THE IMPACT OF CLIMATE CHANGE ON WATER RESOURCES: AN OVERVIEW

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Summary

Global climate change involves numerous variables that could have an impact on the life support systems of our planet. Water as an important resource is likely to be affected by current and projected changes in the earth's climate and weather patterns. Because the hydrologic cycle is closely related to climate and weather, a change in climate could have either a positive or negative influence on this global source of water.

Climate change is one of the most important issues on the international agenda. It is seen as a threat to ecosystems around the world. Causes of global climate change can be divided into two categories: those that are created by natural circumstances and those resulting from human activities. The scientific community can also be categorized along these lines, with those advocating natural causes and those who argue that human determinants are influential in climate change.

The different dimensions of global climate change can have different effects on the water resources of the planet. It is not sure what influences ozone depletion hold for the hydrologic cycle and human use and demand for water. The greenhouse effect, on the other hand, seems to have indirect effects on water resources, with severe consequences for human civilization and ecosystems. Acid rain is a dimension that could have a direct influence on water resources, but the phenomenon is a much localized feature.

It is a sure thing that global climate change is influenced by many variables produced by a great deal of sources. Not only that, the effects of climate change will vary from region to region and season to season. Because of this, the impacts on water resources and ultimately the management of water will differ from these regions, and will be

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influenced by the socio-economic and political milieu operating in these regions.

1. Introduction

Global climate change has in the last 35 to 40 years become one the most pressing issues on the international political agenda. The reason for this seems quite unimaginable at first. Notwithstanding this, closer inspection will reveal that global climate change is an important issue, because of the impact it could have on ecosystems on which humans are so dependent on. Furthermore, global climate change, although it can occur over an extended period of time, could alter our way of living and have severe consequences for our social, cultural, economic and political way of life. During the previous century, humans have done more damage to the environment than ever before since humans first appeared on earth. The global environment is the latest addition to the international environmental and political agendas, because of the recent acceleration in the degeneration of the environment and the slowness of the awareness of the consequences. Nonetheless, evidence exist that global climate change is a reality which cannot be wished away. Notwithstanding this perception, there are still those scientists and scholars who believe that global climate change is a natural event, and that a great deal of resources should not be poured into the study of its causes, effects and political ramifications. From the outset this claim will be refuted and the study will move forward in such a manner that global climate change is something more than a natural phenomenon. That global climate change has a natural component attached to it cannot be denied, but we are interested here with the impact that humans have had in the past and at present on the changing climate of the world.

Planet earth supports a great variety of ecosystems and biological organisms that are dependent on these systems. This is possible because earth is the only planet in the solar system that exhibits the correct combination of variables which makes the supporting of life, in all its forms, possible. Humans are part of the environment. We are not unnatural in the sense that we do not constitute another environment, divorced from the other aspects of the natural environment and living organisms. It might seem at first that we are unnatural, for we are living in our environment in a different way that other species. However, we share the planet with other biological creatures and are most of the time dependent on these organisms for food and shelter. We are also dependent on the other constituents making up the environment: water, the climate, land, and soil. We use these elements in a number of ways to produce economic goods, produce fuel to drive our economies, and to better our standard of living. Because we are natural beings there is nothing unnatural about our presence on earth.

In spite of this, we can also impact on the environment while using it. One of the most import effects involves the pollution of the atmosphere. On a daily basis human activities release a number of pollutants into the atmosphere that can have severe consequences on the environment and ourselves. The atmosphere is not exclusively important to our environment and the different life support systems, but a great assortment of other systems depend on a stable atmosphere for their existence. Anthropogenic shocks on the atmosphere can alter it to such an extent that it could one day, and paradoxically enough, become a threat to life itself. Because the environment consists of a number of interdependent life support systems and elements, any change in

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one or a number of these aspects could have a domino effect across the entire globe. Human induced changes to the atmosphere and the influence these can have on water resources is the focus of this study.

Water is one of the most important life giving substances on our planet. In fact, water is vital for human and non-human survival. Since the dawn of time earth was covered in water. This layer of water was, in combination with the ultraviolet raise of the sun, responsible for the formation of an atmosphere that was conducive to life on earth. Without water, in combination with other substances such as oxygen, life would not have been possible. Animal and plant life is to a considerable extent dependent on the water resources found in the environment. Because humans are also natural beings we are just as part of the environment than any other living creature inhabiting the environment. We consume water on a daily basis to keep our cells alive in order for our bodies to keep on functioning. When it comes to the use of water resources by humans this is not different from other creatures.

Where a distinction between humans and non-human species and the use of water and other natural resources comes in, is that we make use of the resources to produce economic goods. These commodities set us apart from other organisms, in a way that makes us look more advanced and civilized. However, while producing these wares we consume and use a great quantity of natural resources. Everything from office furniture, computers, motor vehicles, trains, fuel, food etc. requires natural resources. During the production process water is also needed in large volumes. For instance, to produce one tonne of maize requires something in the order of 1 200 tonnes of water. The same goes for wheat and sugar and other agricultural commodities. A tonne of wheat, for instance, requires approximately 1 000 tonnes of water to produce, and one tonne of sugar cane 111 tonnes of water to grow. These quantities of water are used only to produce the primary commodities. To refine these products requires a great deal more. In fact, in most developing regions of the world agriculture is the largest consumer of water. Also, some of the goods we consume on a day-to-day basis produce, during the production process, a lot of pollutants and by-products, than can be harmful to the environment. Humans can have an impact on the environment just as the environment can have an influence on us. It has been argued for the past 40 years or so that humans have had a severe influence on the biosphere. The main culprit is the global production of economic goods and sometimes capitalism is accused upfront.

In other words, humans are a part of nature and uses natural resources available in the environment to acquire and produce a number of economic goods. Water resource is sometimes seen as a renewable resource. Our production systems can pollute water to such an extent that it can become harmful for human consumption and the use by other non-human species. Also, the pollution of the atmosphere, and subsequent global climate change could have impacts on the availability of the water resources in the environment that can severely affect the social, economic and political aspects of human live on earth.

2. The Atmosphere and the Hydrologic Cycle

There exist and inextricable link between the atmosphere and the hydrologic cycle.

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2.1. The Atmosphere

The atmosphere is the layer of air that shrouds the entire earth. This layer is composed of different gasses, suspended liquids and solid particles (aerosols). Together with the earth, the atmosphere is a closed interdependent environment. The atmosphere as part of a closed system, performs a number of interrelated functions. These activities have allowed humans and other life forms to develop and survive almost anywhere on the planet; hence the concept "the living planet". This is the main function of the atmosphere. Other purposes the atmosphere fulfills include the following:

- It maintains and provides the oxygen supply that is required for organisms to survive.
- It controls the environment's energy budget via elements such as the ozone layer and the greenhouse effect. It also accomplishes this role by the internal circulation through the distribution of moisture and heat across the earth's surface.
- The atmosphere has, furthermore, the ability to dispose of wastes that enter it by ways of environmental and anthropogenic activity.

It is generally accepted that the earth's prehistoric atmosphere contained nothing more than a trace of oxygen and a predominance of other elements which had less oxygen that hydrogen. Methane and ammonia, together with water made up the bulk of earth's ancient atmosphere. Other compounds may also have been present in that early stage of earth's history. These components could include carbon dioxide (CO_2), nitrogen (N_2), and trace elements of hydrogen (H_2). Another view holds that earth's atmosphere was mainly composed of carbon dioxide and water. Other elements were to a lesser extent present such as H_2, N_2, ammonia, hydrogen sulfide, sulfur dioxide, and methane.

During the early stages of earth's development, it is suggested that throughout the first billion years of earth's history, wide spread volcanic activity occurred and a great number of asteroids and comets collided with earth. These activities would have generated a great deal of heat that would have evaporated part or all of the oceans. Water therefore played an important role in the stabilization and composition of earth's atmosphere as we know it today. Oxygen was produced by the breakdown of water by either the photolytic action of ultraviolet radiation from the sun or photosynthesis by cyanobacteria. These views are the major impressions with respect to the formation of the earth's atmosphere. In the first instance, the hydrogen that is produced by photolytic action escapes from the earth's gravitational pull, leaving oxygen to amass in the atmosphere. This process, which breaks down water into hydrogen and oxygen, produced, at first, small quantities of these gasses, but over a significant period the process must have been quite significant. At present almost all oxygen is produced by cyanobacteria, or blue-green algae, eukaryotic algae, and plants. Every day these biological organisms combine about 400 million tons of carbon with 70 million tons of hydrogen. The result is the release of 1.1 billion tons of oxygen. The oceans are also a major source of oxygen. Almost all oxygen that is produced in the environment is consumed by organisms. These organisms oxidize their food into carbon dioxide. If this did not take place the volume of oxygen would have doubled in approximately 3 000 years. Because Precambrian fossil cyanobacteria resemble modern cyanobacteria, it is

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probable that most of the oxygen in the early atmosphere was produced by these living organisms, through the process of photosynthesis.

The earth's atmosphere is today, in contrast to its ancient state, highly oxidizing, and consists of a number of gasses that is, in combination, air. Air is not a gas in itself. The different gaseous elements that make up the atmosphere individually have their own properties. This is not the case with air. Nitrogen makes up the bulk of these gasses - 78 %, while free oxygen comprises 21 %, argon 0.93 %, and carbon dioxide 0.03 %. Oxygen and nitrogen therefore makes up 99 % of the atmosphere and can therefore be seen as the major gasses in the atmosphere. Oxygen participates readily in chemical reactions, and provides one of the important necessities of life on earth. Not only that, oxygen is also responsible for much of the absorption of radiation from the sun. Nitrogen, on the other hand, is inert and does not get involved in chemical and biological reactions except under extraordinary circumstances. For example, during thunderstorm activity, the energy released by lightning may trigger a reaction between oxygen and nitrogen to form oxides of nitrogen.

The recycling processes in the atmosphere ensure that the volumes of both these gases are maintained. Together with these recycling processes, turbulent mixing ensures that the two gas elements are evenly distributed throughout the atmosphere. It should be noted that no evidence exists that the relative levels of nitrogen and oxygen are changing to any significant extent. This is in contrast with other gasses contained in the atmosphere. Nonetheless, changes in the nature of oxygen are involved in the depletion of the ozone layer, which is recognized as one of the major environmental factors that can lead to a global environmental crisis.

As noted earlier, other minor gases are also present in the atmosphere. These gases, although they are found in minimal volumes relative to nitrogen and oxygen, have an influence in the atmosphere that is out of proportion to their volume. Argon is the most abundant of these minor gases - 0.93 % - but it exists in an inert state in the atmosphere. Carbon dioxide plays a more active role in environmental processes, although in comparison to argon, it makes up only 0.03 % by volume of the atmosphere. Carbon dioxide plays a major role in the heating of the atmosphere. It is also responsible for the numerous chemical reactions that take place during the process of photosynthesis. During photosynthesis sugars, starches and other complex organic compounds are produced in plants. Carbon dioxide is also a significant role player in the natural greenhouse effect that heats up the atmosphere from solar radiation.

Other minor gasses apart from argon and carbon dioxide become from time to time part of the earth's atmosphere. These gases include sulfur dioxide, oxides of nitrogen, hydrogen sulfide, carbon monoxide, and a great variety of other exotic gasses such as hydrocarbons. These gases, even though they are found in small quantities in the atmosphere, can be harmful to the environment. Notwithstanding this, they are natural components of the atmosphere, and are released by natural processes such as biological activity during volcanic eruptions and wood and grass fires. The release of these gases is also part of the process of industrial production systems and the burning of fossil fuels in motor vehicles. These gases, whether released naturally or by anthropogenic activities, have in recent years became a great concern for the impact they could have on

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the environment. For example, they, and most notably sulfur and nitrogen oxides, combine with water in the atmosphere and are the main ingredients of acid rain.

Not only does earth's atmosphere consist of a variety of gasses. Other elements also make up its composition. Water is one of those elements. The atmosphere is never completely dry, even above the surface of deserts, like the Sahara, Namib, Kalahari, Gobi, Atacama and the deserts of Australia and North America. The volume of water in the atmosphere is constantly very small. For example, if this small volume would precipitate at once over the entire surface of the earth, it would create rainfall of only 25 milli meters (mm). Water is also unevenly distributed across the earth's surface. Furthermore, it is also unequally disseminated across states, regions in states, socio-economic dimensions, time spans and climatological seasons. For instance states like Canada is "blessed" with nearly 120 000 cubic meters (m^3) of water per capita, while a country like South Africa only has 1 740 m^3 of water available to its population. Bangladesh suffers annually from terrific climatic cyclone activity, while in the dry season it experiences significant dry-spells. Also, a thunder storm can precipitate as much as 70 mm of rain in a few minutes, while in another place the same amount of rain can take months or even years to fall.

Water in the atmosphere plays a number of very important roles. It is responsible for energy transfers and the reflection of the sun's rays into outer space. Water in its vapor form contributes to the greenhouse effect in that it absorbs radiation from the earth's surface. In its liquid state and solid form - ice sheets and ice in polar caps and glaciers - it helps with the reflection of solar radiation back into space. As clouds and snow it can mediate as much as 90 % of the sun's radiation. It is interesting to note that this reflection of sunlight does not contribute to any significant extent to the energy budget in the environment.

It is on the earth's surface that water plays a more visible role. It helps to sustain intricate biotic systems and humans also use water in everyday life to survive and to produce economic goods. In spite of that, and in part because of the consequence of the use of water by humans, water has become an important part of global environmental and political issues. It plays a central role in droughts, floods, desertification, acid rain, conflict and co-operation between states over water resources, in food security, gender issues and water, the role and involvement of non-state entities, such as interest groups and non-governmental organizations (NGOs), in water politics and economic development. Some of these issues relating to water are discussed in other parts of the EOLSS. In addition to these matters, water can also be central to the issue of global climate change. Because it plays an important part in the earth's energy budget, any change in the distribution of water, in all its forms, in the earth/atmosphere environment, water might well heighten or lessen the effects of the greenhouse effect, ozone depletion and acid rain. The greenhouse effect and ozone depletion are present and forms part of the energy budget, of which water is also an important component.

The atmosphere does not only consist of a number of gasses such as oxygen or nitrogen and water in its various forms, but other particles also make up the atmosphere. These particles can either be found in the form of solids or liquids. These are called aerosols which include soot, dust, crystals, spores, bacteria, viruses and other microscopic

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materials. Sometimes they are seen as pollutants, but their origin can also be the direct consequence of natural phenomena such as grass and wood fires, volcanic activity, evaporation, atmospheric turbulence like strong winds and thunderstorms, and biological processes. Recall how some diseases like the common cold can be transmitted from one person to the other on localized wind currents in a building. These trace elements have over the earth's history increased or declined in concentration, sometimes in quite a dramatic way. Notwithstanding some of these increases, the atmosphere has always been able to cleanse itself from the excess of these materials. For instance, in 1883 the island of Krakatoa exploded after a period of volcanic activity and spewed several cubic kilo meters of volcanic ash into the atmosphere. Almost all of it returned to the earth's surface within five years, through particle coagulation, dry sedimentation and wash-out by precipitation. Anthropogenic sources of these materials can also play a considerable role in the increased concentrations of these particles. Human use of coal and other fossil fuels for energy production and industrial processes can be major contributors. The evidence of the increasing levels of aerosols in the atmosphere due to anthropogenic activities is somewhat contradictory, though.

Some scientists claim that the increase of aerosols can lead to a decline in the temperature on the earth's surface. This might be caused by a reduction of the amount of solar radiation entering the atmosphere and penetrating to the earth's surface. Water vapor may also increase in greater volumes around these aerosols which could cause a larger concentration of cloudiness in the atmosphere. This could cause more solar radiation to be mirrored back into space and therefore a subsequent drop in temperatures. Others claim that the increase of aerosols in the atmosphere could have less serious effects. A reduction in the isolation properties of the atmosphere is accepted by these advocates. An offset of the cooling effect could take place as less radiation escapes back into space which could result in the warming of the lower atmosphere. These effects would depend on the distribution and the altitude of the aerosols present in the atmosphere.

From the above discussion it is clear to note that water, in all three forms - solid, liquid and vapor - is one of the elements that make up the atmosphere. Water is also an important part of the environment and fulfils significant roles in the global climate. What needs to be discussed next is how water is exchanged between the atmosphere and earth. The process responsible for this is the hydrologic cycle.

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Bibliography

Ayers M.A., Wolock D.M., McCabe G.J., Hay L.E., and Tasker G.D. (1994). *Sensitivity of Water Resources in the Delaware River Basin to Climate Variability and Change*, pp. 42. Denver: The U.S. Geological Survey. [This book outlines the different causes and effects of climate variability and change on the Delaware River system in the United States]

Boyle S. (1990). The Global Effect. *Greenhouse Effect and its Impact on Africa* (ed. M. Suliman), pp. 19-31. London: The Institute for African Alternatives. [This book presents the dimensions of the greenhouse effect and the impact thereof on the economy of Africa]

Downing T.E., Harrison P.A., Butterfield R.E., and Lonsdale K.G. (eds.). (2000). *Climate Change, Climatic Variability and Agriculture in Europe: An Integrated Assessment*, 445 pp. Oxford: Environmental Change Institute, University of Oxford. [This report gives a detailed account of the likely impacts of climate change and climatic variability on the European agricultural sector]

Frederick K.D. and Gleick P.H. (1999). *Water & Global Climate Change: Potential Impacts on U.S. Water Resources*, 48 pp. Arlington: PEW Center on Global Climate Change. [This report outlines, in detail, the possible impacts of global climate change on the water resources of the United States]

Gleick P.H. (1998). *The World's Water, 1998-1999: The Biennial Report on Freshwater Resources*, 307 pp. Washington, D.C., Covelo, California: Island Press. [This report on freshwater resources across the globe, which is published every second year, gives a comprehensive study on different aspects of freshwater resources across the globe]

Guyot G. (1998). *Physics of the Environment and Climate*, 632 pp. Chichester, New York, Weinheim, Brisbane, Singapore, Toronto: John Wiley & Sons, in association with Praxis Publishing. [This seminal book outlines the major components regarding the physics with respect to the climate, and the different components thereof, and the environment]

Hickman C.P., Roberts L.S. and Larson A. (1995). *Integrated Principles of Zoology*, 983 pp. Dubuque, Melbourne, Oxford: Wm. C. Brown Publishers. [This book explains the various aspects of zoology from the origins of life to the classification of different living organisms to be found on the planet]

Hugo M.L., Viljoen A.T., AND Meeuwis J.M. (1997). *The Ecology of Natural Resource Management: The Quest for Sustainable Living, a Text for South African Students*, 242 pp. Pretoria: Kagiso Publishers. [This book outlines the different approaches to the study of the ecology and its numerous dimensions and human causes of the degradation of the environment from a South African point of view]

Intergovernmental Panel on Climate Change (1998). *The Regional Impacts of Climate Change: An Assessment of Vulnerability*, 517 pp. Cambridge: Cambridge University Press. [This report outlines the various impacts of global climate change on the different regions of the world]

Kemp D.D. (1994). *Global Environmental Issues: A Climatological Approach*, 224 pp. London and New York: Routledge. [This book describes the processes in existence in the atmosphere and the related atmospheric environmental issues and concerns faced by humanity]

Morgenstern R.D. (1991). Towards a Comprehensive Approach to Global Climate Change Mitigation. The American Economic Review 81(2), 140-145. [This article outlines some of the approaches to mitigate the effects of global climate change in the international policy environment]

Ponting C. (1998). *Progress and Barbarism: The World in the Twentieth Century*, 561 pp. London, Sydney, Auckland, Parktown: Chatto & Windus. [This book outlines the history of the twentieth century by looking at the various processes, dimensions and the problems associated with human live on our planet during this period]

Singer S.F. (1997). *Hot Talk Cold Science: Global Warming's Unfinished Debate*, 110 pp. Oakland California: The Independent Institute. [This book outlines the various scientific arguments against Global Climate Treaty and certain issues that need to be resolved with respect to the global climate change debate]

Stockholm Environment Institute and Maunder W.T. (1994). *Dictionary of Global Climate Change*, 257 pp. London: UCL Press. [This book gives a comprehensive description of the different concepts relating

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to global climate change]

Strahler A. and Strahler A. (1997). *Physical Geography: Science and Systems of the Human Environment*, 637 pp. New York, Chichester, Brisbane, Toronto, Singapore, and Weinheim: John Wiley & Sons, Inc. [This book gives a description of the different aspects of physical geography in explaining earth's different environments and how they are altered by both natural and anthropogenic changes]

Biographical Sketch

Richard Meissner received his training as a political scientist at the Rand Afrikaans University (RAU) in Johannesburg. He obtained a Magister Artium (M.A.) degree in Political Studies from the same university in 1999 and is currently busy with a D.Phil. in International Relations at the University of Pretoria (UP). He was one of the first students in South Africa to complete a Master's thesis on water politics.

He was employed by the Political Studies department at the Rand Afrikaans University from 1996 to 1998 as a research assistant. He is currently employed as a research associate by the African Water Issues Research Unit (AWIRU) which he joined in 1999. He was involved in a number of studies regarding the management of national and international water resources in Southern Africa and the Middle East. He has also written a number of articles which were published in accredited journals. His scope of interest lies within the field of water politics and particularly the interaction of diverse actors within the domestic and international domains regarding water resource issues. Richard Meissner is a member of the South African Political Studies Association and the South African Institute of International Affairs.

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