

Role of information and communication technologies (ICTs) in mitigating, adapting to and monitoring climate change in developing countries

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1. Abstract

Climate change is an unbearable reality because climate has changed, is changing and will continue to change. As of now, the global village is just beginning to understand the potential magnitude and severity of climatic change impacts, not just now but for future generations. Some of the symptoms of climate change include global warming, loss of crops during over extensive periods of drought, unpredictable rainfall patterns, melting glaciers, displaced populations seeking refuge after floods, or entire villages devastated by the implacable force of cyclones and hurricanes. It is quite unfortunate that poorest, most vulnerable countries of the world are hardest hit. It is believed that information and communication technology is a tool which can be used to mitigate, adapt to and monitor climate change. The signs and effects of climate change were examined in this paper. Further, this paper explored how information and communication technologies are contributing to climatic change and proposed information and communication technology strategies that can be adopted to mitigate, adapt to and monitor climatic change. The paper also dwelt on the challenges that are faced in using information and communication technologies in mitigating, adapting to and monitoring climatic change especially in developing countries.

Keywords: ICT, Climate Change, Mitigating climate change, monitoring climate change, adapting to climate change, role of ICT in climate change, Climate change in developing countries

2. Introduction

This study examined the potential of information and communication technologies (ICTs) in combating climate change. More specifically, this work established the role of ICTs in mitigating climate change, adapting to climate change and monitoring climate change. The fact that climate change has already occurred and will continue to occur requires a three-tier solution which focuses on mitigating further changes while monitoring and adapting to changes that have already occurred. Further, the research also examined the role of ICTs in reducing the impact of signs of climate change like floods, heat waves, hurricanes and so on. Research has shown that ICTs have the potential to arrest climate change as evidenced by GeSi & EC. Europa (n.d) that *“the use of ICT is predicted to reduce total global GHGs by 15% by 2020 ...and grow to 40% by 2050.”* However, it is impossible to realise the full potential of ICTs in combating climate change due the current fundamental problem with the design of the existing ICT Network Infrastructure. If this design problem is rectified, it is believed that ICT can play an immeasurable role in mitigating, adapting to and monitoring climate change. Further supporting evidence is given by Young (2007) that ICTs are to reduce climate change in other industrial and domestic sectors through de-materialising and de-carbonising the economy.

In line with the foregoing arguments, WWF (n.d.) asserts that *“The ICT industry is responsible for approximately 2% of global CO₂ emissions. ICT solutions have the potential to be an **Enabler** to reduce a significant part of the remaining 98% of total CO₂ emitted by*

non-ICT industries.” From this quotation it is clear that ICTs are a tool that can be used to mitigate, monitor and adapt to climate change.

Russell (2008) quoting climate experts asserts that, *“Africa is steadily warming, climate is changing and that there will be further changes in rainfall and temperatures. Africa is warmer by 0.5 degrees Celsius than it was a century ago. Climate experts say Africa is particularly vulnerable to climate change because of various factors such as widespread poverty, the unsustainable use of natural resources, over-dependence on rain-fed agriculture and weak institutional support structures.”* On global trends in climate change, Russell (2008) indicates that *“the global surface temperatures have warmed by up to 0.8 degrees Celsius and climate change statistics indicate that globally the sea level has risen by 10-25 cm in the last 100 years.”* This evidence is more than enough to convince anyone that climate is changing and will continue to change if no measures are taken to militate against climate change.

The rest of the paper is organised as follows, the next sections will present the research problem, objectives and research questions. After that, related literature will be presented and from this literature we will propose strategies that can be adopted by developing countries to combat climate change through use of ICTs. The paper will then present the conclusion before giving recommendations.

3. Problem Statement

There is no doubt that the global village is experiencing the negative impacts of climatic change some of which include global warming, floods, droughts, heat waves, just to mention but a few. These effects are impacting on both developing and developed countries even though the poor developing countries are the hardest hit. This is supported by Russell (2008) who asserts that *“Zimbabwe is suffering more from the impact of global warming like most other countries in Africa signalling the burden of climate change risks to be felt more by the poor in the near future.”* It is important to note that, even those nations that are not in any way contributing to climate change or whose contributions are minimal are also being affected by the negative consequences of climate change and in some cases are being affected more than the real culprits. This is also supported by Russell (2008) quoting climate experts as saying, *“Africa will be hit hardest and earliest when it is the rich industrialised countries in the North that are responsible for 75 percent of green house gas emissions.”* Further to that, The Fourth Assessment Report of the Inter-governmental Panel on Climate Change indicates that Africa will suffer the most from the impacts of climate change. It is a sad fact that more people are dying now than ever before as a result of climate change and more property is being destroyed now than ever before due to climate change. Also, more diseases are surfacing as a result of climate change and the frequency of natural disasters has increased. Climate change has and continues to be a major economic setback for most people especially in developing countries.

4. Research Objectives

This research is six-pronged in that it seeks to:

- 4.1. document signs and effects of climate change
- 4.2. articulate the causes of climate change
- 4.3. establish how ICTs are contributing to climate change,
- 4.4. determine the role of ICTs in mitigating climate change,
- 4.5. establish the role of ICTs in adapting to climate change,

“International Conference on ICT for Africa 2013, February 20 -23, Harare, Zimbabwe”

4.6. determine the role of ICTs in monitoring climate change

5. Research Questions

This study seeks to answer the research questions listed below.

- 5.1. What are the signs and effects of climate change?
- 5.2. What are the major causes of climate change?
- 5.3. How ICTs are contributing to climate change?
- 5.4. What is the role of ICTs in adapting to climate change
- 5.5. What is the role of ICTs in adapting to climate change
- 5.6. What is the role of ICTs in adapting to climate change

6. Related Work

Some work has been done on ICTs and climate change even though most of it focused on strategies that are not pro-poor developing nations. Further, the work that has been done so far needs to be consolidated as there is no a single study which ties together all the issues raised in the foregoing sections. This research will provide literature on the signs and effects of climate change, the causes of climate change, how the ICTs are contributing to climate change, the role played by ICTs in mitigating climate change, the role of ICTs in adapting to climate change and the role of ICTs in monitoring climate change.

6.1. Definition of climate change

IPCC (2007) defines climate change as any change in climate over time, whether due to natural variability or as a result of human activity. This definition points to the fact that there are two major causes of climate change, however research has shown that human activity is the major contributor to climate change. It is imperative to note that the single human activity that has a large impact on the climate is the burning of "fossil fuels" such as coal, oil and gas. Other human activities whose contributions are modest include deforestation, fertilizers and other chemicals.

6.2. Signs and effects of climate change

Previous studies (IPCC, 2007) have shown that climate change can have serious developmental effects that hit particularly hard those countries that are already experiencing the hardships of poverty and marginalization. From the foregoing statement, it is crystal clear that that climate change has developmental effects especially on poor developing nations. Regarding the main characteristics of climate change, the United Nations Framework Convention on Climate Change (2007) cites, increases in average global temperature (global warming); changes in cloud cover and precipitation particularly over land; melting of ice caps and glaciers and reduced snow cover; and increases in ocean temperatures and ocean acidity – due to seawater absorbing heat and carbon dioxide from the atmosphere. Further supporting evidence is presented by Meehl *et al* (2007) that global warming has changed the type, frequency and intensity of extreme events, such as heat waves, tropical cyclones (including hurricanes and typhoons), floods, droughts and heavy precipitation. Few *et al* (2004) and Christensen *et al* (2007) agree with Meehl *et al* (2007) on drought and flooding in new areas.

The United Nations Framework Convention on Climate Change (2007) establishes that Africa is already a continent under pressure from climate stresses and is highly vulnerable to the impacts of climate change. They noted famine and widespread disruption of socio-economic well-being as some of these impacts in Africa. Further to that, Guernier *et al* (2004) argue that Africa is vulnerable to a number of climate sensitive diseases including malaria, tuberculosis and diarrhoea. This is further supported by Boko *et al* (2007) who note

"International Conference on ICT for Africa 2013, February 20 -23, Harare, Zimbabwe"

that migration of the malaria mosquito to higher altitudes will expose large numbers of previously unexposed people to infection in the densely populated east African highlands. Boko *et al* (2007) also establish that climate change is an added stress to already threatened habitats, ecosystems and species in Africa, and is likely to trigger species migration and lead to habitat reduction.

Hassanin (2012) avers that Egypt is facing increasing soil salinity and erosion of its agricultural lands in the Delta due to water level rises in the Mediterranean and decreasing flow of Nile waters. Matarira *et al* (1995) carried out a study in Zimbabwe to investigate the effects of climate change on agriculture. In their study, it was found out that climate change negatively affects maize production and some areas in Zimbabwe might be turned into non-maize producing as a result of drought. Further to that, Zimbabwe's Initial National Communication under the United Nations Framework Convention on Climate Change (1998) indicates that climate change has adverse effects on human health for example, in Zimbabwe, in 1996; the incidence of malaria was very high after heavy rains and high temperatures throughout the country. Due to climate change, Zimbabwe is experiencing an increase in the frequency of floods and examples of cyclone-induced flooding included cyclone Bonita 1996, Eline 2000, Japhet 2003 and another in 2007 (Russell, 2008).

With regards to climate change in Mozambique, Eduardo Telhano (n.d) cited in Ehrhart and Twena (2006) asserts that "Temperatures in certain areas of Manica Province were normally low, and the sun shining used to be as rare as the gold that is explored there. Nowadays, things have completely changed: it has become as hot as other places in Mozambique where sunstroke is common. Villagers living in the north of Inhambane Province say that ... the period between severe droughts has declined from 12 or 13 years to 5. This severe drying trend is also reflected in declining supplies of water in systems (e.g. wells) built during the last 10 to 15 years."

Commenting on climate change in South Africa, Griffin (2012) notes that "South Africa is well known for its immense beauty, rich biodiversity, and abundant wildlife. However, climate change poses a real risk to these natural assets, as well as to the people who live in this beautiful country ... With global warming and climate change becoming more and more of a reality, South Africa is also experiencing a gradual, yet steady, change in climate. Temperatures have risen significantly over the last 60 years, and are predicted to continue this rising trend, with a rise in temperature of 1-2°C expected in coastal regions, and 3-4°C expected in interior regions by 2050. An increase of 3-4°C in coastal regions is predicted and 6-7°C in interior regions is predicted by 2100. Rainfall patterns are also shifting, although this is a little more variable and unpredictable"

Looking at the African continent, Russell (2008) notes that climate change studies say "the main impact of climate change on the continent will be increased frequency of natural disasters, droughts, floods and other weather extremes that lead to loss of life, economic disruptions, social unrest and forced migration as well as major environmental problems." Russell (2008) went on to say "prolonged drought periods will cause stress on water resources and reduce food security due to diminished agricultural productivity, increase outbreaks of vector borne diseases and other health impacts. In addition, climate change poses a threat to forestry, water resources, biodiversity and other natural resources."

All the above cases of the effects and signs of climate change point to the fact that developing countries are experiencing the negative impacts of climate change. Climate change is not affecting only developing countries but all countries in the world. Climate change is a global problem which requires collective solutions and collective effort from all countries. Africa as a continent cannot afford to stand and watch but needs to join the bandwagon of fighting climate change.

6.3. Causes of climate change

ITU (2007) notes that there two classes of causes of climate change namely natural causes and man-made causes. ITU (2007) went to say that natural causes include variations in solar radiation, volcanic activity and so on. Further, ITU (2007) asserts that man-made climate change is of major concern because it appears to be leading to a progressive and accelerating warming of the planet, as a result of the release of greenhouse gases (GHG), primarily carbon-based emissions. On the other hand, the United Nations Framework Convention on Climate Change (2007) names two major causes of climate change which are rising fossil fuel burning and land use changes. The United Nations Framework Convention on Climate Change (2007) notes that these two activities have emitted, and are continuing to emit, increasing quantities of greenhouse gases (such as carbon dioxide, methane, and nitrogen dioxide) into the Earth's atmosphere. The United Nations Framework Convention on Climate Change (2007) went on to say, *"a rise in these gases has caused a rise in the amount of heat from the sun withheld in the Earth's atmosphere, heat that would normally be radiated back into space. This increase in heat has led to the greenhouse effect, resulting in climate change."*

From the foregoing paragraph, it is clear that human activity is the major contributor to climate change. If we are to go by the adage which say "A problem clearly stated is a problem half solved" by Dorothea Brande, we can proffer permanent solutions to this climate change scourge since we now know the causes of the problem.

6.4. How ICTs are contributing to climate change.

It imperative to know the extent to which ICTs are contributing to climate change before we can use them as a tool for combating climate change otherwise we end drawing circles in a desert. Concerning this issue, ITU (2007) indicates that ICTs are far from innocent in contributing to climate change and the major contribution of ICTs to climate change comes from the proliferation of user devices, all of which need power and radiate heat. On this issue, WWF (n.d.) indicates that *"The ICT industry is responsible for approximately 2% of global CO₂ emissions."* ITU (2007) further asserts that the proliferation of users with each owning more than one digital device is another contribution of ICTs to climate change.

6.5. Role of ICTs in mitigating climate change

Information and communication technologies play an important role in significantly mitigating climate change and these technologies can be used in both developed and developing countries even though developing nations lack the much needed information and communication technology infrastructure when it comes to mitigating climate change. On some of the solutions that can used to mitigate climate change, Ospina and Heeks (2010) suggest the use ICTs in controlling carbon dioxide emissions through smart grids, dematerialization or intelligent transport systems and buildings. Dematerialisation refers to replacement of "atoms" with "bits". An example of this is the current shift under way in the market for pre-recorded movies and music away from physical distribution (such as tapes,

DVDs and CDs) to online delivery (ITU, 2008). Another example of dematerialization is the shift away from paper-based to online publishing. Ospina and Heeks (2010) further assert that these strategies have focused mainly on addressing the priorities of developed countries in regards to climate change since it has already been mentioned that developing countries have poor ICT infrastructure.

Apart from the above climate change mitigation strategies, the World Economic Forum (n.d.) put forward seven contributions of ICT to mitigating climate change grouped into following three thematic areas. The first category is infrastructure innovation which focuses on reducing energy consumption and Green House gases (GHGs). The second category is behavioural change and green enablement. This category focuses on the need for global measurement and tracking of carbon reduction, as well as tools that impact positive behavioural change including software tools for measuring carbon footprint, and the use of innovative technologies and opportunities that reduce travel and transportation, such as those for virtual meetings, telecommuting, and on-line services (e.g. online-learning, eHealth, eTourism, eTaxation, eBanking and e-Agriculture). The third category is energy efficiency of ICT products and solutions. This category includes adopting green computing computing which is basically environmentally sustainable computing. It has already been indicated that ICTs' contribution to climate change is 2 %. This contribution must be monitored because the public will judge the whole sector as environmentally unfriendly if the sector does not address its own carbon footprint. First, this would impact ICT's credibility, making it difficult to deliver on the points above. Second, the rapid increase and penetration of ICT products can, if no action is taken, result in increased energy demand (World Economic Forum, n.d.).

Global e-Sustainability Initiative (n.d.) citing *The Smart2020 Report* provides many good examples of transformative solutions that often help reduce emissions by 80% or more and can be used by both developing and developed countries. These solutions can fit well into the three categories suggested by World Economic Forum (n.d.) in the foregoing. However, it is important to just mention them here. The solutions are *e-commerce, virtual meetings and remote working, smart grid, smart motor systems, smart buildings, smart transportation, and dematerialization*.

ITU (2008) proposes mitigation strategies similar to the ones in the foregoing section in that it focuses on the role of ICTs in reducing CO₂ emissions through carbon displacement (e.g. telework, dematerialisation), whereas WWF (2002) proposes the use of energy-efficient applications in "smart" telecommunications, power, transportation and services industries, among others. All these strategies are covered in the three categories proposed by the World Economic Forum (n.d.) in the foregoing section. Specific examples of some of these strategies include replace travel, especially business travel, which range from the routine (for example, e-mail, phone calls, text messaging) to the sophisticated (high-performance videoconferencing) (ITU, 2008). Other local examples include use of e-payment systems like ECOASH being used in Zimbabwe, use of internet banking, mobile commerce and so on. Some of these strategies require a change in lifestyle and attitude for them to be implemented successfully.

6.6. Role of ICTs in Climate Change Adaptation

Some adaptation strategies have been proposed in earlier researches such as Zimbabwe's Initial National Communication under the United Nations Framework Convention on Climate Change (1998). However, the strategies proposed in the context of a developing country

"International Conference on ICT for Africa 2013, February 20 -23, Harare, Zimbabwe"

Zimbabwe are not ICT based. Some of these strategies include changes in management practices, land uses and so on. These strategies should rather be reinforced by ICT based strategies described below.

The International Bank for Reconstruction and Development/The World Bank (2012) in their study in Mozambique asserts that there are four types of ICT tools, namely, Geographic Information Systems (GIS), E-Governance, Early Warning Systems (including telemetry), and Wireless communications commonly adopted by local governments worldwide for helping their cities adapt to the effects of climate change. The International Bank for Reconstruction and Development/The World Bank (2012) further asserts that GIS and E-Governance are commonly leveraged for disaster prevention and recovery purposes, while Wireless communications and Early Warning Systems are adopted to facilitate efficient disaster warning and emergency response. Global e-Sustainability Initiative (n.d.) proposes solutions which are not very much different from the above solutions. Some of the examples of ICT solutions for adaptation proposed by Global e-Sustainability Initiative (n.d.) include, *early warning systems* where ICT systems are used to provide people with warnings and information regarding threats like extreme weather events, *smart planning* in which ICT systems are used to improve urban and rural planning and solutions can be tested based upon their resilience, *e-health* where smart ICT can bring down costs for health and allow correct treatment, especially in case of pandemics and new health challenges where local knowledge might be insufficient and lastly *education* where ICT can help reduce costs, enable access and improve the quality of education through telecentre, use of e-learning systems, virtual lecture theatres like the ones being used at the University of Zimbabwe.

However, Ospina and Heeks (2010) noted that as regards areas of adaptation and climate change strategies in the context of developing countries. Experiences from vulnerable communities in Asia, Africa, Latin America and the Caribbean point to the use of applications such as mobile phones, the Internet and community radio as part of climate change responses, including the strengthening of local livelihoods, natural resources management and training, access to relevant information and networking opportunities, and awareness raising, among others. Ospina and Heeks (2010) research focused on the potential of ICTs towards CO₂ emission reduction, including a variety of highly innovative applications that aim at improving energy efficiency in the telecommunications, transportation, construction and services industries, among others. It is important here to note that focus must then be shifted to adaptation rather than to mitigation only.

IPCC (2007) in its report on climate change tackles the priorities of developing countries through adaptation (i.e. recovery and adjustment in the face of climate change). IPCC (2007) further asserts that the potential of ICTs in adapting to climate change is now evident in use of devices like mobile phones and other applications used in adapting to climate change.

6.7. Role of ICTs Climate Change Monitoring

Information and communication technologies (including radio and telecommunication technologies, standards and supporting publications) are being used for weather forecasting, climate monitoring, predicting, detecting and mitigating the effects of natural disasters. ITU (2008) cites technologies which allow remote monitoring and data collection using ICT-equipped sensors (telemetry). In addition to that, ITU (2008) also cites aerial photography, satellite imagery, grid technology and in particular the use of global positioning by satellite (GPS) for tracking slow, long-term movement, for instance of glaciers or ice floes. These

satellites and weather radars also track the progress of hurricanes and typhoons and tracking tornadoes, thunderstorms, and the effluent from volcanoes and major forest fires. Also, the radio-based meteorological aid systems collect and process weather data. It is further asserted that apart from monitoring the effects of climate change, ICTs have also proved invaluable in computer modeling of the earth's atmosphere (ITU, 2008). Further to that supercomputers are being used in meteorological services to produce complex general circulation models of climate. Further, different radio-communication systems (satellite and terrestrial) are used for dissemination of information concerning different natural and man-made disasters (ITU, 2008).

In addition to the foregoing solutions, ITU (n.d.) indicates that the role of ICTs in weather and climate monitoring is shown in the structure of the World Meteorological Organization's (WMO) World Weather Watch (WWW), which comprises three integrated core system components as follows:

- The Global Observing System (GOS) which provides observations of the atmosphere and the Earth's surface (including oceans) from the globe and from outer space. The GOS uses remote sensing equipment placed on satellites, aircraft, radios and relay data to environment control centres.
- The Global Telecommunication System (GTS) — radio and telecommunication networks for real-time exchange of a huge volume of data between meteorological centres.
- The Global Data Processing System (GDPS) — thousands of linked mini, micro and supercomputers, processes an enormous volume of meteorological data and generates warnings and forecasts.

Zimbabwe's Initial National Communication under the United Nations Framework Convention on Climate Change (1998) notes that "*of the three Global Climate Models (GISS, GFDL and CCC), the CCC reasonably simulates current temperatures particularly in the Gwayi, Odzi and Sebakwe catchments. Therefore, this model was used to develop both temperature and precipitation scenarios for the doubling of CO₂ case.*"

From the above discussion, it is clear that ICTs play a major role in monitoring climate change through helping with data collection, dissemination, storage, collaboration, processing and management.

7. Challenges in combating climate change

The United Nations Framework Convention on Climate Change (2007) asserts that many factors contribute and compound the impacts of current climate variability in Africa and will have negative effects on the continent's ability to cope with climate change. These include poverty, illiteracy and lack of skills, weak institutions, limited infrastructure, lack of technology and information, low levels of primary education and health care, poor access to resources, low management capabilities and armed conflicts. The overexploitation of land resources including forests, increases in population, desertification and land degradation pose additional threats (UNDP 2006). Still on challenges, Economic Forum (n.d.) asserts that there remains no single, unified message that is being delivered to senior-most decision makers from governments and in other industries regarding use of ICTs in combating climate change.

8. Conclusions

This paper discussed the major causes of climate change, signs of climate change and its effects. The role of information and communication technologies in mitigating, adapting to and monitoring climate change was also discussed. From the above discussion it is clear that

"International Conference on ICT for Africa 2013, February 20 -23, Harare, Zimbabwe"

the major contributor to climate change is human activity notably the emission of green house gases into the atmosphere. The paper reached the conclusion that ICTs have huge potential to mitigate, adapt to and monitor climate change in developing countries even though these countries are facing a lot of challenges that are making it difficult to implement some of the proposed solutions.

In the area of climate change adaptation, ICT based strategies include, i) infrastructure innovation which is aimed at reducing energy consumption and Green House gases (GHGs), ii) behavioural change and green enablement which focuses on need for global measurement and tracking of carbon reduction, as well as tools that impact positive behavioural change including software tools for measuring carbon footprint, and the use of innovative technologies and opportunities that reduce travel and transportation and iii) energy efficiency of data centres, electronic devices and solutions.

As regards climate change monitoring, ICTs can be used for weather forecasting, climate monitoring, predicting, detecting and mitigating the effects of natural disasters. Some of the ICTs that can be used in this area include i) The Global Observing System (GOS) which provides observations of the atmosphere and the Earth's surface (including oceans) from the globe and from outer space, ii) The Global Telecommunication System (GTS) which are radio and telecommunication networks for real-time exchange of a huge volume of data between meteorological centres and iii) The Global Data Processing System (GDPS) where many networked mini, micro and supercomputers, processes an massive volume of meteorological data and generates warnings and forecasts.

In the area of climate change adaptation, the following strategies can be used, Geographic Information Systems (GIS), E-Governance, Early Warning Systems (including telemetry), and Wireless communications commonly for helping cities adapt to the effects of climate change.

9. Recommendations

It has been indicated that climate change is global problem. This means that a global solution which is based on use of ICT is required. This problem should be addressed at national level by each and every country through creating a budget for climate change. It has been indicate that the developing countries do not have the much needed ICT infrastructure. The infrastructure can be improved through use of the money each country budget for climate change. On setting up the infrastructure, it is recommended that each government must use green technologies only.

The other challenge which has been identified is that of lack of a clear message on the role of ICTs in mitigating climate change. We therefore recommend that all players in the ICT sector, the education sector and the media must take an active role in disseminating information not only about the role of ICTs in mitigating climate change but also about the need for every person to reduce emissions of GHGs into the atmosphere. Here it is recommended that educational institutions must include climate change in their curriculum from the lowest level possible to the highest level.

Further, the ICT sector should develop affordable software tools that can measure the carbon foot print since it is expensive to import software which was developed elsewhere. It is recommended that each and every responsible company should have software tools which measure its carbon foot print. This is very important because its difficult to reduce the CO₂ emissions if we cannot measure the carbon footprint

It is also recommended that the ministries of ICT should enact policies which make it mandatory for companies to use some of the strategies proposed like teleworking, use of plastic money, e-commerce, e-agriculture and so on.

It is also recommended that all countries that ratified the United Nations Framework Convention on Climate Change (UNFCCC) must provide periodic country reports that include data on climate, climate change and climate change effects, and also details of the adaptive, mitigative and monitoring initiatives the country is implementing or is planning to implement. Effective monitoring and reporting (M&R) systems to collect all the different types of data from a wide variety of stakeholders are required in order to produce country reports and to develop climate change policies and plans.

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