Managing Factors Responsible for Climate Change in Nigeria using Mathematical Modelling Technique

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Abstract

Climate Change is a major threat to sustainable development and growth in Africa, and more especially in Nigeria and the achievement of Millennium Development Goals (MDGs). The consequences include intensified desertification, flood disasters, degradation of land, erosion and the rise in tidal water along coastline. Thus, the understanding of Climate Change and the use of mathematical programming can help to deal with the complex constraint and parameters in order to manage the factors responsible for climate change in Nigeria. Furthermore, intensive efforts and realistic approach towards minimizing these factors according to the relative optimal solutions from this paper will have to be adopted in order to adequately manage climate change for economic growth and development. The aim of this article is to apply operational research methodology in managing factors responsible for climate change. Computer software – LINGO 17.0, was used to solve the resulting initial tableau derived from the Linear programming standardized model. The results show that in order to minimize climate change in Nigeria, the most important factor in transportation related. So, more money should be spent on transportation system in order to combating climate change in Nigeria.
Keywords: Operational Research Method, Climate Change, sustainable development

1. Introduction

In recent years, climate change has become a serious environmental concern on a global scale. Scientists and individuals around the globe have become increasingly concerned in its impact which can have serious consequences for both human and their environment [1,2]. According to recent studies, Africa is seen as one of the most vulnerable regions in the world to climate change due to a combination of naturally high levels of climate variability, high reliance on climate sensitive activities, such as rain fed agriculture, and limited economic and institutional capacity to cope with, and adapt to, climate variability and change. Nigeria is expected to suffer from climate change in terms of reduced agricultural productivity and increased water insecurity. Climate change is now a global threat with the potential to affect the entire world. Currently, the impact of climate change is already felt in many sectors. Recent reports indicates that global temperature could reach around 2ºC by 2060 [3]. In Nigeria, DFID (2009) predicts a possible sea level rise from 1990 levels to 0.3 m by 2020 and 1m by 2050, and rise in temperature of up to 3.2°C by 2050 under a high climate change

scenario. This is based on IPCC climate change assumptions, latest research findings and results of a consultation exercise in Nigeria. The low estimate predictions are for sea level rise of 0.1 m and 0.2 m by 2020 and 2050 respectively, and a temperature increase of 0.4 to 1°C over the same time periods. Sea level rise of 1m could result in loss of 75% of the Niger Delta. In complete reference to Nigeria, DFID's (2009) study predicts that climate change could result in a loss in GDP of between 6% and 30% by 2050, worth an estimated US$ 100 to 460 billion dollars. By 2020, if no adaptation is implemented, between 2-11% of Nigeria's GDP could potentially be lost. Scientist around the world have studied the factors responsible for climatic change and the causes can be divided into two main categories – natural and human causes. Some of the prominent natural causes of climate change are continental drift, volcanoes, oceon currents, the earth's tilt, comets and meteorites. [3]

Recent climate changes, however, cannot be explained by natural causes alone. Research indicates that natural causes do not explain most observed warming, especially warming since the mid-20th century. Rather, it is extremely likely that human activities have been the dominant cause of that warming [3]. Humans are increasingly influencing the climate and the earth's temperature by burning fossil fuels, cutting down rainforests and farming livestock. This adds a very large amount of greenhouse gases to those occuring naturally in the atmosphere, thus increasing the greenhouse effect and global warming. Furthermore, human activities that reduce the amount of carbon sinks are deforestation, alterations in land use, water pollution, and agricultural practices [4,5] As described by Gaber(2011), the take-off stage of development and industrialization progress can lead to increased environmental damage due to greater use of natural resources, more emission of pollutants, the operation of less efficient and relatively dirty technologies, and disregard for the environmental consequences of growth. A collection of gases that keep amount of solar energy in atmosphere and cause the atmosphere to become warm are called greenhouse gases [6,7,8]. Some gases in the Earth's atmosphere traps the sun's heat and stops it from leaking back to the space. Many of such gases naturally occur in the atmosphere but human activity is increasing the concentration of some of these gases. Some of the greenhouse gases include Carbon dioxide (CO_2), methane, nitrous oxide, fluorinated gases and so on. Carbon dioxide is undoubtedly, the most commonly produced greenhouse gas in the atmosphere by human activities [8,9,10] Changes in land use pattern, deforestation, land clearing, agriculture, and other activities have all led to a rise in the emission of carbon dioxide. Carbon dioxide (CO2) emissions are the common type of gas emitted from the burning of fossil fuels [10,11,12,13]. The higher the carbon content in the fossil fuel or the more inefficient the burning process is, generally the more CO2 that is produced. Carbon emissions can be defined as 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 [14,15,16]. Operations research method – Linear programming, is usually used to model one criteria problem or real life situation as a mathematical programming problem, with one objective function. Another operations research technique used for modelling a multi criteria real life situation is the goal programming, always with more than one objective function. Linear programming model is a planning method which uses mathematical model in optimizing appropriate measure to optimize the value of some objective after identifying some limitation otherwise known as constraints [17,18,…,22]. Linear programing algorithm was applied in this paper to manage the identified factors responsible for climate change in Nigeria.

Fig 1: Emission of carbon dioxide from vehicles in Nigeria

Linear programming is a mathematical technique for finding optimal solutions to problems that can be expressed using linear equations and inequalities [17,18]. The best solution of a real-world problem can be derived if the problem is represented appropriately. Realistic representation can be achieved through linear programs especially through the application of creativity in the mathematical formulation. Linear programming is a procedure to optimize the value of some objectives (e.g. maximize or minimize) when the factors involved are subject to some constraints [19,20,21]. This paper attempts to minimize climate change in Nigeria by managing the factors responsible for climate change in Nigeria using a mathematical method.

2. Problem Formulation

The table below shows the causes, their contributions and the cost required to combat the factors. The sources of the data is shown below.

Causes of Climate	Percent	Resources to	Details	Cost to combat

Change	age (%)	combat factors		factors ((N) million)
Transportation	14.8	Efficient gasoline cars and diesel truck	CO_2 reduction capacity of 247.05 and 60.096 MTon respectively	26,538,000,000
Construction/Manufacturing	13.3	Fuel-oil to natural gas fuel substitution	CO_2 reduction capacity of 7.49 MTon	138,000,000
Agriculture	11.1	Capital requirement	758.4 million for 40 years	7,584,000,000
Gas Flaring	8.2	Gas flare tracker (gasflaretracker.ng)	Penalty at $3.5/Mscf ($CO_2$ reduction capacity of 41.313 MTon)	427,000,000
Industrial processes	5.8	Introduction of efficient industrial motors	CO_2 reduction capacity of 10.738 MTon	171,000,000
Deforestation	5.7	Afforestation	17million trees to be planted before 2030 (CO_2 reduction capacity of 197.353 MTon)	686,000,000
Fugitive emission	5.3	Improved Electrical Appliances, Industrial and commercial sectors	CO_2 reduction capacity of 14.431 MTon	2,485,000,000
Waste	3.1	Waste management, preventive mechanism	CO_2 reduction capacity of 18.369 MTon	72,000,000
Bunker fuel	2.2	Refurbishments of Vessels	CO_2 reduction capacity of 18.735 MTon	24,000,000
Electricity/Heat	30.6	Renewable energy	CO_2 reduction capacity of 919.201 MTon	45,534,000,000

Table 1: Data on the causes of climate change (Sources: [1] [2] [5] [8])

Mscf - One thousand standard cubic feet
MTon – Megaton

Using the information in table 1, the linear programming model is formulated as follow:
Linear programming involves the objective function, the constraints and the non-negative constraints. The Objective is to minimize the factors responsible for climate change in Nigeria.

Minimize $Z = \sum^{n} C_j X_j$

Subject to $\sum_{j=1}^{n} a_{ij}x_j \geq bi \quad i = 1, 2, 3, \ldots\ldots\ldots\ldots m$

$$x_j \geq 0, \; j = 1, 2, 3, \ldots\ldots\ldots\ldots n$$

where,

i = resources (there are m resources)
j = activities (there are n activities)
Z = Performance measure
C_j = Performance measure coefficient for activity j (contribution)
X_j = Level of activity (j = 1,2,…….,n)
a_{ij} = amount of available resources used to produce 1 unit of product
bi = available resources

2.1 The Objective and Decision Variables

The Objective of this paper is to minimize the effects of the factors responsible for Climate Change in Nigeria using Operations Research Model. This paper suggests how to effectively allocate money in order to combat and minimize the effects caused by factors of climate change in Nigeria. These factors, which constitute the decision variables in the model, include: Transportation, Construction/Manufacturing, Agriculture, Gas flaring, Industrial Process, Deforestation, Fugitive emission, Waste, Bunker fuel, Electricity/Heat.

Let,

x_1 represents the amount of money for combating climate change caused by Transportation
x_2 represents amount of money for combating climate change caused by Construction/Manufacturing
x_3 represents amount of money for combating climate change caused by Agriculture
x_4 represents amount of money for combating climate change caused by Gas flaring
x_5 represents amount of money for combating climate change caused by Industrial process
x_6 represents amount of money for combating climate change caused by Deforestation
x_7 represents amount of money for combating climate change caused by Fugitive emission
x_8 represents amount of money for combating climate change caused by Waste
x_9 represents amount of money for combating climate change caused by Bunker fuel
x_{10} represents amount of money for combating climate change caused by Electricity/Heat

2.2 Contributions

From the data considered, the contributions of each factor of climate change to the overall causes of climate change are as follows respectively:

$C_1 = 14.8$	$C_2 = 13.3$	$C_3 = 11.1$	$C_4 = 8.2$	$C_5 = 5.8$
$C_6 = 5.7$	$C_7 = 5.3$	$C_8 = 3.1$	$C_9 = 2.2$	$C_{10} = 30.6$

That is, $Z = \sum_{i=1}^{10} C_i X_i$

$= C_1X_1 + C_2X_2 + C_3X_3 + C_4X_4 + C_5X_5 + C_6X_6 + C_7X_7 + C_8X_8 + C_9X_9 + C_{10}X_{10}$
$= 14.8X_1 + 13.3X_2 + 11.1X_3 + 8.2X_4 + 5.8X_5 + 5.7X_6 + 5.3X_7 + 3.1X_8 + 2.2X_9 + 30.6X_{10}$

2.3 Constraints

- Inflation rate in Nigeria is 12% up from January, 2015 to January, 2016 (8.6 – 9.6). This is applicable in the following activities: Transportation, Construction/Manufacturing, Industrial processes, Fugitive emission and Bunker fuel.

  That is 12% of the summation of cost projections of the activities:
  12% of 29,356,000,000 = 3522720000
  29,356,000,000 – 3,522,720,000 = 25,833,280,000

- Interest rate/Exchange rate in Nigeria (January, 2015 – January, 2016) is 13%. This is applicable in the following activities: Transportation, Construction/Manufacturing, Industrial processes, Fugitive emission.

  That is 13% of the summation of the cost projections of the activities:
  13% of 29,332,000,000 = 3,813,160,000
  29,332,000,000 – 3,813,160,000 = 25,518,840,000
- For the major sectors in Nigeria with billions of allocation, cost of corruption account for 15% of allocation and the Gross Domestic Product of Nigeria. This is applicable in the following activities: Transportation, Fugitive emission, Electricity/Heat

  That is 15% of the summation of all the cost projections of the activities:
  15% of 76,833,000,000 = 11,524,950,000
  76,833,000,000 – 11,524,950,000 = 65,308,050,000

- Mismanagement and debt financing takes an estimate of 22% of the capital expenditure in Nigeria. This is applicable mostly in the following activities: Transportation, Construction/Manufacturing, Agriculture, Industrial processes, Electricity/Heat.

  That is 22% of the summation of the cost projections of the activities:
  22% of 73,139,000,000 = 16,090,580,000
  73,139,000,000 – 16,090,580,000 = 57,048,420,000

Let a_i be the amount of money to combat a unit of each of the factors responsible for climate change i.e. a_i = Total amount to combat climate change caused by a factor of climate change
Percentage of each of the factors to the overall causes of climate change

a_1 = Amount of money to combat a unit of climate change as caused by Transportation

$$a_1 = \frac{26{,}538{,}000{,}000}{14.8} = 1{,}793{,}108{,}108$$

a_2 = Amount of money to combat a unit of climate change as caused by Construction/Manufacturing

$$a_2 = \frac{138{,}000{,}000}{} = 10{,}375{,}939$$

13.3

a_3 = Amount of money to combat a unit of climate change as caused by Agriculture

$a_3 = \frac{758,400,000}{11.1} = 68,324,324$

a_4 = Amount of money to combat a unit of climate change as caused by Gas flaring

$a_4 = \frac{427,000,000}{8.2} = 52,073,170$

a_5 = Amount of money to combat a unit of climate change as caused by Industrial processes

$a_5 = \frac{171,000,000}{5.8} = 29,482,758$

a_6 = Amount of money to combat a unit of climate change as caused by Deforestation

$a_6 = \frac{686,000,000}{5.7} = 120,350,877$

a_7 = Amount of money to combat a unit of climate change as caused by Fugitive emission

$a_7 = \frac{2,485,000,000}{5.3} = 468,867,924$

a_8 = Amount of money to combat a unit of climate change as caused by Waste

$a_8 = \frac{72,000,000}{3.1} = 23,225,806$

a_9 = Amount of money to combat a unit of climate change as caused by Bunker fuel

$a_9 = \frac{24,000,000}{2.2} = 10,909,090$

a_{10} = Amount of money to combat a unit of climate change as caused by Electricity/Heat

$a_{10} = \frac{45,534,000,000}{30.6} = 1,488,039,215$

The constraints are as follows: $= \sum_{i=1}^{10} a_i x_i \geq b_i$

3. The Model

Minimize $Z = 14.8X_1 + 13.3X_2 + 11.1X_3 + 8.2X_4 + 5.8X_5 + 5.7X_6 + 5.3X_7 + 3.1X_8 + 2.2X_9 + 30.6X_{10}$

Subject to:

$1,793,108,108X_1 + 10,375,939X_2 + 29,482,758X_5 + 468,867,924X_7 + 10,909,090X_9 \geq 25,833,280,000$

$1,793,108,108X_1 + 10,375,939X_2 + 29,482,758X_5 + 468,867,924X_7 \geq 25,518,840,000$

$1,793,108,108X_1 + 468,867,924X_7 + 1,488,039,215X_{10} \geq 65,308,050,000$

$1{,}793{,}108{,}108X_1 + 10{,}375{,}939X_2 + 68{,}324{,}324X_3 + 29{,}482{,}758X_5 + 1{,}488{,}039{,}215X_{10} \geq 57{,}048{,}420{,}000$
$X_i \geq 0$, i = 0,1,2,3,……,10

3.1 Standardized Model

Minimize $Z = 14.8X_1 + 13.3X_2 + 11.1X_3 + 8.2X_4 + 5.8X_5 + 5.7X_6 + 5.3X_7 + 3.1X_8 + 2.2X_9 + 30.6X_{10}$
Subject to:
$1{,}793{,}108{,}108X_1 + 10{,}375{,}939X_2 + 29{,}482{,}758X_5 + 468{,}867{,}924X_7 + 10{,}909{,}090X_9 - X_{11} = 25{,}833{,}280{,}000$
$1{,}793{,}108{,}108X_1 + 10{,}375{,}939X_2 + 29{,}482{,}758X_5 + 468{,}867{,}924X_7 - X_{12} = 25{,}518{,}840{,}000$
$1{,}793{,}108{,}108X_1 + 468{,}867{,}924X_7 + 1{,}488{,}039{,}215X_{10} - X_{13} = 65{,}308{,}050{,}000$
$1{,}793{,}108{,}108X_1 + 10{,}375{,}939X_2 + 68{,}324{,}324X_3 + 29{,}482{,}758X_5 + 1{,}488{,}039{,}215X_{10} - X_{14} = 57{,}048{,}420{,}000$
$X_i \geq 0$, i = 0,1,2,3,……,10
where X_{11}, X_{12}, X_{13} and X_{14} are excess variables.

Sol.Var.	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	Soln. Qty
X_{11}	1,793,108,108	10,375,939	0	0	29,482,758	0	468,867,924	0	10,909,090	0	-1	0	0	0	25,833,280,000
X_{12},	1,793,108,108	10,375,939	0	0	29,482,758	0	468,867,924	0	0	0	0	-1	0	0	25,518,840,000
X_{13}	1,793,108,108	0	0	0	0	0	468,867,924	0	0	1,488,039,215	0	0	-1	0	65,308,050,000
X_{14}	1,793,108,108	10,375,939	68,324,324	0	29,482,758	0	0	0	0	1,488,039,215	0	0	0	-1	57,048,420,000
Z	14.8	13.3	11.1	8.2	5.8	5.7	5.3	3.1	2.2	30.6	0	0	0	0	

Table 1: Initial Simplex Tableau

4. Problem Solution and Discussion

Computer software, LINGO, is applied to the initial tableau to arrive at the values of the decision variables. The results show that the most important factor that should be managed to minimize climate change in Nigeria today is Transportation. More money should be spent on the transportation system of Nigeria in order to combat Climate change. As a matter of fact 36.4217 billion naira should be spent on transportation system in Nigeria in order to combat climate change adequately.

5. Conclusion

This paper set out to explore how the factors responsible for climate change in Nigeria can be managed in order to minimize climate change in the region. Data was collected to model the situation. The linear programming model formed was standardized and solved using computer software – LINGO. Among order factors, transportation seems to be the most important factor to be combated if climate change problem in Nigeria is to be solved. Going by the results obtained, transportation factor is very significant unlike other factors responsible for climate change. So, a lot of money should be spent on the transportation sector. A strong government policy that would encourage clean transportation should be in place, to avoid excess emission of carbon dioxide, especially from old poorly maintained vehicles.

Appendix

Lingo 17.0 - [Solution Report - Lingo1]

File Edit Solver Window Help

```
Global optimal solution found.
Objective value:                              539.0412
Infeasibilities:                              0.000000
Total solver iterations:                             1
Elapsed runtime seconds:                          0.03

Model Class:                                        LP

Total variables:                     10
Nonlinear variables:                  0
Integer variables:                    0

Total constraints:                   15
Nonlinear constraints:                0

Total nonzeros:                      37
Nonlinear nonzeros:                   0


                              Variable           Value        Reduced Cost
                                    X1        36.42170            0.000000
                                    X2        0.000000            13.30000
                                    X3        0.000000            1.000000
                                    X4        0.000000            8.200000
                                    X5        0.000000            5.800000
                                    X6        0.000000            5.700000
                                    X7        0.000000            1.430046
                                    X8        0.000000            3.100000
                                    X9        0.000000            2.200000
                                   X10        0.000000            18.31799

                                   Row    Slack or Surplus      Dual Price
                                     1        539.0412           -1.000000
                                     2        36.42170            0.000000
                                     3        0.000000            0.000000
                                     4        0.000000            0.000000
                                     5        0.000000            0.000000
                                     6        0.000000            0.000000
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