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Modelling atmospheric temperature rise due to pollutants and its implications on agriculture

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Abstract

Using a mathematical model we show that temperature increases (warming) as the Hartman number due to pollutant increases. Thus, temperature and pollutants contribute to global warming. We also discuss the implications of the result on agriculture and forestry.

Keywords
Global warming, pollutants, mathematical model, agriculture and forestry

1.0 Introduction

Most literature on global warming has origin in physics and chemistry. The greenhouse effect means that increasing carbon concentrations reflect the long wavelength radiation emitted by the Earth itself thus heating the atmosphere. While chemistry shows that carbon is the result of human activity and carbon is increasing in the atmosphere [10].

Some scientists have studied the flow of dusty fluids. These include [2] who studied the influence of temperature dependent viscosity on the MHD Couette flow of dusty fluid with heat transfer. Gupta and Gupta [5] studied the flow of dusty gas through a channel with arbitrary time varying pressure gradient. Dixit [3] examined the unsteady flow of a dusty fluid through rectangular duct. Singh [13] earlier examined the problem [3] examined in a rectangle. Ghosh [4] also examined the flow of a dusty fluid through horizontal pipes while [10] examined the hydromagnetic effects on a dusty fluid flowing between parallel plates.

In this paper we examine a hydromagnetic dusty flow over a plate (surface of Earth). To simulate the Earth's atmosphere, we assume that the outer boundary is far away.

2.0 Mathematical model

The dusty fluid is assumed to be flowing over a flat plate located at $y = 0$ while the other plate is a infinity. The dusty particles are assumed to be uniformly distributed throughout the fluid. The two plates are assumed to be electrically non-conducting and kept at constant temperatures T_1 and T_2. The lower plate is assumed to be moving with a uniform velocity U while the upper plate is kept constant.

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The steady equations are

$$\mu \frac{d^2u}{dy^2} - \sigma B_0^2 u = 0 \ (Mometum) \tag{2.1}$$

$$k\frac{d^2T}{dy^2} + \mu\left(\frac{du}{dy}\right)^2 + \sigma B_0^2 u^2 \ (energy) \tag{2.2}$$

The boundary conditions are

$$u(0) = U \ , u(\infty) = 0, T_2 > T_1 \tag{2.3}$$

$$T(0) = T_1 \ , T(\infty) = T_2 \ , \tag{2.4}$$

where T_1 and T_2 are to be determined from the solutions.

Let $$\theta = T/(T_2 - T_1), \quad z = \frac{y}{L}, \ \phi = \frac{u}{U}, \ L = \frac{\mu}{\rho U} \tag{2.5}$$

We obtain $$\frac{d^2\phi}{dz^2} - H_a^2 \phi = 0 \ (Momentum) \tag{2.6}$$

$$\frac{1}{\Pr}\frac{d^2\theta}{dz^2} + Ec\left(\frac{d\phi}{dz}\right)^2 + Ec\,H_a^2\phi^2 = 0 \ (energy) \tag{2.7}$$

$$\phi(0) = 1, \quad \phi(\infty) = 0 \tag{2.8}$$

$$\theta(0) = \alpha, \theta(\infty) = \beta, \tag{2.9}$$

where $$\alpha = \frac{T_1}{T_2 - T_1}, \ \beta = \frac{T_2}{T_2 - T_1} \tag{2.10}$$

$$H_a^2 = \sigma B_0^2 \ L^2/\mu ,$$

H_a is the Hartman number.

$$\Pr = \mu c_p / k$$

is the Prandth number.

$$Ec = U^2/(c_p(T_2 - T_1))$$

is the Eckert number
Equations (2.6) – (2.9) give

$$\phi = \bar{e}^{H_a z} \tag{2.11}$$

$$\theta = -\frac{\Pr Ec}{4} \ \bar{e}^{H_a z} + \beta , \tag{2.12}$$

and $$\alpha = \beta - \frac{\Pr Ec}{4} \tag{2.13}$$

3.0 Discussion of result

$\frac{d\theta}{dH_a} = \frac{\Pr Ec\, z}{2} \ e^{-2H_a z} > 0$, for all z > 0. That is, temperature increases (warming) as the Hartman number due to the pollutants increases.

4.0 Implications of the result

4.1 Climate

Climate change is emerging as one of the most challenging problems facing the world in the 21st century. Global data indicate that weather patterns are changing and natural disasters such as droughts, floods, and tropical storms are increasing in frequency and intensity. Human activity has already changed atmospheric characteristics such as temperature; rainfall, levels of carbon dioxide (CO_2) and ground level ozone. Increases in the amount of gases such as carbon dioxide in the atmosphere are occurring because of emissions from human activities such as the burning of fossil fuels (coal, oil and gas) or through deforestation and other industrial activities. These increases are sufficient to lead to substantial increased warming [6]. If carbon dioxide concentration increases during the 21st century to more than twice its pre-industrial value, then calculations show that global average temperature will rise by about 2.5ºC (range of uncertainty estimated as 1.5 to 4.5ºC).

A number of studies have addressed the role of global corporations in fostering climatic change. Mason [9], [12] and [14] each examined the environmental practices of transnational corporations (TNCs) and their contribution to greenhouse gas emissions. Robbins [12] and [14] opined that TNC are major contributors to global emissions of greenhouse gases. Mason [9] looked at the emissions patterns and environmental impacts of TNC activity, focusing on the aluminum industry. There is a growing consensus that anthropogenic greenhouse gas emissions have contributed to a change in the climate, and that such trends will continue into the future unless dramatic mitigation measures are adopted [6].

Increases in atmospheric temperature and other emissions into the atmosphere, is more likely to make man to experience different changes in terms of extreme weather such as floods, droughts, storms and disease occurrences including deaths. Such extremes may continually occur because of large natural variability of climate. Climate change can be considered a spatially differentiated process. Although many areas could experience temperature increases in the order of 1.5 to 4.53oC, some areas may be cool under `global warming conditions (Houghton et al., 1996). Patterns and amounts of precipitation are also likely to change, and it is projected that rainfall will increase in some areas and decrease in others [6].

The physical and social impacts of climate change are not considered to be homogenous for two reasons. First, global circulation models project spatial differences in the magnitude and direction of climate change. Second, even within a region experiencing the same characteristics of climate change, the impacts are likely to vary because some ecosystems, sectors, or social groups are more vulnerable to climate change than others. Most climate change, especially if the change is fast, it is likely to have negative impacts as earlier mentioned. The main impacts are likely to be changes in sea level and rainfall. Another major impact of global warming is likely to be on water supplies for man, animals and plants. Warming of the earth's surface means greater evaporation from the earth surface and higher water vapour content in the atmosphere. In many areas, rainfall may become heavier while the semi-arid areas may receive less rainfall, while the sub-tropical areas may experience more frequent and intense floods or droughts, especially in vulnerable areas. In some areas, water may likely become a critical.

To obtain a better understanding of the future of world agriculture and other environmentally sensitive sectors, the joint impacts of globalization and climate change should be examined. In this paper, we establish a framework for examining how pollutants contribute to global warming and the implications on agriculture and forestry

4.2 Agriculture, forestry and global warming

Agriculture is highly sensitive to climate variability and weather extremes, such as droughts, floods and severe storms. The forces that shape our climate are also critical to farm productivity. While food production may benefit from a warmer climate, the increased potential

for droughts, floods and heat waves will pose challenges for farmers. Also, the continuous changes in climate, water-supply and soil-moisture could make animal and crop production more difficult in certain regions of Africa especially Nigeria; where poverty is the other of the day for farmers and can not afford the needed technology. Several factors directly connect climate change and agricultural productivity, average temperature increase, change in rainfall amount and patterns, rising atmospheric concentrations of CO_2, pollution levels such as tropospheric ozone, change in climatic variability and extreme events.

4.3 Average temperature increase

Literature made us to understand that an increase in average temperature can (a) lengthen the growing season in regions; (b) adversely affect crops in regions where extreme heat already limits production; (c) increase soil evaporation rates, and (d) increase the chances of severe droughts. Photosynthesis slows down as temperature rises; research has shown that rice yields are declining by 10% for every degree Celsius increase in night-time temperature. One approach explored by the International Rice Research Institute (IRRI) involves modifying the plant to boost its photosynthetic capabilities. Research has also suggested that higher mean temperature range will increase pest developmental rates and fecundity, frequency of occurrence leading to a wide range of insect pests/diseases, and weed species. In the cold region according to literature, higher winter temp increases lead to higher incidence of green leaf hoppers and stem borers. In Malawi, farmers noted that summer periods which used to run august to December, but now according to a study it runs from October to January, and they confirmed that temperatures have been increasing over the years. Phiri et. al. [11] also observed that mean temperatures in the lower Shire had increased by 2.30%, while mean maximum temperatures increased by 2% between 1970 and 2002.

4.4 Rising atmospheric concentrations of CO_2

Increasing atmospheric CO_2 levels, driven by emissions from human activities, can act as a fertilizer and enhance the growth of some crops such as wheat, rice and soybeans. CO_2 can be one of a number of limiting factors that, when increased, can enhance crop growth. Other limiting factors include water and nutrient availability. While it is expected that CO_2 fertilization will have a positive impact on some crops, other aspects of climate change (e.g., temperature and precipitation changes) may temper any beneficial CO_2 fertilization effect [8].

4.5 Pollution levels such as tropospheric ozone

Higher levels of ground level ozone limit the growth of crops. Since ozone levels in the lower atmosphere are shaped by both emissions and temperature, climate change will most likely increase ozone concentrations. Such changes may offset any beneficial yield effects that result from elevated CO_2 levels.

4.6 Change in rainfall amount and patterns

Changes in rainfall can affect soil erosion rates and soil moisture, both of which are important for crop yields. Disaster trends around Africa due to changing rainfall amount and pattern can be viewed as below:

In Kenya, communities living along River Tana according to literature face the problem of inadequate water, which is threatening the area. Of recent according to [1], the waters have receded while farmers with farms adjoining the river-banks have been left dry. Many of the farmers are said to be leaving the area. An interview conducted on the chairman of the Tana River District's small-scale farmers association as stated by Abjata [1], indicated that 20 settlements had closed as at the time of the interview. He was found saying:

“Farmers are leaving and moving into urban centers in search of other jobs and better living standards,” Despite various visits from NGOs and agriculture ministry officials in the country, many farmers attribute the changes not to climate change but to a curse from ancestors who are unhappy due to lack of appeasement.

Another farmer, Alice Lopo, was found to say that many schools have closed down as people move to towns. “The river has dried up, leaving people no alternative but to move out of the settlements or practise nomadism.”

Some farmers have switched from growing one crop to another, e.g. maize to sorghum as this can grow in hotter weather, with less water. All the farmers who have stayed behind say they realise that things will never be the same as they once were. For years, Albert Bouda has grown vegetables in fields washed by water from the River Tana. But now, he says, “We have to dig wells to get enough water for our crops.” He adds, “The temperatures are higher, water evaporation from the ground is very fast, and there is a spread of agricultural pests on our crops” [1]. Changing rainfall patterns and higher temperatures have forced farmers to reduce the growing season and they are adopting the use of more expensive hybrid crops. Meanwhile, inadequate fund for farm investment will make food availability an issue. Incessant droughts and floods are making farmers to loose their hard earned farm assets, leaving the farmers more vulnerable. All these will eventually lead to food production fluctuations. Land degradation also occurs as a result of frequent flooding, drought, deforestation and poor land use; all of which can be attributed to global warming.

4.7 Suggested cooping strategies

To cope with changes in weather conditions across the globe farmers may need change their planting dates, change the crops and crop-varieties they grow as coping strategies: sorghum may fare better than maize in the drier conditions for some parts of Africa. For example in South Africa, farmers as learnt are already delaying planting of maize to take account of changing rainfall patterns. In Mali farmers in the relatively cool, wet region of Sikasso, who grow maize and cotton, are now turning to sorghum and millet as these are crops grown in the hotter, drier north of the country. The real challenge lies in finding an option for the farmers as their climate becomes even warmer. Other options for farmers may be the use of hybrid varieties, the use of irrigation when there is drought, forest conservation – farmers should stop unnecessary felling of woods all in the name of land clearing/preparation. A better way of do this is to practice agro-forestry, allow woods that feed very deep into the soil to stay while we clear the shrubs. Continuous education about climate change, the consequences and coping strategies should be given a priority both for farmers and the larger society.

5.0 Conclusion

We have shown that action is needed to reduce human – induced emissions of carbon-dioxide. We have also shown that there is a need to find other sources of energy that will reduce carbon dioxide emission levels. Our paper shows that we may not have warming of atmosphere if we reduce deforestation, increase forestation sequester carbon dioxide.

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