the certificates that are issued to countries by UNFCCC, that have successfully reduced GHG emissions that are the major cause of global warming. A single carbon credit generally denotes the permit to emit one metric ton of carbon dioxide or the equivalent mass of another GHG. This can be used by governments, industry or private individuals to offset damaging carbon emissions that they are generating. In brief, carbon credits create a market for mitigating greenhouse emissions by providing an economic incentive (i.e., assigning monetary value to the cost of polluting the air). This mechanism, automatically, stimulates and promotes sustainable development initiatives and emission reduction mechanisms. The carbon credit system was ratified in concurrence with Article 17 of the Kyoto Protocol.

Each carbon credit denotes one tonne of CO_2 either eliminated from the atmosphere or held back from being emitted. Carbon credits can be generated in various ways; however, there are two broad forms:

1. Sequestration (retaining or capturing CO_2 from the atmosphere) such as afforestation &reforestation activities (Dumanski, 2004).
2. CO_2 saving projects such as the use of renewable energies (wind power, solar energy, biomass power, hydel power).

Figure 4. Working of Carbon Credit System.



Source: Authors' adaption from online sources.

Carbon credits can be bought and sold in the international markets at the prevailing market prices in the carbon market. They are bought and sold through a number of international brokers, online retailers, and trading platforms. Businesses that have a deficit of carbon credits could offset their emissions by investing in renewable energy projects, reforestation projects, and forest protection. This would help the business in mitigating the emissions and to comply with the UNFCCC standards. Projects that sell carbon credits include wind, solar, geothermal, and biomass projects (Figure 4).

4.2.2. Mandatory Carbon Credits

The Kyoto Protocol was the forerunner to mandatory carbon credits. A few of the main outcomes of the protocol are as follows:

- Cap-and-trade systems—Under a cap-and-trade program, a limit on specific types of emissions or pollution is placed, and companies are allowed to sell the unused part of their limits to other companies that are struggling to comply.
- CDM—The Clean Development Mechanism only urges countries to partially comply with Kyoto goals via the financing of carbon reduction vehicles in primarily developing countries.
- EU-ETS—The European Union Emissions Trading Scheme is a group of countries that have all been provided an overall cap to work from as a sole body; it came into effect in 2005.

5. OVERVIEW OF THE FLUOROCHEMICAL INDUSTRY IN THE WORLD AND INDIA

The global fluorochemical market was 3.3 mtpa (in terms of elemental fluorine content) in 2015 valued at approximately US$ 17.5 billion. As per the industry reports, it is set to grow at approximately 5.3% CAGR to US$ 25 billion by 2020. The volume growth is expected to be lower at 4–4.3%, signifying the increase in value-added products. Fluorochemicals market can be classified into three main categories, namely fluorocarbons, fluoropolymers, and inorganic fluorides. Of the aggregate anticipated growth of about 5%, fluoropolymers and specialty chemicals (within fluorocarbons) are expected to grow at a faster pace. The inorganic fluoride segment is slated to grow at a rate of 2–2.5%, mainly in sync with the steel and aluminum industry. The refrigerants industry is going through environmental regulatory changes. Now, approximately two-third of its current portfolio is HCFCs, which needs to be phased out under the Montreal Protocol. Hence, the segment will see more value growth via replacement of HCFCs with higher-value HFC refrigerants. Fluorspar is the basic and only raw material used for the manufacturing of any fluorine compound globally. Total global production of fluorspar is approximately 6.5 million tons. China accounts for 65% of the production and the top five countries account for nearly 90%. Mexico, South Africa, Mongolia and Kenya are other key producers. China has increased its dominance in the fluorine market by increasing its share in the fluorspar production from 54% to 65% over the past decade. Production share from Mexico has also increased over the period from 14% to 18%.

Although fluorine chemistry is a hazardous and difficult science, the Indian players have been operating in it for over five decades. Till the previous decade, the Indian companies limited themselves to inorganic fluorides and refrigerants but this has changed with the gains from selling the carbon credits (earned under the Kyoto Protocol) over 2006–2013. The cash flows from the sale of carbon credits have been used to create manufacturing facilities for high-margin fluoropolymers and fluorochemicals. GFL, Shri Ram Fibres Ltd. (SRF), and Navin Fluorine International Ltd. (NFIL) are the major players to ride growth in the fluorine industry.

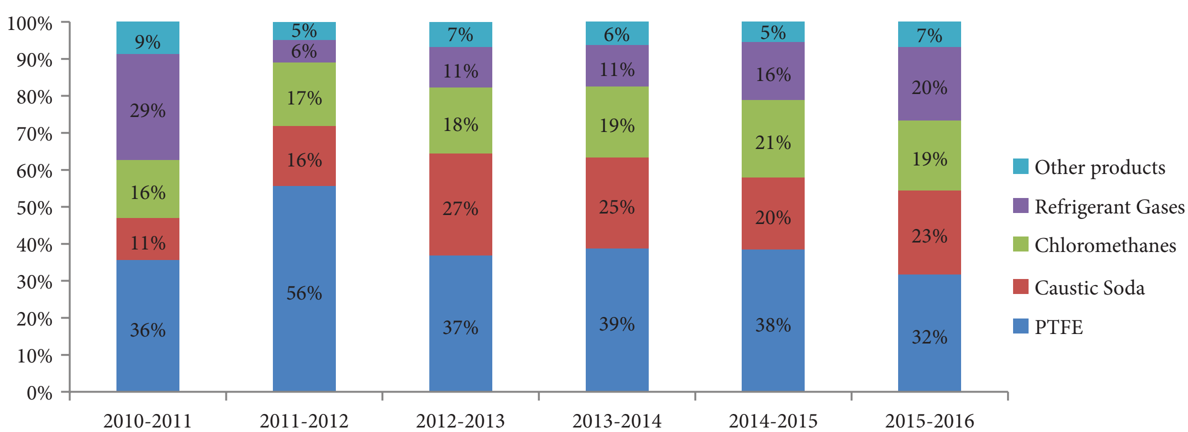
6. OVERVIEW OF GUJARAT FLUOROCHEMICALS LTD.

GFL is a part of the $3 billion INOX group of companies. GFL was incorporated in 1987 and commenced its commercial operations in 1989 by setting up India's largest refrigerant plant in Ranjit Nagar, Gujarat. GFL is one of the pioneers in the country to invest in CDM under the Kyoto Protocol by cutting down carbon emissions. The company has successfully implemented a CDM Project, which affects GHG emission reductions by thermal oxidation of HFC23, and earns carbon credits. HFC23 is a waste-product generated during the production of hydrochlorofluorocarbon, HCFC22. In fact, this project became the first project in the world, to be registered by the Executive Board of the CDM, established under the Kyoto Protocol. During FY07-14, it made Rs 35 billion windfall gains from the sale of CER. This was significantly higher compared with peers like SRF (approximately Rs 17 billion) and Navin Fluorine (nearly Rs 4 billion).

Instead of distributing the one-off gains as dividend, GFL used the money to upgrade itself from a pure commodity (CFC and HCFC) player, and to strengthen its chemicals business. The company went for forward integration and set up India's largest and the world's fourth-largest poly-tetra-fluoro-ethylene (PTFE) plant. To make itself further cost competitive, the company invested in associated raw materials such as HCFC, chloromethane, and caustic soda. Primarily a player in the refrigeration business till 2007, GFL decided to forward integrate and invested in PTFE, as HCFCs are to be phased out by 2030. It started with a PTFE capacity of 6 ktpa in financial year 2008 and expanded it to 16.2 ktpa by financial year 2014. Thus, it became the only vertically integrated player in the industry.

Over the last 7–8 years, GFL has consolidated its position in the PTFE space and enjoys a top 4 ranking based on PTFE capacity. With the PTFE market facing surplus global supply over the last 3–4 years, GFL has reduced its capacity utilization for TFE and PTFE. This spare capacity can be put to use for making a range of fluoropolymers, with minimal capex infusion. These fluoropolymers require a higher value added compared to PTFE, and therefore fetch 3–6 times the realization per kilogram of PTFE products. Since 2011, GFL has moved into Wind and Film Exhibition business and the revenue from Wind has increased at a staggering rate (from 5% to 55%). However, last year, the wind business (Inox Renewables) agreed to sell its operating wind power farms to Leap Green Energy Pvt. Ltd., a Chennai-based wind power company and the main

Figure 5. Shift in Revenue Mix.



Source: Company's annual reports.

reason for this was to decrease the leverage of GFL at a consolidated level by reducing the best of around Rs. 800 crores that was attributable to the wind farm business. The second reason was to focus on its key strengths, the chemical business, and the turbine manufacturing business. Refrigerants alone contributed nearly 94% of the total revenues in financial year 2007. However, the situation changed after setting up of the integrated chemical complex at Dahej. At present, PTFE is the largest revenue contributor with a share of 40% in financial year 2017. Caustic soda (20%), chloromethane (21%), and HCFC (16%) are the other key products. The share of PTFE is likely to rise to 65% by financial year 2018–2019 with the increase in capacity utilization (Figure 5).

7. QUANTITATIVE ANALYSIS OF GFL

The valuation model is prepared for GFL using a DCF Method.

7.1. Valuation of GFL and Its Subsidiaries

First, Weighted Average Cost of Capitals (WACC) have been calculated for GFL and its subsidiaries, INOX Wind Ltd. and INOX Lesiure Ltd. (after making necessary assumptions for using DCF). G-securities, 10-year bonds, have been taken as proxies for calculating the risk-free rate and the equity risk premiums have been calculated by subtracting the risk-free rate from the 10-year market returns. Second, DCF Analysis has been conducted for all the three companies. Last, the final year cash flows have been used to calculate the terminal values by using the perpetual growth rate model and then discounting them back to get the present values. The terminal growth rate used is 4%, which is also the rough estimate of India's long term growth rate as in 2010.

For detailed workings, please refer to Appendices 1, 2, and 3.

7.2. Enterprise Value Calculations

The overall value of the GFL is calculated based on the stakes of 63.09% and 43.09% of INOX Wind Ltd. and INOX Leisure Ltd., respectively, in the company (Table 3). The Enterprise Value of GFL is approximately Rs 91.30 billion as determined by the discounted cash flow analysis of the company. The Equity Value of the company is computed in Table 4. The Equity Value from the DCF valuation is compared with the present equity value of the company (Table 5).

Table 3. Computation of Enterprise Value.

Total enterprise value (lakhs)	
EV of GFL	4,45,670
EV of INOX Wind Ltd. (stake in GFL)	3,45,727
EV of INOX Leisure Ltd. (stake in GFL)	1,21,620
Enterprise value of total entity	9,13,017

Table 4. Computation of Equity Value.

Total equity value (lakhs)	
Equity value of GFL	4,05,015
Equity value of INOX Wind Ltd.	2,46,785
Equity value of INOX Leisure Ltd.	1,11,835
Equity value of total entity	7,63,635

Table 5. Comparison of Computed Equity Value Vs. Actual Present Equity Value.

Total equity value (lakhs)	
Equity value of total entity	7,63,635
Present equity value	7,68,950
Over valued	0.69%

As shown in Table 5, the equity value of the company is slightly overvalued even though the revenue from the new business verticals is yet to begin. The gestation period for the commercialization of specialty chemicals is large, and the company has already about 28 products that are in the pipeline, out of which commercial plants for five products have been set up. Going forward, there are 12 products in the pilot stages for commercial production. These would take around 6–9 months to contribute to the top line of the company.

8. IMPACT OF CARBON CREDIT REVENUE ON THE FINANCIALS OF GFL

8.1. Revenues from the Carbon Credits

GFL has successfully implemented a CDM Project, which affects GHG emission reductions by thermal oxidation of HFC23, and has earned carbon credits. The company is among the largest carbon credit generating projects in the world. Table 6 presents an overview of carbon credits in terms of million tons and carbon credit revenues earned by GFL over the period 2007–2014.

8.2. Margin Analysis

There has been a positive impact on the margins due to the revenues earned from selling the carbon credits. The company has enjoyed higher margins due to the incoming cash flows. From Figure 6, it is evident that Earnings before Interest, Tax, Depreciation and Amortization (EBITDA) margins are much higher after the inclusion of the revenues earned from the sale of the carbon credits over the entire period 2011–2017. Similar can be witnessed in the context of Earnings before Interest and Tax (EBIT) and Profit after Tax (PAT) margins (Figures 7 and 8). Based on the turnover and the margin analysis, we can easily interpret the variations in

Table 6. GFL's Overview of Carbon Credit and Carbon Credit Revenues.

Year	Carbon credit revenue (lakhs)	Carbon credit (million ton)
2007	39,002.88	2.781
2008	45,393.83	3.141
2009	62,931.2	6.960
2010	47,295.89	4.811
2011	20,243.24	1.799
2012	87,614.1	13.495
2013	44,169.26	11.091
2014	58.1	0.011
Total	3,46,708.5	44.090

Figure 6. EBITDA Analysis.

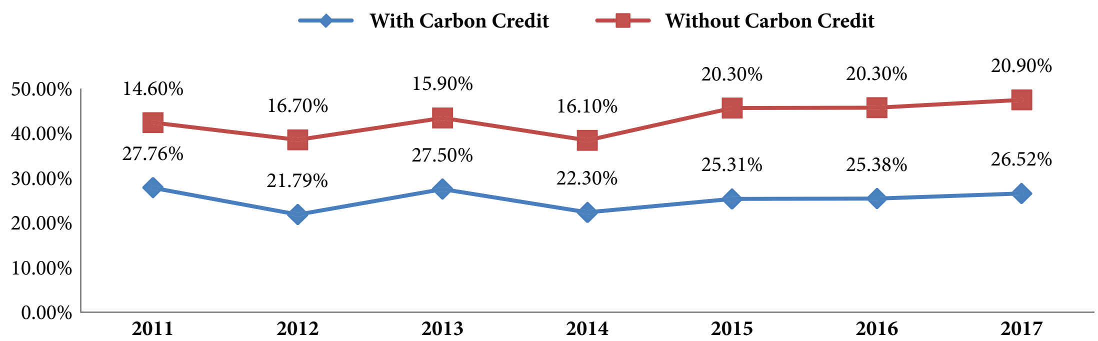


Figure 7. EBIT Analysis.

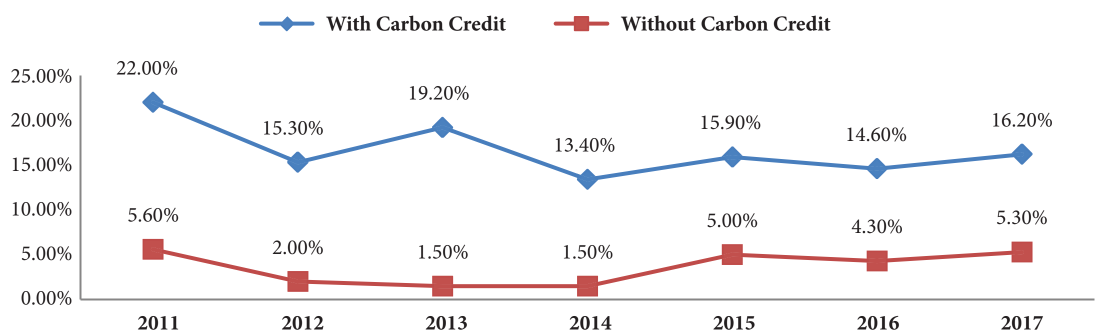
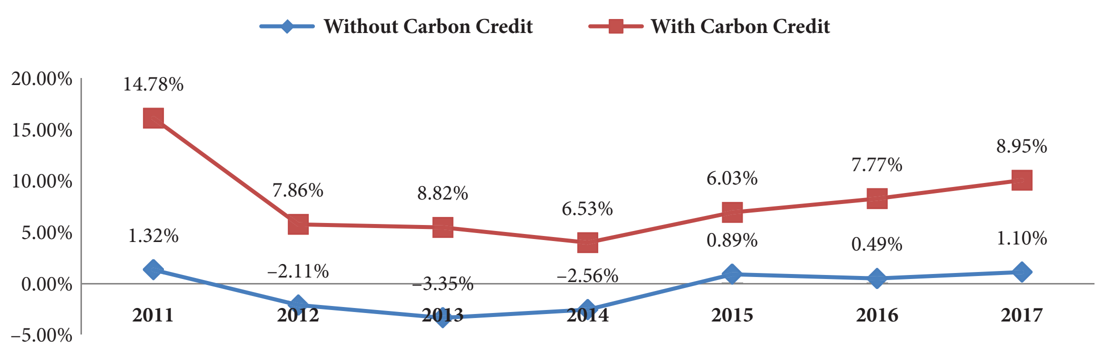


Figure 8. PAT Analysis.



the performance of the company post and past the carbon credit revenues that it has accrued. The EBITDA and EBIT margins of the company are hovering around 25–27% and 13–16%, respectively, for the duration under consideration. These margins are increasing for the last 3–4 years due to the increase in the business efficiencies. These margins were higher in 2011–2013 due to the incoming cash flows from the carbon credits. The dip in the margins in 2012 is because of the increase in the cost of raw materials (mainly Fluorspar). However, now the company has a long-term contract with the suppliers of Fluorspar from the international market and the company is also venturing into the speciality segment of the fluorochemical industry, where the margins would be double of what the company is having now. Hence, these percentages would be on an increasing trend for the next few years with the increase in the capacity utilization of the assets. As of now, the capacity utilization is under 60%, and it will increase above 90% in the next couple of years.

8.3. Solvency Analysis

The cash flows from the sale of carbon credits were used to establish and increase the capacities in the PTFE plant. If the inflow of cash was absent, then the company would have taken loans to establish the industry; thus, the balance sheet of the company would have been impacted (Figure 9). The interest payment would also be on a higher side if not for the carbon credit revenue (Figure 10).

8.4. Return Analysis

The Return on Equity and the Return on Assets are analyzed for the company with and without considering the revenue from the carbon credits. We could observe that the returns for the company would be below average if there was no revenue from the carbon credits (Figure 11). The Return on Equity is negative if the revenue from the carbon credit is not considered. The Return on Assets is also negative if the carbon credit revenue is not considered. The value of the company would have been much lower if not for the credits from carbon emission reductions (Figure 12).

Figure 9. Debt to Equity Analysis.

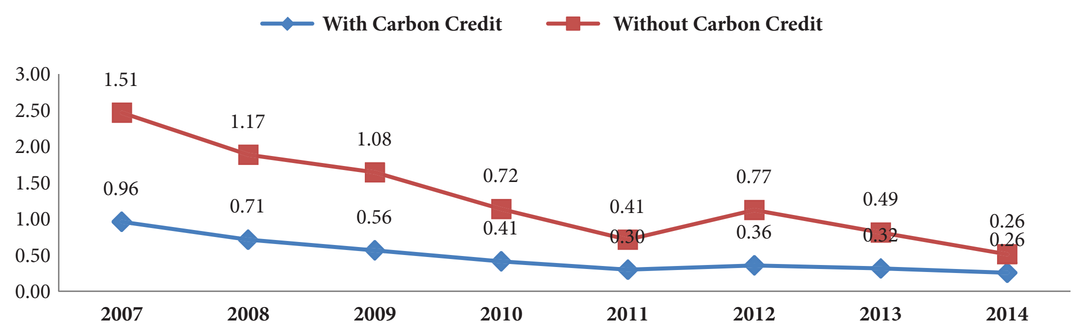


Figure 10. Financing Cost Analysis.

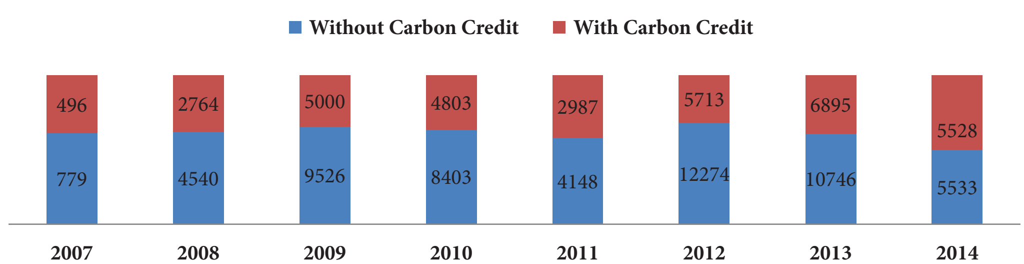


Figure 11. Return on Equity Analysis.

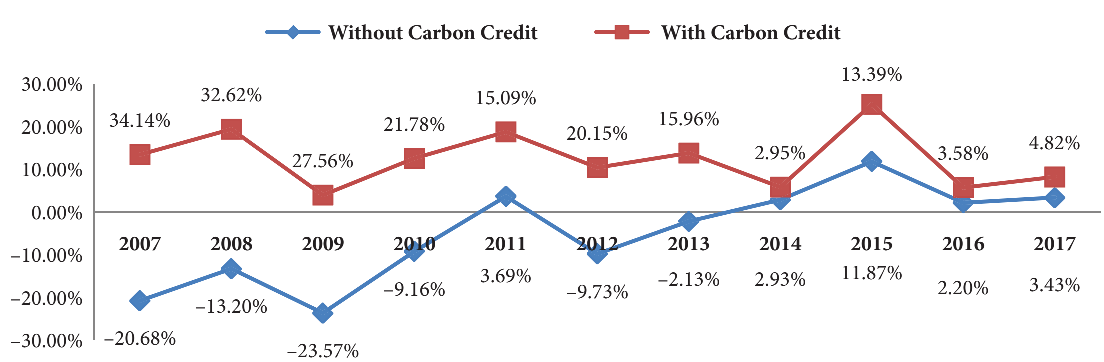


Figure 12. Return on Assets Analysis.

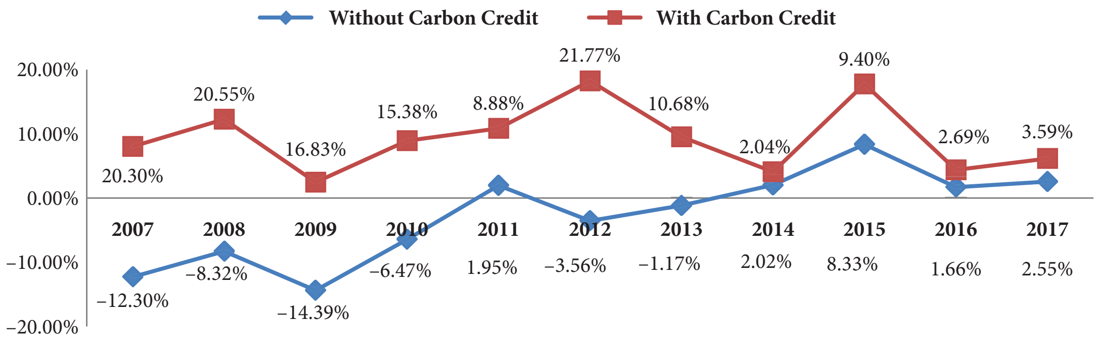


Table 7. Change in % Valuation Due to Carbon Credits.

Enterprise value of total entity	9,13,017
Enterprise value of GFL (chemical)	4,45,670
Enterprise value (carbon credits)	1,94,376
% EV of total entity due to carbon credits	21.29%
% EV of GFL (chemical) due to carbon credits	43.61%

8.5. Impact on the Valuation of the Company

With the implementation of CDM, GFL has reduced the emission of R22 gas and hence accrued the carbon credits. The R22 gas production is not reduced by the company, but this refrigerant gas is used as a raw material for the PTFE division. Thus, the emission of this gas is reduced, and this is primarily due to the Kyoto Protocol by UNFCCC. GFL has used the money from the carbon credits to enter into new business vertical and expand on that. It has gone through a huge capital expenditure from 2008 to 2016, in expanding into PTFE division. Now, the company is also foraying into a specialty segment of the PTFE division, the fluororubbers and fluoroelastomers divisions. GFL has entered into high margin business, leaving behind the refrigerants business.

Hence, there is a huge impact of the revenues from the carbon credit on the valuation of the company. The revenue was used as an investment for entering into a new business and an analysis could be performed in terms of the percentage of the valuation of the company because of this revenue. The WACC used for the chemical business has been used for the valuation of the carbon credit revenue. To investigate the impact of carbon credit revenues on the valuation of the company, a detailed valuation analysis has been performed for the revenue generated from the sale of the carbon emission reductions (for detailed workings, refer to Appendix 4) and the comparison of this value with the total enterprise value of the company, would give a clear understanding of the impact on the valuation of the company (Table 7).

From Table 7, it can be observed that 43.61% of the Enterprise Value of GFL (Chemical Business) is due to the carbon credit revenues that it has accrued by selling the excess carbon emissions that are saved during each year.

9. CONCLUSION

Climate change is one of the biggest and most incessant sustainability megatrends of the present generation and for various companies, the pinch points are quite evident. Although certain companies may not recognize climate change as the utmost pressing issue they confront today, it cannot be denied that the issue is pertinent for virtually all companies as it poses a wide range of risks, as well as presents novel business opportunities for generating revenues in the form of carbon credit trading.

India holds tremendous opportunities for its industries to generate carbon credits and harness gains out of its trading because it has lower carbon emission levels as compared to other developed economies. Currently, next to China, India is generating the highest number of carbon credits in the world. India's average annual CERs stand at 12.6% or 11.5 million that can escalate up to 25% (Nair and Nandakumar, 2013).

The specialty segment of the chemical industry in India is expected to be one of the fastest growing segments in the upcoming years. The company discussed in this paper, GFL is the only company with the whole integrated manufacturing plant in India, with a huge capacity (11% of the global PTFE market). With the shutdown of the chemical manufacturing plants of China and all the environmental implications that are changing, GFL would fill in the void of demand and increase its capacity utilization, and hence its operating revenues. The paper concludes that climate change in the form of increased carbon credits has positively impacted the financial valuation of the company in question, as it has forayed into different verticals of the chemical business. It has been observed that an increase of approximately 44% in the valuation of the GFL is owing to the revenue from the sale of the carbon credits as per the Kyoto Protocol. The financial performance analysis gauged through various parameters such as EBITDA, EBIT, PAT, and Return on Assets further reveals that the company has a great future potential in the forthcoming years, owing to the generation of carbon credits. However, there exists still a huge potential for the development of the CDM project by GFL in exploring the potentialities through future planning and documentation.

In brief, it can be said that companies that look forward and that can transform comprehensive climate risk assessments into innovation potentials coupled with rigorous economic valuations and planning can stand better equipped to tackle the emerging risks, fluctuating marketplace conditions, and policies, in a world highly influenced by climate change.

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APPENDIX 1

Gujarat Fluorochemicals Ltd.

Table 1A. WACC Calculation.

Last financial results	31- Mar-2017
WACC calculation	
Risk-free rate	7.00%
Equity risk premium	6.00%
Beta	0.60
Cost of equity	10.60%
Pre-tax cost of debt	8.51%
Marginal tax rate	30%
Post-tax cost of debt	5.96%
Equity to total capital ratio	87.17%
Debt to total capital ratio	12.83%
WACC	10%

Table 1B. DCF Analysis.

Particulars	2016-17	2018F	2019F	2020F	2021F	2022F
Total revenue	1,60,318	1,79,289	1,92,979	2,07,625	2,23,650	2,39,403
Cost of sales	38,606	46,285	44,753	48,313	52,208	56,667
Gross profit	1,21,712	1,33,004	1,48,226	1,59,312	1,71,442	1,82,736
SG&A	84,598	88,351	95,382	1,02,914	1,11,140	1,19,499
EBITDA	37,115	44,653	52,845	56,398	60,303	63,237
D&A	14,884	15,549	14,361	14,436	14,711	15,248
EBIT	22,230	29,104	38,484	41,962	45,592	47,989
Finance costs	3,518	4,628	4,228	3,028	5,228	7,028
PBT	18,712	24,476	34,256	38,934	40,364	40,961
Tax	4,612	7,343	10,277	11,680	12,109	12,288
PAT	14,100	17,133	23,979	27,254	28,255	28,673
Adjustments						
D&A	14,884	15,549	14,361	14,436	14,711	15,248
Capex	11,471	5,000	2,000	2,000	10,000	10,000
Working capital change	569	9,589	6,585	10,421	5,845	7,660
Interest paid after tax	2,675	3,240	2,960	2,120	3,660	4,920
FCFF	19,619	21,333	32,714	31,388	30,780	31,181
Discount rate		1.10	1.21	1.33	1.46	1.61
Present value		19,393	27,037	23,583	21,023	19,361

Table 1C. Computation of Terminal Value.

Final year cash flow	31,181
Growth rate	4%
Discount rate	10%
Terminal value	5,40,471
PV of terminal value	3,35,273
Enterprise value using forecasted performance	4,45,670

APPENDIX 2

Inox Wind Limited

Table 2A. WACC Calculation.

Last financial results	31- Mar-2017
WACC calculation	
Risk-free rate	7.00%
Equity risk premium	6.00%
Beta	0.60
Cost of equity	10.60%
Pre-tax cost of debt	8.51%
Marginal tax rate	30%
Post-tax cost of debt	5.96%
Equity to total capital ratio	42%
Debt to total capital ratio	58%
WACC	8.67%

Table 2B. DCF Analysis.

Particulars	2016-17	2018F	2019F	2020F	2021F	2022F
Total revenue	3,96,284	4,15,683	4,36,052	4,53,161	4,70,955	4,80,208
Cost of sales	2,71,481	2,85,282	2,99,546	3,11,528	3,23,989	3,30,469
Gross profit	1,24,803	1,30,401	1,36,506	1,41,634	1,46,967	1,49,740
SG&A	45,132	64,399	67,449	71,486	75,975	77,206
EBITDA	79,672	66,002	69,057	70,147	70,992	72,534
D&A	3,023	3,325	3,488	3,625	3,768	3,842
EBIT	76,649	62,676	65,569	66,522	67,224	68,692

(*Continued*)

Table 2B. DCF Analysis (*Continued*).

Finance costs	10,286	13,631	14,486	13,729	12,652	13,194
PBT	66,363	49,045	51,082	52,793	54,572	55,498
Tax	16,400	12,261	12,771	13,198	13,643	13,874
PAT	49,963	36,784	38,312	39,595	40,929	41,623
Adjustments						
D&A	3,023	3,325	3,488	3,625	3,768	3,842
Capex	13,452	14,818	34,082	16,053	36,119	24,079
Working capital change	8,320	9,410	–966	1,236	1,256	1,258
Interest paid after tax	7,744	10,223	10,865	10,297	9,489	9,896
FCFF	38,959	26,105	26,550	36,228	16,811	30,023
Discount rate		1.09	1.18	1.28	1.40	1.52
Present value		24,015	22,470	28,207	12,042	19,784

Table 2C. Computation of Terminal Value.

Final year cash flow	30,023
Growth rate	4%
Discount rate	8.67%
Terminal value	6,68,964
PV of terminal value	4,41,472
Enterprise value using forecasted performance	5,47,990

APPENDIX 3

Inox Leisure Limited

Table 3A. WACC Calculation.

Last financial results	**31- Mar-2017**
WACC calculation	
Risk-free rate	7.00%
Equity risk premium	6.00%
Beta	0.60
Cost of equity	10.60%
Pre-tax cost of debt	11.97%

(*Continued*)

Table 3A. WACC Calculation (*Continued*).

Last financial results	31- Mar-2017
Marginal tax rate	32%
Post-tax cost of debt	8.14%
Equity to total capital ratio	58.46%
Debt to total capital ratio	41.54%
WACC	9.02%

Table 3B. DCF Analysis.

Particulars	2016-17	2018F	2019F	2020F	2021F	2022F
Total revenue	1,22,977	1,47,391	1,76,688	2,03,056	2,33,378	2,68,249
Expenses	1,07,594	1,27,619	1,53,720	1,79,204	2,08,835	2,40,606
EBITDA	15,383	19,773	22,968	23,851	24,543	27,643
D&A	8,407	8,789	10,547	10,108	9,299	10,694
EBIT	6,976	10,983	12,421	13,744	15,245	16,949
Finance costs	2,528	4,058	4,292	4,531	4,786	5,058
PBT	4,448	6,925	8,129	9,212	10,458	11,891
Tax	1,473	2,234	2,622	2,972	3,374	3,836
PAT	2,975	4,691	5,507	6,241	7,085	8,055
Adjustments						
D&A	8,407	8,789	10,547	10,108	9,299	10,694
Capex	5,476	3,327	6,820	3,492	7,157	3,665
Working capital change	1,394	364	−133	1,310	1,194	1,386
Interest paid after tax	1,691	2,749	2,908	3,070	3,242	3,426
FCFF	6,202	12,538	12,275	14,615	11,275	17,125
Discount rate		1.09	1.19	1.30	1.42	1.55
Present value		11,482	10,294	11,224	7,929	11,029

Table 3C. Computation of Terminal Value.

Final year cash flow	17,125
Growth rate	4%
Discount rate	9.20%
Terminal value	3,54,678
PV of terminal value	2,30,289
Enterprise value using forecasted performance	2,82,247

APPENDIX 4

Valuation of GFL after considering the carbon credit revenues

Table 4A. DCF Analysis.

Particulars	2016-17	2018F	2019F	2020F	2021F	2022F
Total revenue	57,938	70,194	78,618	87,708	1,02,154	1,14,866
Expenses	45,414	54,335	59,212	67,153	77,747	87,641
EBITDA	12,524	15,859	19,406	20,554	24,407	27,226
D&A	4,726	5,017	4,633	4,658	4,746	4,920
EBIT	7,798	10,843	14,772	15,897	19,660	22,306
Tax	1,922	3,253	4,432	4,769	5,898	6,692
PAT	5,876	7,590	10,340	11,128	13,762	15,614
Adjustments						
D&A	4,726	5,017	4,633	4,658	4,746	4,920
Capex	8,642	1,936	968	283	3,267	3,388
Working capital change	216	3,963	2,824	4,623	2,797	3,844
FCFF	1,744	6,708	11,182	10,880	12,445	13,302
Discount rate		1.1	1.21	1.33	1.46	1.61
Present value		6,098	9,241	8,180	8,524	8,262

Table 4B. Terminal Value Calculation.

Final year cash flow (discounted)	8,062
Growth rate	4%
Discount rate	10%
Terminal value	2,79,701
PV of terminal value	1,18,620
Enterprise value using forecasted performance	1,94,376

Does Climate Change Have Real Negative Impact on Economic Growth in Poor Countries? Evidence from Cote d'Ivoire (Ivory Coast)

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Abstract

The objective of this paper is to determine the impact of climate change on Cote d'Ivoire's economic performance via per capita gross domestic product (GDP) growth, change in agricultural value added, and change in the country's cereal yield. The data ranged from 1960 to 2016. An autoregressive distributed lag (ARDL) model is used to investigate the long run dynamics between climate variables (precipitation and temperature) and the country's per capita GDP, agricultural value added as % of GDP, and cereal yield. We found that climate change has not significantly impacted the economic performance of the country. However, precipitation has been found to have positively and significantly influenced the country's cereal yield and agricultural value added contribution to GDP at large, and thus there is no need to worry more than it is necessary.

Keywords: Climate change; Economic performance; Cointegration; Bounds tests.

1. INTRODUCTION

On December 2015, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) gathered in Paris, France, to deliberate on the faith of our planet given concerns that global warming is undermining our livelihood and that actions should be taken before it is too late. Indeed, according to the World Health Organization, more than 140,000 people are dying per year as a direct result of climate change (Harris and Jones, 2017). Batten (2018) cited a survey of experimental studies conducted by Dell, Jones, and Olken (2014) that led to the conclusion that each degree greater than 25°C is associated to a productivity loss in various cognitive tasks of approximately 2%. Moreover, extreme temperatures could lead to negative health effects and increase the mortality and morbidity rates (Fankhauser and Tol, 2005). In the same vein, global warming could also cause mass migration and increase poverty, inequality, crime, and social unrest (Dell et al., 2014).

The results of the Paris deliberations led to the adoption of what is now known as the Paris Agreement. Among the key features of the Paris Agreement is the establishment of a global warming goal set to less than 2°C on preindustrial averages with efforts to limit the temperature increase to 1.5°C (Art. 2.1.a), and it defines a universal legal framework to strengthen the global response to the threat of climate change (The Paris Agreement, 2015—Art.2).

Although this agreement may seem ambitious, doing nothing could be catastrophic given that according to Reyer et al. (2017) warming in 2016 has reached 1.1°C compared to preindustrial (1800–1900) average.

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Several scholars (Dell et al., 2014) have empirically investigated the impacts of climate change on economic output worldwide (in the Americas, Europe, and Asia) but only few studies are focused on Africa in general and Cote d'Ivoire in particular. This impact on economic output could be via temperature's impact on conflict and mortality especially in developing countries as argued by Curriero et al. (2002), Deschênes and Moretti (2009), Deschênes and Greenstone (2012), and Miguel, Satyanath, and Sergenti (2004). Adiku et al. (2015) also argued that the increased warming and shifts in rainfall patterns associated with climate change would adversely affect the agricultural growth in West Africa. This is worrisome because agriculture contributes between 40% and 60% of gross domestic product (GDP) in the region and is dominated by smallholder farmers. Knowing that global temperatures in particular are expected to increase over the next century and that developing countries are to suffer most from global warming if nothing is done (Dell, Jones, and Olken, 2012), it has become critical to understand and provide additional evidence on the relationship between climate change and economic growth so as to assess its possible impacts and call on policy makers for action.

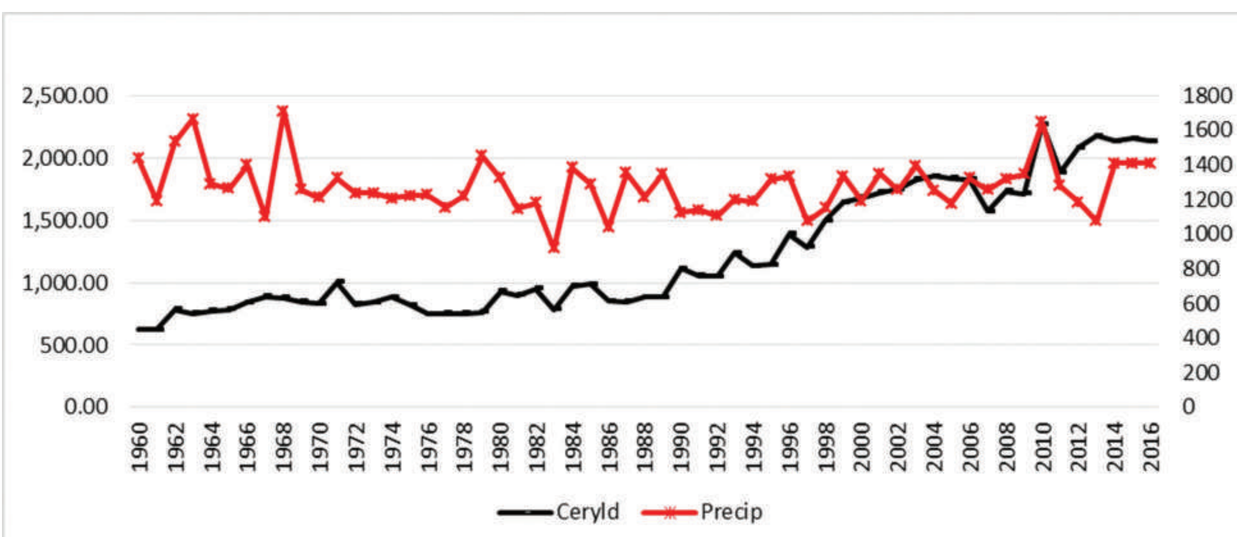
In line with that mentioned earlier, the primary objective of this paper is to analyze the impact of climate change in Cote d'Ivoire. The specific objectives are as follows: (1) to determine the impact of climate change (temperature, precipitation) on the country's economic growth rate, (2) to determine the impact of climate change (temperature, precipitation) on the country's agricultural value added, and (3) determine the impact of climate change (temperature, precipitation) on the country's cereal yield.

The remainder of the paper is organized as follows: Stylized facts on the trends of temperatures and precipitations are presented together with cereal yield, per capita GDP growth, and trend of economically active population (Section II). Section III reviews selected literature, Section IV presents the method of analysis and data to be used for the study, Section V presents the empirical results and discussions, while Section VI concludes the paper.

2. STYLIZED FACTS

One of the climate variables that is widely used is precipitation measured in millimeter of rain fall. In general, it is trivial that precipitation affects crop production and agricultural performance ceteris paribus. In addition, it impacts a country's economic performance. In Figure 1, we look at the trend of precipitation together with that of cereal yield and see how they evolved over time. From Figure 1, we observe an upward sloping trend for cereal yield whereas precipitation has a slight downward sloping trend. The precipitation trend exhibits ups and downs throughout the period of interest. The country registered an average precipitation

Figure 1. Trend of Precipitation (in mm) and Cereal Yield per Hectare in Cote d'Ivoire from 1960 to 2016.

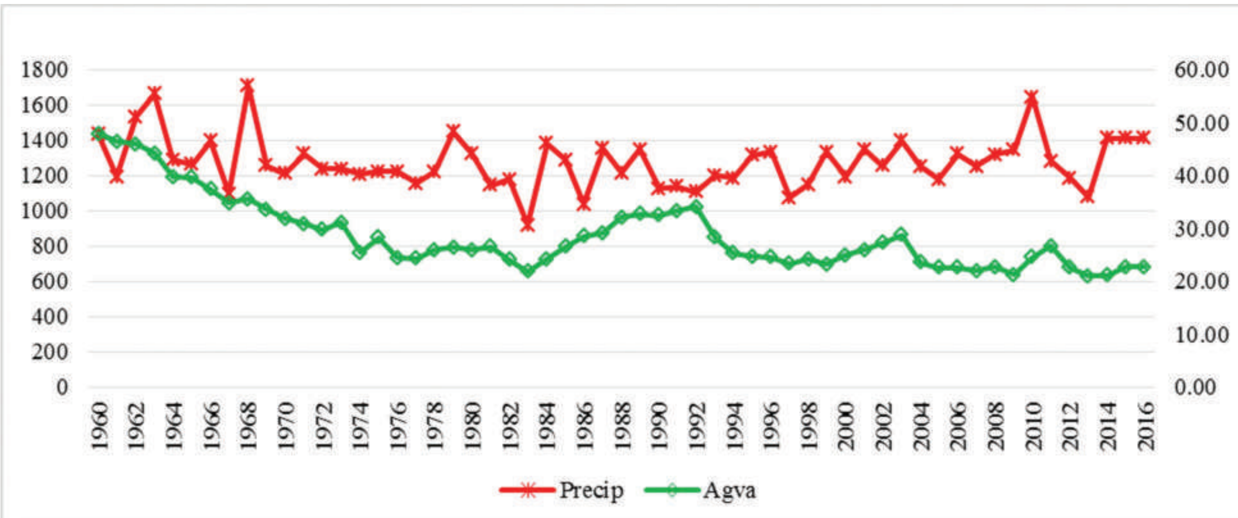


Source: World Development Indicators and World Meteorological Organization.

of 1,276 mm with a minimum of 917 mm and a maximum of 1,708 mm. The graphical representation does not exhibit any link between the country's cereal yield and the level of precipitation. This is confirmed by a very low correlation coefficient that is not statistically significant (see Table 1A).

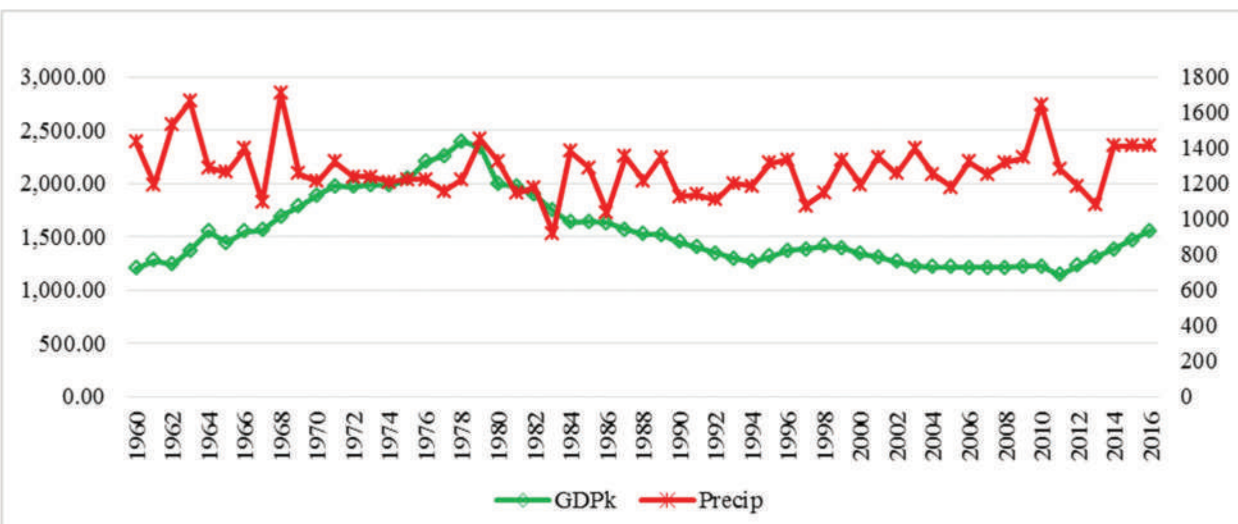
Different from Figure 1, Figure 2 shows how agricultural value added and precipitation evolved together over the period ranging from 1960 to 2016. We observe that both variables are downward sloping. They are positively correlated with a correlation coefficient of 0.241 that is significant at the 10% probability level. We then look at the trends of per capita GDP and precipitation (Figure 3). Here, we observe no clear pattern between the two variables. The correlation coefficient between these two variables is −0.142, and it is not statistically significant (see Table 1A in the appendix).

Figure 2. Trend of Annual Precipitation (in mm) and Agricultural Value Added in Cote d'Ivoire from 1960 to 2016.



Source: World Development Indicators and World Meteorological Organization.

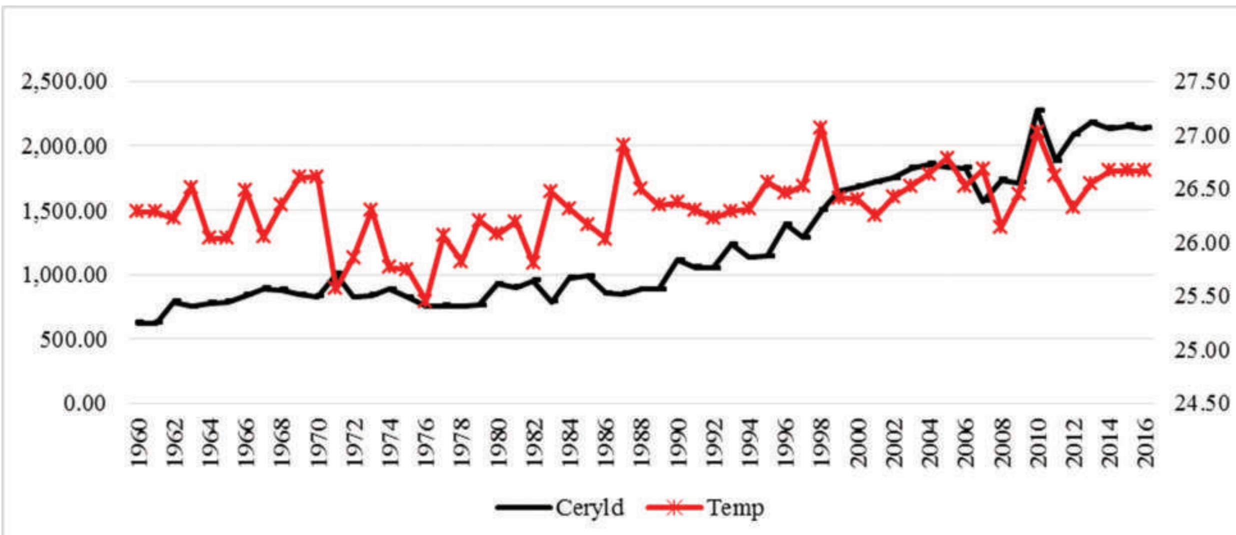
Figure 3. Trend of Annual Precipitation (in mm) and per Capita GDP in Cote d'Ivoire from 1960 to 2016.



Source: World Development Indicators and World Meteorological Organization.

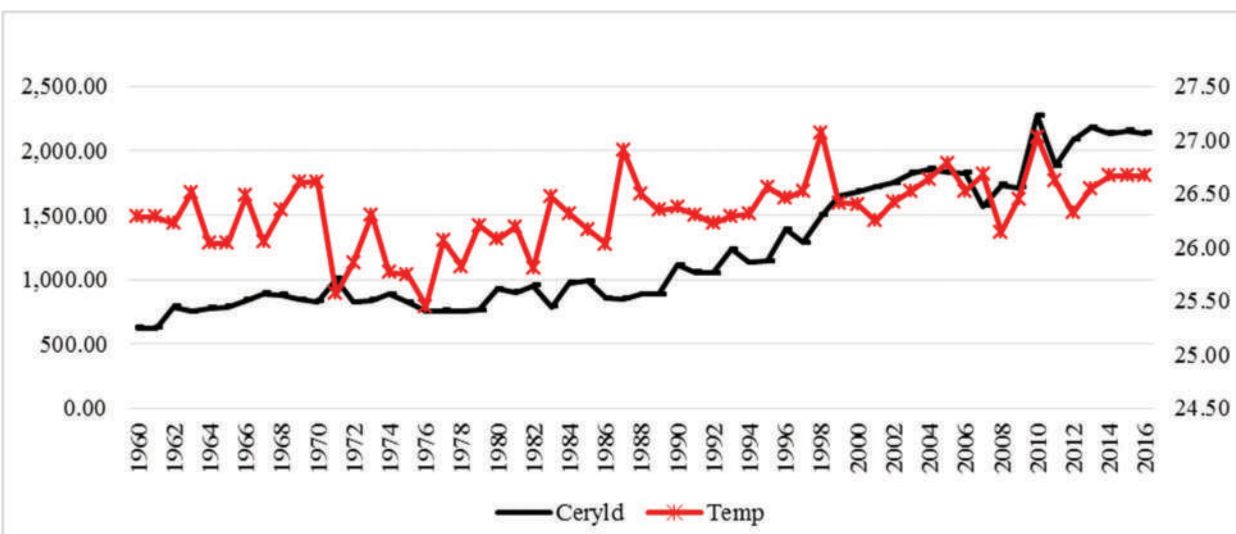
We then looked at the temperature variable and observed how it has evolved over time. We first compare the trend of temperature to that of cereal yield (Figure 4). We observe that both variables are upward sloping and are thus correlated. The correlation coefficient is 0.526 and is significant at 1% probability level. The country registered an average temperature of 26.33°C over the period of interest with a low temperature of 25.45°C in 1976 and a high temperature of 27.06°C in 1998. Thus, the temperature in the country has alternated from high to low but within 25.45°C and 27°C. The variation of the country's temperature around its mean level is approximately 0.33°C. This national reading of temperature could hide extreme temperatures in some regions of the country. The positive correlation observed between temperature and cereal yield will be investigated further in the empirical analysis.

Figure 4. Trend of Average Annual Temperatures (in °C) and Cereak Yield per Hectare in Cote d'Ivoire from 1960 to 2016.



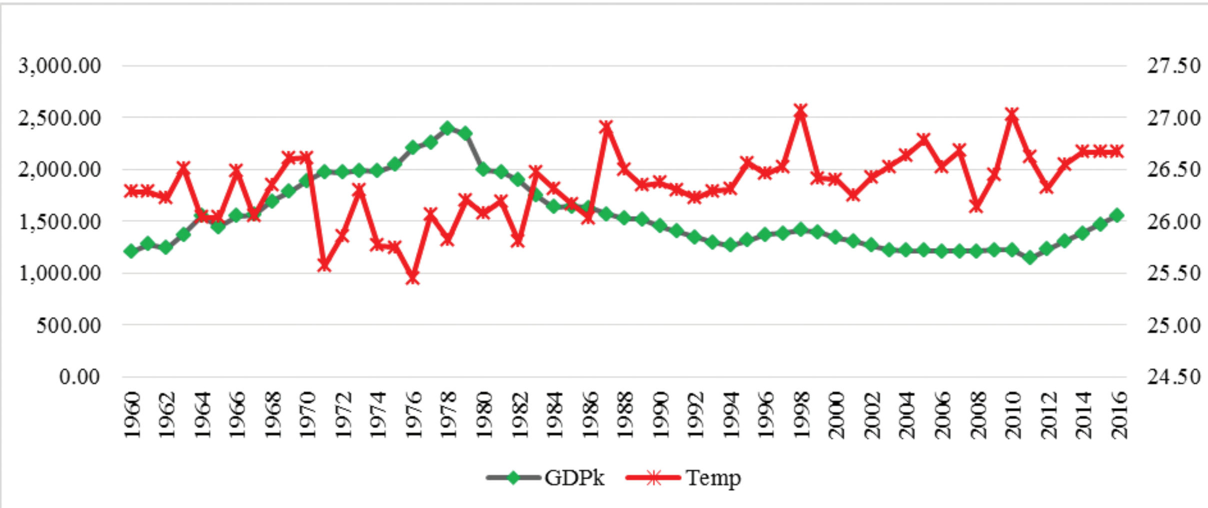
Source: World Development Indicators and World Meteorological Organization.

Figure 5. Trend of Average Annual Temperatures (in °C) and Agricultural Value Added (% of GDP) in Cote d'Ivoire from1960 to 2016.



Source: World Development Indicators and World Meteorological Organization.

Figure 6. Trend of Average Annual Temperatures (in °C) and per Capita GDP in Cote d'Ivoire from1960 to 2016.



Source: World Development Indicators and World Meteorological Organization.

We move to look at how the trend of temperature compares to that of the country's agricultural value added (Figure 5). Here, we observe two phases. The first one goes from 1960 to 1992, where we can see similar trends between temperature and agricultural value added. But from 1992 onward we observe a divergence of trend. Indeed, temperature is upward sloping, whereas agricultural value added is downward sloping. The correlation coefficient is −0.194, and it is not statistically significant, which tells us that the decline in the agricultural value added contribution to GDP is not due to the rising temperature in the country.

In Figure 6, we look at the trend of temperature in line with that of the country's per capita GDP. We observe that they do not have a similar trend. The correlation coefficient calculated is negative (−0.591) and statistically significant. Hence, the rising temperature has an adverse effect on the country's economic performance. This will be investigated further in the empirical analysis section. The point of divergence started in 1986. Let us recall that the years 1983, 1984 were years of drought in the country. Temperature reached its highest point in over 10 years (1971–1983). We can see that from 1986 the country's temperature kept increasing although not in a linear manner.

3. LITERATURE REVIEW

The literature on the climate-economy nexus is quiet diverse. Three types of outcomes are obtained from the literature. The first type found positive impact of climate variables on Economic output (Zilberman et al., 2004; Deschênes and Greenstone, 2007). The second (in majority) found negative relationship between climate variables and economic performance see Dell, Jones, and Olken (2008); Serdeczny et al. (2017); Akram (2012); Abidoye and Odusola (2015); Mearns, Katz, and Schneider (1984); Moriondo, Giannakopoulos, and Bindi (2011); and García-León (2015). The last type combines studies that found both positive and negative impacts of climate variables on economic performance (Colacito, Hoffmann, and Phan, 2014; Zilberman et al., 2004). Agriculture has taken a large portion of this research (Adams et al., 1990; Mendelsohn, Dinar, and Sanghi, 2001; Deschênes and Greenstone, 2007; Guiteras, 2009; Fazal et al., 2013), and it is followed by ocean fisheries, fresh water access, migration tourism, etc. Let us look at studies that found positive impacts of climate on economic output.

3.1. Climate Change and Economic Output: A Positive Relationship

Deschênes and Greenstone (2007) measured the economic impact of climate change on US agricultural land by estimating the effect of random year-to-year variation in temperature and precipitation on agricultural profits. They found climate change to increase annual profits by 4%.

Zilberman et al. (2004), in a paper on "The Economics of Climate Change in Agriculture," presented a conceptual framework of the impact of climate change on agriculture. They assumed that climate change results in a fertilization effect and a shift of agroecological conditions away from the equator toward the poles. The shift was likely to reduce yield because of reduced acreage, whereas the fertilization effect will increase yield. The aggregate effect depends on whichever of the two dominates.

3.2. Climate Change and Economic Output: A Negative Relationship

Dell et al. (2008) using annual variation in temperature and precipitation over 50 years examined the impact of climatic changes on economic activity throughout the world. They found that, first, higher temperatures substantially reduce economic growth in poor countries but have little effect in rich countries. Second, higher temperatures appear to reduce growth rates in poor countries, rather than just the level of output. Third, higher temperatures have wide-ranging effects in poor nations, reducing agricultural output.

Dell et al. (2012) used panel's distributed lag structure to inform whether temperature affects aggregate economic activity in developing countries. They concluded that the increase in temperature correlates with a slowing of economic growth in developing economies but has no significant correlation in developed countries. They also documented that in poor countries, a 1°C increase in temperature in a given year reduces economic growth by approximately 1.3 percentage points in the same year, with agriculture, industry, and political instability as significant channels.

Serdeczny et al. (2017) in their paper on climate change impacts in Sub-Saharan Africa argued that the repercussions of climate change will be felt in various ways throughout both natural and human systems. They project a warming trend for the region, particularly in the inland subtropics that renders particularly vulnerable the rain-fed agricultural systems on which the livelihoods of a large proportion of the region's population depend.

Lee, Villaruel, and Gaspar (2016), in study titled "Effects of Temperature Shocks on Economic Growth and Welfare in Asia," using the Burke, Hsiang, and Miguel (2015) framework, examined the nonlinear response effect of economic growth to historic temperature and precipitation fluctuations. They confirmed a significant negative effect of rising temperature on agricultural production and industrial production.

Akram (2012), in a study to investigate whether climate change is hindering economic growth of Asian economies and using data ranging from 1972 to 2009 with a growth model incorporating temperature and precipitation as proxies for climate change in a panel setting, found that economic growth is negatively affected by changes in temperature, precipitation, and population growth. His results also indicate that agriculture is the most vulnerable sector to climate change.

Akram and Gulzar (2013) investigated climate change on economic growth in Pakistan using data ranging from 1973 to 2010 and temperature as proxy for climate change found that temperature has a negative and significant relationship with GDP and productivity in agriculture, manufacturing, and services sectors. However, severity of these negative impacts was higher in agriculture in comparison with manufacturing and services.

Ali (2012) conducted a study titled "Climate Change and Economic Growth in a Rain-fed Economy like Ethiopia." Using cointegration analysis he found that both inter-annual and within-annual rainfall variations have negative effect on growth and that variability in rainfall has a long-term growth-drag effect through changes in its amplitude and frequency.

Abidoye and Odusola (2015), in a study titled "Climate Change and Economic Growth in Africa: An Econometric Analysis," using annual data for 34 countries from 1961 to 2009, found a negative impact of climate change on economic growth. The climate variable used is temperature. Their results reveal that a 1°C increase in temperature reduces GDP growth by 0.67 percentage point.

Nyangena (2016) explored the influence of weather change on the economic performance in Kenya. Using time series data ranging from 1964 to 2013 in a Vector Error Correction Model setting found that total rainfall had a negative relationship with gross domestic product while change in temperature indicated a positive relationship.

Adiku et al. (2015) found that the effects of climate change on yields relative to baseline climates were generally negative for cereal crops (i.e., millet and maize). They also cited studies by Mearns et al. (1984) and Moriondo et al. (2011) that found negative effect of temperature on crop yield. These studies described temperature as having the most adverse effect on crop yield among all weather parameters. Indeed, this is so because certain stages of crop growth are particularly sensitive to temperature change. Increased temperature greater than certain thresholds, for majority of crops, can result in significant yield loss during the reproductive stage, through its effect on grain-filling, grain numbers and even sterility. It also exerts stress on the crop through high evapotranspiration and energy demands that otherwise would result in crop production but are instead used to manage the stress (Adiku et al., 2015).

García-León (2015), in his paper titled "Weather and Income: Lessons from the Main European Regions," making use of a detailed weather and economic dataset covering the main regions of the five largest economies in the Euro area, found that global warming negatively affects, although in a modest manner, all regions within well-developed countries in the long term.

3.3. Climate Change and Economic Output: Both Positive and Negative Relationships

Colacito et al. (2014), in a study titled "Temperatures and Growth: A Panel Analysis of the U.S.," provided empirical evidence that temperature affects economic growth in the United States. Their results revealed that (i) rising Summer temperatures depress growth, and (ii) rising Fall temperatures increase economic growth. Given that Summer temperatures are expected to increase at a faster pace relative to that of Fall temperatures, rising temperatures can decrease the growth rate of US GDP by as much as one third, thus resulting in large welfare losses.

The study by Zilberman et al. (2004) cited earlier is also an indication of how climate change can impact output. In this case, shift in agroecological conditions reduces agricultural growth, whereas the fertilization effect of climate change will increase yield.

Burke et al. (2015) analyzed the relationship between historical temperature fluctuations and macroeconomic growth. They found that, different from past studies, aggregate macroeconomic productivity is nonlinear, with productivity peaking at an annual average temperature of 13°C and declining strongly at higher temperatures. For cooler countries, warming will lead to an economic boom. Thus, given the presence of nonlinearities, climate change has a positive impact up to a threshold and shifts to a negative impact on economic output.

In addition, some studies try to dedramatize the impact of climate change on economic growth. Indeed, Mendelsohn et al. (2001), for instance, examined whether a country's stage of development affects its climate sensitivity. They found that increasing development reduces climate sensitivity. Moreover, Mendelsohn (2009) in a paper on climate change and economic growth argued that the descriptions of the long-term consequences of climate change in the literature have given the impression that the climate impacts from greenhouse gases threaten long-term economic growth. However, the impact of climate change on the global economy is likely to be quite small over the next 50 years.

It results from the previous brief review of the selected literature that there is no consensus in terms of the effect (level and magnitude) of climate change on a country's economic growth. It is argued in part of the literature that in developed countries, although exposed, they have the means to mitigate its effect and thus climate change impact is modest. Different from developed countries, poor countries are set to suffer the most because they lack resources to mitigate the possible negative effects of climate change. It is also found instances where climate change has both positive and negative impacts in developing countries. The impact depends on the agroecological conditions of the countries considered. This should be considered when analyzing the impact of climate change in panel data setting for West Africa (our next research work). There is no empirical evidence, to the best of our knowledge, provided for Cote d'Ivoire. This study intends to fill this gap.

4. METHOD(S)

The data to be used for this study is a time series and cover the period ranging from 1960 to 2016. Table 1 provides a brief description of the data and variables used for this study. The nonclimate variables are obtained from the World Development Indicators of the World Bank (2017). The climate variables are from Harris and Jones (2017). All the variables were transformed into logarithm. Thus, $lngdpk_t$ is the natural logarithm of $gdpk_t$ and so on. Given the time series nature of the data, it is critical to investigate its time series characteristics. This entails determining whether the variables to be analyzed are stationary or not. This is

Table 1. Brief Description of the Data and Variables Used.

Name of variable	Data source/Time period (1960–2016)	Comment
$gdpk_t$	WDI	GDP per capita in constant 2010 US dollars
agvat	WDI	Agricultural value added as % of GDP
ceryldt	WDI	Cereal yield in kilogram per hectare
$Invt_t$	WDI	Gross fixed capita formation as % of GDP
$Pop64_t$	WDI	Population aged 15–64 as % of total population
$Temp_t$		Country level annual temperature in °C
$Precip_t$		Country level annual precipitation millimeter of rainfall

Table 2. Results of Unit Root Tests.

	Test using ADF		Test using Philip Perron	
	Level	1st Diff.	Level	1st Diff.
$lngdpk_t$	−1.284 (0.636)	−3.393* (0.011)	−1.529 (0.519)	−5.288* (0.000)
$lnagva_t$	−2.470 (0.123)	−7.416* (0.000)	−2.468 (0.124)	−7.417* (0.000)
$lnceryld_t$	−0.969 (0.764)	−11.330* (0.000)	−0.657 (0.858)	−11.829* (0.000)
$lnprecip_t$	−7.138* (0.000)		−7.138* (0.000)	
$lntemp_t$	−4.529* (0.000)		−4.519* (0.000)	
$lninv_t$	−1.408 (0.578)	−4.424* (0.000)	−1.687 (0.437)	−6.113* (0.000)
$lnpop64_t$	−0.913 (0.783)	−2.156* (0.018)	−1.361 (0.601)	−2.725*** (0.070)

Author's calculation.

performed using the traditional unit root test, that is, the Augmented Dickey Fuller (ADF) Unit Root Test and the Philip Perron (PP) Unit Root Test. This is important, because a regression of nonstationary variables on other nonstationary variables produce what is known as spurious regression.

The characteristics of the data via the unit root test show that the climate variables are stationary, that is, I(0), whereas the other three variables are stationary after first differencing, that is, I(1). The unit root test results are presented in Table 2.

In line with the previous results, we cannot use the traditional Granger and Johansen approached to investigate any long run relationship (cointegration). Indeed, the nonclimate variables are all I(1), that is, they stationary after first difference. The climate variables are all I(0), which means that they are stationary in levels. The appropriate approach therefore is to use the Bounds test proposed by Peseran, Shin, and Smith (2001 and 2004) to investigate any long run relationship.

For this purpose, we formulate our model in a way that shows both the short run and long run dynamics. The autoregressive distributed lag (ARDL) model allows us to do this. The generalized ARDL(*p,q*) model is as follows:

$$Y_t = \alpha_i + \sum_{i=1}^{p} \delta_i Y_{t-i} + \sum_{i=0}^{q} \beta'_i X_{t-i} + \varepsilon_{it} \tag{1}$$

where Y_t is the endogenous variable, X_t represents the explanatory variables that are all allowed to be *I(0)* or *I(1)*, α is the constant, δ and β are parameters to be estimated, and p and q are optimal lag orders. In this paper, we use the Akaike information criterion (AIC) to determine the optimal lag that provides us the unrestricted error correction model (Peseran et al., 2001 called it conditional ECM) or put differently, conditional ARDL(*p,q*) presented below:

$$\begin{aligned}\Delta lngdpk_t &= \delta_{01} + \delta_{11} lngdpk_{t-1} + \delta_{12} lnprecip_{t-1} + \delta_{13} lntemp_{t-1} + \delta_{14} lninv_{t-1} + \delta_{15} lnpop64_{t-1} + \\ &\sum_{i=0}^{q} \beta_{10} \Delta lngdpk_{t-i} + \sum_{i-0}^{q} \beta_{11i} \Delta lnprecip_{t-i} + \sum_{i=0}^{q} \beta_{12i} \Delta lntemp_{t-i} + \sum_{i=0}^{q} \beta_{13i} \Delta lninv_{t-i} + \\ &\sum_{i=0}^{q} \beta_{14i} \Delta lnpop64_{t-i} + \varepsilon_{1t}\end{aligned} \tag{2}$$

$$\begin{aligned}\Delta lnagva_t &= \delta_{02} + \delta_{21} lnagva_{t-1} + \delta_{22} lnprecip_{t-1} + \delta_{23} lntemp_{t-1} + \delta_{24} lninv_{t-1} + \delta_{25} lnpop64_{t-1} + \\ &\sum_{i=0}^{q} \beta_{20} \Delta lngdpk_{t-i} + \sum_{i=0}^{q} \beta_{21i} \Delta lnprecip_{t-i} + \sum_{i=0}^{q} \beta_{22i} \Delta lntemp_{t-i} + \sum_{i=0}^{q} \beta_{23i} \Delta lninv_{t-i} + \\ &\sum_{i=0}^{q} \beta_{24i} \Delta lnpop64_{t-i} + \varepsilon_{2t}\end{aligned} \tag{3}$$

$$\begin{aligned}\Delta lnceryld_t &= \delta_{01} + \delta_{31} lnceryld_{t-1} + \delta_{32} lnprecip_{t-1} + \delta_{33} lntemp_{t-1} + \delta_{34} lninv_{t-1} + \delta_{35} lnpop64_{t-1} + \\ &\sum_{i=0}^{q} \beta_{30} \Delta lnceryld_{t-i} + \sum_{i=0}^{q} \beta_{31i} \Delta lnprecip_{t-i} + \sum_{i-0}^{q} \beta_{32i} \Delta lntemp_{t-i} + \sum_{i=0}^{q} \beta_{33i} \Delta lninv_{t-i} + \\ &\sum_{i=0}^{q} \beta_{34i} \Delta lnpop64_{t-i} + \varepsilon_{3t}\end{aligned} \tag{4}$$

The disturbance terms are such that, $\varepsilon_{1t} : N(0, \sigma_1^2)$; $\varepsilon_{2t} : N(0, \sigma_2^2)$ and $\varepsilon_{3t} : N(0, \sigma_3^2)$. The disturbance terms are uncorrelated.

The Bounds test is equivalent to testing the following hypotheses:

$$\begin{cases} H_0 : \delta_{1i} = \delta_{2i} = \delta_{3i} = 0 \\ \qquad vs \\ H_1 : \delta_{1i} \neq \delta_{2i} \neq \delta_{3i} \neq 0 \end{cases} \tag{5}$$

The null hypothesis H_0 tests the absence of a long run equilibrium relationship between the dependent variable and the explanatory variables. The statistics underlying this hypothesis test is the familiar Wald or *F*-statistics in a Generalized Dicker Fuller-type regression used to test the significance of lagged levels of variables under consideration in an unrestricted equilibrium error correction regression (Peseran et al., 1999). Thus, if we accept H_0, we can conclude that there is no long run relationship between the variables and that they are not cointegrated. However, if we reject the null hypothesis, then we conclude that there is a long run relationship between the variables. A key assumption in the ARDL Bounds Testing methodology of Peseran et al. (2001) is that the error terms in the previous equations be serially independent, that is, no autocorrelation. Once this condition is satisfied, we need to ensure that the model is dynamically stable.

It is important to understand the fact that the asymptotic distribution of both Wald and *F*-statistics is nonstandard under the null hypothesis of no long run relationship irrespective of whether the variables are I(0), I(1), or mutually cointegrated. However, Pesearan et al. (2001) have provided asymptotic critical values bounds for all classifications of the regressors into I(1) and/or I(0). Thus, if the computed *F*-statistics fall below the lower bound, then we accept the null hypothesis of no cointegration. In such situation, we proceed to estimate the short run dynamics using Ordinary Least Squares (OLS) regression technic. If the *F*-statistics are greater than the upper bound, then we reject the null hypothesis and conclude that there exists a long run relationship between the variables. When this is the case, estimation of the ARDL model provides us with both the long run (levels equation) and short run dynamics (difference equation). If the *F*-statistics fall between the bounds, then the test is inconclusive. In this case, knowledge of the cointegration rank of the forcing variables (explanatory variables) is required to proceed further (Peseran et al., 1999).

In addition to the *F*-test performed earlier, we can also perform a "Bounds *t*-test" to cross-check the results. The test is as follows:

$$\begin{cases} H_{01}: \delta_{1i} = 0 \\ \quad vs \\ H_1: \delta_{1i} < 0 \end{cases}; \quad \begin{cases} H_{02}: \delta_{2i} = 0 \\ \quad vs \\ H_2: \delta_{2i} < 0 \end{cases} \quad \text{and} \quad \begin{cases} H_{03}: \delta_{3i} = 0 \\ \quad vs \\ H_3: \delta_{3i} < 0 \end{cases} \tag{6}$$

Here also, the null hypothesis H_0 tests the absence of a long run equilibrium relationship between the dependent variable and the explanatory variables. If the *t*-statistics are greater than the I(0) bound tabulated by Peseran et al. (2001, pp. 303-304) and Kripfganz and Schneider (2018, pp. 30-33), then accept the null hypothesis and conclude that there is no cointegration between the variables. If the *t*-statistics are less than the I(1) bound, then reject the null hypothesis and conclude that there is long run relationship between the variables. Here again, if the *t*-statistics fall between the two bounds, the test is inconclusive. All computations were performed using the statistical software Stata 14.2.

5. RESULTS AND DISCUSSION

5.1. Empirical Results

In this section, we present the empirical results. We start with the descriptive statistics presented in Table 3. The country's average GDP per capita stood at US$ 1,547 in constant 2010 US dollars. The highest level reached was US$ 2,391 in 1978 couple of years before the country entered a severe recession in 1980. The contribution of agricultural value added stood on average at 28.6%. It ranges from 20.9% (2013) to 47.9% in 1960. The country's cereal yield stood at 1,226 kg/ha on average and ranged from 624 kg/ha (1960) to 2,270 kg/ha in 2010 right before the civil war in 2011. It reduced to 1,882 kg/ha in 2011. Capital formation in the country has been minimal and stood at an average of 15.9% over the period of analysis with a low level of 8.2% of GDP in 2003 and a high level of 29.66% of GDP in 1978 (period categorized as the Ivorian Miracle).

The investigation of the time series characteristics of the data shows that with the exception of the climate variables, that is, precipitation ($lnprecip_t$) and temperature ($lntemp_t$), that are stationary, that is, I(0), the remaining variables are all I(1), that is, first difference stationary. These results were obtained using both

Table 3. Descriptive Statistics of Variables of Interest.

Variable	Obs	Mean	Std. Dev.	Min	Max
Gdpk	57	1,547.043	330.909	1,138.660	2,391.920
Agva	57	28.617	6.758	20.980	47.910
Ceryld	57	1,226.240	495.375	624.200	2,270.500
gfcf	57	15.997	5.668	8.250	29.660
pop1564	57	52.926	0.813	51.710	54.620
precip	57	1,276.100	147.829	917.033	1,708.070
temp	57	26.331	0.331	25.450	27.060

Table 4. Bounds Test for Cointegration Among Economic Growth and Climate Variables, Equation 2.

Model 1 Bounds test ARDL(1,0,0)		Model 2 Bounds test ARDL(1,0,0,1)		Model 3 Bounds test ARDL(2,0,0,1,2)	
$H_0 \rightarrow$ **No levels relationship**					
F-stat =	**4.293**		**5.414**		**2.333**
Crit. val. at 5%	[I(0) I(1)]		[I(0) I(1)]		[I(0) I(1)]
k = 2	[3.79 4.85]	**k = 3**	[3.23 4.35]	**k = 4**	[2.86 4.01]
Test is unconclusive		Reject H0 if F > F-val for I(1)		Accept H0 if F < F-val for I(0)	
t-stat	**−2.547**		**−3.204**		**−2.157**
Crit. val. at 5%	[I(0) I(1)]		[I(0) I(1)]		[I(0) I(1)]
k = 2	[−2.86 −3.53]	**k = 3**	[−2.86 −3.78]	**k = 4**	[−2.86 −3.99]
accept H0 if t > t-val. for I(0)		Test is unconclusive		Accept H0 if t > t-val. for I(0)	

the Augmented Dickey Fuller and Philip Perron Unit Roots tests (Table 2). This clearly indicates a case for applying the ARDL Bounds Testing to investigate any long run relationship. Given that none of the variables of interest is I(2), we determine the number of lags (*p,q*), where *p* is the number of lags for the dependent variable and *q* is the number of lags for the independent variables. As indicated earlier, we used the AIC to determine the number of lags for each of the model to be considered before conducting the Bounds test.

Let us recall that we have three (03) models (three dependent variables). The first model (Equation 2) deals with the impact of the climate variables on the country's economic growth (Gross Domestic Product per capita). The second model looks at the impact of the climate variables on agricultural productivity measured as agricultural value added as a percentage of GDP (Equation 3). The third model deals with the impact of climate variables on the country's cereal yield (Equation 4). For each Equation (2, 3, and 4), we consider different variants ranging from a restricted model with only the climate variables (Model 1) to a full model with all the explanatory variables (Model 3). Model 2 is the restricted model augmented with the capital formation variable ($lninv_t$). Let us start with Equation 2 (Table 4).

Using the AIC, the lags order for Model 1 is (1, 0, 0), that of Model 2 is (1, 0, 0, 1), and that of Model 3 is (2, 0, 0, 1, 2). The Bounds test results indicate that no long run relationship between the variables in both the restricted and the unrestricted Model (1 and 3). In the case of Model 1, the *F*-statistic falls between the bounds making the test inconclusive; however, the *t*-statistic has a value (**−2.547**) greater than the lower bound for I(0), which is **−2.860**. We therefore accept the null hypothesis and conclude that the variables are not cointegrated and hence, no long run relationship. The test on Model 3 (the full model) confirms the absence of a long run relationship. Here, both the *F*-statistic and *t*-statistic provide support to the null hypothesis of no long run relationship. For these two models, we estimate the short run dynamics that is equivalent to running OLS on first difference. The results are presented in the Table 5. The Bounds test on Model 2 provides different results. Let us recall that in Model 2 we augmented the restricted model with only the capital formation variable. The *F*-statistic (**5.414**) is greater than the upper bound critical value for I(1), that is, **4.35**. We therefore reject the hull hypothesis and conclude that there is a long run relationship. We estimate both the level Model and the short run dynamics. The results are presented in Table 5.

Let us now consider Equation 3 (with agricultural value added as the dependent variable). We also consider three models as mentioned earlier (Table 6). Using AIC, the lags order for Model 1 is (1, 0, 0), and that of Model 2 is (1, 0, 0, 3), and that of Model 3 is (1, 0, 0, 1 , 0). The Bounds tests yield the following results: For Models 1 and 3, the null hypothesis of no long run relationship cannot be rejected. Indeed, although the *F*-statistics are unconclusive, the *t*-statistics are higher than the critical values at the 5% probability levels. Hence, we accept the null hypothesis of no cointegration and we estimate the short run dynamics. Here also,

Table 5. Results of the ARDL Estimation of the Impact of Climate on Economic Growth in Cote d'Ivoire (Equation 2).

Model 1	ARDL(1,0,0)		Model 2 ARDL(1,0,0,1)		Model 3 ARDL(2,0,0,1,2)
			Long run dynamics		
Constant	2.453 (0.302)		2.331 (0.221)		6.657 (0.186)
ECT_{t-1}			-0.138^{*} (0.002)		
$lnpre_t$			0.413 (0.346)		
$lntemp_t$			−4.271 (0.241)		
$lninvt_t$			0.572^{*} (0.000)		
			Short run dynamics		
$\Delta lngdpk_{t-1}$	0.936^{*} (0.000)				0.978^{*} (0.000)
$\Delta lngdpk_{t-2}$					−0.188 (0.209)
$\Delta lnpre_t$	0.103 (0.096)				0.057 (0.296)
$\Delta lntemp_t$	−0.830 (0.215)				−0.386 (0.480)
$\Delta lninvt_t$			0.102^{*} (0.026)		0.182^{*} (0.000)
$\Delta lninvt_{t-1}$					−0.092 (0.067)
$\Delta lnpop64_t$					-8.693^{*} (0.022)
$\Delta lnpop64_{t-1}$					14.516^{*} (0.028)
$\Delta lnpop64_{t-2}$					−6.959 (0.051)
Adj R-squared	0.938		0.391		0.961
F(3, 52) →	278.790^{*} (0.000)	F(5,47) →	8.070^{*} (0.000)	F(9;45) →	149.84^{*} (0.000)
			Breusch-Godfrey LM test for absence of autocorrelation		
chi2 (1)	3.798 (0.051)		0.015 (0.903)		0.056 (0.813)
			White's test for Ho: homoscedasticity		
chi2(9)	9.680 (0.377)		df(20) 15.770 (0.731)		df(54) 55.000 (0.436)
			See graph for stability test		

For each model, we tested for the absence of serial correlation as well as homoscedasticity. In both cases, the null hypothesis of no autocorrelation and homoscedasticity could not be rejected.

Table 6. Bounds Tests for Cointegration in the Agricultural Productivity Model.

Model 1 Bounds test ARDL(1,0,0)		Model 2 ARDL(1,0,0,3)		Model 3 ARDL(1,0,0,1,0)	
$H_0 \rightarrow$ **no levels relationship**					
F-stat	**4.293**		**4.895**		**3.015**
Crit val at 5%	[I(0) I(1)]		[I(0) I(1)]		[I(0) I(1)]
k = 2	[3.79 4.85]	**k = 3**	[3.23 4.35]	**k = 4**	[2.86 4.01]
Test is unconclusive		Reject H0 if F > F-val for I(1)		Test is unconclusive	
t-stat	**−2.547**		**−3.307**		**−2.429**
Crit val at 5%	[I(0) I(1)]		[I(0) I(1)]		[I(0) I(1)]
k = 2	[−2.86 −3.53]	**k=3**	[−2.86 −3.78]	**k=4**	[−2.86 −3.99]
Accept H0 if $t >$ t-val for I(0)		Test is unconclusive		Accept H0 if $t >$ t-val for I(0)	

Table 7. Results of the ARDL Estimation of the Impacts of Climate on Agricultural Productivity.

Model 1	ARDL(1,0,0)	Model 2 ARDL(1,0,0,3)	Model 3 ARDL(1,0,0,1,0)
		Long run dynamics	
Constant	−2.227 (0.400)	−3.713 (0.206)	−1.026 (0.760)
ECT_{t-1}		−0.174* (0.002)	
$lnpre_t$		1.296* (0.037)	
$lntemp_t$		4.539 (0.419)	
$lninvt_t$		0.166 (0.376)	
		Short run dynamics	
$\Delta lnagva_{t-1}$	0.880* (0.000)		0.886* (0.000)
$\Delta lnpre_t$	0.202* (0.025)		0.210* (0.026)
$\Delta lntemp_t$	0.357 (0.661)		1.013 (0.291)
$\Delta lninvt_t$		−0.148* (0.043)	−0.127 (0.085)
$\Delta lninvt_{t-1}$		−0.058 (0.430)	0.133 (0.081)
$\Delta lninvt_{t-2}$		−0.152* (0.046)	
$\Delta lnpop64_t$			−0.867 (0.259)

(*Continued*)

Table 7. (*Continued*)

F(3, 52)	131.030* (0.000)		3.580* (0.004)		70.400* (0.000)
R-squared	0.883		0.353		0.896
Adj R-squared	0.876		0.254		0.883
Breusch-Godfrey LM test for absence of autocorrelation					
chi2 (1)	0.153 (0.696)		1.835 (0.175)		2.763 (0.096)
White's test for Ho: homoscedasticity					
$chi^2(9) \rightarrow$	10.400 (0.319)	$chi^2(35) \rightarrow$	33.650 (0.533)	$chi^2(27) \rightarrow$	27.500 (0.437)
See graph for stability test					

Author's calculation (* significance at 5% probability level).

Model 2 behaves the same way as in the Economic Growth Equation, that is, the *F*-statistic is higher than the upper bound for I(1) at the 5% probability level. Hence, we reject the null hypothesis of no cointegration and conclude that there is a long run relationship between the variables and estimate both the level model together with the short run dynamics. Estimation results are presented in Table 7.

Let us consider now Equation 4 (with cereal yield as dependent variable). Here also, we consider three models as mentioned earlier. Using AIC, the lags order for Model 1 is (2, 0, 1), and that of Model 2 is (2, 0, 1, 0) /and that of Model 3 is (2, 0, 1, 0 ,1). The Bounds tests (Table 8) yield the following results: The *F*-statistic is unconclusive in all the three specifications. However, the *t*-statistics are all greater than the lower bounds for I(0). Hence, we accept the null hypothesis of long run relationship between the variables. We therefore move on to estimate the short run dynamics. Results are presented in Table 9.

5.2. Climate Change and Economic Growth

Based on the stability test provided by the graph below, we consider the unrestricted Model (3) and found no long run relationship between climate change and economic growth as measured by per capita GDP growth. Although the two climate variables did not impact significantly the economic performance of the country, we noticed that precipitation is positively associated with economic growth whereas temperature is negatively associated with the country's growth. The negative association between temperature and growth is in line with previous work by Abidoye and Odusola (2015); Dell et al. (2008, 2012). It is rather the

Table 8. Bounds Test for Cointegration in Cereal Yield's Model.

Model 1	**ARDL(2,0,1)**	**Model 2 ARDL(2,0,1,0)**		**Model 3 ARDL(2,0,1,0,1)**	
$H_0 \rightarrow$ **No levels relationship**					
F-stat	**4.725**		**3.576**		**3.436**
	[I(0) I(1)]		[I(0) I(1)]		[I(0) I(1)]
k = 2	[3.79 4.85]	**k = 3**	[3.23 4.35]	**k = 4**	[2.86 4.01]
Test is unconclusive		Test is unconclusive		Test is unconclusive	
t-stat	**−2.050**		**−2.114**		**−2.645**
	[I(0) I(1)]		[I(0) I(1)]		[I(0) I(1)]
k = 2	[−2.86 −3.53]	**k = 3**	[−2.86 −3.78]	**k = 4**	[−2.86 −3.99]
Accept H0 if $t >$ *t*-Val. for I(0)		Accept H0 if $t >$ *t*-val. for I(0)		Accept H0 if $t >$ *t*-val. for I(0)	

Table 9. Results of the ARDL Estimation of the Impact of Climate on Cereal Yield in Cote d'Ivoire.

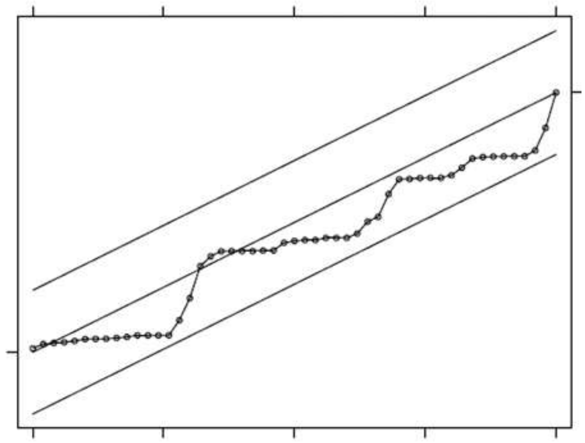
Model 1	**ARDL(2,0,1)**	**Model 2 ARDL(2,0,1,0)**		**Model 3 ARDL(2,0,1,0,1)**	
		Short run dynamics			
Constant	−12.207* (0.009)		−11.180* (0.025)		−14.506* (0.014)
$\Delta lnceryld_{t-1}$	0.529* (0.000)		0.522* (0.000)		0.471* (0.000)
$\Delta lnceryld_{t-2}$	0.385* (0.001)		0.386* (0.001)		0.383* (0.002)
$\Delta lnpre_t$	0.243* (0.027)		0.257* (0.024)		0.238* (0.050)
$\Delta lntemp_t$	0.026 (0.982)		−0.107 (0.928)		−0.376 (0.751)
$\Delta lntemp_{t-1}$	3.368* (0.005)		3.191* (0.010)		2.764* (0.027)
$\Delta lninvt_t$			−0.023 (0.572)		−0.032 (0.460)
$\Delta lnpop64_t$					8.157 (0.133)
$\Delta lnpop64_{t-1}$					−6.609 (0.195)
F(5, 49) →	188.820* (0.000)	F(6,48) →	155.240* (0.000)	F(8,45) →	116.600* (0.000)
Adj R-squared	0.946		0.945		0.946
		Breusch-Godfrey LM test for absence of autocorrelation			
chi2 (1)	0.000* (0.993)		0.000* (0.986)		0.000* (0.993)
		White's test for Ho: homoscedasticity			
chi2(20)	15.980 (0.718)	df(27)	19.190 (0.863)	df(44)	43.30 (0.501)
		See graph for stability test			

Author's calculations.

level of Gross Fixed Capital Formation (Investment) that has positively and significantly affected the country's economic growth. This calls for a revisit of the country's investment policy. As indicated earlier in this paper, the highest level of investment stood at 29.66% of GDP and this was several decades back in 1978 during what was categorized as the Ivorian miracle. The current level of investment that stood at 20.46% is still less than its 1978 level. More productive investments are needed if the country is to ascend to emerging country status.

The other variable of interest is the growth of the economically active population. It has a significantly negative impact on the country's economic performance. This is of no surprise given the high level of unemployment in the country. To mitigate the negative impact of this variable on the country's economic performance, it is important that the country's employment policy be revisited to ensure that skills are built to address present and future challenges of the country and sectors such as agriculture, construction, health, security, and education are on the forefront. Here, we emphasize education because it is key for skill building, and it should therefore be lifelong in nature.

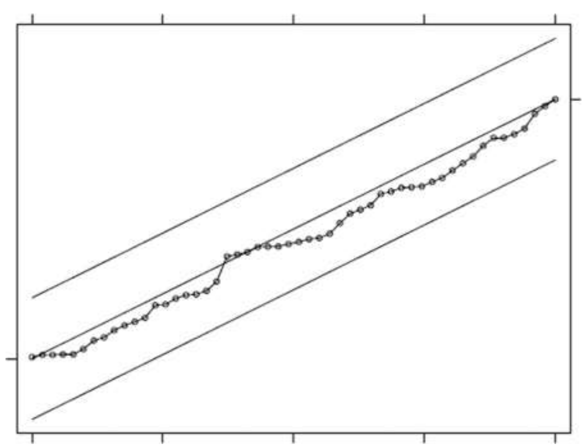
This graph shows that the estimated model is stable (Model 3).



5.3. Climate Change and Agricultural Value Added

Here, in line with the stability test (see graph below) we consider Model 2. The Bounds test indicate a long run relationship between the climate variables and agricultural value added. Indeed, the error correction term is negative (−0.174) and highly significant. It confirms the cointegration between the variables. The results also indicate that there is long run causality running from precipitation to agricultural value added. Indeed, precipitation has a positive (1.296) and significant impact on agricultural value added. Different from precipitation, temperature does not have a significant impact on agricultural value added. When we consider the short run dynamics, we observe that the investment variable has a negative impact on agricultural value added. This is understandable, especially if investments are done outside the agricultural sector to enable the processing of agricultural products. In such an instance, the contribution of agricultural value added to GDP will decline while that of the Industrial sector will increase. The tests of the null hypotheses of no autocorrelation (P-value of 0.175) and homoscedasticity (P-value of 0.533) could not be rejected.

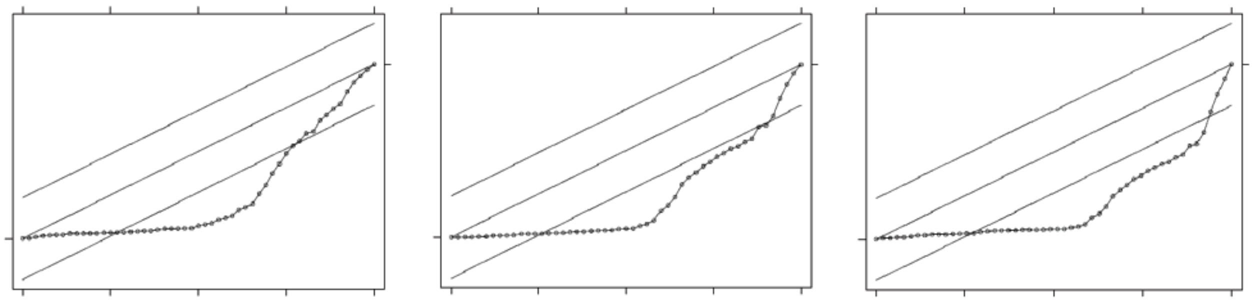
This graph shows that the estimated model is stable (Model 2).



5.4. Climate Change and Cereal Yield

For this model, although the tests for the null hypotheses of no serial correlation and homoscedasticity could not be rejected for all the three equations, the results for the stability tests were not satisfactory (see the three graphs that represent Models 1, 2, and 3, respectively). We therefore considered the restricted model (Model 1), that is, the model with only the climate variables. The estimated coefficients did not vary much from one equation to the other. We observe positive and significant impact of lagged values of cereal yield on cereal yield at time *t*. Change in precipitation positively (0.243) and significantly (*P*-value of 0.027) impacted cereal yield in the country. Lagged value of change in temperature also positively (3.368) and significantly (*P*-value of 0.005) affected the country's cereal yield. The tests of the null hypotheses of no autocorrelation (*P*-value of 0.993) and homoscedasticity (*P*-value of 0.501) could not be rejected.

It appears from the previous results that climate change has not been damaging so far, to the country's agricultural production.



6. CONCLUSION

The objective of this paper was to determine the impact of climate change on Cote d'Ivoire's economic performance via per capita GDP growth, change in agricultural value added and change in the country's cereal yield. The Analysis was conducted using data ranging from 1960 to 2016. The climate variables considered in this analysis were precipitation (millimeter of rainfall) and temperature (degree Celsius). We found that climate change has so far not significantly impacted the economic performance of the country. Climate change (precipitation) has been found so far to have positively and significantly influenced the country's cereal yield and agricultural value added contribution to GDP at large, and thus there is no need to worry more than it is necessary. Notwithstanding the previous results, it would be important to investigate whether there is a threshold level of precipitation and temperature beyond which the country's economic performance and cereal yield will be at risk.

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APPENDIX

Table 1A. Pairwise Correlation between the Variables of Interest.

	lngdpk	lnagva	lnceryld	lnpre	lntemp	lninvt	lnpop64
lngdpk	1.000						
lnagva	0.007 (0.957)	1.000					
lnceryld	−0.606* (0.000)	−0.660* (0.000)	1.000				
lnpre	−0.142 (0.291)	0.241** (0.071)	0.096 (0.480)	1.000			
lntemp	−0.591* (0.000)	−0.194 (0.149)	0.536* (0.000)	0.191 (0.155)	1.000		
lninvt	0.701* (0.000)	0.217 (0.104)	−0.548* (0.000)	0.113 (0.404)	−0.425* (0.001)	1.000	
lnpop64	−0.674* (0.000)	0.115 (0.393)	0.476* (0.000)	0.345* (0.009)	0.401* (0.002)	−0.061 (0.651)	1.000

Author’s calculation.

Climate Change Fiasco: What Multilateral Arrangements Have to Offer?

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Abstract

Multilateral arrangements have been a talking thing for decades now. As the globalization process unleashed nations' potential to converge on matters of concern, there has been a spiraling increase in agreements and arrangements. Climate change is the buzzword in multilateral arrangements now. In the recent past, startling changes in environment have caught the attention of countries, both developed and developing, to take a call of action. The present discourse seeks to understand multilateral arrangements' itinerary in facing global climate change.

Keywords: Climate change; Multilateral agreements; UNFCCC.

1. INTRODUCTION

As Barack Obama rightly said, "There's one issue that will define the contours of this century more dramatically than any other, and that is the urgent threat of a changing climate (The White House, 2014)." Climate change has taken over as the "first thing first" in the agenda of multilateral organizations and arrangements. Climate change came aboard for discussion the very first time at the World Climate Conference in 1979. It is defined as "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean or the variability of its properties, and that persists for an extended period, typically decades or longer" (Cubasch *et al.*, 2013). The discussion on climate change has suddenly taken a major upturn as earth faces an ever-fastening increase in temperature, a swell in sea levels, and an imbalance in ecosystem. A part of it gathers weightage from the alarming accentuation in greenhouse gas (GHG) emissions on account of mounting industrial activities, and the remaining hullabaloo is nonabidance by many parties to the climate change motto. The kickoff of industrialization brought manufacturing advances in many nations, viz. England, Europe, and North America, in gradual steps. This gradual aggravation in industrial activity, in addition to bringing economic outcomes, led to environmental concerns as well. The environmental impact of industrialization followed a superior fashion than that of economic and societal impact. Records suggest early signs of climate change via increase in earth's temperature showed in as early as the 1830s (The Conversation, 2016). However, the whole process has its roots in the industrial revolution, which began from Great Britain in the 1750s. The trigger to climate change was pulled by the extensive use of coal in the newly explored production processes. Coal usage has propelled climate change to take the devastating form it now is. Being a carbon exhaustive fuel, coal increases carbon content in the atmosphere. The total temperature increase since preindustrial times amounts to approximately 1.2 degrees Celsius. We have now surpassed the 1-degree mark, an important marker as it brings us more than halfway to the global limit of keeping warming below 2 degrees Celsius (Ritchie and Roser, 2018). The main players in wreaking havoc with earth's natural level of temperature include a whole combination of GHGs, like carbon dioxide, methane, nitrous oxide, and F gases. Other elements also have a part in the climate wreck, however.

As the global civilization underwent transition from a primitive society to an industrial-based one, countless innovations and inventions brought into fore a whole lot of new production functions. These involved generous employment of coal and fossil fuels and the usage just multiplied with centuries passing

Table 1. Primary Coal Consumption (Thousand Short Tons).

Country	2015	2014	2013	2012	2011
China	4,376,326	4,537,257	4,678,490	4,538,507	4,287,557
India	879,608	917,731	837,899	841,320	770,315
United States	79,815	875,891	924,442	889,185	1,002,948
Germany	262,922	263,008	270,152	271,234	258,751
Russia	228,176	219,360	229,820	256,226	244,615
Japan	210,734	210,608	209,934	197,483	189,619
South Africa	169,607	201,392	203,601	204,801	194,735
Australia	130,585	130,458	130,711	139,312	145,301
Indonesia	95,901	83,776	79,366	73,855	72,752
Canada	46,297	45,545	46,447	47,395	51,471
Vietnam	41,650	35,423	33,934	31,277	30,546
U.K.	41,195	53,192	66,154	70,593	56,776
Thailand	37,443	39,683	41,484	39,691	40,474
Malaysia	24,472	26,852	26,344	27,770	25,829
Philippines	24,258	22,877	20,891	17,817	15,690
Mexico	24,251	24,529	25,580	25,278	28,430

Source: EIA (International Energy Statistics); EIA, 2011; EIA, 2012; EIA, 2013; EIA, 2014; EIA, 2015.

by. Amplified energy need as communities flourished further raised coal consumption, thus infusing more carbon into the atmosphere. Table 1 reflects the pattern in coal usage lately for a plethora of countries.

As Table 1 makes clear the quantity of coal consumed by major economies across a five-year range starting from 2011 to 2015, it also reflects the notion that when coal consumption has risen, the carbon venting must be following a similar path.

It follows from Tables 1 and 2 that China is the greatest consumer of coal and its consumption over the years has taken an average of more than 50 percent of the world coal consumption. Following China are India and the United States, switching their places occasionally to take the second and third spots in their obsession of coal. Reasons contributing to the countries dependence on coal over the century include a step up in gross domestic product numbers, amplified energy demand, and a liberal attitude in coal production by major economies, like China, themselves. The pattern in coal consumption from 2016 to 2017 is quite interesting. While for China coal consumption increased by 14 metric tons in 2017 vis-à-vis 2016, India saw an increase by almost double of that of China. India's coal consumption swelled by 28 metric tons in 2017 vis-à-vis 2016. Contrary to China and India, the United States displayed a great show of decline in its coal usage and thus reducing carbon emissions. Table 3 displays the trends in carbon emissions by coal usage over the years.

The carbon dioxide emission data spill beans on the why and wherefore of climate change. Repeated pronouncements by world leaders on the control of fossil fuel consumption coupled with the exploration of alternatives to carbon exhaustive energy come in line of this alarming amounts of carbon dioxide in the atmosphere. In isolation to other GHGs, carbon dioxide content in the global atmosphere has reached a hazardous point. China, being an extensive user of coal, has infused a great deal of carbon. The rank in carbon content diffusion shows the same pattern as reflected in coal consumption. The United States and India garner the second and third spots. However, there has been a decline in the United States' carbon

Table 2. Total Coal Consumption (in Metric Tons).

Country	2017	2016
China	3,607	3,593
India	953	925
United States	649	661
Russia	232	224
Germany	222	230
Japan	196	191
South Africa	192	197
Australia	119	123
Indonesia	100	94
Canada	39	39

Source: Global Energy Statistical Year Book 2018, Ener Data.

Table 3. Carbon Dioxide Emissions from Fuel Combustion (in Metric Tons).

Country	2017	2016	2015	2014	2013	2012
China	9,297	9,086	9,095	9,070	9,026	8,613
United States	5,073	5,071	5,099	5,258	5,191	5,125
India	2,234	2,151	2,052	2,003	1,840	1,786
Russia	1,697	1,622	1,608	1,598	1,610	1,666
Japan	1,118	1,107	1,122	1,159	1,209	1,193
Germany	782	764	754	749	787	766
Canada	624	590	569	572	574	561
Indonesia	485	464	454	446	–	–
South Africa	440	446	436	443	430	420
Australia	408	407	388	384	393	398

Source: Global Energy Statistical Year Book 2018, Ener Data.

diffusion consistently but political rendezvous tells a different story for coming years. In Asia, China alone was responsible for 61 percent of total carbon dioxide diffusion in 2017, displaying no shift from its 2016 mark, whereas India made sure to extract a share of 15 percent and 14 percent in 2017 and 2016. For the whole of North America, the United States' share of carbon emission was an astounding 89 percent, dropping by one percentage point in 2017 vis-à-vis 2016. The drop in coal consumption by the United States as evident in Table 1 and thereby a reduction in carbon diffusion is reflected on account of an increase in use of renewable sources of power generation. Table 4 explains this phenomenon.

From Table 4, only Canada displays a shoot-up in renewable sources of power generation over the time frame. Out of Canada's total energy consumption, renewable sources make up for a promising 65 percent while the nonrenewable sources only account for 35 percent. The United States however is a laggard when compared to Canada in the renewables' share of power consumption but is a step forward from its

Table 4. Share of Renewables in Power Generation (in Percentages).

Country	2017	2016	2015	2014	2013	2012
China	26	25.4	24.1	22.8	20.5	20.1
United States	17.7	15.4	13.6	13.4	13	12.4
India	16.3	15.5	15.3	16.3	17.3	15.7
Russia	17.5	17.4	16	16.7	17.3	15.7
Germany	34	30	29.9	26.8	24.8	23.7
Canada	64.7	64.1	63	62.8	63.3	63.2
Indonesia	12.3	12.6	10.7	11.5	12.3	11.2
South Africa	4.2	4	3.4	2.5	1.7	1.8
Australia	14.9	15.8	13.7	14.9	13.3	10.6

Source: Global Energy Statistical Yearbook 2018, Ener Data.

previous state. China's position is also improving in renewable energy from its previous standpoints. This boost can be attributed to the role of multilateral arrangements and their climate policies and a multitude of committees over shaping energy strategies in a way that reduces environment threats. Several multilateral organizations are put in place since the early signs of planet heating started. Though the world is endowed with numerous multilateral arrangements specifically for climate change policy formulation, there exist in the vicinity of bilateral and regional trade agreements consistent efforts to mitigate climate catastrophe triggered by extensive fossil fuel deployment.

2. CONCEPTUAL FRAMEWORK

Article 1(2) of the United Nations Framework Convention on Climate change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." Human activity has increased extraordinarily with the upgradation in technology. The astounding use of fossil fuels has brought about a tidal change in the natural composition of atmosphere. Rise in sea levels, melting down of glaciers, depletion of ozone, rising temperatures, droughts, and floods are all a result of climate change. Carbon emissions are believed to be the single-most contributing element in global warming. The UNFCCC article 1(2) goes on to define emissions as "the release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time." These GHGs are those gaseous substances that traps the heat in the atmosphere and do not provide an outlet, thus absorbing and rejecting into the atmosphere infrared radiations. With gradual advancement in the understanding of the scope of climate change, several GHGs came to be acknowledged, like methane, nitrous oxide, and chlorofluorocarbons, apart from the leading GHG, carbon dioxide.

Multilateral arrangements or organizations mean the coming together of three or more countries for certain objectives or causes. Keohane (1990) defines multilateralism in a similar vein as "the practice of coordinating national policies in groups of three or more states, through ad hoc arrangements or by means of institutions." In layman lexicon, it is a state of international cooperation where some core issues and concerns are at the center. These multilateral arrangements act as the key movers of national objectives at the international stage. For instance, the UNFCCC is a multilateral arrangement in that it is a conglomeration of more than three countries and it revolves around a central idea of tackling global climate change. The multilateral framework of creating international bonds is the product of the aftermath of the Second World War. The relevance of multilateral arrangements is visible in its affluence, which has shifted many economies onto the path of growth.

3. REVIEW OF LITERATURE

Climate change has been a cause of concern for the developed as well as developing world since the 19th century. The lookout for climate change mitigation has evolved in varying degrees and form. The entry of multilateral organizations in dealing with climate change is not a new thing to ponder. Climate change and multilateral arrangements go hand in hand. Over the course of history, the shift of climate change policy from a unilateral perspective to bilateral, quadrilateral, multilateral, and eventually minilateral ones has been searched upon in detail by a great number of literati. Many have discussed this transition in negotiations regarding climate change since the start of 19th century. Gupta (2010) studied the transition over a broad spectrum of time. While analyzing the shift in perspectives over climate change policies, Gupta clubbed those showcasing an environmental case and those marking a development case distinctly. Thus, identifying five major periods over which the climate change agenda took twists and turns, Gupta surmised for a total period of 30 years the gradual development in conventions, committees, and policies. Pre-1990 policies and commitments were marked by an understanding of different responsibilities by developed and developing countries, as the contribution to climate change was believed to be forged differently by the first world and the third world. The transition over 30 years witnessed the establishment of IPCC (Intergovernmental Panel on Climate Change) in 1988 under the auspices of the United Nations. Prior to this, a plethora of reports, like the Brundtland report, and the Toronto conference equated climate change to be as dangerous as a nuclear war. Further declarations and commitments focused on attaching limits to carbon emissions. By 1990, the world saw the second world climate conference, where the potential of limiting carbon emissions by 20 percent by 2005 was discussed. The goals however widened as climate change erupted more voraciously than the mitigation efforts could ever. The 1990 era proved the most promising. Represented as an era of political upheavals, the 1990s witnessed the coming into action of the Rio declaration on Environment and Development, biodiversity convention, and UNFCCC. This phase concentrated on mitigation efforts and activities implemented jointly (AIJ). As the coming together of countries went on expanding with the climate change in shambles, the leadership on climate change underwent a change. Post 1996, the Kyoto Protocol emerged as the mighty effort in climate change. Until now, the IPCC brought into fore a chain of reports on technologies that could help mitigate climate wreck. The major advancement in the mitigation efforts was the recognition of six GHGs and their targets of bringing them down. The 2002-2007 period recorded profligacy in GHG emissions brought into public domain by the fourth assessment report of the IPCC. The leadership dynamics was shaken to the core by the United States walking out of the Kyoto Protocol. However, this time frame also registered relevant agreements in Montreal and Bali, respectively. With more and more countries joining the cause of climate change, it became tougher to arrive at consensus over policies and targets, which was reflected in this phase particularly because of an extended EU and umbrella countries. This period pressed over nationally appropriate mitigation actions (NAMAs), biofuels, and clean development mechanisms (CDMs). The period beyond 2008, represented by global financial turmoil, saw the climate change leadership also in shambles. The highlights of this period included the Copenhagen Accord, which confined parties to set rules on emissions. This period acknowledged the human rights chapter of climate change, which remained at a zilch in previous discussions. The unfolding of global climate change governance became the tipping point of the study by Bodansky (2001). The phases were demarcated by a change in stance and the role of governmental and nongovernmental advocates of climate change. The five phases identified were foundational period, agenda setting phase, prenegotiation phase, formal intergovernmental negotiation phase, and post agreement phase. These phases were in operation until the coming of Kyoto Protocol in 1997. From the first phase to the final phase, the roles of governmental and nongovernmental players witnessed a huge shift. In the agenda setting phase, the demarcation between governmental and nongovernmental players was near to zero. The only players who set out differently were a scant group of entrepreneurs. Till the formal intergovernmental phase, the equation however turned around reckoning government officials for greater roles than any nongovernmental actor.

A deeper and more pressing shift widely searched is the journey from multilateralism in climate change to minilateralism. Multilateralism appears to have surrendered to the loopholes in its make. The reasons of its submergence in guiding climate change and the evolution of alternatives form the subject matter of the debate between multilateralism and minilateralism. The two terms defining the congery of countries is such that one contains the other to certain extent. While multilateralism is the coming together of three or more countries for an agreed cause or concern, minilateralism cuts short the number of parties on an agreement and is quick in building consensus. This is the point that adds to the positive of minilateralism. The debate on multilateralism versus minilateralism revolves around each of their efficiency in nearing consensus among parties involved and providing a solution to blockade and deadlock in negotiations. The presence of *n* number of parties brings disadvantage to the actualization of objectives, as it has been the case numerous times. This is the situation because of the ever-widening scope of multilateral organizations in bringing under its umbrella countries heterogeneous in character. However, minilateralism has with it many negatives too. Minilateralism is seen as all gain only if it complements multilateralism and adds another feather in the cap if it reinforces multilateralism (Brandi, 2015). The proposal to the establishment of climate council under the aegis of the UNFCCC seems to push minilateralism in the front when the UNFCCC as the multilateral institution appears to be weakening in passing further recommendations (Eckersely, 2012). However, it is in the fitness of things to not let, in the follow up of minilateral arrangement the greater motive of multilateral arrangements to wander. Engelbrekt (2015) reckons minilateralism to be the final word in pulling off locked negotiations. In his words, minilateralism appears more "feasible" when past trajectory reflects inability of multilateralism.

The movement from multilateralism to minilateralism appears plausible to many commentators. Falkner (2015) analyzes the need of alternatives for climate change mitigation outside of the state-led multilateral institutions. However, his final stance reflects that although the UNFCCC negotiations haven't offered a unified action yet and have failed in many of its negotiations, there is yet to emerge a minilateral arrangement that could garner enough support from the masses (governmental and nongovernmental actors) to establish itself as a complete alternative to multilateralism. Similar views are echoed in Hjerpe and Nasiritousi's (2015) survey of climate change advocates over multilateralism or minilateralism. Through their survey of 922 respondents over 2013 and 2014 in consecutive conferences of parties (COPs), they find a difference of opinions. While government officials favor more of multilateralism, nongovernmental players prefer institutions that are not state led, and minilateralism finds support in European and North American actors. The lack of unanimity in response yet again reflects no promising alternative yet in sight that could replace the UNFCCC. A progress in UNFCCC negotiations can put the minds wandering for alternative options back onto multilateralism, and conversely further disturbance in negotiations can push actors to venture for alternatives like minilateralism. This dripping support for minilateralism or "climate clubs" could see a correction mechanism in resetting the design of the agreement, including provision of club goods to members and propelling sanctions against nonmembers (Gampfer, 2016). In the same vein, Weischer, Morgan, and Patel (2012) have identified incentives to propel countries to join and commit to climate clubs. In short, for climate clubs to emerge feasible, they should reconsider their current configuration and attach greater importance to economic incentives like trade, investment, financial support, and labor transfer to drive players to commit. Minilateralism is prospective of, according to commentators and policy makers, strengthening even more and is believed to shape the entire global climate change governance (McGee, 2011). Multilateralism has spread its wings to the entire globe and has included almost every country in the process. A delay in its negotiations has placed it in a fray with minilateralism. However proficient minilateralism may seem on the out, it still befits for the world to be in the direction of multilateralism, as it has grown consistently over time and minilateralism might take another decade or so to come up with a design feasible for its players.

4. MULTILATERAL ARRANGEMENT FOR CLIMATE CHANGE GOVERNANCE

International governance on climate change has been at the front of environmentalists, policy makers, and governmental and nongovernmental players since the 1970s. The realization of thinkers about the threat of climate change to earth came as scientists, through their climatic models, predicted a rise in earth's temperature in the coming decades. Many climatic jolts also drove the world community to ponder over and take the scientists' prediction to be true. For instance, the detection of ozone hole in 1987 sent chills to the international community, thereby making the climate change movement more pronounced in the public sphere. Another encounter that fueled public and government's attention toward climate change threat was the heat wave and drought of 1988. These events moved policy makers to converge over an action plan. In vein of these developments in climatic behavior, a major multilevel coming of parties happened at Rio de Janeiro.

United Nations Framework Convention on Climate change (UNFCCC)

The UNFCCC adopted in May 1992 is by far the largest legally binding framework on climate change. The framework saw ratification by 154 parties in June, 1992, at Rio De Janeiro under the functioning of the United Nations Conference on Environment and Development (UNCED). The main objective of the convention being to stabilize the GHG emissions to reduce anthropogenic substance in the atmosphere, there has been a series of annual COPs since the UNFCCC came into force. The first conference of parties was concluded at Berlin in 1995 and several mandates were thought over. The mandates went on magnifying with successive COPs. The UNFCCC offers varied benefits for climate change mitigation only if the negotiations are timely put into action.

Berlin Mandate (COP-1)

The Berlin mandate marked the first venturing together of parties signatory to the UNFCCC, and apart from a plethora of discussions, the mandate revisited one of its objective as noted in article 4.2 (d). The article stated that parties signing to the UNFCCC will decide over the criteria for carrying out AIJ as described in article 4.2 (a). The COP-1 thus decided the following in the context of AIJ:

(i) To set up a pilot phase for AIJ amid Annex I parties and with nonannex parties, which remains as per their willing
(ii) The activities jointly adhered to must comply with the national and global interests, national in the context of being complacent with environment and development concerns and international in the context of being cost impressive.
(iii) A prerequisite for the carrying out of AIJ is approval and advocacy on the part of governments partaking
(iv) AIJ should accompany long-term environmental favors in line of climate change mitigation
(v) No brownie points in the event of any party meeting emission reduction targets during the pilot phase. (United Nations, 1995)

Kyoto Protocol (COP-3)

The third COP of the UNFCCC was given substance at Kyoto during December 1-11, 1997. In addition to talks over future course of action taking into purview the emission levels on the rise, the major takeaway from the conference was the commitment of developed countries to lower down GHG emissions to specific levels. A consensus was reached over curtailing down GHG emissions to 5.2 percent below the levels established in 1990. This target was set for a period of 2008-2012. However, the United States walked out of the Kyoto Protocol in 2001, referring to Kyoto not binding on India and China, which, according to the United States, will lead to carbon emission profligacy.

Marrakesh Accord (COP-7)

The Marrakesh Accord of the parties signatory to the UNFCCC was held in October 2001 as a mechanism to push ahead the deadlocked Kyoto Protocol. With the United States already out of the deal, there required support by other major emitters in succession to the United States. Japan, Russia, and Canada converged over objected to the proceedings over their nonconformity with market mechanism. The obstruction was finally ruled over by a proposal on carbon sinks. The catching point of the Marrakesh Accord thus emerged out to be the smooth sail of the Kyoto Protocol, wherein 40 countries abided by cutting down their emissions by 5.2 percent below 1990 levels.

Bali Roadmap (COP-13)

The COP-13 mapped out a path of action beyond 2009. Under its talks, key points that made rounds were pulling bottomward emissions resulting from deforestation. The Bali Roadmap is built on four blocks: mitigation, adaptation, technology, and financing. The different roles for developing and developed countries in battling climate change came out as the lead in the COP-13 at Bali. As for the developed countries, climate change mitigation came in through reducing emissions; developing countries were mandated to follow a bottom-up approach, limiting their emissions from the minimum degree assorted. Also, developing countries were mandated to garner technology support and financial cushion to their dealings.

Copenhagen Accord (COP-15)
The Copenhagen Accord setting into action the fifteenth session of the COP was a mixed deal for many. Those not content over its working were parties that were not involved in talks. However, the Copenhagen accord created ripples on the United States involvement in climate treaty. The annual conference reaffirmed previous accords in the context of technology transfer, carbon sinks, etc. The key getaways of the accord were its setting of emission reduction agenda and mitigation rulebook for developed and developing countries for 2020. On the global temperature front, a ceiling of below 2 degrees Celsius was decided upon. Short-term and long-term financing of $30 billion and $100 billion were sought to be achieved by 2012 and 2020, respectively.

Cancun Climate conference (COP-16)
The 16th annual conference of parties of the UNFCCC in 2010 came into bright picture as against its predecessor, the Copenhagen Accord, which received scathing attack on being all gong and no dinner. At Cancun, the glitter to eyes was the decision of structuring a green fund for climate action with a balanced representation from both developed and developing countries. Also, the developing and developed countries under this agreement agreed to comply with GHG emission clampdown.

Paris Climate Accord (COP-21)
Forged into action in December 2015, the twenty-first annual conference of parties of the UNFCCC is both a happy juncture and a locked point. Its major provisions for climate change include confining temperature rise to 1.5 degrees Celsius above preindustrial levels and achieving net zero emissions as its far-extending goals. The strong point of this conference was the conjoining of more than 100 countries called as the "high ambition coalition." The agreement proved historical in its acknowledgment of different starting points of countries party to the agreement. The agreement this time pledged to carry out implementation in conformity with the "principle of common but differentiated responsibilities and respective capabilities." This is in a way reflected in its doing away of emission reduction targets demarcation, while this time reclining on voluntary mitigation contribution (Climate Focus, 2015).

5. CONCLUSION

Climate change is a top-tier matter now and has involved advocates and supporters from every walk of life. The extension of members involved in the UNFCCC from 154 to 194 is an astounding achievement in itself. Apart from the collective goals devised under the UNFCCC, there are a plethora of other agreements and the clubbing together of economies for the objective of tackling climate change. For instance, the G-8 and G-20 are groups of leading economies working at the front of economic issues, but off late they have placed their foot forward in mitigating climate change. Similarly, the European Union, whose 28 members are part of the UNFCCC, has increased its participation in dealing with global climate change through arranging and concluding individual level events in line with the issue. In the Asia Pacific, the Asia Pacific Economic Cooperation Forum has contributed measly but still has pulled off its operation on climate change. BRICS, in consecutive annual meetings, goes on establishing and reinforcing its pledge toward tackling climate change. However, all these regional groupings are not formal as against the UNFCCC because these regional groupings are non-legal in nature.

It is widely believed and proved at the hand of scientists that the trigger to global climate change was let loose at the onset of industrial revolution. Since then, the earth's temperature has risen and gained pace with the increase in economic activity. It was, given weightage by developed countries, like the United States, and since 1990s the developing economies have partaken generously due to the development path they have embarked upon. The descriptive lookout suggests that to this day it is China that is at the top of carbon emissions and the United States for the greater part takes the second spot with India often displacing it. Even the now pronounced as imperative use of renewable sources of energy for achieving sustainable development reflects a long way to go so as to reach GHG emissions in conformity with regulating earth's temperature. Nevertheless, many economies have shown a remarkable progress in mobilizing renewable energy, like Canada, China, and Germany. For other economies, it reckons there is a long way to go. Norway stands first in galvanizing renewable energy. However, a lot of these developments in the case of climate change owe to one all-binding multilateral arrangement, i.e., the UNFCCC. The mere act of clubbing together a number of countries as huge as 197 for consecutive annual meetings is in itself laudable. Apart from the members, the proceedings draw nonofficials too, which make it a figure outranging 200 participants. Notwithstanding numbers, the on-ground activity has been perturbed several times and came in for criticism at several occasions. The Copenhagen Accord, for instance, was a strict letdown in the eyes of developing nations, as they felt devoid of any say in the binding talks. In reality, the talks were dragged onto the next summit, where they surrendered to many people's hopes and were eventually brought into work with the adoption of agreements. Earlier in the Copenhagen Accord, the parties only took notice of the agreement and nothing formal could emerge out from the COP. Cancun provided a formal translation of agreements into workable actions. The latest COP-21 in Paris was all eyes by spectators and policy makers, commentators, and pundits all across the globe hailed it as a "milestone." Undoubtedly, the promise to abide by emission levels that will regulate earth's temperature rise between 1.5 and 2 degrees Celsius is a great development to relish but this appears to be more of an emotional success than an actual ground movement. The Paris Climate Treaty is expected to pitch in not before 2020 and this is a huge disappointment in the way that the global warming limits set by the treaty may become a mere promise when actually the emissions will be something beyond control in and around 2020. The rate at which global GHG emissions have taken a toll speaks volume on the uncertainty of the actualization of global warming limits by 2020. Also, the nonabidance of some economies that emit a substantial amount of GHGs in the atmosphere to national emission targets is a negative in the multilateral arrangement. The United States' recent pulling out of the Paris Climate Accord is a strong sign of irresponsibility toward a goal whose maturity is integral to the entire world. However, the United States' rebuttal has not deterred other parties and the unison is stronger than ever on climate change. The only part sour about the UNFCCC is its inclusion of a vast array of countries. The heterogeneity impedes the progress of agreements to translate into action. Overall, the multilateral structure of the UNFCCC is both a celebrating characteristic and much ado about nothing. The conglomeration is nevertheless worth something relative to doing nothing at all. A revamp in the procedures can be reached at by abiding countries sticking to the targets and taking a step forward in reducing emissions, consuming more from renewables and clean energy, and not letting the action held back until 2020. The action is to be taken now. Strike while the iron is hot. In this context, Barack Obama's standpoint is apt: "Climate change is no longer some far-off problem. It is happening here; it is happening now (The White House, 2015)."

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Environmental Policy in Brazil after the 2016 Coup: An Analysis of Government Expenditure

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Abstract

An emerging power since the last decade and a participant in BRICS—a bloc composed of Russia, China, India, and South Africa—Brazil would be the weakest link of an opposition to U.S. hegemony in the world order established since 1991 with the end of the Cold War. The 13-year advances of Luiz Inacio Lula da Silva's reformist and progressive government, continued by his successor Dilma Rousseff, appear to have reached a tolerance limit regarding the retrograde domestic forces and outside interests of the metropolitan center. The coup happened in 2016, following a two-year process of political and economic destabilization of the government. This paper seeks to show, through the exposition of an earlier history and the analyzed narrative of the events, besides the analysis of the federal public expenditures, that this movement of linkage and regression occurred in the ambit of issues related to the environment. The coup government launched in 2016 has abandoned any environmental policy, is interested in dissolving the institutional framework established after 20 years of insertion of Brazil in the global debate on the environment, and does not even supervise and protect the country's natural resources, in an attitude characteristic of a state of exception.

Keywords: 2016 Brazilian coup; Brazil; Environment; Natural resources; Public spending.

1. INTRODUCTION

The second decade of the 21st century saw an unfortunate return: the cycle of coups in peripheral democracies. Taken together, the political crises that have permeated these countries since the beginning of 2010 show the following common points: (1) a significant performance of the International Labor Division's center toward the political realignment of these countries, which until then had come to rehearse some autonomy; (2) an extraordinary uprising of reactionary forces marked by the most backward thinking present at this time, and (3) retrogression in all spheres that make up human life on the planet, ranging from economics, society, culture, politics, and mass psychology to the environment, the subject of this text.

The relation of society with the environment is given by the social relations of production. Under capitalism, they follow its logic. The environmental discourse, therefore, under capitalist hegemony, can be understood only as a fight from the periphery or as an ideological justification of the center for increases in the rate of profit, with correlated increases in the exploitation rate (or surplus rate) on the periphery. Government policy, both at the center and the periphery, follows this duality of interests, depending on the level of conjunctural autonomy of the periphery. When this has flashes of autonomy, there is some opposition, and the environmental discourse gains some practical materiality in government policies. When this is subject to metropolitan dictates, the discourse is not reflected in more policies of cost reduction, increase of the average rate of profit of capitalist productive activities, and consequent increase of the exploitation of capital over work, especially the employee, in the transformation of natural resources into commodities.

An emerging power since the last decade and a participant in BRICS (a bloc of countries that include Russia, China, India, and South Africa), Brazil would be the weakest link of an opposition to U.S. hegemony in the world order established since 1991 with the end of the Cold War. The 13-year advances of the reformist and progressive government—which could be characterized as developmentalism—by Luiz Inacio Lula da

Silva (2003-2010), and unconcluded by his successor Dilma Rousseff (2011-2016), seemed to reach a tolerance limit for the domestic retrograde forces and external interests of the metropolitan center in 2016.

The coup d'état would happen in 2016, after a two-year process of political and economic destabilization of the government. From then on, there would be, for external interest, the reconnection with the neoliberal agenda imposed since 1990 on Latin America. For the domestic interest, a series of political, economic, and social setbacks would be put in place by the coup group that ascended to power.

This paper seeks to show, through the exposition of an earlier history and the contextualized narrative of the events, besides the analysis of the federal public expenditures, that this movement of linkage and regression occurred in the ambit of issues related to the environment. If the linkage goes back to the last decade of the last century, the setback shows an even more dramatic issue in Brazil's political history. This has occurred even more remotely, and its future consequences are still difficult to estimate.

2. BACKGROUND

2.1. 1930-1988

As a matter of fact, Brazil began to formalize its environmental policy in the 1930s, with the main goal of organizing the use of its natural resources.[1] However, only in the second half of the 20th century was there more effective action, mainly in response to pressure from international organizations such as the World Bank and the United Nations.

One should not, however, assume the interference of international bodies in Brazilian environmental policy as something fortuitous, exempt, or even limited to the scope of the question itself. There were interests at stake, and they were relevant in the performance of those organizations with Brazil. For example, the pressure exerted by such organizations over Brazil on the Amazon question kowtowed much more to U.S. economic interests than to the purported purity of intentions (Bandeira, 1978).

Initially linked to development policies, environmental demands became independent, especially from the end of the 1960s onward, even acquiring a critical tone to the so-called developmentalism, proposing the cessation or deceleration of the process of industrialization and urbanization of the periphery, which resonated in his discourse both in the post-1968 environmental discourse and in the policy of containment of Latin America, established in U.S. foreign policy since the mid-1960s.

The first initiatives considered the environmental issue tangentially, focusing on the exploitation of natural resources, from the point of view of the efficiency of the use of these resources. The first legislation aimed at the administration of natural resources was the Water Code (Decree n.24.643/1934), under the control of the Ministry of Mines and Energy (MME), due to the interest in hydroelectric power generation; the Forest Code (Decree n.23.793/1934), initially linked to the Ministry of Agriculture with a focus on soil protection for agricultural use and the Law on Protection of Fauna (Law No. 5197/67).

Throughout the period, despite the changes in the Brazilian political scene, the position of the governmental authorities presented a strange constant, marked by a solemn and respectful space given to manifestations of dissatisfaction with the Brazilian position, answered with an equally respectful silence. Meanwhile, granted or promulgated, the legal text was established.

The policy of establishing environmentally protected areas (PAs) began in 1937, with the creation of the Itatiaia National Park. From then on, several national parks were created, whose administration and inspection were submitted to the Federal Forest Service, an organization linked to the Ministry of Agriculture.

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1 Part of the existing historiography, particularly rooted in the colonial and imperial period (1822-1889), attributes, anachronistically, the existence of favors from the Brazilian monarchy to causes that are now considered "progressive," such as environmental issues. However, the lack of documents and the logical problem of assigning a progressive mentality to a political system based on slavery and subordinate to the international division of labor are not enough to prove such thesis. The mentioned historiography still tries to reproduce itself today by simple self-reference, which justifies our choice here to summarily discard it based on previous arguments. Hence, the beginning of the formalization of environmental policy in Brazil begins at the start of the Vargas Era (1930-1945), since the First Republic (1889-1930) followed the same political path of the empire in relation to such questions. (Carone, 1971, 1977, 1979, 1985).

In 1967 the Brazilian Forestry Development Institute (IBDF) was created, also linked to the Ministry of Agriculture. Subsequently, the management of PAs became subordinated to IBDF, which was also responsible for compliance with the Forest Code and all legislation related to renewable natural resources.

In the 1970s, the *Limits of Growth Report* was published by the Club of Rome and the Massachusetts Institute of Technology (MIT), which highlighted concerns about the depletion of natural resources (Moura, 2015a). In 1972 the Stockholm Conference was organized by the United Nations Conference on the Environment. Brazil participated in the conference with a position of defense of national sovereignty, as it was argued that the economic and population growth of developing countries should not be sacrificed and that developed countries should pay for efforts to avoid environmental pollution—a position advocated by the countries of the so-called third world.

In 1973, the first institution to deal with environmental issues at the federal level was created: the Special Secretariat for the Environment (SEMA) linked to the Ministry of the Interior. SEMA's agenda focused on the problem of controlling industrial and urban pollution, with action limited to verify complaints. The IBDF continued to function as a body to promote actions for forests and management of PAs (Conservation Units, UCs).

In the 1980s, the National Environmental Policy was created (Law No. 6,938/81), which created the National Environmental System (SISNAMA) and established the principles, guidelines, instruments, and attributions for the various public agencies that were active in national environmental policy. In general, federal environmental norms approved in the 1980s were mainly related to institutional organization, pollution control and environmental degradation, and strengthening social participation mechanisms in the environmental area (Moura, 2015a).

2.2. From the 1988 Constitution to Agenda 21: 1988-2002

One of the topics of the political agenda of Brazilian democratization in the mid-1980s was the issue of natural resource management (Moura, 2015a). When the new constitution was enacted in 1988, an Environmental Chapter (Art. 225) was established that defined the "ecologically balanced environment" (Art. 225, caput) as a citizen's right, specifying several activities to be developed by the public authority with a view to its guarantee. The Federal Constitution of 1988 also presented other references, such as property rights, urban management, and water resources management. However, for such guidelines to be put into practice, it would be necessary to create specific laws and regulations, some of which have never been fully developed.

Several new public institutions were created, such as: the Superintendency of Fisheries Development (SUDEPE), the Rubber Superintendence (SUDHEVEA), the Brazilian Forest Development Institute (IBDF), and the State Secretariat for the Environment (SEMA), all around the main federal body—namely, IBAMA, Brazilian Institute of Environment and Natural Resources (Law n.7.735, of February 22, 1989).

In 1990, the Secretariat of the Environment of the Presidency of the Republic (SEMAM/PR) was created, as the environmental issue gained international visibility and also with the prospect of organizing Rio-92 in Brazil. Brazil prepared for the conference through the Inter-Ministerial Commission on the Environment (CIMA), coordinated by the Ministry of Foreign Affairs (MRE), with representatives of 23 public agencies, which resulted in the elaboration of a report that explained the Brazilian position on environmental issues.

It is remarkable that, following the institutional pattern of the development model in peripheral countries, several agencies and even some key members of Brazilian development have at some point mentioned the environmental issue, from the Superintendency of Development Northeast (SUDENE), created in 1959 by and for Celso Furtado, to the governments of the military dictatorship (1964-1985). The broad political scope of the use of the term also shows its semantic emptying, especially with regard to the actions and policies of the state. It is possible to observe a certain continuity in this way such that the state receives reflection on the environmental issue in the postdictatorship period, and even after the promulgation of the so-called Citizen Constitution of 1988. But it is necessary to consider the external pressure on Brazil, which holds a large portion of the planet's natural resources. The external tactic at that moment would be to involve Brazil in a "global" discussion about the environment. Brazil, then, would be entrusted with the task of organizing Rio-92.

Rio-92 (United Nations Conference on Environment and Development, UNCED) was held in Rio de Janeiro in 1992. Important environmental agreements were signed at the conference that still reflect its influence today:

i) the Climate and Biodiversity Conventions
ii) Agenda 21

iii) the Rio Declaration on Environment and Development
iv) the Declaration of Principles for Forests

It is important to note that this reflects much more an external demand from international agencies than from the part of their political backroom boxes at the United Nations, or even less in Brazil. On the other hand, domestic authorities seem to have maintained the consolidated response in previous decades: to assimilate the language, to agree with the guidelines, and to leave it to the remote future. In spite of incidents that have gained international recognition, such as the assassination of the political leader of the Amazonian rubber tappers Chico Mendes at the time, the institutional action of the government in the matter, would seldom leave the movement of offices until the end of the century.

The Ministry of the Environment (MMA) was created in 1992 with the extinction of SEMAM/PR. In that decade, the MMA operated with few human and financial resources, most of which was financed by the World Bank, the Inter-American Development Bank (IDB), and the United Nations Development Program (UNDP). Only six years later, in 1998, there would be a first practical result: the Law of Environmental Crimes (Law n.9.605/1998) was granted. With this, Brazil become one of the few countries to have an environmental criminal law.

The National Environment Program (PNMA) began operating in 1991, with a first large investment from the World Bank. The program is still in force and focuses on improving the performance of environmental agencies. Its first phase of action (1991-1999) aimed to build the administrative structure of IBAMA and the MMA, with the main goal of enforcing the management of federal UCs, aimed at the protection of ecosystems such as the Pantanal, Atlantic Forest, and Coastal Zone.

In 2000, the National System of Nature Conservation Unit (SNUC) was created (Law 9.985/2000), aiming to take care of the UCs. In the same year, the second phase of PNMA started, which was extended until 2006, and worked on two main lines: integrating environmental asset management and state institutional development. The focus was on environmental licensing, water quality monitoring, and coastal management.

From then on, the focus would be on the generation of economic instruments for environmental management, environmental monitoring, and environmental licensing. If on one hand this reflects a maturation of the character of environmental policies in the country, on the other hand it also generated a tax-based thinking on the part of the public managers involved in the subject (poses the possibility of generating revenue in an environment of pressure by the reduction of public expenses) and a true bureaucracy industry linked to environmental reporting, which in a country with a secular history of patrimonialism and corruption such as Brazil would led to obvious results in the sense of a certain demoralization of the institutions created for that purpose.

In 2002, the Rio + 10 Environmental Conference was held in Johannesburg, South Africa, with one of the main objectives being the evaluation of agreements ratified in Rio-92. At the meeting, the issues of coping with poverty dominated the debates. The main focus of the conference was climate change (Clean Development Mechanism, CDM, Kyoto Protocol) and renewable energy sources. The logical response of the agents to the general political movements was the expected one: evaluation of the commitments made in 1992, recognition of the shortcomings, ratification of the objectives to be achieved, and new commitments assumed in the same degree as the previous ones.

Also in 2000, the National Water Agency (ANA), linked to MMA, was created to implement the National Water Resources Policy (Law No. 9.433/97) with the objective of managing the river basins and monitoring rivers and the use of water.

The Brazilian Agenda 21, whose preparation began in 1997, was only launched in 2002 and did not fulfill its role of directing Brazilian environmental policy and guiding development policies for the country.

Between Rio-92, Agenda 21, and Rio + 10 there is an international and economic policy context that provides some insight into the effectiveness of institutional actions. Between 1992 and 2002, there were at least two major global financial crises (in 1994 and 1997), with very serious effects on the Brazilian economy (especially in 1998-1999, when the country suffered a severe currency crisis). In 1999, economic authorities such as Finance Minister Pedro Malan acknowledged that the country was fiscally paralyzed until 2002, the next electoral year (Lesbaupin and Pinheiro, 2002). The impact of the fiscal stranglehold resulting from the pressure of international usury and the government's recessive and surrender policies of the period—to a greater or lesser extent of intensity—would greatly affect the effectiveness of actions on the environmental issue.

2.3. The Lula Era: 2003-2016

With the election of Luis Inacio Lula da Silva for the presidency in 2002, a unique period began in the history of Brazilian environmental policies. Despite the commitment at the first hour to the interests of financial capital, agribusiness, and the primary export industry,[2] there was real political autonomy in the participation of MERCOSUR and BRICS in international politics.

The economic model—characterized by economists such as Bresser Pereira as neodevelopmentalist—guided an economic policy that could be basically characterized as a simple Keynesian model of economic growth, which would be complemented by income distribution policies (Paula, 2003; Sicsu, 2013; Souza, Previdelli, Silva Neto, 2010). This theoretical foundation of economic policies was based on a rather precarious political balance, for a progressive government; as proposed by the Lula (and Dilma) government, it was the so-called coalition presidentialism in which sectors related to archaic structures and reproduction of underdeveloped structures of the country (i.e., large state owners, lagging productive social relations, financial industry plundering, and judicial autocracy) would give the government "sustenance and governability," as long as they did not threaten its condition.

This kind of balance usually does not last long and ends in quite dramatic ways, as one can see in the history of Latin American countries since their independence. On the other hand, it can be argued that both the Lula and Dilma governments (2003-2014) could hardly be viable without such a coalition, which can be based on the speed at which the second Dilma government (2015-2016) became unfeasible and was deposed, as the above-mentioned perpetrators of the archaism and underdevelopment found political exit from continuity, without the need to follow the concessions with the strategic project of Lula-PT. In this sense, it is possible to characterize this period as a brief progressive break, in which some practical measures can be observed along with some institutional development, which in the end suffers a setback, by way of a coup, and return to the position previously consolidated. The following movements reside in the scenario outlined.

In 2007, the Chico Mendes Institute for Biodiversity Conservation (ICMBio) was created, an entity linked to MMA that emerged from the dismemberment of IBAMA as a separation of functions between the two bodies. IBAMA focused its activities on licensing and inspection actions while ICMBio was responsible for managing the UCs, a total of 887 units of integral protection and sustainable use, about 754,854 square kilometers of Brazilian territory.

In 2012, the Rio + 20 Conference (UN Conference on Sustainable Development, UNCSD) was held in Rio de Janeiro. The conference marked the 20th anniversary of Rio-92 and had the following objectives:

(i) ensure renewed political commitment to sustainable development,
(ii) assess progress in the implementation processes of key sustainable development decisions, and
(iii) identify new and emerging challenges.

Two objectives were also established: an economy for sustainable development and poverty eradication and an institutional framework for sustainable development.

Considered the largest event ever held by the United Nations, Rio + 20 counted the participation of about 190 countries although it occurred in an unfavorable international context, as several countries were in an economically depressed environment: Europe in financial crisis and the United States in the process of presidential elections did not give priority to the conference in its agendas—the American president and the German chancellor were expected until the last day but did not attend, only sent representatives. Moreover, the United Nations system itself had been eroding its real power. Thus, Rio + 20 was not successful. (Moura, 2015b).

The results of the conference were generally analyzed as insufficient and even disappointing. The final document approved at the conference, *The Future We Want*, did not make binding commitments and was

2 What can be seen in the document "Carta aos Brasileiros," at https://www1.folha.uol.com.br/folha/brasil/ult96u33908.shtml, link seen on 07/22/2018, at 18:53.

considered as a declaration of intent, or the "least common denominator," to be reached among the 188 signatory countries. Within the analysis made to date of environmental policies, this result follows the established standard. On the one hand, although there are effective glimpses in the policies adopted by the Lula and Dilma governments (2003-2016) regarding advances in the environmental issue, the long-term structural movement did not observe change, which, to some extent, favored the setback that would follow.

On the other hand, the effective interest of international pressure—coming from the central countries—for control of Brazilian natural resources was not contemplated during the period. The same small ears offered earlier were at the table, courtesy of the efficient Brazilian foreign policy in the period, headed by foreign minister Celso Amorim.

As of 2010, changes in the international context will have a reflection on the Brazilian political environment (Pereira, 2017; Souza *et al.*, 2010). The Brazilian peripheral participation in international politics was seen as an inconvenience by the dominant center countries. At the same time, the cycle of commodity expansion, largely dominated by China, would be inflected, reflecting the international financial crisis of 2011, which marked a counter cyclical period in the expansionary phase of the Brazilian economy that started in 2005.

On the other hand, the development model in use by the Brazilian economy went through a deadlock that could be called "supply adjustment." Considered as a simple Keynesian model, the first movement of demand expansion toward the level of effective demand, leading the economy toward full employment, should be accompanied by an adjustment of aggregate supply in favor of marginal capital efficiency and investment stock, to achieve economic growth at a higher level of income, with stability and without price fluctuation. In order to do so, it would be necessary to carry out progressive fiscal policy and restructure the ownership of productive assets, which would mean tax and agrarian reform beforehand, questions that would prevent the continuity of coalition presidentialism agreed by the reformist government elected in 2002. The popularity of the Lula/Dilma governments seemed to favor the reformist strategy within the democratic game. The reformist strategy, therefore, seems to have forgotten that the democratic order is bourgeois, and that the interests of capital subvert order when it does not suit it.

These two factors would lend the substratum to the rise of political forces contrary to the seemingly dominant developmental perspective since 2003. Dilma Rousseff's victory in the 2014 presidential elections would not prevent a fierce rise of more reactionary and backward looking (in environmental terms too) political force in more than half a century of history. It is embedded in the political commitments made for reelection, with a parliament in agribusiness, evangelical Pentecostalism, and arms sales (the so-called BBB bench: ox, bible, and bullet). As a result, the first president elected in the last country to abandon slavery as a form of work would be blackmailed permanently by a judiciary force politically committed to the task of overthrowing the reformist government. It is even admirable that the president was able to remain in office until being deposed in 2016, in a process that later acknowledged that there was no factual evidence or proof against her—another blow that would be added to the historical dump of Latin America, with direct interference of U.S. diplomacy and participation of international organizations that defend imperialist interests.

The environmental issue, from the beginning of the second Dilma Government (2014-2016) was completely paralyzed. From the coup of 2016 onward, the silence on environmental issues is no more embarrassing than the work of the coup government until now (2018). Institutional advances in a number of areas ceased and retreated to the situation prior to 1930. Labor legislation, for example, was simply suppressed in collusion between government and congress. Scandals have become a daily issue, with disasters marked by impunity, such as the case of SAMARCO, an environmental disaster that destroyed the ecosystem of the Rio Doce Basin in Minas Gerais, to cite a closer example of the environmental issue. The following indicators show in quantitative terms, also in the environmental issue, the dramatic situation that the coup of 2016 brought to Brazil.

3. FEDERAL EXPENDITURES WITH ENVIRONMENTAL MANAGEMENT

The monitoring of public expenditures on the environment, or so-called environmental management, is a good measure to evaluate the relevance that the topic occupies in the agenda of the country, as it indicates the direction of state action, in environmental matters, as a whole on public policies, and the position that the subject occupies in the dispute between diverse topics of interest.

Table 1. Federal Government Expenditures with Environmental Management (2009-2017).

Year	Reais (1)	%GDP (2)	Anual variation
2009	3,526,300,000.00	0.106%	nd
2010	3,872,000.00	0.100%	−99.89%
2011	3,952,000.00	0.090%	2.07%
2012	4,363,800.00	0.091%	10.42%
2013	5,056,000.00	0.095%	15.86%
2014	3,677,900.00	0.064%	−27.26%
2015	3,695,200.00	0.062%	0.47%
2016	3,510,000.00	0.056%	−5.01%

Source: Elaborated by the authors with data from IPEADATA, Transparency Brazil and MMA. (1) in millions of Reais, (2) percentage of gross domestic product at market prices.

In the 1990s, research on environmental expenditures in Brazil resulted in the production of several studies. However, these have been done in an unsystematic way (limited periods) and with different methodologies, which do not allow a comparison between the studied periods and also do not allow the formation of historical series.

For the present paper, data from the official budget of the MMA and the Ministry of National Integration were used, as they are the main managers of environmental policies. In addition, data from the World Wide Foundation (WWF) document, prepared in conjunction with the Open National Accounts on the theme, and data of from the Transparency Portal of the federal government were used.

In concrete financial terms, Table 1 displays the expenditures in terms of the federal government budget for implementing environmental policies from 2009 to 2017.

The first element reported by the data is the drop in the percentage of environmental management expenditures as a proportion of the gross domestic product (GDP) after 2010. From 2013 on, this decrease becomes more pronounced in relative terms, from 0.1% of GDP to 0.6%, showing the priorities of the coup staff in terms of economic policy and long-term development objectives. The fall, by what is observed in absolute terms, by annual variation, becomes more pronounced in 2016, stabilizing the new level of public spending with environmental management in 0.6% of GDP. The setback is clear.

Regarding 2018, the expenditures authorized for the MMA and its municipalities, such as IBAMA, ICMBio, ANA, and the Brazilian Forest Service, were R$ 3.7 billion. The amount is lower than that authorized by law by the National Congress for 2017 (R$ 3.953 billion) and even lower than the authorization of expenses granted in 2013 (R$ 5.056 billion), the best year of the decade in values adjusted for inflation.

According to the study released by the WWF-Brazil in partnership with open accounts, budget programs and actions that deal with PAs had a budget of R$ 236 million for 2018, against R$ 252 million in 2017. The budget for programs that support the creation, management, and implementation of PAs was hardest hit and lost resources in the Congress decision in relation to the government's proposal. Thus, ICMBio, mainly in charge of PAs, had R$ 708 million in the 2018 budget, against R$ 1.256 billion in authorized expenditures in 2017, a 44% reduction. The value that ICMBio has this year is already lower than the total payments registered in 2017.

The deepest cut hit the Bolsa Verde, a program that pays R$ 300 (about US$ 80) every three months to extremely poor families living in PAs areas as an incentive to conservation. Bolsa Verde disbursed R$ 61.7 million in 2017, R$ 78 million in 2016, and R$ 106.1 million in 2015. This program has been losing resources in the last years, and it disappears in the 2018 budget, as proposed by the Executive, and accepted by Congress. The government said it would pass on the Bolsa Verde to the Amazon Fund, which also suffered significant cuts as a result of increased deforestation in the Amazon Area (http://bit.ly/orcamento-wwf).

ANA also lost resources in relation to the 2017 budget. The proposal for the implementation of the National Water Resources Policy falls from R$ 181.7 million to R$ 136 million in 2018.

The deforestation control program was also affected. Under the management of the Ministry of Science, Technology, Innovation and Communications, monitoring of deforestation in the different areas had, in 2018, a budget of R$ 3.2 million for satellite monitoring, against R$ 4.3 million in 2017, lower than in 2015 and 2016. The National Institute of Space Research (INPE) is responsible for the data that guides the fight against deforestation in Brazil and works together with IBAMA (Brazilian Institute of Environment and Natural Resources).

In relation to the Brazilian Forest Service, the approved budget was R$ 8.1 million in 2018, against R$ 8.6 million in 2017. In 2015, the amount spent on this program alone reached R$ 68 million. This shows the loss of political will to fight deforestation.

An important source of funds to combat deforestation in the Amazon region, the Amazon Fund was targeted in 2017, and its impacts will appear in 2018. The government of Norway reduced to less than half the annual pass-through of funds to the Amazon Fund, managed by the National Bank of Economic and Social Development. In December 2017, the Norwegian government transferred US$ 41,791,000 to the fund, about 43% of the amount transferred in December 2016, from US$ 97,953,000 (Amazon Fund, 2018). In a note, the Norwegian government attributed the reduction of the pass-through to the increase in deforestation recorded in Brazil between August 2015 and July 2016. In October it reaffirmed: this year's payment for reduced deforestation will be less than half the amount passed to Brazil, that contributions to the fund depend on the effective reduction of carbon emissions from deforestation (Norway Government, 2017).

Norway is the main donor to the Amazon Fund. By the end of 2016, it had contributed 97.4% of the R$ 2.8 billion deposited in the fund since the beginning of the operation, seven years before. The German government and Petrobras contributed the rest. Of the total deposited, R$ 1.4 billion was disbursed to finance projects to combat deforestation and sustainable forest use.

The other international environmental cooperation agreements totaled approximately US$ 400 million in the last decade, according to the Brazilian Cooperation Agency, linked to the MRE. The resources came mainly from the World Bank, the Global Environment Facility (GEF), and the European Union, according to information obtained on the WWF Brazil website.

4. CONCLUSION

The 2016 coup affected not only Brazil's international image and its economic and social development but also the morale of its most progressive political forces. The impact of the reaction and the regression on an even limited advance on the historical distributive conflict that motivated previous coups in the history of the country has been difficult to assimilate by those who wish to see the country occupy an autonomous position in the international order. The opportunity for the increase of control by the central countries over Brazil's natural resources is becoming more feasible after the initial surprise that followed the success of the coup. The situation demands urgent reversal, even for the resumption of the course of the environmental policies before it, although relatively timid, but comparatively superior to its antecedents and impossible in comparison with the absence marked by the present ones.

The history of the Brazilian government's relations with the environmental issue shows that, until 2003, the usual strategy was to use the debate to build a domestic institutional environment for the discussion of possible policies, at best. From 2003 to 2010, these policies materialized in public expenditures that reached 0.1% of the GDP, still insufficient to supply all environmental demands, but superior to their antecedents, where such cost was not even present. And such expenditure is more than double the one that can be found in the coup government that uses the fiscal austerity policy as an excuse to cut deep in the majority of projects in the environmental area. The loss of resources, widespread in strategic sectors as well, such as Education and Health, marks a clear strategy of the coup government in power since 2016. The mentioned strategy could be summarized as: favoring external agenda, disabling the institutions created between 2000 and 2007, and relaxing control over the misuse of natural resources by extinguishing the MMA through budgetary asphyxia. Such an agenda has clear interests and beneficiaries, which are being disseminated with increasing intensity.

As a final note, it is interesting that there are no international groups that declare themselves as supporters to the 2016 coup in Brazil. Not that there are no beneficiaries among them, such as the groups interested in exploring the natural resources of the country, resources that the coup government have already allowed the foreign companies to explore at ridiculous prices as one can see in the Pre Sal auction. But perhaps these agents bear the reminder that history is not condescending to those who promote delay, deliberately and out of pure self-interest. The coup will be reversed, at some point, with the possibility of consequences to the agreements made in a state of exception. Hence the silence, even discomfort, of the supporters of the 2016 coup in Brazil.

As a matter of fact, the former president Lula continues, even as a political prisoner, as the most strong and eligible candidate. There is even the possibility of social upheaval if his political prison is sustained for a long time. This last possibility becomes increasingly risky as time passes.

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Green Energy as a Driver for Green Economy and Organizations' Sustainability

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Abstract

Since the last decade, the concepts of green innovation and green economy have become more and more attractive to researchers and policymakers. This research brings some light to the association of those themes with the concept of green energy. Therefore, this paper is a critical review of the green innovations directed explicitly to the green energy challenges faced by organizations and the world economies. The research question is as follows: What are the main dimensions of a model to implement a green innovation process focused on green energy in organizations? The methodology used to answer the research question was qualitative, and the main techniques included a systematic literature search and survey. The main findings of the study were the identification of the most relevant dimensions of a green innovation model to be implemented in organizations. The article structure is based on the different concepts about innovation and green innovation, related to the green economy, and the analysis of two situational cases on green energy. Finally, we present the analysis made on the articles identified by the literature survey and the green innovation model. By making this research on green economy and related concepts of green innovation and green energy, this paper seeks to make a valid contribution to their definitions and for operationalizing the green innovation model in organizations.

Keywords: Green economy; Green innovation; Green energy; Organizations; Literature review; Case studies.

1. INTRODUCTION

Managerial and technological innovation enables enterprises to boost their leverage against competitors and to achieve desirable revenue streams, to acquire and retain market share. The internal development initiatives and capabilities of firms have been found to play a crucial role in green innovation (Zailani *et al.*, 2015) (Huang *et al.*, 2016). To strengthen their brand-positioning capabilities, firms are pursuing a green innovation approach to achieve economic and organizational sustainability with a circular economy business model.

This paper begins by stating what is green innovation, what for it can be used, and how organizations can become greener. For this purpose, it includes a systematic literature review of internal and external challenges that enterprises may face while implementing and developing a green innovation culture, their engagement with stakeholders, segmentation as well as social, economic, and ambient externalities.

With the intent to understand theories of innovation, namely the green innovation, two case samples of REN - Redes Energéticas Nacionais, SGPS, S.A. (Euronext: RENE.LS) in Portugal and Carbon Recycling International (CRI) in Iceland are mentioned, to perceive the contrasts and competitive advantages differences between these two significant enterprises: first, in terms of business opportunities that arise from a sustainable use of natural resources, strategically leveraged with credible research and development (R&D) projects and second, the importance that engaging with international business networks have to create valuable intellectual property.

2. THE GREEN INNOVATION PROCESS

2.1. Innovation Theories

The literature on innovation theory shows that innovations occur mostly within the national system of innovation (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997). However, another perspective was studied by organizational academics in innovation in organizational microsystems (Van de Ven, 1986; Aldrich and Fiol, 1994; Van de Ven *et al.*, 1999; den Hertog and Huizenga, 2000): the literature shows that the concept of innovation is very complicated, which makes it difficult to have a single definition. The Green Book on Innovation from the European Commission (1996) defines innovation as "the successful production, assimilation and exploration of something new." Mulgan and Albury (2003) made their contribution to the concept indicating the importance of the innovation implementation results: "new processes, products, services and methods of delivery which result in significant improvements in outcomes efficiency, effectiveness or quality."

Leadbeater (2003) exposes the complexity of the concept, including its interactive and social dimensions: he argues that "the process of innovation is lengthy, interactive and social; many people with different talents, skills and resources have to come together." The literature assumes various categorizations of innovation. OECD (2002) structures the concept around three areas: (i) the renewal and broadening of the range of services and associated markets; (ii) the creation of production, procurement, and distribution methods; (iii) the introduction of changes to management, work organization, and workers' qualifications. Baker's (2002) typology also differentiates three types of innovation: (i) process, (ii) product/service, and (iii) strategy/business. Process innovation (i.e., work organization, new internal procedures, policies, and organizational forms) and the strategic and new business models (i.e., new missions, objectives, and strategies) are called organizational innovation.

OECD's (2002) organizational innovation includes three broad streams: (i) the restructuring of production and efficiency processes, which include business reengineering, downsizing, flexible work arrangements, outsourcing, greater integration among functional lines, and decentralization; (ii) human resource management practices, which include performance-based pay, flexible job design and employee involvement, improving employees' skills, and institutional structures affecting the labor-management relations; (iii) product/service quality–related practices emphasizing total quality management and improving coordination with customers/suppliers (Table 1).

2.2. Green Innovation for a Circular Economy

Schiederig, Tietze, and Herstatt (2012) clarified green innovation and sustainable development through a comprehensive literature review of the matter, in its different interpretations by the academia, and the authors identified six critical aspects: (i) innovation object, that is, products, services, or processes; (ii) market orientation, meaning satisfying the needs and to be competitive; (iii) the environmental aspect, in which the optimal level corresponds to inexistent negative externalities; (iv) phase, meaning that the full product life cycle must be considered, namely, the recycling stage; (v) impulse, the degree of compliance in the operations with the green innovation vision of the enterprise; (vi) level to which the company is willing to invest in R&D for new technology and green standards.

Table 1. Types of Innovation.

Production and efficiency practices	Human resources management practices	Product/service quality
• Business reengineering • Downsizing • Flexible work • Outsourcing • Greater integration among functional areas • Low degree of centralization	• Performance-based pay • Flexible job design and employee involvement • Developing skills • Labor-management cooperation	• Total quality management (TQM) • Improving coordination with customers/suppliers • Improving customer satisfaction

Source: Gu and Gera (2004).

Saunila, Ukko, and Rantala (2018) analyzed what drives green innovation investment and exploitation with regard to sustainability, and their theoretical contribution is as follows: (i) the more a company relies on economic, institutional, and social sustainability, that is, circular economy, the more likely is willing to invest in R&D or implementation of green innovation in their operations; (ii) higher estimates of an increase in the institution and financial sustainability of the organization, more willing it is to exploit green innovation; (iii) the valuation of environmental sustainability was not correlated to the rate of investment in or to exploit green innovation. Therefore, organizations are most willing to invest in green innovation if it contributes to their enterprise value instead to invest in the same technology for a positive environmental contribution. Another aspect that has been found to be significant in attaining green innovation is the element of social recognition, which according to Doran and Ryan (2012) concluded that firms are willing to pay to brand themselves as eco-friendly.

Jacobsen (2006) explained the concept of industrial ecology, which comprehends the tangible benefits of recycling residual wastes from production systems. Aligned to this vision is the core element of the circular economy in which from the usual end point of industrial waste (materials to be disposed and destroyed either with artificial methods or naturally), can be reutilized by enterprises on their production systems, moreover, decreasing the use of virgin raw materials for the economic activity (Andersen, 2007). However, aligning a green innovation approach to a circular economy business model is a challenging mission on a hypercompetitive and globalized economic environment: therefore, the operations and executive decisions of an enterprise must capitalize the investments made on R&D, up to the point that it becomes viable to be commercialized. To understand how a company might incorporate a green innovation culture while pursuing the organizational sustainability, it will be analyzed what is done by REN in Portugal and by CRI in Iceland. Moreover, it analyses the importance of the green innovation enterprises for a circular economy.

The innovation processes are influenced and facilitated by the way an organization is structured, mainly, by the way, the top management perceives its meaning (Sousa and Martins, Innovation Competencies to Potentiate Global Trade, 2018). Considering the top-managerial element defining the operations and compliance with the mission and vision of an enterprise as defined by the shareholders, the following table reflects necessary managerial aspects of green innovation: (i) the top management innovation sponsorship, green corporate culture emphasis, and support in its implementation, (ii) R&D and technology such as intellectual property, (iii) stakeholders (Table 2).

2.2.1. The Example of REN in Portugal

REN supplies and delivers natural gas and electricity to Portugal. The company is responsible for the transportation of high-pressure natural gas and the technical management for the Natural Gas System in Portugal, in regards to its reception, storage, and regasification of liquefied national gas and its underground storage. Simultaneously, concerning electricity, it maintains the technical needs of the National Electricity System of

Table 2. Green Innovation Corporate Aspects.

Top management innovation sponsorship	Research & Development (R&D)	Stakeholders
Created a separate department/unit specialized in environmental issues related to the organization	Investment in low-carbon technology for the production processes	Engagement with business networks
Segmentation for the environmentally conscious consumers	Investment in R&D for pro-environmental products/services	Dialogue with the stakeholders about externalities
The enterprise absorbs the extra cost of an environmental product/service	Use recycled or reusable raw materials in the production system	Use of specific environmental policy for selecting partners
Efforts are made to use renewable energy sources in the production system	Implementation of research to detect green innovation needs in the market	Use of international consortiums' research funds

Table 3. Projects Codeveloped and Funded by R&D Nester.

Project codename	Project details	Funding scheme
ISSWINDEMO	"Integrated Supporting Services for the Wind Power Industry Demonstrator." (European Space Agency, 2016)	European Space Agency (ESA)
SUSCITY	"Urban data-driven models for creative and resourceful urban transitions." (SusCity, 2016)	(i) Fundação para a Ciência e Tecnologia (FCT) (ii) Ministry of Education and Science—Portugal (iii) EDP (iv) ADENE (v) R&D Nester (vi) Novabase (vii) ITds
SMARTNET	"The SmartNet project arises from the need to find answers and propose new practical solutions to the increasing integration of Renewable Energy Sources in the existing electricity transmission network. The subsequent technological (r)evolution is not only affecting the structure of the electricity markets, but also the interactions between TSOs and DSOs." (SmartNet, 2018)	Total cost = EU contribution: €12,657,928.00 European Commission—Horizon 2020 22 partners from academia, research organizations, and industry from 9 European countries
BigDataOcean	"Aims to enable maritime big data scenarios for EU-based companies, organizations and scientists, through a multi-segment platform that will combine data of different velocity, variety and volume under an inter-linked, trusted, multilingual engine." (EU Publications Office, 2017)	European Commission—Horizon 2020 Total cost: €3,566,172.50 EU contribution: €2,998,569.50 Coordinated in: Greece 10 partners

Portugal. Moreover, while maintaining its core portfolio, REN has total ownership over Enondas, S.A., a company that received a concession given by the Portuguese government to operate a pilot area with the goal to generate green electricity from the sea waves. With the green sustainability as a long-term strategy for the energetic system of Portugal, REN produces wind energy with its turbines spread over the Portuguese territory.

To pursue the strategic innovation business model of REN, the necessity for credible R&D projects with tangible results and by the inevitable need to secure financial assets for such investments, a significant consortium was made between the Portuguese company and the Chinese to build R&D Nester, based in Lisbon, the capital of Portugal, "Centro de Investigação em Energia REN—State Grid, S.A.," with 50% of its shares owned by REN and the remaining by the State Grid Corporation of China (SGCC) via the China Electric Power Research Institute (CEPRI; Table 3; R&D Nester, 2018). Moreover, the goal was to synergize intellectual capital to promote and implement applied research in an international innovation context for smart and green energy systems.

As a result of strong R&D investments and green innovation corporate aspects (see Table 1), REN renewables production supplied over 60% of the electricity consumption in Portugal for the first quarter of 2018. REN published its net profit for the first quarter of 2018, resulting in €13.1M, an EBITDA of €128.4M, and a year-over-year increase of 3.8%, reflecting the integration of Portgás in its consolidated portfolio: Portgás per se contributed positively to the EBITDA with €10.9M (REN Press Release, 2018). This acquisition among others provides the means for REN to continuing pursuing R&D for a greener technology and business model, which can only be made through (i) top management innovation sponsorship, (ii) technology, research & development (R&D), and (iii) stakeholder engagement.

2.2.2. The Example of CRI in Iceland

CRI aims to recycle CO_2 from other businesses so that it can be transformed into liquefied fuel for vehicles specially designed for this type of energy. CRI named its first plant as George Olah, in honors to this author's publication entitled "Beyond Oil and Gas:The Methanol Economy." Presenting this enterprise example rather than exploring technological procedures will showcase the importance of stakeholders for the CRI R&D as well as some of the accomplishments of these consortiums.

According to Sousa and Martins (2018), "the creation of a business environment conducive to innovation necessarily involves the creation of a culturally open environment to receive new initiatives, the formation of new skills for innovation and technological development in companies and the business environment. This is a scenario that has to be built by all actors involved in the economic and social processes of the country." The aforementioned George Olah plant is located in the proximities of the Blue Lagoon in Iceland, which is a thermal silica-infused water spa, for its emissions of carbon dioxide. Moreover, through the recycled geothermal energy from the same infrastructures that supply for the city of Reykjavik, the capital area, CRI can acquire its raw materials at a low cost compared to other European companies. The executives of this enterprise certainly understand that to contribute for a circular economy as a green innovation company, taking advantage of the low-cost prices that a circular economy can afford, would be the astute approach to partially financially leverage CRI in its continuous operations.

Nonetheless, this strategy per se does not deliver economic viability for their operations, nor sustainability: CRI did not have an IPO, at least yet, and its R&D is of such complexity that it requires financial, productive, and commercial partnerships. The company's expansion plans included an increase from its current 5 million liters of fuel a year to 10 times larger in China, through CRI Ji Xin, a joint venture that CRI Iceland

Table 4. Three European Union–Funded Projects of CRI.

Project codename	Project details	Stakeholders
MefCO2 (EU Publications Office, 2016)	Synthesis of methanol from captured carbon dioxide using surplus electricity From December 1, 2014, to November 30, 2018, ongoing project Total cost: €11,041,537.46 EU contribution: €8,622,292.60 Coordinated in: Spain	I-Deals Innovation & Technology Venturing Services SL—Spain Kemijski Institut—Slovenia Mitsubishi Hitachi Power Systems Europe GMBH—Germany Cardiff University—United Kingdom CRI EHF—Iceland Universita Degli Studi Di Genova—Italy Hydrogenics Europe NV—Belgium Universitaet Duisburg-Essen—Germany
CIRCLENERGY (EU Publications Office, 2018)	Production of renewable methanol from captured emissions and renewable energy sources, for its utilization for clean fuel production and green consumer goods From December 1, 2017, to March 31, 2018 Total cost: €71,429 EU contribution: €50,000 Coordinated in: Iceland	CRI EHF—Iceland
GAMER (EU Publications Office, 2018)	Game changer in high-temperature steam electrolysis with novel tubular cells and stacks geometry for pressurized hydrogen production From January 1, 2018, to December 31, 2020 Total cost: €2,998,951.25 EU contribution: €2,998,951.25 Coordinated in: Norway	Stiftelsen Sintef—Norway Coorstek Membrane Sciences AS—Norway Agencia Estatal Consejo Superior De Investigaciones Cientificas—Spain CRI EHF—Iceland Universitetet I Oslo—Norway MC2 Ingenieria Y Sistemas SL—Spain Shell Global Solutions International BV—Netherlands

incorporated, other than the existent shareholders Geely Holdings and Zixin Industrial Co. Notwithstanding the importance that the foreign capital brought into CRI to maintain its operational costs (the equity acquired by the Chinese investors) there is a contrast in the relationship of CRI with its stakeholders: the European Union partially co-funded R&D projects of CRI without taking part of it as a shareholder (acquiring equity) or receiving any annuities from an European Research. In the end, the intellectual property and revenues, resulted of CRI R&D will belong to the Chinese group, in proportion to its shares. Table 4 lists three of many EU projects in which CRI was an active member. MefCO2 is the project with the most available data about CRI R&D for public access, published in Cordis, the official website of the EU that publishes the mandatory reports for funded projects.

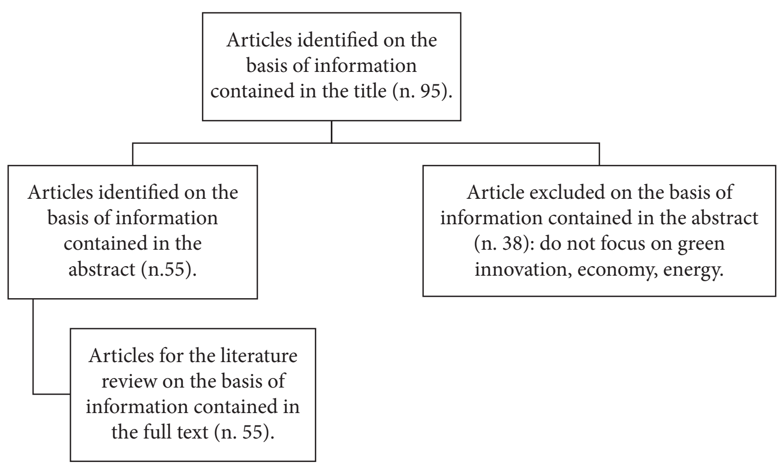
3. SCOPE OF THE REVIEW

A systematic search of online scientific databases using b-on, a scientific information research tool, was conducted in the middle of July 2018. The search was made using several queries, containing the keyword "green innovation." The first results showed 617,641 articles, and if the keyword "energy" was included, 156 articles were listed. Finally, when the publication date criteria was set between "2015-2018" and "Scientific Reviews" included, 95 articles were listed. Only the articles reporting clear empirical data and a scientific methodology were considered for a more in-depth review (55) (Figure 1).

The summary of the articles organized by the research attribute is shown in Table 5.

The green energy attribute is the one with the most articles (34 or 62%), followed by the attribute green economy (12 or 22% of the articles) and, finally, green innovation (9 or 16% of the articles) as presented in Table 2 and Graph 1:

Figure 1. Flowchart Outlining the Literature Review.



Graph 1. Percentage of Articles by Research Attributes.

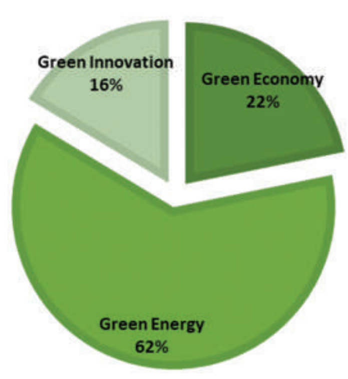


Table 5. Number of Articles.

Research attributes	Articles (N = 55)
Green Energy	34
Green Economy	12
Green Innovation	9
Total	**55**

The analysis of the articles selected can be found in Table 6, which summarizes the research attributes and the major research topics of each selected article for this analysis.

For the analysis, it is essential to state what are (a) green innovation, (b) green economy, and (c) green energy:

(a) **Green Innovation**—Chen *et al*. (2006) defined green innovation as "hardware or software innovation in technology that is related to green products or process, consists of the innovation in

Table 6. Selected Papers for the Literature Review, 2015–2018.

Author(s)/year(s)/title/journal	Attributes researched	Key research topics
Ferrara R. 2015. The smart city and the green economy in Europe: a critical approach. Energies (19961073) 8(6): 4724-4734.	Green Economy	Cities & Towns; Environmental Physics; Europe; Renewable Energy Sources; Urban Planning; Directives; Energy Efficiency; Green Economy; Legal Framework; Regulations; Renewable Energy Sources; Smart City; Soft Law
Holley C. 2016. Linking law and new governance: examining gaps, hybrids, and integration in water policy. Law & Policy 38(1): 24-53.	Green Economy	Biological Adaptation; Cohesion (Linguistics); Government Policy; United States; Water
Thompson NA, Herrmann AM, Hekkert MP. 2015. How sustainable entrepreneurs engage in institutional change: insights from biomass torrefaction in the Netherlands. Journal of Cleaner Production 106: 608-618.	Green Economy	Biomass Burning; Biomass; Collaborative Action; Economic Competition; Entrepreneurship; Institutional Change; Netherlands; Sustainable Development; Sustainable Entrepreneurship; Torrefaction
Rubashkina Y, Galeotti M, Verdolini E. 2015. Environmental regulation and competitiveness: empirical evidence on the Porter Hypothesis from European manufacturing sectors. Energy Policy 83: 288-300.	Green Economy	Competitiveness; Empirical Research; Environmental Regulation; Environmental Regulations; Europe; Innovation; Manufacturing Industries; O31; Porter Hypothesis; Productivity; Q50; Q52; Q55; Q58; Statistical Hypothesis Testing
Pitkänen K, Antikainen R, Droste N, Loiseau E, Saikku L, *et al*. 2016. What can be learned from practical cases of green economy? Studies from five European countries. Journal of Cleaner Production 139: 666-676.	Green Economy	Green economy; Critical factors; Case studies; Practical implementation; Circular economy; Bioeconomy

Continued

Author(s)/year(s)/title/journal	Attributes researched	Key research topics
Hodgson E, Ruiz-Molina M, Marazza D, Pogrebnyakova E, Burns C, *et al*. 2016. Horizon scanning the European bio-based economy: a novel approach to the identification of barriers and key policy interventions from stakeholders in multiple sectors and regions. Biofuels, Bioproducts & Biorefining 10(5): 508-522.	Green Economy	Bioeconomics; Emissions (Air Pollution); Europe; Stakeholders; Sustainable Development; Best-Worst; Best-Worst; Bio-Based; Bioeconomy; Biorefining; Bio-Based; Innovation System; Max-Diff; Max-Diff
Muscio A, Reid A, Rivera Leon L. 2015. An empirical test of the regional innovation paradox: can smart specialisation overcome the paradox in Central and Eastern Europe? Journal of Economic Policy Reform 18(2): 153-171.	Green Economy	Economic Development; Empirical Research; Europe; Eastern Europe; European Funding; O18; O31; O38; Public Spending; R11; R58; Strategic Planning; Regional Innovation Systems; Smart Specialization
Bergquist A-K, Söderholm K. n.d. Transition to greener pulp: regulation, industry responses and path dependency. Business History 57(6): 862.	Green Economy	Environmental Regulations; Paper Industry & The Environment; Paper Mills & The Environment; Path Dependence (Social Sciences); Pulpwood Industry; Sweden—Politics & Government; Sweden; Technological Innovations; United States; Business Strategies; Chlorine-Free; Dioxin; Environmental Legislation; Pulp And Paper (P&P); Technological Path-Dependency; The Us; Transition
Cowley R, Joss S, Dayot Y. n.d. The smart city and its publics: insights from across six UK cities. Urban Research & Practice 11(1): 53.	Green Economy	Bifurcation Theory; Business Enterprises; Government Policy; Great Britain; Smart Cities; Technocracy; Uk; Assemblage Theory; Future Cities; Public; Publicness; Smart Cities
Portney KE, Hannibal B, Goldsmith C, McGee P, Liu X, *et al*. n.d. Awareness of the food–energy–water nexus and public policy support in the United States: public attitudes among the american people. Environment & Behavior 50(4): 375.	Green Economy	Food; Government Policy; Public Opinion; United States; Water Power; Energy–Food Nexus; Public Opinion; Public Policy; Water-Energy Nexus; Water–Food Nexus
Carlet F. n.d. Understanding attitudes toward adoption of green infrastructure: a case study of US municipal officials. Environmental Science & Policy 51: 65.	Green Economy	Attitudes Toward Green Infrastructure; Green Infrastructure (Economics); Industrial Organization (Economic Theory); Innovation Adoption; Innovation Diffusion; Local Government; Municipal Officials & Employees; Technological Innovations; Technology Acceptance Model; Technology Acceptance; United States
Kaledinova E, Langerak T, Pieters R, Van Der Sterre P, Weijers SJCM. n.d. Learning from experiences in sustainable transport practice: green freight Europe and the implementation of a best cases database. Logforum 11(1): 78.	Green Economy	Cost Control; Economic Competition; Europe; Green Freight Europe; Green-Logistic; Innovations In Business; Sustainable Transportation; Willingness To Pay; Green Freight Europe; Green Logistics; Sustainability;

Continued

Table 6. *Continued*

Author(s)/year(s)/title/journal	Attributes researched	Key research topics
Barbose G, Darghouth NR, Weaver S, Feldman D, Margolis R, *et al*. n.d. Tracking US photovoltaic system prices 1998-2012: a rapidly changing market. Progress in Photovoltaics 23(6): 692.	Green Energy	Photovoltaic Cells—Sales & Prices; Pv; Renewable Energy Sources; Solar Energy; Solar Thermal Energy—Equipment & Supplies; United States; Cost; Historical; Photovoltaic; Price; Solar
Verhees B, Raven R, Kern F, Smith A. 2015. The role of policy in shielding, nurturing and enabling offshore wind in The Netherlands (1973-2013). Renewable & Sustainable Energy Reviews 47: 816-829.	Green Energy	Energy Policy; Empowering; Netherlands; Nurturing; Offshore Wind Power Plants; Offshore Wind; Policy; Renewable Energy Sources; Sustainability; Shielding; The Netherlands
Hannon MJ, Foxon TJ, Gale WF. 2015. 'Demand pull' government policies to support Product-Service System activity: the case of Energy Service Companies (ESCos) in the UK.	Green Energy	Product Service System (PSS); Sustainable business model; Government 'demand pull' policy; Energy Service Company (ESCo); Innovation system
Raunbak M, Zeyer T, Zhu K, Greiner M. 2017. Principal mismatch patterns across a simplified highly renewable European Electricity Network. Energies (19961073) 10(12): 1-13.	Green Energy	Electric Power Transmission; Europe; Renewable Energy Sources; Solar Energy; Spatio-Temporal Variation; Wind Power; Energy System Design; Large-Scale Integration Of Renewables; Principal Component Analysis; Renewable Energy Networks; Solar Power; Super Grid; Wind Power
Sgobbi A, Simões SG, Magagna D, Nijs W. 2016. Assessing the impacts of technology improvements on the deployment of marine energy in Europe with an energy system perspective. Renewable Energy: An International Journal 89: 515-525.	Green Energy	Carbon Sequestration; Eu28; Europe; Energy System Model; Low-Carbon; Marine Energy; Ocean Energy Resources; Ocean Energy; Renewable Energy Sources; Technological Innovations; Times
Dvarioniene J, Gurauskiene I, Gecevicius G, Trummer DR, Selada C, *et al*. 2015. Stakeholders involvement for energy conscious communities: the Energy labs experience in 10 European communities. Renewable Energy: An International Journal 75: 512-518.	Green Energy	Decision Making; Energy Consumption; Europe; Energy Conscious Communities; Energy Labs; Renewable Energy Sources; Stakeholders; Stakeholders' Involvement; Sustainable Communities
Ruby TM. 2015. Innovation-enabling policy and regime transformation towards increased energy efficiency: the case of the circulator pump industry in Europe. Journal of Cleaner Production 103: 574-585.	Green Energy	Energy Conservation; Energy Consumption; Environmental Policy; Europe; Energy Efficiency Policy; Industry Driven; Innovation Processes; Pumping Machinery Industry; Regime Transformation; Technological Innovations; Voluntary Energy Labelling Agreement
Littlechild S. 2016. Contrasting developments in UK energy regulation: retail policy and consumer engagement. Economic Affairs 36(2): 118-132.	Green Energy	Customer Relations—Great Britain; Economic Competition; Energy Industries—Great Britain; Energy Policy; Government Regulation; Great Britain; Price Regulation—Great Britain; Consumer Engagement; Energy Regulation; Retail Competition

Continued

Author(s)/year(s)/title/journal	Attributes researched	Key research topics
Geth F, Brijs T, Kathan J, Driesen J, Belmans R. 2015. An overview of large-scale stationary electricity storage plants in Europe: current status and new developments. Renewable & Sustainable Energy Reviews 52: 1212-1227.	Green Energy	Electric Power Distribution Grids; Energy Storage; Europe; Pumped Hydro Energy Storage; Renewable Energy Sources; Review Current Status Europe; Stored Energy; Technological Innovations
Ifelebuegu AO, Aidelojie KE, Acquah-Andoh E. 2017. Brexit and Article 50 of the Treaty of the European Union: Implications for UK Energy Policy and Security. Energies (19961073) 10(12): 1-15.	Green Energy	Brexit; British Withdrawal From The European Union; Energy Policy; Energy Security; European Union; Great Britain; Renewable Energy Sources; Shale Gas; Uk; Energy Policy
Rexhäuser S, Löschel A. 2015. Invention in energy technologies: comparing energy efficiency and renewable energy inventions at the firm level. Energy Policy 83: 206-217.	Green Energy	Dynamic Count Data; Energy Conservation; Energy Consumption; Energy Efficiency; Europe; Innovation; Invention; Renewable Energy; Renewable Energy Sources; Technological Innovations
Lazarević A. n.d. The process of developing decentralised energy policies in the City of London. Energy & Environment 28(5/6): 639.	Green Energy	Decentralization In Management; Developing Countries; Decentralized Energy Sources; Economic Development; Energy Policy; Great Britain; London (England); Renewable Energy Source Management; Strategic Planning; Energy Planning; Spatial Planning; Strategic Documents
Altenburg T, Sagar A, Schmitz H, Xue L. 2016. Guest editorial: comparing low-carbon innovation paths in Asia and Europe. Science & Public Policy (SPP) 43(4): 451-453.	Green Energy	Asia; Carbon; Europe; Evolutionary Economics; Globalization; Government Policy; Technological Innovations
Newbery DM. 2016. Towards a green energy economy? The EU Energy Union's transition to a low-carbon zero subsidy electricity system – lessons from the UK's Electricity Market Reform. Applied Energy 179: 1321-1330.	Green Energy	Auctions; Clean Energy; Contract Design; Electric Power; Electric Power Systems; Great Britain; Innovation Support; Renewable Energy Sources; Renewable Electricity; Support Mechanisms; Technological Innovations
Dyckman CS. 2016. Sustaining the commons: the coercive to cooperative, resilient, and adaptive nature of state comprehensive water planning legislation. Journal of the American Planning Association 82(4): 327-349.	Green Energy	Sustainable Development; United States; Urban Planning; Water Laws; Water Management; Water Rights; Water Use; Social–Ecological Resilience; State Comprehensive Water Planning Legislation; Sustainable Commons Management
Regueiro-Ferreira R, García XD. n.d. Comparing wind development policies in Europe, Asia and America. Energy & Environment 26(3): 319.	Green Energy	Asia; Energy Industries; Europe; Renewable Energy Sources; United States; Wind Power—Government Policy; Regulatory Framework; Renewable Energy; Wind Energy; Wind Promotors

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Table 6. *Continued*

Author(s)/year(s)/title/journal	Attributes researched	Key research topics
Cohen R, Bordass B. 2015. Mandating transparency about building energy performance in use. Building Research & Information 43(4): 534-552.	Green Energy	Electric Power Distribution; Electric Power Production; Electricity; Energy Consumption; Energy Policy; Great Britain; Management; Building Energy Use; Energy Benchmarking; Energy Efficiency; Energy Performance; Energy Policy; Energy Rating; Governance; Operational Rating Regulation
Lindman Å, Söderholm P. 2016. Wind energy and green economy in Europe: measuring policy-induced innovation using patent data. Applied Energy 179: 1351-1359.	Green Energy	Energy Economics; Europe; Government Policy; Green Economy; Innovation; Patent Counts; Public Policy; Research & Development; Technological Innovations; Wind Power; Wind Power
Birch K, Calvert K. 2015. Rethinking "drop-in" biofuels: on the political materialities of bioenergy. Science & Technology Studies 28(1): 52-72.	Green Energy	Biomass Energy; Carbon & The Environment; Energy Policy; European Union; Renewable Energy Sources; United States; Bio-Economy; Bioenergy; Drop-In Biofuels; Political Materialities; Sustainable Transitions
Strachan PA, Cowell R, Ellis G, Sherry-Brennan F, Toke D. 2015. Promoting community renewable energy in a corporate energy world. Sustainable Development 23(2): 96-109.	Green Energy	Carbon & The Environment; Communities; Energy Consumption; Great Britain; Renewable Energy Costs; Scotland; United Kingdom; Community Energy; Devolution; Energy Transition; Renewable Energy; Sustainable Development
Pollans MJ. 2015. Regulating farming: balancing food safety and environmental protection in a cooperative governance regime. Wake Forest Law Review 50(2): 399-460.	Green Energy	Agricultural Laws & Legislation; Agriculture; Agriculture—Methodology; Cost Effectiveness; Environmental Protection—United States; Food Safety Measures Laws; Government Policy; Government Regulation; Harvesting; United States; United States. Food & Drug Administration
Renewable energy innovation 'hub' opens in UK's Western Isles. 2015. Renewable Energy Focus 16(3): 10.	Green Energy	Clean Energy; Great Britain; Partnership (Business); Renewable Energy Sources; Western Isles (Scotland)
Cohen S. 2015. What is stopping the renewable energy transformation and what can the US government do? Social Research 82(3): 689-710.	Green Energy	Electric Power Production; Energy Policy—United States; Government Policy; Government Policy On Renewable Energy Sources; Infrastructure (Economics)—United States; Political Systems; Technological Innovations—United States; United States
Curtin J, McInerney C, Johannsdottir L. n.d. How can financial incentives promote local ownership of onshore wind and solar projects? Case study evidence from Germany, Denmark, the UK and Ontario. Local Economy 33(1): 40.	Green Energy	Capital Investments; Citizens; Denmark; Germany; Great Britain; Labor Incentives; Ontario; Renewable Energy Sources; Citizen; Financial; Incentive; Investment; Local; Renewable

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Author(s)/year(s)/title/journal	Attributes researched	Key research topics
Hammond GP, O'Grady Á. n.d. The potential environmental consequences of shifts in UK energy policy that impact on electricity generation. Proceedings of the Institution of Mechanical Engineers – Part A – Power & Energy (Sage Publications, Ltd.) 231(6): 535.	Green Energy	Biomass Energy; Carbon Sequestration; Electric Power Production; Energy Policy; Electricity Futures; Fossil Fuels; Great Britain; Bioenergy; Carbon Capture And Storage; Fossil Fuels; Life-Cycle Assessment; Policy Shifts; Sustainability
Price CW, Zhu M. 2016. Non-discrimination clauses: their effect on british retail energy prices. Energy Journal 37(2): 111-132.	Green Energy	Autoregressive Processes; Deregulation; Economic Competition; Energy; Great Britain; Nondiscrimination Principle (International Law); Non-Discrimination; Petroleum Sales & Prices; Retail Industry; Regulation; Vector Autoregressive Model
Drummond P, Ekins P. 2016. Reducing CO_2 emissions from residential energy use. Building Research & Information 44(5/6): 585-603.	Green Energy	Commercial Policy; Carbon Dioxide Reduction; Energy Consumption; European Union Countries; Great Britain; Greenhouse Gases; Buildings; Climate Policy; Energy Efficiency; Energy Policy; Policy Formation; Policy Measures; Regulations
Schweber L, Lees T, Torriti J. 2015. Framing evidence: policy design for the zero-carbon home. Building Research & Information 43(4): 420-434.	Green Energy	Built Environment; Carbon & The Environment; Energy Policy; Government Policy; Great Britain; Policy Sciences; Building Regulations; Energy Policy; Evidence-Based Policy; Net-Zero; Policy Design; Policy Formation; Public Policy; Regulatory Impact Assessments; Zero Carbon
de Boer J, Zuidema C, van Hoorn A, de Roo G. 2018. The adaptation of Dutch energy policy to emerging area-based energy practices. Energy Policy 117: 142-150.	Green Energy	Adaptation; Energy Initiatives; Energy Policy; Environmental Impact Analysis; Local; Netherlands; Renewable Energy; Renewable Energy Sources; Technological Innovations; The Netherlands
Cheng M-H, Yang M, Wang Y. 2016. American's energy future: an analysis of the proposed energy policy plans in presidential election. Energies (19961073) 9(12): 1-17.	Green Energy	Energy Consumption; Energy Policy; Government Policy; Government Policy On Renewable Energy Sources; Least Squares; Presidential Candidates; Regression Analysis; United States; United States Presidential Election; Energy Future; Party Polarization; President Election; Public Opinion; Renewable Energy
Potočnik J, Khosla A. 2016. Examining the environmental impact of demand-side and renewable energy technologies. Journal of Industrial Ecology 20(2): 216-217.	Green Energy	Renewable Energy Sources; Supply & Demand; Technological Innovations; Technological Innovations In Environmental Protect; United States
Keijzer EE, Leegwater GA, de Vos-Effting SE, de Wit MS. n.d. Carbon footprint comparison of innovative techniques in the construction and maintenance of road infrastructure in The Netherlands. Environmental Science & Policy 54: 218.	Green Energy	Comparative Studies; Carbon Footprint; Ecological Impact; Greenhouse Gas Mitigation; Green Procurement; Infrastructure; Innovation; Netherlands; Pavements; Road Design & Construction; Road Maintenance & Repair; Technological Innovations

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Table 6. *Continued*

Author(s)/year(s)/title/journal	Attributes researched	Key research topics
Hicks AL, Theis TL, Zellner ML. 2015. Emergent effects of residential lighting choices: prospects for energy savings. Journal of Industrial Ecology 19(2): 285-295.	Green Energy	Consumers; Energy Consumption; Light Sources; United States; Visual Environment; Agent-Based Modeling (Abm); Agent-Based Modeling (Abm); Complex Systems; Life Cycle Assessment (Lca); Light Emitting Diodes; Lighting; Rebound
Watson KJ. n.d. Understanding the role of building management in the low-energy performance of passive sustainable design: practices of natural ventilation in a UK office building. Indoor & Built Environment 24(7): 999.	Green Energy	Building Management; Building Management; Energy Conservation In Buildings; Energy Consumption Of Buildings; Great Britain; Natural Ventilation; Natural Ventilation; Office Buildings & The Environment; Passive Sustainable Design; Performance Gap; Sustainable Development; Social Practices
Dey S. n.d. Does a robust patent regime discourage innovation? Economics of Innovation & New Technology 25(5): 485.	Green Innovation	L00; L24; License Agreements; O34; Patent Applications; Patent Paradox; Semiconductor Industry; Technological Innovations; United States; Complex Industries; Licensing
Schmitz H, Altenburg T. 2016. Innovation paths in Europe and Asia: divergence or convergence? Science & Public Policy (SPP) 43(4): 454-463.	Green Innovation	Asia; Europe; Globalization; Technological Innovations; Technology Convergence; Carbon Lock-In; Convergence; Divergence; Dominant Design; Innovation Path; Low Carbon Innovation
Hansen E, Knowles C, Larson K. n.d. A modified lead-user approach for new product development: an illustration from the US of a marketing research tool for the forest industry. International Wood Products Journal 6(3): 131.	Green Innovation	Forest Products Industry; Forests & Forestry; Innovations In Business; Innovation; Lead-Users; Marketing Research; New Product Development; New Product Development; Success In Business; United States
Rainville A. 2017. Standards in green public procurement – a framework to enhance innovation. Journal of Cleaner Production 167: 1029-1037.	Green Innovation	Commercialization; Environmental Impact Analysis; Europe; Eco-Innovation; Government Purchasing; Green Public Procurement; Pre-Commercial Procurement; Public Purchasing; Standardization; Standardization; Standards; Technological Innovations
Bryson D, Atwal G, Chaudhuri A, Dave K. 2016. Antecedents of intention to use green banking services in India. Strategic Change 25(5): 551-567.	Green Innovation	Anking Industry; Europe; Green Marketing; Social Responsibility of Business; Stakeholders; Sustainable Development
Scarpellini S, Valero-Gil J, Portillo-Tarragona P. 2016. The “economic–finance interface” for eco-innovation projects. International Journal of Project Management 34(6): 1012-1025.	Green Innovation	Business Planning; Corporate Finance; Eco-Innovation; Europe; Organizational Aims & Objectives; Project Management; Sustainable Development; Technological Innovations
Peyravi B. 2015. South East European Countries: the needs of innovations in the context of enlargement of the European Union. Public Administration (16484541) 3/4(47/48): 112-120.	Green Innovation	Economic Competition; Economic Development; Europe; European Union; Innovation; Job Creation; South East European Countries; Sustainable Development; Transfer;

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Author(s)/year(s)/title/journal	Attributes researched	Key research topics
Triguero A, Moreno-Mondéjar L, Davia MA. n.d. Eco-innovation by small and medium-sized firms in Europe: from end-of-pipe to cleaner technologies. Innovation: Management, Policy & Practice 17(1): 24.	Green Innovation	Business Networks; Environmental Regulations; Europe; Eco-Innovation; Europe; Innovations In Business; Size Of Business Enterprises; Small Business; SMEs Firms; Cleaner Technologies; End-of-Pipe
Küçüksayraç E, Keskin D, Brezet H. 2015. Intermediaries and innovation support in the design for sustainability field: cases from the Netherlands, Turkey and the United Kingdom. Journal of Cleaner Production 101: 38-48.	Green Innovation	Business Models; Design For Sustainability; Empirical Research; Eco-Design; Great Britain; Innovations In Business; Intermediaries; Netherlands; Sustainable Development; Turkey; The Netherlands; The United Kingdom; Turkey

technology like energy-saving, waste recycling, green product designs or corporate environmental management. From the various definition of green innovation existing in the previous literature, this paper then concludes it as a new environmental approach, idea, product, process or services that concern on minimizing negative environmental impact and also create differentiation of developed product among competitors. Green innovation is categorized into four types of innovations including (i) product innovation, (ii) process innovation, (iii) managerial innovation, and (iv) marketing innovation."

(b) **Green Economy**—has been defined by UNEP (2011) as one that results in improved "well-being and social equity, while significantly reducing environmental risks and ecological scarcities" and it is "low-carbon, resource efficient and socially inclusive" focus on the "preservation of natural capital, which includes ecosystems and natural resources."

(c) **Green Energy**—"is clean sources of energy that have a lower environmental impact compared to conventional energy technology. It plays a significant role in the strategic energy planning process for any country" (Bhowmik *et al.*, 2017).

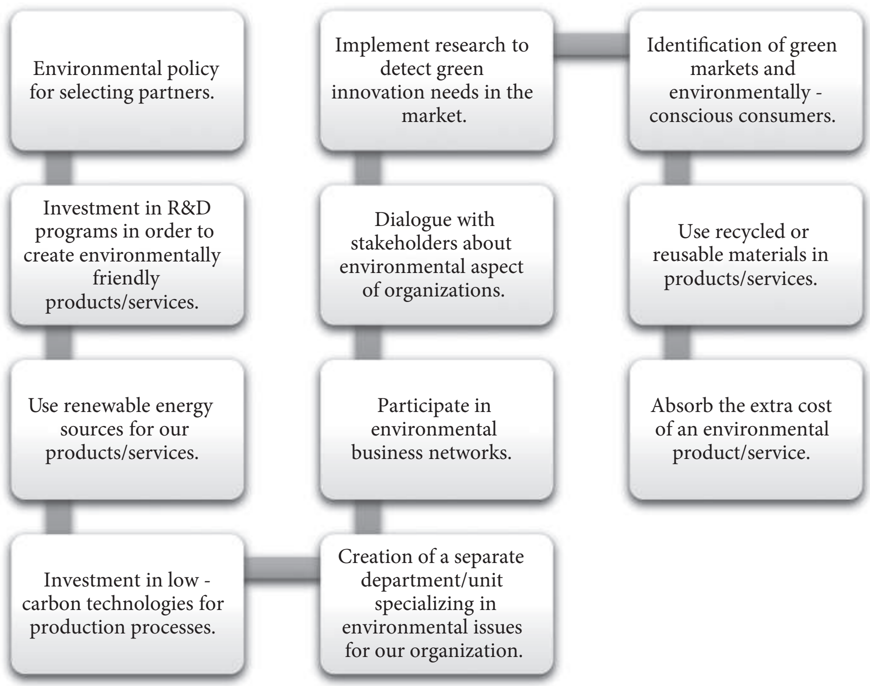
4. GREEN INNOVATION MODEL PROPOSAL FOR ORGANIZATIONS

Innovation is crucial to organizations particularly in encouraging the creation of new products and services, and in the implementation of new practices and processes. In this context, two elements need to be managed together: people and knowledge. Assuming that people are the source of knowledge, practices such as communication, skills development, and recognition are core to promote innovation in organizations. Consequently, it is essential to implement mechanisms for a systematic involvement of employees, either through meetings, technological platforms allowing discussion forums or specific systems of innovation. Besides those as mentioned earlier, it is necessary to highlight the importance of such mechanisms as personal support for solving problems, identifying solutions, and creating new ideas in the workplace. Knowledge sharing practices have a profound effect on the creation of an innovation culture, and in developing conditions to implement new management practices and organizational changes. The model in Figure 2 proposes a set of dimensions that should be nuclear to any green organization:

The most critical questions (see Table 2) that organizations should answer and reflect when adopting and implementing a model of green innovation should be the following:

1. Do we invest in low-carbon technologies for our production processes?
2. Do we use specific environmental policy for selecting our partners?
3. Do we invest in R&D programs to create environmentally friendly products/services?
4. Do we make efforts to use renewable energy sources for our products/services?

Figure 2. Model Green Innovation for Sustainable Economy.



5. Do we have created a separate department/unit specializing in environmental issues for our organization?
6. Do we participate in environmental business networks?
7. Do we engage in dialogue with our stakeholders about the environmental aspect of our organization?
8. Do we implement research to detect green innovation needs in the market?
9. Do we target environmentally conscious consumers?
10. Do we use recycled or reusable materials in our products/services?
11. Do we absorb the extra cost of an environmental product/service?

When answering those questions, the organizations can define a strategy based on the dimensions of green innovation, green energy and green economy.

5. CONCLUSION

The political and economic environment plays a vital role in entrepreneurship development (Sousa *et al.*, 2018) and most of the enterprises that dedicate a significant part of their resources in R&D for green energy, regardless of their contribution for a circular economy as part of the business model, shall be considered entrepreneurs if they pursue the commercialization of that same technology.

This paper included two brief situation analysis of REN and CRI, both enterprises highly engaged with their stakeholders, national and international business networks, and intending to raise capitals and to acquire specialized human capital. Notwithstanding, Portugal does not have as many natural resources regarding green energy as Iceland does; however, REN holds the management of most of electric and gas distribution while CRI is a medium enterprise without a significant commercial and industrial market share. Moreover, CRI has been financially resilient to continue its pursuit of a greener energy within a circular economy business model while REN continues to expand its R&D projects and will comply with its vision for 2018-2021, defining three objectives as: (i) to consolidate the core business and maintain operational excellence that characterizes REN operations, (ii) maintain a discipline of growth, and (iii) ensure a solid financial performance.

Green energy is the predominant research topic found in the literature review; however, green economy and green innovation present potential from the social science subjects, that is, management and business administration. Finally, it appears to be correct to infer that successful businesses that promote green innovation have common traces of (i) top management innovation sponsorship, (ii) technology, research & development (R&D), and (iii) stakeholder engagement.

6. LIMITATIONS AND FUTURE RESEARCH

New expectations of technological innovation are emerging as this research field is becoming strategically crucial for organizations. In this context, a consistent framework needs to be developed. Directly related to the findings from this research, other aspects could be developed:

- A model for facilitating the creation of an innovation culture in large and small organizations.
- A case study of an implementation of the model and its implications on the organization.
- The creation and applicability of an instrument to diagnose innovation profiles in organizations is also a potential for people involvement and development. The results could be used in the training plans to develop organizational actors' potential for innovation.

Further research could also be undertaken:

- Studies on innovation processes integration across organizational functions and in several types of organizations.
- Studies that develop and test a theoretical framework that relates innovation and organizational outcomes.
- Studies that analyze the capabilities of employees' informal networks to achieve efficient integration of innovations into their work practices.

Furthermore, future studies are required to determine the importance of different types of innovation for different organizational activities.

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Curtin J, McInerney C, Johannsdottir L. n.d. How can financial incentives promote local ownership of onshore wind and solar projects? Case study evidence from Germany, Denmark, the UK and Ontario. Local Economy 33(1): 40.
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Will Africa Be Able to Keep Its Promises to Reduce Greenhouse Gases? A Review of African Countries' Commitments at COP 21

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Abstract

This study describes the different types of commitments made by Africans in their National Determined Contributions (NDCs) and tries to explain whether or not it will be possible for them to fulfill their commitments. For this purpose, we operate all African NDCs formally presented at COP 21 in Paris in 2015 in which the greenhouse gas (GHG) reduction commitments are presented. The analysis reveals three types of commitments—namely, conditional commitments, not conditional on international aid, and both at the same time. Countries with conditional commitments subject to external financing are likely to fulfill their commitments that are stronger. Only countries with unconditioned commitments are more realistic not relying on external assistance that is becoming more and more hypothetical. Beyond the types of commitments, other types of obstacles such as the blurred legal form of the Paris Agreement and the preference for Adaptation could make it difficult to fulfill the commitments of African countries.

Keywords: COP 21; Greenhouse gas; Commitment; Conditional; Unconditional; Africa.

1. INTRODUCTION

In the context of international negotiations about climate within the United Nations Framework Convention on Climate Change (UNFCCC), 193 countries around the world including 53 from the African continent[1] submitted their Nationally Determined Contributions (NDCs) to the 21st Conference of Parties (COP 21) in Paris.

The overall objective of this conference was to come to an agreement about limiting global warming to 2°C. These NDCs should therefore provide an overview of countries' intents to reduce their Greenhouse Gas (GHG) emissions.

Being solely responsible for about 3.8% of global GHG emissions (Diop, 2015[2]), African countries have focused on climate change adaptation and the financial mechanisms that need to be put in place to facilitate climate change. However, they made more or less relevant commitments regarding GHG reduction.

These GHG reduction commitments also include significant investments because the world's countries, in general, and Africans, in particular, must fund the necessary ecological transition to achieve a more environmentally friendly development and, consequently, producing fewer GHGs.

The African continent has experienced significant economic growth for nearly a decade. In 2017, the growth rate of regional GDP (Sub-Saharan Africa) was estimated at 2.4% against 1.3% in 2016. The growth projections for the year 2018 are 3.2% (World Bank, 2017) and could even reach 4.5%[3] on average by 2020.

[1] To date, there are 54 African countries. Only Libya could not provide NDCs.
[2] Makhtar Diop is the World Bank's vice president for Africa.
[3] This is calculated based on the average of the projections provided by each African country.
Source: International Monetary Fund, World Economic Outlook Database, April 2017.

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These displayed ambitions of African economies are likely to be achieved without a real change in economic models based for the most part on the exploitation of natural resources. African countries, despite their goodwill and the apparent health of their economies, could therefore have trouble without international support (investments in renewable energies, clean technological innovations, technology transfer) to maintain or increase their growth while considering commitments made at COP 21.

In this context, can African countries with the ambition of becoming "emerging" more or less sooner truly fulfill the commitments made at COP 21? Most African NDCs at the same time set low unconditioned reduction commitments and relatively stronger commitments based on the aid of developed countries, historically responsible for GHG emissions.

The objective of this study is therefore to determine whether it is possible for African countries to respect their commitments, considering their development objectives.

After this introduction, we review and summarize the level of engagement of all African countries. Then, we analyze how, from the types of commitments made, these countries could respect or not their commitments. Finally, we determine whether there are other difficulties that could prevent Africans from fulfilling their commitments.

2. SYNTHESIS OF COMMITMENTS OF AFRICAN COUNTRIES IN GHG REDUCTION

By going through the NDCs of each country, there exist three categories in terms of commitment: countries that only have proposals not conditioned by international aid, countries that only have proposals conditioned by aid, and countries that have both. The summary is provided in Figure 1.

2.1. Only Unconditional Commitments

Among the 53 countries that have submitted their NDCs, 26 countries have made an unconditional[4] commitment on international assistance. This indicates that these countries have included in their global development policies GHG reduction options that can be sustained by their economies. Although some countries, such as Egypt or Swaziland, have no quantified commitment, detailed sectoral measures are being considered for mitigation. An average of their proposals is estimated at about 30% GHG reduction. These countries are mainly located in West Africa and along the entire eastern coast of Africa, including South Africa.

2.2. Only Conditional Commitments

Eight African countries made commitments that are conditioned[5] just on international aid. These commitments imply that the countries concerned will not take GHG reduction measures until they explicitly obtain government aid from developed countries. This type of commitment could mean that these states totally place the responsibility for climate change on the developed countries. Their commitments are therefore conditioned by help from those who are supposed to have significantly participated in global warming for several decades. An average of their proposals is about 45% GHG reduction. It is essentially the countries of Central Africa except Namibia.

2.3. Conditional and Unconditional Commitments

For this category, 18 African countries[6] made two GHG reduction proposals. This type of proposal implies that these countries can make personal efforts but feel that they can do better with international aid.

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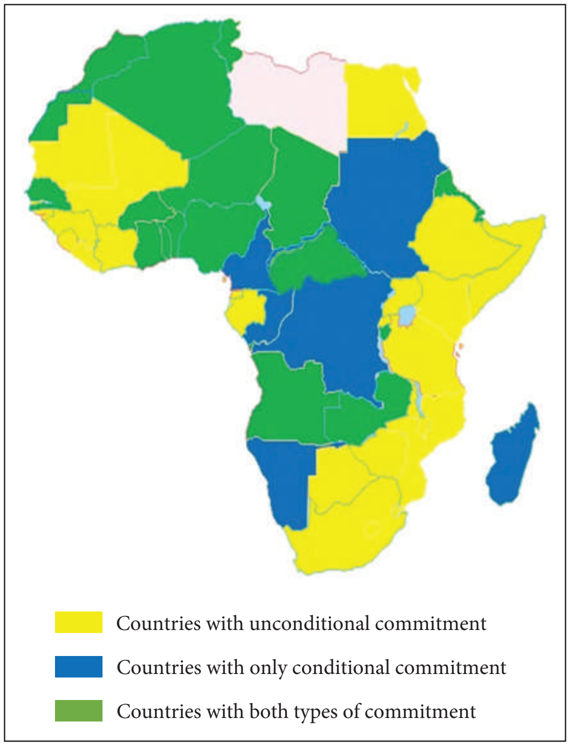
[4] The countries concerned are South Africa (No quantified commitment), Botswana (15%), Cape Verde (No precise percentage), Ivory Coast (28%), Egypt (No quantified commitment) Ethiopia (64%), Gabon (50%), Gambia (45.4%), Guinea (Sectoral commitments), Guinea Bissau (No quantified commitments), Equatorial Guinea (20%), Kenya (30%), Lesotho (No quantified commitment), Liberia (No quantified commitment), Malawi (Sectoral measures), Mali (Sectoral defined percentages), Mauritania (22.3%), Mozambique (Sectoral measures, no firm commitment), Rwanda (Sectoral measures), Sao Tome (24%), Sierra Leone (Sectoral measures), Somalia (No quantified commitment), Swaziland (No quantified commitment), Uganda (22%), Tanzania (10–20%), Zimbabwe (33%).

[5] Cameroon (32%), Comoros (84%), Congo (48%), Madagascar (14%), Mauritius (30%), Namibia (89%), Democratic Republic of Congo (17%), Sudan (Not quantified), South Sudan (No specific number).

[6] The percentages of this list are, respectively, unconditional commitment for the first, and conditional for the second. Algeria (7%, 22%), Angola (35%, 50%) Benin (3.5%, 17.9%), Burkina Faso (6.6%, 11.6%), Burundi (3%, 20%), Djibouti (40%,

Figure 1. Map of African Countries by Type of Commitments at COP 21.



Source: Author, built based CDNs.

The average of the proposals without international aid is about 15% against about 35% with international aid. It can therefore be seen that in this category, countries are ready to double their reduction efforts if they receive support.

2.4. Current Situation: Signature versus Ratification

The situation just described on the commitments has changed considerably. In fact, after COP 21, the countries present should first sign the agreement, which means that they *act* on the agreement and are *aware* of what has been performed. This signature does not include a commitment to respect what each country writes in its NDC. As all the countries committed to COP 21 have signed it, this means that they have adopted it.

However, the agreement, which entered into force on November 21, 2016, the day before COP 22 in Marrakech, has been ratified by only 45 African countries. Ratification is the final commitment of the parties to respect the agreement. For the commitment made in the ratification to be implemented, there are country-specific legal procedures. There are nine countries that have not yet ratified[7] the agreement as shown in Figure 2.

Countries that have not ratified the agreement belong to the three different types of commitments. We cannot say anything about the profound reason for their nonratification.

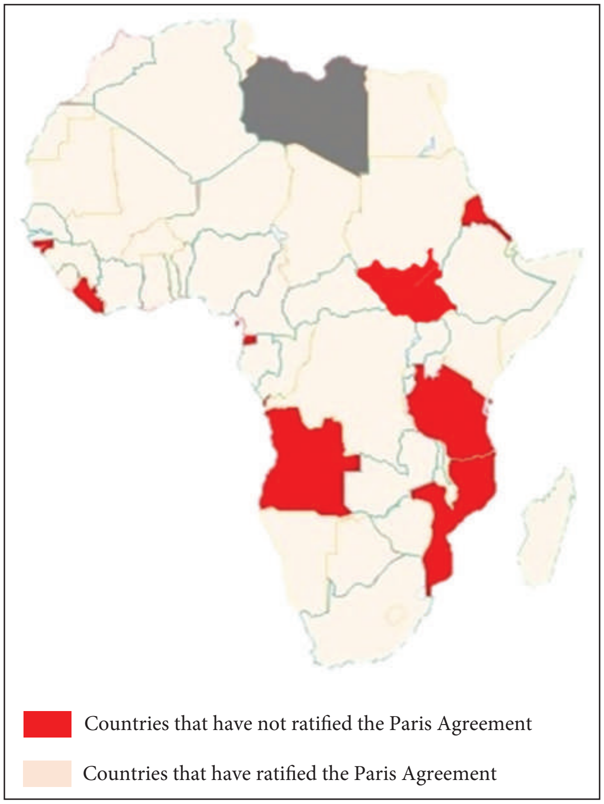
3. ANALYSIS OF TYPES AND COMPLIANCE WITH COMMITMENTS

The commitments presented above have shown us that the three categories do not have the same objectives in terms of GHG reduction. Countries with only unconditional commitment offer about 30% GHG

60%), Eritrea (23%, 39.2%), Ghana (15%, 45%), Morocco (13%, 32%), and Niger (3.5%, 6%), Nigeria (20%, 45%), Central African Republic (5%, 25%), Senegal (5%, 21%), Seychelles (21.4%, 29%), Chad (18.2%, 71%), Togo (11%, 31%), Tunisia (13%, 28%), and Zambia (25%, 47%).

[7] These countries are as follows: Angola, Eritrea, Equatorial Guinea, Guinea Bissau, Libya, Liberia, Mozambique, Tanzania, and South Sudan.

Figure 2. Map of Countries that Have Not Ratified the Paris Agreement.



Source[8]: Author.

reduction, compared to 45% for those with just conditional commitment. We realize that countries with only conditional commitments offer a better reduction of GHGs. However, the first type of commitment, even if it is weaker, is more realistic as these countries will not officially wait for aid before implementing their GHG reduction plans. The rates of the countries with the two proposals vary between the first (unconditional commitment) and the second (conditional commitment), respectively, between 15% and 35% (Table 1). The unconditional proposal of these countries is far lower to those which make an unpacked proposition. Their conditional proposal is close to that of only unconditional commitment countries. This could mean that by making these weak proposals, these countries want to "force" the richest countries to fund them to achieve at least 30% GHG reduction.

Table 1 also shows that each time unconditional commitments are lower. This indicates that funding really plays an important role in implementing GHG reductions, not necessarily in the same way as adaptation, but to allow African countries to continue low-carbon development.

4. POTENTIAL OBSTACLES TO MEETING AFRICAN COMMITMENTS

The obstacles that may hinder the fulfillment of the commitments made by African countries are political, economic, and legal.

4.1. Political and Economic Obstacles

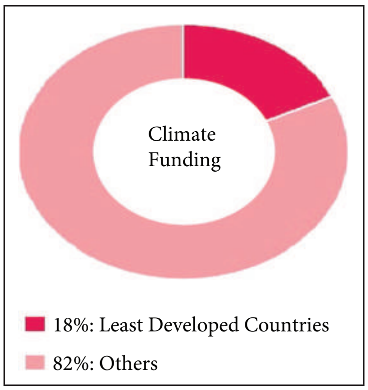
As we have just examined it, international aid is an important condition for many African countries to reduce their GHGs. Countries with unconditional commitments could respect them without outside help.

[8]This map is built based the UN FCCC, Paris Agreement, Signature Ceremony. Friday, April 22, 2016.

Table 1. Summary of GHG Reduction by Type of Commitment.

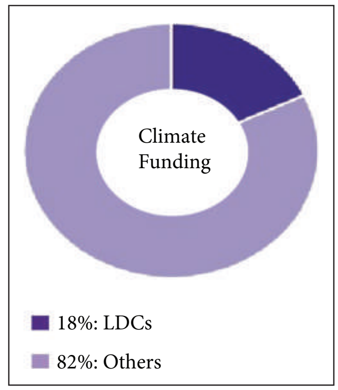
Countries with only unconditional commitment		30%
Countries with only conditional commitment		45%
Countries with both types of commitments	Unconditional	15%
	Conditional	35%

Figure 3. Estimated Share of Climate Fund Allocated to LDCs in 2013–2014 (before COP21).



Source: OECD, 2016.[9]

Figure 4. Estimated Share of Climate Fund Allocated to LDCs in 2015–2016 (before COP21).



Source: Shadow, F. Climate Finance Shadow Report, 2018.

However, the process of withdrawing from the agreement initiated by the USA[10] is blurring the promise of $100 billion a year for adaptation and mitigation for developing countries. Countries that have related their commitments to international donations may therefore lack the resources to begin low-carbon development.

This situation is confirmed by the low allocation to the least developed countries (LDCs). The majority of them are in Africa. Figures 3 and 4 from the following reports[11] of OXFAM International (2016 and 2018) show that the shares of climate fund allocated to LDCs have not evolved since COP 21.

In addition, some recipient countries have simply not ratified the Paris Agreement (Figure 2). This decision simply indicates that they may not fulfill their commitments.

Some of these countries such as Angola, having been through two decades of civil war, are gradually getting a stable economy.

Angola became a member of the Organization of Petroleum Exporting Countries (OPEC) in 2007 and is the fifth largest economic power in Africa. Therefore, there is a need for this country to continue to exploit its oil resources that are still important. Its unwillingness is not a surprise.

4.2. Legal Obstacles

There is a profound ambiguity about the legal value of COP 21. In fact, before and during the negotiations, COP 21's president and minister of foreign affairs at the time, Laurent Fabius, insisted that it is a *legally*

[9] From Shadow, F. Climate Finance Shadow Report 2016.
[10] Announced by US President Donald Trump on June 1, 2017.
[11] Shadow, F. Climate Finance Shadow Report 2016 and 2018.

binding—that is, a *mandatory*—agreement to be respected. Looking through the Paris Agreement, it turns out that there is no sanction mechanism or jurisdiction in charge of implementing the Agreement, as was the case with Kyoto Protocol adopted in 1997 and implemented in 2005.

In reality, countries that have ratified the agreement are "obliged" to respect it, but this obligation is moral, and it is based on the goodwill of countries. Therefore, this goodwill is subject to the internal policies of the countries—that is to say, the visions and priorities of the governments in place. For example some countries will have to pass their GHG reduction measures as a bill in their national assemblies. These constraints may, even after ratification, limit a country in the effective fulfillment of its commitment. The political instability of African countries that engender repetitive constitutional changes can therefore be detrimental to the implementation of commitments and consequently play against the implementation of the commitments.

4.3. The Preference for Adaptation

During COP 21, African countries claimed greater consideration of adaptation in the negotiations. Schuller and Stokkink (2016) reports that the distribution of the $100 billion commitment places developed countries in opposition to developing countries. In fact, donor countries would like only 20% of this amount to go to adaptation. As African countries were responsible for only very low emissions, they were more vulnerable and struggled to make adaptation the focus of the debate. Diop (2015) explained that the *slogan* for Africa must be adaptation, and that if Africa is to succeed in fighting poverty, adaptation to climate change needs to be set as its priority.

COP 22 that followed did not define strategies to mobilize this amount of 100 billion. These uncertainties in terms of funding coupled with the concern for an increasingly urgent adaptation may therefore favor for several African countries the failure to fulfill their commitments.

5. CONCLUSION

This study analyzed the possibility of fulfillment or not of African countries' GHG reduction commitments at COP 21.

The summary of commitments revealed that African countries have suggested three types of commitments—namely, only unconditional commitments, only conditional commitments, and both types of commitments at the same time.

Analysis of the percentages of reductions displayed in the various NDCs and according to these different types of commitments has shown that the levels of reductions in conditional commitments are higher than the unconditional ones, which shows that international aid is important for greater GHG reduction on the continent. However, unconditional commitments are proposals that can be achieved without international assistance and on the basis of resources owned by these countries.

This study also allowed us to see that several African countries have not ratified the Paris Agreement. Therefore, we can assume that these countries will not respect their commitments. These countries having made the three types of commitments, it is difficult to deeply know the reasons for their nonratification.

Other obstacles may also prevent African countries from fulfilling their commitments, despite the goodwill of some of them. First, the low allocation to LDCs for both mitigation and adaptation is a serious constraint especially for countries with only conditional commitments. Second, the fact that the Paris Agreement does not have legal tools for sanctions in case of noncompliance with these commitments can lead several African governments to simply exit the Agreement or not pursue GHG reduction policies. Finally, adaptation was the focus of the negotiations for African countries at COP 21. It is clear that the latter is more important than mitigation because, globally, Africa emits only about 3.8% of global emissions. Commitments can therefore be "neglected," as there is no urgent need for reduction for Africans.

In order for African countries to meet their commitments, developed countries should respect their funding promises because Africa has the "chance" to initiate a different development to the one already adopted by today's developed countries. Without real funding, sustainable development would be almost impossible given the amount of nonrenewable natural resources still available on the continent.

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Lesson Learned from Killer Floods in Kerala: Time for Retrospection

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Abstract

We know that the climate of the earth has undergone drastic change over periods of time. Natural factors and anthropogenic factors both contributed to climate change. Kerala is one of the most famous tourist destinations in India. The state saw one of its worst monsoon disasters in August 2018. There is huge loss and displacement of more than a million of people due to unusually high and persistent monsoon rains in Kerala. The objectives of this paper are to find out the reasons of disaster in Kerala and lessons learned from it. Some people believe that Kerala's disaster is man made, while others say that it is a natural calamity. Whatever it may be, we have to identify the reasons for the same. Due to climate change and natural disasters, the impact on water, air, agriculture, infrastructure, health, education, bio-diversity, forests, and socioeconomic sectors is bound to increase. Nobody can stop the natural disasters, but we can take certain steps to lower the intensity. It is very much important to understand the lessons so that the effect of such type of events is minimized.

Keywords: Climate change; Disaster; India; Kerala; Monsoon; Rainfall; Flood.

1. INTRODUCTION

There are several issues faced by mankind. Climate change, global warming, and so on are some widely discussed issues at the global level. The impact of climate change and global warming is quite visible around the world. The increasing temperature, irregular changes in seasonal rainfall, and so on, directly and indirectly, affect human life. The impacts of climate change are expected to be different within and between regions and nations, and thus it is important to investigate where climate change impacts (Allison *et al.*, 2009). There are changes noticed in climate condition of Kerala, one of the most beautiful states of India. The trends are related to the rainfall in the state. Intraseasonal and intraannual variability and uncertainties were found in recent decades. In 2018, Kerala experienced one of its biggest disasters due to which millions of people have suffered. There was tragic loss and displacement of more than a million of people due to unusually high and persistent monsoon rains in Kerala. There were huge discussions about the disaster to know whether it was man made or natural. Whatever it may be, we have to identify the reasons and its impact. Due to the availability of advanced technology, it is now somewhat easy to forecast the weather accurately, and this information can be easily circulated to general public. There are several methodologies available to forecast the weather, but the most important question is about minimizing losses due to certain climate conditions. Why do we every time talk only after some major incidents have taken place and then after some time, we forget the same?

2. METHOD(S)

As we all know, proper research objectives enable the researcher to be on the track. Thus, defining a research objective properly is a prerequisite for any study. The present study has been undertaken with the major objectives of knowing the reasons for the disaster in Kerala and the lessons learned from it. The data for this study are taken from primary and secondary sources. Primary data is collected through the interview method: sixty-seven postgraduate students from a management background were contacted to know their opinion about Kerala disasters. The secondary information has been obtained from different sources. While collecting secondary data, the researcher considered the following factors: reliability, suitability, and adequacy of data. The researcher got the information through various websites. Side by side, standard literature on the subject was also studied. The research work already done with a similar end was also reviewed for clarification of the conceptual and descriptive part of the study. All the information gathered by the researcher was properly studied and analyzed so that meaningful conclusions could be drawn from it.

3. LITERATURE REVIEW

The study titled "Detection and Attribution of Climate Change Signals in Precipitation in the Chaliyar River Basin, Kerala, India," done by Chithra N. Rao and Santosh G. Thampi from the Department of Civil Engineering, National Institute of Technology, Calicut, Kerala, detected climate change signals in the precipitation data of the Chaliyar river basin in Kerala, India, and attributes reasons for the same.[1]

The study by Rao and other researchers found cyclical patterns in rainfall with a declining trend in annual and southwest monsoon rainfall during the past 60 years in Kerala. In contrast, there was an increasing trend in postmonsoon rainfall, indicating likely shifts in rainfall patterns (Prasada Rao *et al.*, 2010).

An attempt is made by G.S.L.H.V. Prasada Rao, A.V.R. Kesava Rao, and others scholars in their study titled "Impact of Climate Change on Food and Plantation Crops in the Humid Tropics of India" to understand the impact of climate change or climate variability on major crops of Kerala based on a long series of climatological data on temperature and rainfall. They recommended for climate change adaptation strategies to mitigate the ill effects of weather aberrations and sustain crop production under projected the climate change scenario.[2]

The impact of climate change was studied in relation to the agricultural and fisheries sectors. There is increasing concern noticed over the consequences of climate change and climate variability on fisheries production and marine ecosystems (Brander, 2010; Cheung, 2010; Mora, 2013).

A study was done by Dr. V. Ambilikumar, Dr. M.S. Raju and Shri. Mathew Sebastian titled "The Changing Climate: Impact and Observations of Fisher Folk of Kerala"; it revealed the impact of climate change on the socioeconomic condition of the fisherfolk. The major objective of this study was to know whether the livelihood of marine fisherfolk of Kerala was influenced by climate change and seasonal variations in fish landings or not. The study found that there is direct impact of climate change on the livelihood of people. It directly and indirectly affects the economic and social condition of the fisherfolk in the coastal districts of Kerala. The study recommended for formulation of policies for minimizing the negative effects of climate change.[3] According to Nurse (2011), there already exists a good generic understanding of the potential impacts of climate change and climate variability on key factors and processes. Research by the *Economic Times* (August 25, 2018) has projected that average annual temperatures in India will increase from 1.5 degree Celsius to 3 degree Celsius. It will be difficult to live in northeast India if carbon emissions continue persistently.[4]

A commissioned research report titled "India: The Impact of Climate Change to 2030," prepared by the Joint Global Change Research Institute and Battelle Memorial Institute, Pacific Northwest Division, revealed that India is experiencing changes in climate and the impacts of climate change, including water stress, heat waves and drought, severe storms and flooding, and the associated negative consequences on health and livelihoods. In India, glaciers are melting at an average rate of 10-15 meters per year. Melting glaciers suggest that climate change as flooding is likely in river valleys resulting in water scarcity for drinking and irrigation purpose. Further, this study shows a trend of general warming in mean annual temperature in India. A warming of 0.5 degree Celsius is likely over all India by the year 2030. The report also talked that the timing

1 https://ac.els-cdn.com/S2214241X15001595/1-s2.0-S2214241X15001595-main.pdf?_tid=9a1348a7-e34c-4107-b844-0adb45393e5a&acdnat=1536578786_b7efbba0210c39c3aed12858f32879e8

2 http://www.isprs.org/proceedings/xxxviii/8-W3/b2/9-B9-95_ISRO%20F.pdf

3 http://www.ijset.net/journal/1429.pdf

4 https://economictimes.indiatimes.com/news/environment/global-warming/worst-yet-to-come-kerala-rains-match-climate-change-forecasts/articleshow/65543264.cms

of rainfall in India may also shift, causing a drying during the late summer growing season. The study also found that uncertainties about monsoonal changes will affect farmers' choices about the timing of planting. The productivity can be reduced as which crops to plant or not plant due to irregular season and rainfall. This report also recommended for government relief programs on a massive scale.[5] In the studies, Nicholls (2007) confirmed that coasts are experiencing the adverse consequences of climate change with sea-level rise and other slow-onset changes.

4. KERALA: GOD'S OWN COUNTRY

Kerala in known the "Gateway of monsoon" to India and is also famous as the "Spice Garden of India" and "Land of Coconuts" due to its natural beauty. Better known as "Gods Own Country," Kerala is one of the most famous tourist destinations in India due to its golden beaches, emerald backwaters, high mountain ranges, powerful art forms, Ayurveda, diverse wildlife, coconut trees, rich culture and traditions, and so on. Kerala's accomplishments in education and health care are all remarkable. Kerala is a state on the south-western Malabar coast of India. It was formed in November 1956 through the State Reorganization Act. Kerala is spread over 38,863 square kilometers and is bordered by Karnataka to the north and northeast, Tamil Nadu to the east and south, and the Lakshadweep Sea to the west. Malayalam is the most widely spoken and official language of Kerala.[6] As per census 2011, the rural population in Kerala is 17,455,506. Out of this, 8,403,706 are males and 9,051,800 are females whereas urban population in this state is 15,932,171. Out of this, 7,617,584 are males and 8,314,587 are females. The decadal decline of rural population was -25.96%, whereas the urban population has grown by 92.72%.[7]

5. RAINFALL TRENDS IN KERALA: A SNAPSHOT

Figure 1 depicts the monsoon trends in India from June 1 to August 16, 2018, which clearly shows the excessive rainfall in Kerala.

Generally, a significant amount of rainfall is noticed ever year in Kerala, but there are irregular trends in rainfall during winter and summer seasons. Increasing uncertainties in rainfall were also noticed in the state. Weather-related disasters like landslides, sunburns, cloudbursts, floods, droughts, and so on are common in Kerala. There are some studies that reveal that rainfall in the postmonsoon season is increasing in Kerala while southwest monsoon rainfall is declining. Kerala is moving from a wet and humid climate to a dry and humid climate. The annual rainfall has also been declining in recent decades, although Kerala falls under the heavy-rainfall zone.[8]

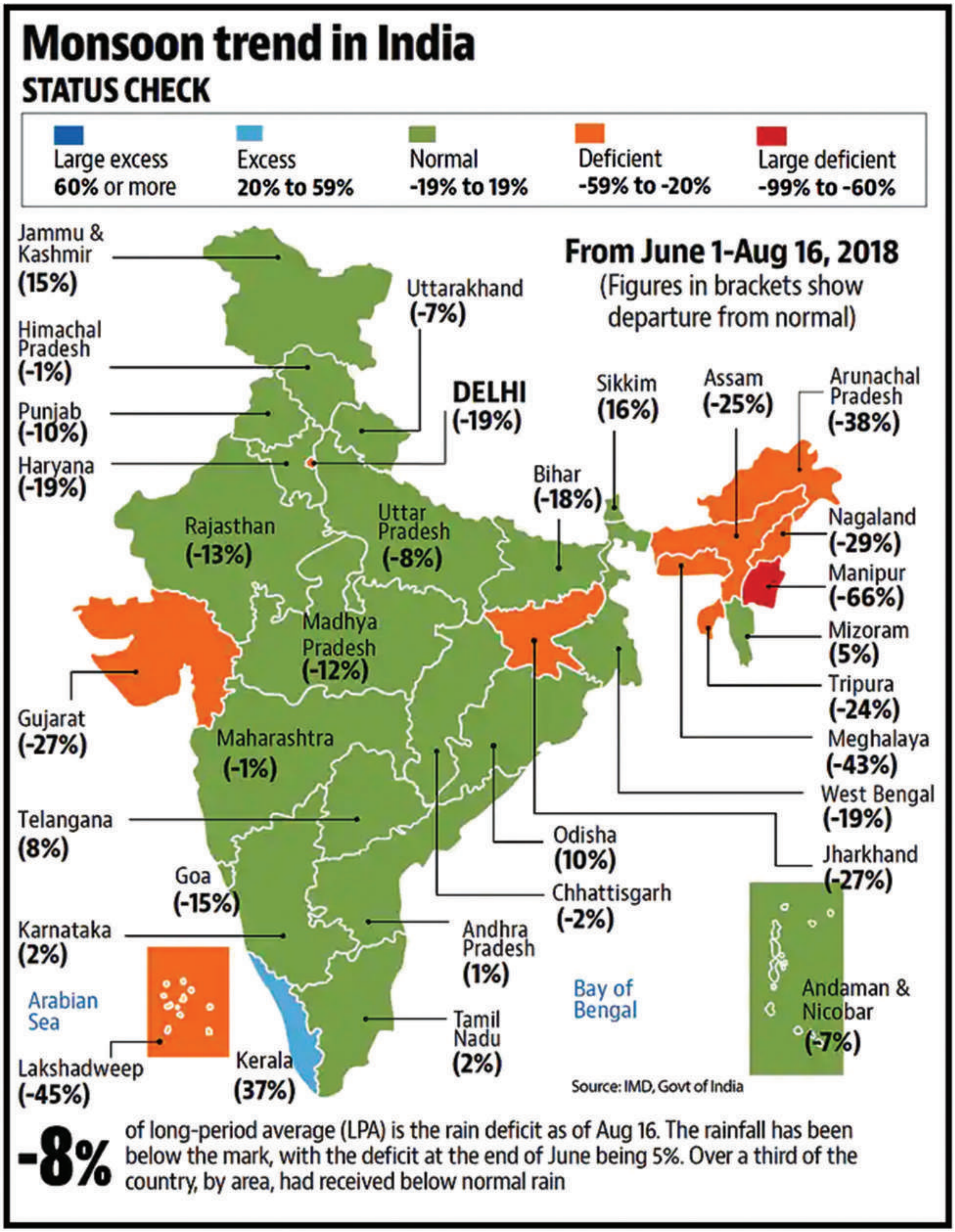
Tables 1-14 show the trends in rainfall in the different districts of Kerala during the last five years. Data were collected from Hydromet Division, India Meteorological Department (IMD), Ministry of Earth Sciences, New Delhi, India.[9] The analysis shows decrease in southwest monsoon rainfall while increase in rains during the postmonsoon season in Kerala.

6. MONSOON DISASTER

In August 2018, Kerala faced one of the worst floods in its history. The Indian government declared it a "calamity of a severe nature," which is also known as Level 3 Calamity.[10] The state has seen the worst monsoon disaster in 2018 since 1924. The southwest monsoonal rainfall for 1924 remains the highest in the

5 https://www.dni.gov/files/documents/climate2030_india.pdf
6 https://en.wikipedia.org/wiki/Kerala
7 https://kerala.gov.in/census2011
8 http://shodhganga.inflibnet.ac.in/bitstream/10603/5210/14/14_chapter%2010.pdf
9 http://hydro.imd.gov.in/hydrometweb/(S(hmw10s55pq5wpiauftwxzc45))/DistrictRaifall.aspx
10 https://en.wikipedia.org/wiki/2018_Kerala_floods

Figure 1. Monsoon Trends in India.



Source: https://www.hindustantimes.com/india-news/what-is-behind-the-kerala-monsoon-fury/story-2NxvHfTDAmS10k9h-HofiiO.html.

Trends of Rainfall in Different Districts of Kerala during the Last Five Years

Note: (1) The district rainfall in millimeters (R/F) shown below are the arithmetic averages of rainfall of stations under the district.
(2) % Dep. are the departures of rainfall from the long period averages of rainfall for the district.
(3) Blank spaces show nonavailability of data.

Table 1. District: Alappuzha.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	24	37	88	217	50	10	40.3	−70	137	−54	936	58	638	20	245	−29	292	6	186	−44	172	−9	15.2	−71
2014	0.2	−99	23	−16	33	−27	144	7	251	−16	363	−39	356	−33	615	79	228	−18	311	−7	93.8	−50	52.3	1
2015	3.2	−82	5.2	−81	99	119	237	77	178	−40	475	−20	236	−56	189	−45	238	−14	376	13	190	1	120	133
2016	5.9	−66	56	101	46	1	24.6	−82	296	−1	524	−12	366	−31	166	−52	79.6	−71	124	−63	63.4	−66	21	−59
2017	29.9	71	0.9	−97	86	91	40.3	−70	288	−4	545	−8	280	−47	324	−6	439	58	226	−32	195	4	63.5	23

Table 2. District: Kannur.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	0	−100	36	1675	38	400	29	−50	97.4	−59	1504	76	1194	13	421	−22	322	46	319	39	50	−45	12	−49
2014	2.3	−8	8.4	320	0	−100	23	−60	253	8	634.2	−26	1027	−3	876	62	325	47	257	12	97.4	6	30	23
2015	5	101	0	−100	12	61	94	62	173	−27	696.6	−18	803	−24	353	−35	317	44	332	44	167	83	29	18
2016	0	−100	0	−100	0.8	−90	1	−98	138	−41	801.8	−6	616.1	−42	437	−19	137	−38	45.1	−80	22	−76	17	−28
2017	12	358	0	−100	6.1	−20	48	−17	181	−23	694.3	−19	623.6	−41	553	2	430	95	171	−26	69.4	−24	5.9	−76

Table 3. District: Ernakulam.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	6.3	−52	65	247	49	56	37.8	−66	151	−50	1259	81	827	23	375	−7	314	6	319	6	211	46	45.2	2
2014	0	−100	11	−41	22	−28	90.7	−19	288	−4	550.1	−21	650	−3	877	119	299	1	435	45	119	−18	94	112
2015	2.4	−82	0.5	−97	37	19	229	105	176	−41	573.9	−18	367	−45	241	−40	394	33	355	18	333	129	182	311
2016	0.4	−97	91	386	3.4	−89	43.8	−61	323	7	624.6	−10	620	−7	239	−41	85.7	−71	161	−46	115	−21	19.5	−56
2017	17	28	0	−100	98	214	31.4	−72	306	2	706.3	1	435	−35	416	4	445	50	293	−2	218	50	28.1	−37

Table 4. District: Idukki.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	0.3	−98	15	−32	51.7	19	110	−27	95.5	−59	1123	72	1026	30	689	31	507	64	230	−33	199	15	13.6	−72
2014	7.9	−41	14	−36	27.1	−38	86.8	−42	237	2	493	−24	898.7	14	905	72	410	33	422	23	127	−26	54.4	13
2015	1.4	−90	14	−35	78.4	80	281	87	166	−29	644.9	−1	436.3	−45	271	−49	344	12	254	−26	248	44	128	165
2016	5.1	−62	5.1	−77	26.4	−39	39.1	−74	293	26	586.3	−10	540.8	−31	323	−39	120	−61	117	−66	37.9	−78	19.1	−60
2017	13	−4	1.1	−95	122	180	71.1	−53	210	−10	517.9	−21	293.4	−63	713	35	535	73	285	−17	117	−32	91	89

Table 5. District: Kasargod.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	0	−100	83	8220	18	112	76.8	64	85.9	−61	1400	40	998	−10	440	−31	248	−6	182	−22	34	−60	4	−78
2014	0	−100	0	−100	0	−100	15.4	−67	243	12	595	−40	747	−33	979	54	399	51	312	33	27	−68	25	34
2015	0.9	−61	0	−100	36	332	118	151	152	−30	549	−45	847	−24	433	−32	204	−23	296	26	92	9	19	4
2016	2.9	24	0.5	−50	0	−100	0.1	−99	138	−36	946	−5	719	−35	456	−28	133	−50	23.8	−90	22	−74	26	39
2017	18	687	0	−100	0	−100	15.5	−67	71.8	−67	859	−14	753	−32	703	10	331	26	126	−46	40	−53	14	−22

Table 6. District: Kollam.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	10	−41	58	72	49.2	−21	90.2	−43	160	−36	750	64	449	13	205	−21	374	71	291	−20	214	−3	39.5	−28
2014	0.5	−97	16	−53	51.4	−18	152	−4	291	17	284	−38	288	−28	592	129	260	19	387	7	152	−31	40.1	−26
2015	7.7	−56	33	−2	34.6	−45	279	76	226	−9	412	−10	185	−54	141	−45	256	17	386	6	308	39	68.6	26
2016	1	−94	50	49	55.3	−12	67.3	−58	384	55	509	11	263	−34	137	−47	42.9	−80	189	−48	198	−10	19.7	−64
2017	22	23	1.3	−96	148	136	138	−13	357	44	533	16	129	−68	282	9	412	89	323	−11	369	67	259	374

Table 7. District: Kottayam.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	7.9	−39	31	24	118	179	88.7	−35	170	−40	1125	73	754	28	405	5	297	10	347	10	245	38	17	−60
2014	11	−15	19	−25	45.2	7	145	7	304	8	496.8	−23	491	−17	805	109	313	16	468	48	157	−12	95	131
2015	9.1	−30	4.4	−82	132	211	302	122	240	−15	615.5	−5	307	−48	293	−24	374	38	403	27	203	14	122	197
2016	12	−11	44	76	72.5	71	56.5	−58	319	13	630.6	−3	431	−27	199	−49	70.4	−74	154	−51	90.7	−49	7.7	−81
2017	28	114	0.2	−99	128	203	58.2	−57	316	12	654	1	342	−42	450	17	482	78	287	−9	267	51	79	92

Table 8. District: Kozhikode.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	1.3	−43	42	972	39	157	22	−73	194	−24	1426	59	1114	17	392	−22	235	−6	269	3	96.6	−26	14	−54
2014	0	−100	0	−100	0.8	−95	91	12	254	−1	508.2	−43	1068	12	879	75	318	27	332	27	106	−19	9.3	−69
2015	0	−100	0	−100	35	134	91	12	190	−26	667.9	−25	780.5	−18	257	−49	290	15	351	34	199	53	8.8	−71
2016	0	−100	0	−100	32	115	5.7	−93	260	1	916.4	2	604.2	−37	269	−46	98.2	−61	42.5	−84	8.9	−93	23	−23
2017	7.7	235	0.1	−97	21	41	68	−16	252	−2	822.5	−8	662.9	−31	545	9	492	96	216	−17	46.1	−65	9.1	−70

Table 9. District: Malappuram.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	0	−100	7.7	97	28	122	8.5	−90	105	−53	1066	61	912	15	352	−11	348	65	201	−31	175	30	12	−48
2014	1.1	−35	0.5	−87	0	−100	50	−43	236	7	542.1	−18	857	8	616	56	297	41	371	28	121	−10	41	79
2015	0	−100	0	−100	37	193	167	92	187	−15	593.8	−10	412	−48	264	−33	267	26	292	0	232	72	36	59
2016	0	−100	1.8	−53	2.6	−80	4.7	−95	155	−30	585.2	−11	407	−49	186	−53	73.2	−65	87.1	−70	14.8	−89	16	−28
2017	4	137	0	−100	29	131	27	−69	123	−44	568.8	−14	427	−46	460	16	473	124	211	−27	95.6	−29	37	63

Table 10. District: Palakkad.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	0	−100	44	569	34	52	34.4	−65	55.6	−65	729	57	797	34	279	−16	284	58	235	−11	74.4	−46	4.6	−82
2014	0	−100	3.1	−52	5.2	−77	36.4	−63	191	20	314	−32	602	1	561	68	231	29	283	7	40.2	−71	12	−53
2015	0	−100	2	−70	27	20	184	87	246	55	455	−2	282	−53	219	−34	199	11	142	−46	186	34	43	69
2016	0.2	−92	0	−100	4.2	−81	4.1	−96	169	7	462	−1	337	−43	159	−52	77.4	−57	88.2	−67	21.7	−84	28	8
2017	0	−99	0	−100	83	269	28.3	−71	140	−12	433	−7	317	−47	398	19	376	110	103	−61	35.2	−75	39	52

Table 11. District: Pathanamthitta.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	9	−55	24	−46	92	24	47	−75	154	−48	729	31	608	13	281	−20	310	17	268	−25	306	43	18	−65
2014	2.9	−85	36	−21	36.4	−51	287	55	295	0	416	−25	429	−20	779	121	290	9	401	12	94.6	−56	77	50
2015	7.8	−61	18	−60	76	3	477	158	177	−40	370	−34	186	−66	269	−24	348	31	546	52	336	57	79	54
2016	0.5	−97	4.6	−90	70	−5	123	−33	427	45	459	−18	345	−36	212	−40	79.5	−70	224	−38	194	−9	7.8	−85
2017	31	56	0	−100	315	326	100	−46	260	−12	554	−1	205	−62	454	29	541	103	427	19	389	82	76	48

Table 12. District: Thiruvananthapuram.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	11	−46	63	199	47	32	31.7	−73	121	−44	525	55	248	8	116	−18	220	36	156	−42	274	43	33.6	−46
2014	46	137	13	−38	35	−1	136	17	273	26	142	−58	119	−48	459	223	189	17	288	8	129	−33	83	32
2015	9.6	−50	0.4	−98	51	42	257	120	337	56	359	6	60.6	−74	71.4	−50	307	90	367	37	276	44	157	150
2016	3.2	−83	3.7	−83	19	−46	58.1	−50	429	98	395	17	119	−48	42.2	−70	15.7	−90	43.4	−84	47.2	−75	21.8	−65
2017	5	−74	0	−100	85	140	54.2	−54	228	5	319	−6	52.9	−77	123	−13	269	67	241	−10	275	43	151	141

Table 13. District: Thrissur.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	0.8	−76	46	513	30	75	9.9	−88	130	−55	1066	51	779	1	337	−24	275	−1	403	36	105	−24	3.9	−89
2014	0	−100	5.9	−21	3.2	−81	47.7	−40	250	−14	456	−36	560	−28	672	53	260	−6	408	38	94.1	−32	21	−40
2015	0.9	−73	0	−100	38	126	140	76	188	−35	622	−12	463	−40	278	−37	314	13	274	−7	183	33	92	163
2016	11	218	4	−46	6.2	−64	37.2	−53	258	−11	588	−17	422	−45	149	−66	60.3	−78	98.2	−67	8.3	−94	46	30
2017	1.4	−58	0	−100	44	156	12.9	−84	176	−39	675	−5	419	−46	427	−3	355	28	188	−37	113	−18	16	−56

Table 14. District: Wayanad.

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2013	0	−100	12	39	86	389	61.5	−26	91.4	−48	1025	47	997.7	−10	414	−30	253	10	186	−13	27.7	−70	17	−35
2014	0	−100	4.2	−49	10	−42	142	70	202	16	539.4	−23	1061	−4	642	8	317	38	251	18	32.8	−65	58	124
2015	0.1	−98	0	−100	46	162	139	67	203	16	829.8	19	304.3	−73	226	−62	233	1	154	−28	113	21	34	33
2016	3.3	−31	0	−100	13	−26	20.1	−76	113	−35	411.2	−41	337.7	−70	243	−59	82.4	−64	58.6	−72	12.1	−87	34	32
2017	15	202	0	−100	50	184	60.9	−27	183	5	343.2	−51	419.6	−62	435	−27	454	97	119	−44	37.5	−60	9.1	−65

recorded history. A total of 3,368 mm water poured from the sky.[11] In 1924, it is said that 1,000 people lost their lives in the flood. It is still the worst natural disaster in the southern Indian state.[12]

Kerala experienced heavy rain in 2018, a surplus rainfall of 42% since June 1, 2018. It received 2,346.6 mm rain till August 19, 2018, as per the data recorded by the IMD, against an expected normal of 1,649.5 mm.[13] According to the IMD data, Idukki district received a surplus of 92% during this period followed by Palakkad, 72% above normal. These two district were the worst affected by Kerala floods.

7. CAUSES OF THE RAIN HAVOC IN KERALA

There are several reasons that were found, studied, and discussed with the management students about the Kerala flood. Some of the reasons are related to climate changes in Kerala. It includes solar radiation, emission of greenhouse gases, discharge of toxic wastes from industries, and so on. However, detailed investigations are required to understand the exact reasons and the short- and long-term effects of climate change in the state of Kerala.

One of the important reasons for the heavy rains in Kerala is the Western Ghats, as it is positioned to enhance rainfall along the west coast as it intercepts the moisture-laden air being drawn in from the warm ocean waters as part of the southwest monsoon circulation.[14] The low pressure in the Arabian Sea attracts the southwesterly winds from the high-pressure Bay of Bengal, gets concentrated over the region due to high moisture in the air and causes rain once it hits the Western Ghats.[15]

Some of the other reasons are as follows:

- High-intensity rainfall in short period
- Heavy rainfall due to climate change
- Human intervention
- Exploitation of nature
- Underlying ground cannot cope with the sheer amount of water
- Deforestation and blockage of natural streams
- Unauthorized encroachments in forest area
- Weak protection of forest resources
- Illegal and rampant stone quarrying
- Changing drainage patterns and sand mining on riverbeds
- Cutting down forests and grasslands
- Digging of pits
- Landslides and landslips
- Wetlands and lakes that acted as natural safeguards against floods have disappeared because of rampant urbanization and construction of infrastructure
- Shoddy urban planning
- Unplanned reservoir regulation
- Cut in mountain slopes and encroached upon
- Choked rivers with sand deposits
- Reduction in the capacity of the rivers and lakes to hold more water due to pollutants in rivers
- Loss of natural support on land
- Insensible use of land, soil, and rocks
- Build of homes and business establishments not as per norms
- Unscientific developmental activities in ecologically sensitive areas

11 https://www.indiatoday.in/india/story/why-kerala-fears-repeat-of-1924-havoc-in-2018-rainfall-1315884-2018-08-16
12 https://www.firstpost.com/tech/news-analysis/what-caused-the-kerala-floods-4993041.html
13 https://www.indiatoday.in/india/story/why-kerala-floods-killed-so-many-destroyed-so-much-1319998-2018-08-21
14 https://in.news.yahoo.com/caused-kerala-floods-nasa-reveals-122224135.html
15 https://www.hindustantimes.com/india-news/what-is-behind-the-kerala-monsoon-fury/story-2NxvHfTDAmS10k9h-HofiiO.html

- Violating norms in place to protect the environment
- Poor planning by the disaster management authority
- Poor or inadequate drainage capacity
- Failure of flood-control structures
- Improper management of dams
- The state did not gradually release water from its dams[16]
- Opening of shutters of 44 dams at the same time without giving prior warning[17]
- Failure in introducing a flood forecasting system to issue warnings in advance
- Weak foresight to prevent a disaster
- The state does not have a single battalion of the state disaster response force (SDRF) to tackle natural calamities[18]

8. IMPACT OF KILLER FLOOD

The flood in Kerala did not discriminate between people and property. All districts of Kerala were placed on red alert. Direct effects on the economy, environment, and people were noticed. Roads, bridges, farms, houses, and automobiles were almost destroyed. People become homeless. Incessant rains, floods, and landslides rendered more than 7.25 lakh people homeless.[19] One-sixth of the total population of the state was directly affected due to this flood. In this flood, 357 people lost their lives. It destroyed approximately 906,400 hectares worth of crops.[20] More than a million people have been displaced and stayed in relief camps.[21] The flooding affected hundreds of villages, destroyed an estimated 10,000 kilometers of roads, and damaged or destroyed thousands of homes.[22] Some of the following effects were observed during flood:

- Loss of several hundred lives
- Death in myriad forms
- Mass burials
- Severe impact on the region's fragile infrastructure
- Complete damage of roads
- Displacement of more than a million people
- Less availability of clean fresh water and hygienic food
- Inoperative network of mobile phones
- Absence of electricity
- Temporary closure of international airport
- Suspension of railway operations
- Submerged vast areas in 14 districts of the state
- Collapse of houses, offices, shops, buildings, and so on

9. RAIN DISASTER FLOOD RELIEF MEASURES

There were several initiatives taken by central and state government of India, which included financial relief assistance in the form of sanction of heavy amount of money for Rain Disaster 2018 from the Chief Minister's

16 http://timesofindia.indiatimes.com/articleshow/65433480.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
17 http://timesofindia.indiatimes.com/articleshow/65507367.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
18 http://timesofindia.indiatimes.com/articleshow/65433480.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
19 https://www.indiatoday.in/india/story/why-kerala-floods-killed-so-many-destroyed-so-much-1319998-2018-08-21
20 https://www.firstpost.com/tech/news-analysis/what-caused-the-kerala-floods-4993041.html
21 https://www.independent.co.uk/news/world/asia/kerala-floods-latest-india-cause-flash-flooding-landslides-explained-a8500801.html
22 https://en.wikipedia.org/wiki/2018_Kerala_floods

Distress Relief Fund, loan assistance to small-scale traders, loan for making houses habitable, repairing of damaged boats, kit for families leaving relief camps, sanitation works in flood-hit regions, immediate restoration of roads, free ration to plantation workers, cattle feed at reduced rate, distribution of relief materials, issuance of duplicate ration cards to families who lost the same in floods, and many more postflood relief operations and initiatives were also taken to safeguard the lives of people in Kerala.[23]

10. LESSON LEARNED

Generally, the role of humans in climate change is discussed. Is it due to global warming or is nature responsible for the same or do any other factors contribute to climate change? In my opinion, most of the climate scientists and scientific organizations around the globe also believe that climate changes are occurring due to human activities over the past century. According to Fifth Assessment Report, the Intergovernmental Panel on Climate Change, a group of independent scientific experts from different countries concluded that human activities warmed our planet over the past 50 years.[24]

For example, the relation between global warming and increase in temperature are well understood. Warmer climate conditions may lead to more evaporation and precipitation, but it will vary from one region to other region. Some regions can become wetter while some others can be dryer in comparison to other regions. It is complicated when we talk about extreme rainfall in some parts of the country. According to Clausius–Clapeyron relation, anticipation of severe rainfall events can be calculated through the relationship of the atmosphere's capacity to hold more water and rise in temperature.[25] At the same time, it is also true that no single factor is responsible in for the changes in climate. Now is the right time to implement the recommendations of the Gadgil committee report, which was given by the Western Ghats Ecology Expert Panel (WGEEP). It recommended that development should be restricted in the Western Ghats. Kerala is among one of the states where the Western Ghats sprawls.[26] The ghats extend over six states: Gujarat, Goa, Karnataka, Tamil Nadu, Maharashtra, and Kerala. WGEEP designated the entire Western Ghats as an ecologically sensitive area (ESA). The recommendations of the Gadgil committee also included use of land for nonforest purposes, restrictions on mining and quarrying, and so on. It also recommended for restrictions on construction of high-rises. It recommends that no new dams based on large-scale storage be permitted in ecologically sensitive zone 1.[27] The panel divided the area into different zones as follows:

1. Ecologically Sensitive Zone 1 (ESZ1)
2. Ecologically Sensitive Zone 2 (ESZ2)
3. Ecologically Sensitive Zone 3 (ESZ3)

Climate projections for smaller locations/regions are difficult. Hence, there is a need to incorporate downscaling techniques in the General Circulation Model (GCM) models for smaller geographical regions as well. There is need to train skilled personnel in the field of disaster management. Further, R&D initiatives are also needed in this area. There is another question for high concern. It is dam management. If dams are not properly managed, it may cause another disaster in Kerala. We all know that we hurt nature very much in the name of development. It is high time to think about nature and implement strategies to protect the environment. It is high time for all of us to prepare a master plan to protect the environment and implement it aggressively in a time-bound manner. It is not the responsibility of only the central government or the state government. Every citizen must understand his or her responsibilities. The most important lesson is that we should not differentiate between doing and saying. Everyone knows about the importance of clean and green environment, but what exactly are we doing for saving the environment?—panel discussions,

23 https://kerala.gov.in/floodrelief-orders
24 http://ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf
25 http://theconversation.com/why-its-so-hard-to-detect-the-fingerprints-of-global-warming-on-monsoon-rains-102006
26 https://www.thequint.com/news/kerala-flood-with-great-damage-less-intense-than-1924-flood
27 http://www.moef.nic.in/downloads/public-information/wg-23052012.pdf

some speeches, lectures, conferences, and preparation of reports. And after that what happened? If we really implement the recommendations and suggestions seriously and everyone feel the responsibilities to implement the same, then only can we safeguard our environment. It is the right time to undertake a real effort to have proper management of our environment to protect ourselves at least from the disasters that have their origins in man-made causes. In the olden times, we did not have the proper means to manage the floods except to pray, but now we can plan in advance with the help of modern technologies to assess the natural calamities so that damage can be minimized. We must know well-structured and efficient disaster-management techniques and deploy them at the time of emergencies. There must be proper coordination and mechanism among the state and the central government to tackle the situation. This mechanism should be permanently there, as natural disasters can occur anytime, anywhere, and at any place, like earthquakes, cyclones, or tornadoes. The decision to tackle the calamities must be beyond politics.

11. CONCLUSION

Now the important question is why did we not sense it before the incident took place? Are we waiting for something bigger to happen? Definitely not. How many lives we saved before the situation got out of control is the prime objective. How we can minimize losses due to such natural climate disasters whatever may be the reasons? Above all, what lessons have we learned from such incidents, and how we are going to apply our learning to safeguard the present and future generations? This is of paramount concern because if we do not wake up today, we will not be able to see the next morning in the near future. It is time to bring together scientists, academicians, government, policy makers, and so on for sharing their knowledge, expertise, and experience for disaster management. The worsening situation in Kerala is an opportunity to learn lessons for future. There is no single approach that may work. Different approaches tackle the problem in different ways. That's why we should adopt the effective approach of not only forecasting the weather but also communicating climate risk to the general public before it's too late. We also require a massive education program for disaster risk mitigation and management that should be taught at the village level also. Still, there is sufficient time and scope to adopt appropriate adaptive mechanisms for the betterment of the future generations. Finally, it can be said that "prevention is better than cure." We should focus on long-term solutions rather than short-term measures to prevent natural disasters. It is a definite need to get ready for a safer and happy future for all of us.

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