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# Climate Change Impacts on Biodiversity and Ecosystem Services

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**ABSTRACT**

Climate change realities cannot be ignored as widespread changes are seen in the environment. It has been documented by the Intergovernmental Panel on Climate Change (IPCC) that global average temperatures have risen by $0.7^0$C and are expected to continue rising. The entire global community evidences climate change adverse impacts as it changes biodiversity at an unprecedented rate on ecosystems, their component species, genes within species and ecological interactions. It is projected to cause species to move, die or change. Change in species richness and evenness causes ecosystem dysfunction, affecting goods and services provided by that biodiversity in question in that particular ecosystem crucial for human survival and well-being. In this review, we consider the impacts of climate change on biodiversity in different ecosystems; terrestrial, freshwater and marine. It considers that climate change affects biodiversity and the ecosystem goods and services that depend entirely on biodiversity. It concludes by summing up the potential stresses imposed by climate change on both biodiversity and ecosystems services and looking at the adaptation and mitigation measures adopted by the individuals, governments and the international community. Additionally, it calls for more extraordinary tools and techniques as adaptation measures and assesses the progress of the issue of climate change. Secondary data from scholarly journals and government archives were used.

## 1. Introduction

United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate associated directly or indirectly to human activity resulting in the alteration of the global atmospheric composition, and that is in addition to natural climate variability observed over comparable periods of time (UNFCCC, nd). It is mainly caused by the consumption of fossil fuels (oil, gas and coal) by human beings. These fuels emit greenhouse gases (GHG) during the production of electricity, transport, industrial processes and other anthropocentric development activities. Even though carbon dioxide (CO2) is the main greenhouse causing climate change, there are some significant GHG's contributing to climate change. Since the Industrial Revolution, the Earth's average temperature has been increasing. (Herrero et al., 2016). The average global surface temperature rose by $0.9^0$ C between 1880 and 2015. Subsequently, the Earth recorded its third consecutive hottest year in 2016 since record-keeping commenced. And the climate has been a major cause of biodiversity decline in this century (Nunez et al., 2019).

Biodiversity refers to the variety of plants, animals and microorganisms, the genes they contain and the ecosystem they form (U.S & N.K, 2015). (Bellard et al., 2012) reviewed that climate change multiple components are estimated to have effects on all levels of biodiversity, from organisms to biome level (Figure 1).

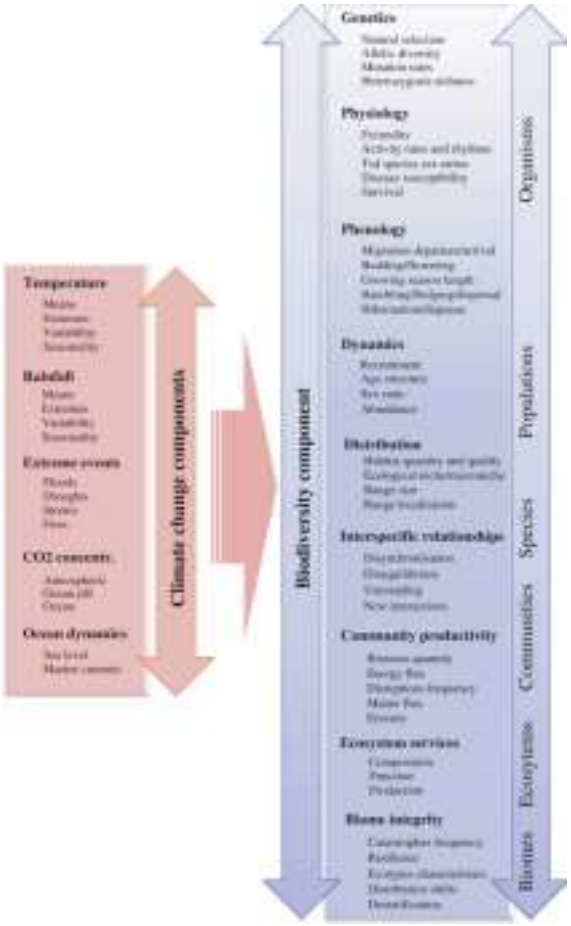


**Figure 1: Summing up some of the anticipated climate change components and their effects on different levels of biodiversity**

Climate change can lower the population's genetic diversity at the most basic level of biodiversity through directional selection and migration. Populations 'web of interactions' gets interrupted at the community level. This happens when some species responses indirectly impact other species they rely on. Additionally, inter-specific relationships can interrupt community structure since climate change can introduce exotic species. Vegetation communities that are large enough to have an effect on biome integrity are estimated to be changed by climate change at higher levels of biodiversity. Major losses of biodiversity because of global climate change and higher rates of species extinction above the current and the fossil records are anticipated. Because of global warming, by 2050, 15-37% of species might be exposed to extinction (Rinawati et al., 2013).

Biodiversity will have to find ways to respond since the environmental conditions will be no longer suitable for them. They may shift, adapt to the environment or get extirpated depending on their exposure, sensitivity and resilience to the new environment. When they shift, their distribution range is directed to environmental conditions that favour them. When they adapt, they choose to remain in that new environment but have to change their genetic composition or use phenotypic plasticity (Fusco & Alessandro, 2010). Whichever adaptation they choose, the timing of events, anatomical variation, and physiology or behaviour will be affected. If they cannot shift their range or adjust to the new environment, they have no option but to face regional or even global extinction (Hetem et al., 2014). Change in range distribution, genetic composition, and phenotypes cause a mismatch in the species interactions, ecosystem function and structure, consequently leading to profound implications on ecosystem services. The irreversible loss of biodiversity leads to ecosystem degradation, thus affecting ecosystem services and human well-being (Sintayehu, 2018).

Ecosystem services are goods and services offered by ecosystems to benefit human beings. These could be food, fuel, timber, water, clean air and medicines. It could also involve regulating local climate conditions and aesthetic value or cultural identity (Environmental Protection Agency, nd). According to the Millennium Ecosystem Assessment, ecosystem services are categorized into four types: Supporting (nutrient cycling, primary production), Regulating (climate and disease regulation), Cultural (spiritual values and recreation), Provision (fuel, food, fibre and freshwater) (Sintayehu, 2018). There is clear evidence that ecosystem

provision of imperative resources, biomass production, decomposition and recycling of vital nutrients is lessened by biodiversity loss (Cardinale et al., 2014). The main aim of this paper is to review climate change effects on biodiversity in different ecosystems around the world. It discusses the impacts of climate change on biodiversity-based ecosystem services that the human race depends on, looking at terrestrial, freshwater and marine ecosystems. It concludes by summing up the potential stressors imposed by climate change's effects on biodiversity and ecosystems services, looking at the mitigation and adaptation measures adopted by individuals, governments, and the international community. Furthermore, it calls for the implementation of extraordinary solutions to greenhouse gases.

## 2. Review and discussion

### *2.1 Terrestrial ecosystems*

The terrestrial ecosystems exist as tundra, taigas, grasslands, tropical rainforest, temperate deciduous forests and the desert (National Geographic Society, nd). High biodiversity indicates healthy ecosystems and good human health. Changes in average climate (average temperature, decreased rainfall and changes in seasonality) and extreme events (increased hot days, fire, increased frequency and intensity of cyclones, heatwaves and intensified wet seasons) are expected to bring gradual and sudden changes amongst the terrestrial biodiversity and ecosystems (NCCARF, nd). Research showed that terrestrial ecosystems are at high risk of compositional and structural changes around the globe if climate change driving factors are not taken care of. As biodiversity disturbances occur, new ecosystems (in composition, function and structure) will be created. Species interactions and ecosystem services will be interrupted as mismatch and reorganization of communities occur (Nolan et al., 2020). Individual terrestrial species distribution and life cycles are sensitive to their local climate. This is because every species has particular climatic conditions they survive and thrive on. Therefore, species are bound to respond if climatic conditions are unsuitable for them.

Numerous ways in which climate change has impacted the natural terrestrial biodiversity has been observed. The physiology of mammals gets adjusted when temperatures go high. Evaporative cooling is the only way mammals lose heat when exposed to extreme heatwaves. Therefore, if they are to face climate change associated with a lack of water, it means that they are at high risk. Consequently, mammals like moose respond to the increase in temperature through Adaptive heterothermy (Fuller, 2016). The changing climate also poses a serious threat to the butterflies because they prefer not to have too cold or too hot. Therefore, they are left with ways of finding suitable temperatures to operate on to avoid very high temperatures. Consequently, they resort to changing their phenology. This means that the timing of some life cycles gets changed. In Britain, where the average spring temperature has increased by 0.5 degrees Celsius, it has been observed that butterflies have been doing things earlier by between three days and a week on average ( Macgregor, 2019). Microevolution resulting from climate change has been witnessed as the tawny grey owl evolves to the tawny brown owl in Finland. Owl is normally found in two different feather colours; grey and brown. The brown is usually found in mild winter environments, while the grey is found in colder winters. Grey coloured owls mostly dominate Finland, but research has found that the number of brown owls has been increasing because of the decrease in snow and rise in temperatures. Since the winters are getting mild, the brown owls survive the change in environmental conditions while the grey face challenges. Consequently, more brown coloured offspring are being born as the brown owls carry their genes around (Plester, 2014). As stated above, with climate change causing increased heat waves, the Homo sapiens species are feeling the effects. It has been reported that because of extremely high temperatures, France got hit by a heatwave in June killing 1, 500 people (France-Presse, 2019).

Terrestrial ecosystems provide the community with goods and services, but they get interrupted by climate changes. There are high chances that they will be impacted by gradual changes in temperature, precipitation and other disturbances related to climate change. The disturbance could be flooding, drought and wildfire. Ecosystem structure and function, ecological interactions and geographical ranges amongst species will be affected by this extreme event leading to interruption of ecosystem services. Water regulations and timber production are expected to be affected by the change of environmental conditions, affecting the society that depends on them. (Locatelli, 2016). The regions of Sahel and the semi-arid drylands in East Africa ecosystem services are vulnerable to climate change. The residents are facing livestock losses, food insecurity, displacement, culture losses, including traditional livelihood systems. In early 2015, in Niger, Nigeria, Mali, and Chad, 20.4 million people were estimated to be food insecure because of the droughts they got exposed to by changing climatic conditions (Geest, 2018). Pandas are one of the most beloved animal species on Earth but threaded by the adverse effects of climate change. It has been projected that the endangered panda will seriously face some food shortages as the temperature rises in China over the next century. This would result from the impacts of climate change imposed on bamboo species that happened to be almost the sole food for pandas. Pandas can only survive if they move to new habits at higher elevations (Moskowitz, 2012). Most forest systems have evolved under natural fire regimes. However, many of the valuable services that forests provide, including timber and space for recreation and aesthetic views, are degraded by wildfire (Nelson, 2013).

### *2.2 Freshwater ecosystems*

Freshwater ecosystems come from rivers, streams, reservoirs, lakes, ponds and part of estuaries (Aldridge, 2019). The ecosystems are prone to the environmental changes posed by climate change. These changes are estimated to cause

irreversible damage to these ecosystems, supporting many biodiversities and offering essential services to the community they depend on. Research shows that noticeable ecological impacts on most freshwater ecosystems in the next few decades will be experienced (Hassan et al., 2019). The ecosystems experience species shifting because of the warming and the interruption of large scale hydrological cycles resulting from Climate change. The interruption happens by increasing atmospheric water vapour content, changing precipitation patterns, widespread melting of ice and changes in soil moisture and runoff. Extreme weather events like flooding, hurricanes, and droughts also contribute to the interruption (Cornel University, 2016).

Some freshwater species can potentially reflect the implications of climate change on biodiversity. The warming leads to changes in the water cycle and precipitation patterns, as stated above. Climate change affects different areas in different ways. Some areas receive increasingly abundant rainfall, while others receive a short supply. Consequently, since rivers are part of the cycle, their flow gets affected by the alteration of the water cycle. (Climate 101, nd). The western rainbow fish in Australia has been found to feel the impacts of river flow alteration resulting from climate change. The species respond with phenotypic plasticity when exposed to change in environmental conditions. An adjustment in the body shape morphology of fish has been experienced when it goes through a few months of that particular continuous flow (Kelley et al., 2017). There is also some evidence that Salmon has shown some behavioural change to respond to climate change. Salmon prefers temperatures ranging from 16.5 degrees to 17.5 degrees. This suggests that if temperatures get very high, which is clear, that happens under climate change; conditions become unbearable for the fish. High temperatures in the water go hand in hand with low dissolved oxygen (DO). Therefore, Salmon finds it hard to survive under such temperatures and low dissolved oxygen waters and end up practising the avoidance behaviour. Under this change of behaviour, Salmon avoids warm surface temperatures and low dissolved oxygen (Stehfest, 2017).

Freshwater ecosystems offer great services to society. Unfortunately, the climate is posing some threats to the services. Many concerns have been raised concerning the effects of climate change on fish and fisheries in Australia since they contribute to the Australian economy through commercial fish farming and recreational purposes and are socially and culturally important. In Australia, Recreational angling (marine, freshwater and estuarine) is a very recognized leisure activity with a 91.5% annual participation rate which is the highest globally. Many species are now of conservation concern and in need of rehabilitation as the freshwater fishes and their habitats in Australia experience some alarming decline. (Koehn, 2012). In Botswana (Africa), the Chobe River has been reported to have a low water volume that has never been experienced and affects tourism (Botswana Television, 2019). Additionally, in Botswana, there is some evidence of diminishing wildlife species because of the lack of resources they depend on. Lake Ngami has been reported drying because of high temperatures, and more than 300 cattle died consequently, which means that farmers do not have enough to provide for their families and even enough to sell meat in the European markets (Botswana Television News, 2019).

### *2.3 Marine ecosystems*

Marine ecosystems can be defined as an environment that interacts with animals, plants in the ocean or sea environment. These ecosystems are normally characterized by salty water. Marine ecosystems can occur as salt marshes, estuaries, the ocean floor, the broad ocean, the inter-tidal zones, coral reefs, lagoons, and mangroves (Biologydictionary, 2017). Population-level shifts are happening in marine ecosystems because species' physiology cannot tolerate the new environment, altered dispersal patterns, and change in species interaction. The ecosystems are becoming an unbearable environment for species to thrive on because they experience a rise in atmospheric $CO_2$ levels in conjunction with changes in temperature, circulation, stratification, oxygen content, ocean acidification, nutrient input and other biological effects( Doney et al., 2011). Recent research indicated the ocean systems being pushed towards risky conditions of irreversible ecological and structural transformation by climate change. Climate change has been noticed to decrease ocean productivity, alter food webs, shift species distribution, etc. The change of the ocean environment will lead to societies that depend on them to face serious challenges (Guldberg & Bruno, 2010).

There is some evidence that climate change is altering the biodiversity of marine ecosystems. Because of the rising temperatures in oceans from climate change, zooplankton like foraminifera have shifted 602km poleward on average from the pre-industrial times to today. However, the degree of displacement ranged between 45 and 2, 557km depending on the temperature change of the sea surface temperatures. Additionally, it has been noticed that in the northern hemisphere, the zooplankton has shifted northward in response to the warming environment. This is having an impact on fish and whales that depend on them since they as well have shifted their distribution. Unfortunately, not all species feeding on this plankton will be able to follow it to cooler waters (Dunne, 2019). Whales normally swim to the bottom of the ocean floor to get their food, but research indicated that whales in the Pacific Ocean showed a unique feeding pattern behaviour as a way of responding or adapting to the challenges of climate change. They can feed on both seafloor and surface levels, allowing them to survive the fluctuations of food supply posed by climate change. This suggests that this fish doesn't need to migrate because they have

the flexible capability (Pyper, 2011). As stated, not all species will be able to withstand the unprecedented impacts of climate change. Dolphins have been identified as one of those species. It has been documented that in Shark Bay in Western Australia, the 2011 heat wave cut down the survival of dolphins by 12%. After the rise of temperature to four degrees above the annual average, the survival and reproduction of dolphins were impacted. Female dolphins were found to give birth to fewer calves, and this went on until 2017(Wild et al., 2019).

The marine ecosystems functioning and services experience a change in biogeochemical cycles, energy and material flow and will face some implications because of climate change. Consequently, this will impact people and society at large depending on those services (Doney, 2012). For example, global fishery catches and species turnover are expected to lower by 3Mt and increase by 10% for every 1degrees Celsius temperature change. Similar patterns are expected for finfish and shellfish aquaculture. This is because around 90% of the current mariculture production of finfish and shellfish is from open water farming, where the condition of the environment matches the ones in the neighbouring ocean (Gattuso, 2018). Seagrass habitats are the world's most financially valuable natural ecosystem in nearshore ecosystems. Seagrass in Melanesia has a value of 151.4 billion $USD, which is 42 billion more than mangroves and 5.7 billion more than coral reefs in the same region. The society in the tropics benefits profoundly from Seagrass, mangroves and coral reefs since they contribute seriously to the health, welfare and daily livelihoods of the majority of the 1.3 billion people estimated to reside within 100km of the coast, especially in developing countries. Despite the social and ecological importance of Seagrass ecosystems, they face a decline challenge annually. About 29% of the global Seagrass already are extirpated by human activities, global warming, and climate change adding to the problem.

In 2009, the US commercial fishing offered 1.03 million full and part-time jobs involving its associated harvesting, processing and dealing, wholesaling, distributing, and retailing sectors. The industry contributed $48 billion in value or 0.34% to US GDP that same year because of the $116 billion in sales generated. These economic impacts may look small, but 1.03 million jobs are almost equal to the number of civilian jobs in the state of New Mexico in 2013. This is to mean that many Americans lives rely on the ecosystem functions that sustain these huge marine fisheries (Nelson, 2013). Beautiful landscapes and coastlines became the foundation of the tourism industry in Wales because economic prosperity and the creation of jobs depend on it. The industry in 2009 was worth £6.2bn to the economy of 13.3% of GDP. Wale in 2011 hosted 0.9 million international visitors and between 2006 and 2009. The coast in Wales was visited by 37% of international holiday tourists, with 37% participating in sports activities. Tourism activities in Wales involve water sports, surfing, diving, climbing, and fishing and boating. And tourism has been booming because of this diversity. Unfortunately, coastal erosion and sea level rises have been noticed on 23% of the coasts due to climate change, putting pressure on tourism. Considerable loss has been observed (Simpson, 2013).

**3. Conclusion**

The alteration of the environment by the climate change disturbances has been shown to affect all the different kinds of ecosystems; terrestrial, freshwater and marine ecosystems. In response to a change in conditions, species can move or adapt to the new environment. When species adapt through both microevolution and phenotypic plasticity, their phenology, anatomy and physiology or behaviour will be affected. This is because every species needs specific conditions to thrive on; consequently, the species composition of the ecosystem changes. It has been discovered that species will be affected and respond differently to the change in environmental conditions since they are phenologically and typographically different. Unfortunately, not all species can cope with the unprecedented climate change, leading to extinction. Because of this shifting and changing of species, ecosystem function gets to be affected, leading to pressure on ecosystem services. Some biological networks affect ecosystem function. If these functions are interrupted, ecosystem services are impacted, together with the society that depends on those services. Numerous ecosystem services failure because of change in climatic conditions has been observed. Food security has been threatened, tourism and other ecosystem services have declined. After noticing the adverse impacts climate change have on biodiversity and ecosystem services, it calls us to search for mitigation and adaptation strategies that will direct us to a more strategic climate response.

**4. Mitigation Measures**

Mitigating climate change covers dealing with the human behaviour or carbon sinks enhancement to cut down carbon emissions to limit the long-term climate change (FAO, 2012). There are some basic mitigation measures that governments and individuals can adopt to mitigate the effects of climate change. By bringing them together, they could make some changes and help reduce people's footprint. For the carbon target to be achieved, everyone will show their effort and be part of the framework. Government departments (from all levels), corporations and individuals should commit themselves to the reduction targets set by the UNFCCC. The governments need to take their leadership role and together as the community embrace the idea of reducing carbon emissions (Glenn, 2010). Climate change mitigation measures by governments and individuals:

*Governments;*

- Create strong, ambitious building codes and municipal by-laws that enable new construction to be installed with green design and building techniques to conserve energy, cut demand and use solar energy and even geothermal heat sources

- Install solar and other renewable energy features in the modern buildings

- Design neighbourhoods that are pedestrian user friendly and that will allow public transport and recycling

- Encourage recycling, pursuing opportunities of energy from waste and capturing methane gas from landfills to cut down greenhouse gas emissions

*Individuals;*

- changing what they eat; eating less meat, and buying locally produced goods

- choosing a fuel-efficient vehicle when buying, resorting to using public transport, riding a bicycle or walking. This helps to lower down the atmospheric gases that drive climate change

- buying fewer things because everything we use in our daily lives has carbon embedded in it. So buying fewer new things will reduce one's carbon footprint

- Re-using materials uses less energy and pollutes less than extracting new materials. So recycling is one of the viable options.

- planting more trees around one's home so that they suck carbon dioxide from the atmosphere ( Renold & Sauls, 2020).

**6. Adaptation Measures**

Adaptation intends to reduce challenges established by climate change results (Clark, 2012). Adaptation strategies are vital at all levels of administration: at the local, regional, national, and international levels. Climate change adaptation is vital for giving individuals, communities, organizations and natural systems opportunities to deal with climate change aftermath that cannot be dealt away with. It includes being practical about climate change impacts management, community protection, and strengthening economic resilience (Australian Government, nd).

We can adapt to climate change by:

-Efficiency use of scarce water resources; considering the future climate conditions and extreme weather events and deciding adaptation building codes for them
-erecting flood defences
-increasing the levels of dykes
-planting crops that can resist drought; going for species of trees and forestry practices that are less vulnerable to storms and fires
-reducing land corridors to improve the migration of species (European Commission, nd)

As part of their mitigation and adaptation strategy, the international community has set up some conventions that engage the member states to deal with climate change's adverse impacts and consequences. The United Nations Framework on Climate Change (UNFCCC) is an international environmental treaty established in 1994 embraced and implemented by 197 global countries to solve the climate change phenomenon. It intends to neutralize the concentration of the greenhouse gases in the atmosphere, so it comes to a level that will not allow humans to interrupt the climate dangerously. UNFCCC was the first worldwide treaty ratified in1992 to address the cause of climate change. It has annual meetings to measure the progress and take appropriate strong steps. The other branch treaties were born; The Tokyo Protocol and the more recent Paris Agreement. The treaty requires the developed countries to be on the front of emissions reduction. Additionally, the treaty has agreed to finance the developing countries to mitigate climate change impacts. The grants and loans system is supervised by The Global Environment Facility (GEF) to pass it on to the emerging economies (Climate Talks, nd)

The UNFCCC established a climate change fund, Special Climate Change Fund (SCCF), in 2001 with the aim of financing activities, programs, and measures relating to climate change. The activities, programs and measures should be related to the Climate Change Focal Area of the GEF. Four windows made up the SCCF, adaptation and transfer of technologies, energy,

transport, industry, agriculture, forestry, waste management, economic diversification for countries that depend on others for fossil fuel (World Bank Group, nd).

Some of the conventions which work with the UNFCCC but focus clearly on biodiversity include the Convention on Biological Diversity (CBD). It's a global legally-binding treaty with three main objectives: biodiversity conservation, sustainably using biodiversity, equal and fair distribution of the benefits obtained using genetic resources. Its umbrella aim is to obtain a sustainable future through engagement. All levels of biodiversity are included under The Convention on Biological Diversity; ecosystems, species, and genetic resources. It covers all the domains that directly or indirectly correlate with biodiversity and its purpose development, moving from science, politics and education to agriculture, business, culture and others. Biotechnology is also covered through Cartagena Protocol on Biosafety (United Nations, nd).

The ecosystem approach established by the Convention on Biological Diversity encourages conservation and proper use and management of land, water, and living resources. Under this approach, the objectives of the Convention are met. It is founded on the good methods of science centred on levels of biological organization, which embraces vital processes and relationships between organisms and their environment. Additionally, the ecosystem approach acknowledges people and their cultural diversity as part of the members of ecosystems (Convention on Biological Diversity, nd).

Further research is still imperative on the issue of climate change. The research shows that the leading global scientists accepted that our planet is in trouble because the recent past five years have been the hottest ones ever recorded. Additionally, in these five years, the sea levels have the highest records in human history, and millions of species verge extinction. It is clear that something is not done to fight this pending climate change crisis. Aljazeera stated that even though COP25 was held in Madrid recently, world leaders have not been able to bring solid solutions to keep the planet temperature cool. They moved the negotiations to next year instead (Aljazeera, 2019). Some ideas were brought forth during the talks. They called for a new ambitious emission-reduced target, more funding and the protection of those vulnerable. When talks ended, countries agreed on motions calling for profound ambitions to reduce the emissions of greenhouse gases so that global warming is brought to a limit of 1.5 degrees Celsius. Strong decisions like having global rules on carbon markets until the next COP to be held in Glasgow in 2020 were reached (Planet SOS, 2019).

The World Economic Forum held in South Africa, 2019 outlined initiatives that could help in mitigating and adapting to climate change: encouraging key governments and businesses to up their game politically by coming up with plans to lower the greenhouse gases emissions and build climate resilience in accordance with scientific recommendations by COP26 in 2020; to engage businesses in the climate change phenomenon so that they play their part in fighting the changing environmental conditions; coming up with good governance and market mechanisms that encourage low carbon economy (World Economic Forum). Some suggest that carbon technology like carbon sequestration storage should be implemented. CarbFix is one of the carbon capture sequestration processes whereby technology captures CO2 and other sour gases from the atmosphere and forever keep it in a rock. It usually captures 95% of CO2. A mixture of carbon dioxide and water is prepared then injected into the ground. The process then turns CO2 into calcite minerals in six months. The process is regarded as one of the most effective ideas of removing CO2 from the environment (Aljazeera, 2017).

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