Implications of climate change on ecosystems and ecosystem services. A case of Volcanoes National Park.

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Abstract

Globally climate change has had a profound impact on the ecosystems as well as their functioning activities. Ecosystems are exposed to the effects of changing climates in different measures and this in turn impacts on the services derived from them by the societies. Although the impacts of climate change are often combined with the effects of other activities, such as land use changes, climatic effects in some ecosystems are pronounced. The study is to assess the effects of climate change on ecosystems and their sustainability. The main aim is to establish different microclimatic elements that impact on sustainability of ecosystems. The problem is climatic changes stress ecosystems in and around the Volcanoes National Park. This is exacerbated in destruction of habitats, wet land degradation, forest destruction, erratic season change, migration of certain animals, change in feeding habits and encroaching among others. The problem is compounded by, intensive agriculture, forest fires, soil erosion and degradation of the ecosystems. These in turn impact on the ecosystem structure and resilience. The literature review mainly focused on ecosystem disturbance as a result of climate change.

The research design includes the use of qualitative data that will be in essay form and quantitative data that will comprise of statistical or measurable aspects like temperature, rainfall, population, land area and distances. The area of study is volcanoes national park that covers an area of 165km^2 and lies on Volcanoes National park lies at the latitude of 1.47^0S $1^0 28^{'} 0^{''}$S longitude of 29.492^0E $29^0 29^{'} 30^{''}$E .The study will use a sample of 30 respondents especially the community leaders, conservationists in the field, the staff from RDB, the porters and tour guides, the tourism association leaders, cultural leaders and agricultural officers. Purposive random sampling will be utilized in conjunction with interview guides and oral interviews. Analysis of data will be done by use of excel and frequencies plus percentages.

Key words: Climate change, ecosystems, ecosystem services, disturbance, effects, sustainability.

1. Introduction

Ecosystems are exposed to the effects of changing climates in different measures. Although the impacts of climate change may be difficult to detect since they are often combined with the effects of other activities, such as land use changes, the most recent Global Biodiversity Outlook report (Secretariat of the Convention on Biological Diversity, 2010) identifies climate change as one of the main factors responsible for the current loss of biodiversity. Some aspects of biodiversity loss through, for example, deforestation and the draining of wetlands, will themselves exacerbate climate change by releasing centuries' worth of stored carbon. Climate change affects different ecosystems in different ways, depending on the complexity and original characteristics of the system, geographical location and on the presence of factors that may regulate the extent of the changes. Degraded ecosystems are generally believed to be less resilient to climate change than intact and healthy ecosystems. The recorded increase in mean annual temperature is already affecting many ecosystems and scientific studies predict that future changes will be of much greater amplitude. The highest rates of warming have been observed at high latitudes – around the Antarctic Peninsula and in the Arctic – with the recorded reduction of the extent, age and thickness of ice occurring at unprecedented speed and even exceeding recent scientific predictions (Secretariat of the Convention on Biological Diversity, 2010). Increased temperatures affect physical systems, as ice melts and snow cover is reduced, as well as affecting biological systems through a series of direct and indirect pressures. Physical systems include deep snow, glaciers and permafrost.

An ecosystem is a complex system of plant, animal, fungal, and microorganism communities and their associated non-living environment interacting as an ecological unit. Human well-being and progress towards sustainable development are vitally dependent upon the earth's ecosystem services. They provide the foundation for all human survival, including a wide range of ecosystem services for improving livelihoods. Ecosystems provide the human population a variety of goods and services such as food production, timber production, diseases control, climate change and air quality regulation, carbon sequestration, water quality and flow regulation, protection of habitats and biodiversity, tourism, flood control, cultural services, recreational, and as well as supporting services such as nutrient cycling that maintain the conditions for life on Earth (Boon and Ahenkan, 2012). Increases in temperature can lead to a drastic unbalancing of the physical system, causing irreversible losses. The water cycle and hydrological systems are affected by changing temperatures, often indicated by dry riverbeds or floods due to increased runoff. In semi-desert areas, the decreased availability of water is already placing additional pressures on wildlife, which aggregate around limited water points and compete with domestic livestock (de Leew *et al.*, 2001). Reduced plant production as a consequence of reduced precipitation increases the probability of soil degradation due to overgrazing by wildlife and domestic animals. Many freshwater species are under serious threat of extinction as a result of rising temperatures and the disappearance of ponds and coastal lagoons (Willets, Guadagno and Ikkala, 2010). Snow and ice melts in mountainous areas have been recorded as occurring at alarming rates. Such processes severely affect mountain ecosystems, which are particularly susceptible to increasing temperatures. The extent of snow cover in the Northern Hemisphere has decreased by about 10 percent since the late 1960s and 1970s (Parry *et al.*, 2007) and mountain vegetation zones are recorded to have shifted upwards.

Improving of functioning natural systems to help minimize negative impacts of climate change on people and biodiversity, is a natural extension of our work on ecosystem services and multi-stakeholder driven conservation planning. An understanding of the likely direct and indirect effects of climate change on conservation targets, key ecosystem processes, and human communities is critical to the Conservancy's work. Understanding exposure to *and* sensitivity to climate change allows us to evaluate vulnerability, and develop priorities with respect to implementing adaptation actions. Several good syntheses of adaptation strategies and approaches are now available and referenced in this primer.

Yet, as a general rule, the conservation community is only now gaining on-the-ground experience in conservation projects that will enable us to eventually provide more specific guidance on how, when, and where to implement adaptation strategies. At the same time, many conservation practitioners inside and outside the Conservancy increasingly recognize that they already have many of the methods, tools, and strategies at their disposal to mitigate to some degree the most deleterious effects of climate change, especially reducing existing stressors to ecosystems (e.g., invasive species, altered fire and flow regimes). In many cases, we simply need to do a better job of explaining how what we are doing contributes to adaptation, how we are updating our strategies to make our contribution to adaption even stronger, and most importantly – disseminate best practices in adaptation across the conservation community as quickly and efficiently as possible.

Ecosystem-based adaptation is a term whose history can be traced to the international climate policy arena. At its core, it refers to taking conservation actions that will benefit both nature and people in the face of climate change impacts. The Conservancy is currently involved in hundreds of conservation projects across the organization, many of which will be impacted by climate change. Some of these projects work closely with local (human) communities while others are only involved more secondarily or indirectly with people. Although our strategic emphasis in the future will be on adaptation strategies that benefit both nature (biodiversity) and people, the methods, tools, approaches, and resources outlined in this primer should be helpful to all conservation projects, regardless of the degree of emphasis on human well-being. Moreover, our methods, tools, and approaches for better incorporating the people side of the equation in adaptation work will clearly be improved in future editions of this primer as well as other guidance materials.

Impacts of climate change have been well-documented for terrestrial, aquatic, and marine ecosystems publicized impacts of climate change such as sea level rise, ocean acidification, insect outbreaks, coral reef bleaching, and melting of sea ice and permafrost, there are many less obvious ecological impacts on ecosystems across the globe. These include changes in the length of the growing season and tratification period in lakes, in the timing of seasonal events (phenology), in patterns of primary production, and in species distributions and diversity (Peñuelas and Filella 2001, Walther 2002, Parmesan and Yohe 2003, Root et al. 2006, Austin and Coleman 2007, Field et al. 2007). Mismatched changes in seasonal timing of interacting species have been documented in terrestrial, aquatic, and marine ecosystems (e.g., Winder and Schindler 2004, Both et al. 2009, Thackeray et al. 2010), and have serious implications for the life cycles and competitive abilities of numerous species. Similarly, as species vary widely in their abilities to shift location in response to climate change, we can expect impacts from disruptions in key species interactions, and additional stress on species from both native and non-native species, and disease vectors that shift into new locations. Researchers have begun to explore the implications of these changes for the provisions of ecosystem services (*sensu* Millennium Ecosystem Assessment 2005).

2. Literature review

Projected impacts of climate change

Climate change is likely to exacerbate further the loss of ecosystems and the services they support and on which humans depend. While ecosystems have always changed over time, the ecosystem effects of climate change are likely to be made more severe by the dramatic loss of natural areas we have experienced in the last half century. Natural area loss is a primary factor leading to the decline in many important ecosystem services worldwide (Millennium Ecosystem Assessment 2005), particularly the loss of terrestrial biodiversity (Wilcove et al. 1998). The amount of land and water currently under conservation status is insufficient to sustain biodiversity, to adequately protect ecosystem services for people into the future, or to facilitate the natural adaptation of the earth's species.

Additional stresses to species and ecological systems are also likely to come from increased invasions from non-native species, more frequent high-intensity fires, increased drought stress, changes in the relative competitive advantage of species as conditions change, and from new barriers to migration that arise as humans change their environment to promote their own adaptation. In rivers and streams, low and high temperature changes will likely cause isolation of nearby wetlands and a loss of habitat for wetland dependent fish. A decrease in the snow pack will yield a weaker spring flood, threatening freshwater wetlands and floodplains which depend on this seasonal inundation. Key wetland services, like the assimilation of nutrients and storage of sediment may also be affected by the changing hydrologic regimes (Grubin et al. 2007). Under pressure from climate change and the full array of stressors, these ecosystems, including the distinctive species associated with these places, will necessarily respond and change. As a result, it is likely that many species and ecosystems, and the direct value we derive from them via ecosystem services will also be altered dramatically.

Climate change and adaptation

According to the Second Ad-hoc Technical Expert Group on Biodiversity and Climate Change1 (AHTEG 2009), "Ecosystem-based adaptation is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. Ecosystem-based adaptation uses the range of opportunities for the sustainable management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change. It aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change. Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies."

Adaptation as used by the IPCC (Schneider et al. 2007) is a broader term defined as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. From this perspective, adaptation is the whole range of activities that society will undertake in response to climate change. Some of these will involve the use of natural ecosystems (e.g., conserving mangroves for flood control) while others will not (e.g., building sea walls). Although The Nature Conservancy and its staff will need to be aware of and in many cases respond to the variety of forms of societal adaptation, our primary focus will be working with natural ecosystems and advancing ecosystem-based adaptation. We acknowledge that many of these ecosystems will change in species composition and function over time under the influence of climate change and that our ecosystem-based strategies will need to account for such changes. Adger (2006) argues that although the Conservancy is moving in a direction of advancing adaptation projects that will benefit both people and biodiversity, we are also engaged in many long-running conservation projects in which our primary interest remains biodiversity conservation and only secondarily or indirectly involve working with human communities. Even though the balance of adaptation projects focused primarily on biodiversity targets versus those aiming to benefit both people and biodiversity may shift in the future, most of the methods, tools, analyses, resources, and strategies outlined in this primer should prove helpful regardless of that emphasis. Even under the umbrella of ecosystem-based adaptation, this first edition of the primer is largely aimed at adaptation activities and strategies within natural ecosystems. At the same time, we acknowledge that we are already engaged in numerous projects to promote "green infrastructure" across a variety of human-dominated and natural ecosystems including, for example, reducing impacts of agricultural practices on freshwater ecosystems in the Midwestern U.S.

Vulnerability is a concept that appears repeatedly in the adaptation literature. The IPCC (2007b) defines vulnerability as the degree to which a system (either a natural system or a human dominated one) is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes. Although these concepts are primarily being applied to ecological systems, they could be applied to human-dominated systems as well. Operationally, vulnerability can also be defined as: Vulnerability = Exposure + Sensitivity – Adaptive Capacity. With: Exposure = general degree, duration, and/or extent in which a system is in contact with a perturbation (Adger 2006) (perturbation in this sense is related to the character, magnitude, duration, and variability of climate change) Sensitivity = the degree to which a system is affected either adversely or beneficially by climate variability or change. The effect may be direct (e.g., change in crop yield.

Ecosystems disturbance and extinction of species.

The world is undergoing an extinction crisis – the most rapid loss of biodiversity in the planet's history and this loss is likely to accelerate as the climate changes. The impact of climate change on wildlife is already notable at local, regional and global levels. The direct impact on species that humans make use of or with which we compete, affects human communities in a very immediate way: the loss of biodiversity is our loss as well. Arguably, we also have an ethical responsibility to address the rapid increase in the rate of global species extinction that has been caused by our own actions. Climate change is expected to become one of the major drivers of extinction in this century as a result of changes in the breeding times of species and shifts in distributions caused by the variation in temperatures and precipitation regimes. It has been estimated that 20–30 percent of plant and animal species will be at higher risk of extinction due to global warming and that a significant proportion of endemic species may become extinct by 2050 as a consequence. Some taxa are more susceptible than others. For example, 566 of 799 warm-water reef-forming coral species are at risk of becoming endangered because of the increasing climate change, as are about 35 percent of birds and 52 percent of amphibians. Moreover, the impact will likely be more severe on species that are already at risk of extinction: 70–80 percent of red-listed birds, amphibians and corals are considered susceptible to the effects of climate change (Vié, Hilton-Taylor and Stuart, 2008).

When climate change disrupts ecosystems that provide global services, the implications are even more serious. With regard to rainfall generation, the potential impact on food security is huge because weather systems that water crops in the temperate world can be traced back to evapotranspiration in the three main tropical forest blocks (as demonstrated by precipitation simulations showing rainfall patterns over the course of a year). Average annual temperatures have risen steadily over recent decades and an even higher increase is predicted for the years ahead. This is most pronounced in Africa where current climate models project a mean temperature rise of 3–4 °C across the continent by the end of this century, approximately 1.5 times the global average increase (Kleine, Buck and Eastaugh, 2010; Seppälä, Buck and Katila, 2009).

All global ecosystems are likely to be affected by climate change to a greater or lesser extent. Forests cover approximately one-third of the global land surface. They provide essential services that support human livelihoods and well-being, support the majority of terrestrial biodiversity and store about half of the total carbon contained in land ecosystems, including in the peat of some tropical forest soils. Tropical and subtropical forests contain many biodiversity hotspots. There are still major gaps in knowledge about the impacts of climate change on forests, associated wildlife and people and how adaptation measures can best be tailored to local conditions. The productivity of tropical forests is projected to increase where water is available in sufficient quantity. In drier tropical areas, however, forests are projected to decline (Seppäla *et al,* 2009).

Major impacts are also predicted elsewhere, particularly in polar ecosystems, inland waters, grasslands and in the oceans, where climate-driven acidification is perhaps the most extreme threat of all (Parry *et al.*, 2007). Even moderate climate change, as projected in both unavoidable and stable scenarios, would put some wildlife at considerable risk; worst-case scenarios would see catastrophic losses. Thomas *et al.* (2004) conclude that “for scenarios of maximum expected climate change, 33 percent (with dispersal) and 58 percent (without dispersal) of species are expected to become extinct. For mid-range climate change scenarios, 19 percent or 45 percent (with or without dispersal) of species are expected to become extinct, and for minimum expected climate change 11 percent or 34 percent of species (again, with or without dispersal) are projected to become extinct. According to the Intergovernmental Panel on Climate Change (IPCC; Parry *et al.*, 2007), roughly 20–30 percent of vascular plants and higher animals on the globe are estimated to be at an increasingly high risk of extinction as temperatures increase by 2–3 °C above pre-industrial levels. The estimates for tropical forests exceed these global averages. It is very likely that even modest losses in biodiversity would cause consequential changes in ecosystem services (Parry *et al.*, 2007; Seppäla, Buck and Katila, 2009).

As average global temperatures rise, the impacts on habitats and species will depend on many factors, including local topography, changes in ocean currents, wind and rainfall patterns and changing albedo. In addition to variations in the rate and extent of temperature increases at different latitudes, there may be changes in the length and severity of seasons, including decreases in temperature in some areas. Rainfall patterns may likewise be affected in terms of overall annual quantity, seasonal distribution of precipitation and year-by-year regularity. Extreme weather events, such as droughts and floods, are expected to occur more often. In particular, droughts are projected to become more frequent and intense in subtropical and southern temperate forests; this will increase the prevalence of fire and redisposition to pests and pathogens (Seppälä, Buck and Katila, 2009). Natural ecosystems are not only threatened by climate change. Loss and degradation due to human encroachment, agricultural expansion for crop and rangelands, invasive species, over-harvesting and trade in natural resources (including wildlife), epidemic diseases, fires, and pollution still exceed the current impacts of climate change. It is widely recognized that measures to limit such non-climatic human-induced pressures can help reduce the overall vulnerability of ecosystems to climate change. Non-timber forest resources, such as fuelwood, charcoal, non-wood forest products and wildlife sustain the livelihoods of hundreds of millions of people in forest-dependent communities. Most rural and many urban populations in developing countries rely on woody biomass as their main energy source and Biological systems are also being affected by increasing temperatures, which introduce changes in biophysical conditions that influence their development and maintenance.

Vissier and Both, (2005) add that changes in water availability affect the flowering and survival of aquatic plant species, as well as the abundance of wildlife species in affected areas. Shifting seasonal changes, which are already being recorded in most temperate regions, affect the timing of animal migrations and the flowering of plants, and thus destabilize the equilibrium of ecosystems that are far apart. One large potential ecological impact of such changes is mistiming, where, for instance, migrating animals arrive at times when their necessary food plants or animals are not available (Vissier and Both, 2005). Rising sea levels are affecting coastal areas through shoreline erosion, the loss of coastal wetlands and modification of coastal vegetation. Marine and coastal ecosystems are also disrupted by storms that damage corals directly through wave action and indirectly through light attenuation by suspended sediment and abrasion by sediment and broken corals. Higher temperatures also cause the expulsion of zooxanthellae (single-celled plants living in the cells of coral polyps), which leads to coral bleaching and has caused the loss of 16 percent of the world's corals (Wilkinson, 2004). Up to a third of corals are considered to be threatened with extinction due to climate change (Carpenter *et al.*, 2008). In a chain reaction, the death of corals causes the loss of habitat for many species of tropical fish. Many studies report changes in fish populations, recruitment success, trophic interactions and migratory patterns related to regional environmental changes due to changing climatic conditions (Edwards and Richardson, 2004; Hays *et al* 2005).

Variations in climate not only lead to the modification of ecosystems. They are also associated with a higher frequency of extreme weather events that have the potential to cause vast property destruction and loss of life. Weather events particularly associated with sudden natural disasters include extreme river floods, intense tropical and extra-tropical cyclone windstorms and their associated coastal storm-surges and very severe thunderstorms. The IPCC notes that "increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas" (Bates *et al.,* 2008). The IPCC reports that future tropical cyclones will probably become more intense, with larger peak wind speeds and heavier precipitation (Parry *et al.,* 2007). Extreme weather events are usually rare, with return periods of between 10 and 20 years. The relationship between extreme weather events and climate change is not easy to establish, given that the record of significant temperature increase has been reported only since the 1970s. Thus, the number of events may not yet statistically support a correlation. Nevertheless, the links are now widely accepted by specialists (Helmer and Hilhorst, 2006).

Changing environmental conditions facilitate the establishment of introduced species, which may become invasive and out-compete native species, leading to the modification of entire ecosystems (Chown *et al.*, 2007; McGeoch *et al.*, 2010). For example, invasive species have been measured as growing faster than native species due to changing climatic conditions in the Mojave Desert, the United States of America (Smith *et al.*, 2000). Globalization of markets and the increased movement of people and merchandise have increased the translocation of species on local, regional and continental scales. Some species have expanded their range as temperatures have become warmer. Warmer temperatures have created opportunities for pathogens, vectors and hosts to expand their range, thereby enabling pathogens to be present in new geographical locations and, potentially, to infect new naïve hosts, which in some cases can result in morbidity or mortality of wildlife, livestock or humans. Diseases that were kept at low infection levels because of temperature restrictions are now reported to have become fatal and endemic.

Major impacts of climate change on ecosystems and wildlife

Disturbance and extreme weather events

The frequency and severity of extreme weather events is widely reported to be on the rise, making it more difficult to plan for such events. Past records have previously been used to predict the likelihood of future droughts, floods, hurricanes and storm surges, but this approach is becoming less reliable as precipitation patterns change on local, regional and global scales. In addition, land shortages are forcing human communities to live in less stable areas, further increasing the risk that earthquakes or extreme weather events will develop into natural disasters. Today, half the world's human population is exposed to hazards that could develop into disasters (Dilley *et al.*, 2005).

This unpredictability makes planning for climate change extremely challenging. It is clear that extreme weather events not only impact wildlife and human communities directly, they also hamper people's very capacity to survive, let alone to protect threatened and endangered species and habitats. As the interval between extreme events shortens, there is less time to allow a return to normal conditions before the next event hits. The Amazon Basin, for example, has historically been subjected to severe droughts once or twice in a century. In 2010, the region experienced the third drought in only 12 years (Sundt, 2010; University College London, 2011). The 2010 drought was reported to be more widespread and severe than the previous drought in 2005, which itself was identified as a once-in-a-century event (Lewis *et al.*, 2011).

The worst hit areas, such as the Brazilian state of Mato Grosso, received only 25 percent of the normal precipitation during July to September 2010, and most of Amazonia saw a significant reduction in rainfall. River levels reached record lows, impacting all river users, from shipping vessels to pink river dolphins (*Inia geoffrensis*). In August, the Bolivian Government declared a state of emergency because forest fires were burning out of control. Overall, this has led to concerns that the mazon forest might have reached, or be close to reaching, a "tipping point" from which it will be unable to recover. Although the popular perception of climate change is of global warming, the phenomenon might be more accurately termed "global water problems". Managing water for human activities frequently impacts wildlife and natural habitats, whether by flooding dammed river valleys or lowering river levels and water tables when water is extracted to supply cities or to irrigate large-scale agriculture. Extreme weather events can exacerbate these problems and bring about new ones. "When world leaders speak about climate, they invariably speak of water – of floods, droughts and failed harvests – and express their alarm. They are right to do so: because climate change is primarily about water." This was the message delivered by the Global Water Partnership (GWP; 2010) to the 16th Conference of the Parties to the United Nations Framework Convention of Climate Change in Cancun, Mexico. The GWP called on the 193 parties to make sustainable water resources management and disaster risk management an integral part of the global response to climate change.

Reduced precipitation not only places animals and plants under stress, but increases the risk of forest fires. Globally, more than 350 million ha are estimated to be affected by vegetation fires each year, of which some 150 to 250 million ha are tropical forests (Appiah, 2007; UNEP, FAO and UNFF, 2009). Much of this arises from deliberate use of fire for clearing scrub or improving pasture, but extremes of dry weather increase the likelihood of such fires getting out of control. The FAO recommends two approaches in fire management. The first aims to establish balanced policies dedicated to fire suppression as well as to fire prevention, preparedness, restoration, etc. The second is a participatory and community-based approach involving all stakeholders, including at the field level (FAO and FireFight South East Asia, 2002).

Ecosystem and landscape changes due to climate change

It has been recognized that these changes in temperature and precipitation will affect individuals, species, ecosystems and whole regions. Individual variation and topographic differences will mean that, within any species, an individual plant or animal may be genetically predisposed to survive the stresses of dehydration, high winds or inundation for longer than another. Thus, at the micro-habitat level, each tiny location may see changes in species composition; these changes will have ramifications up and down the trophic levels and throughout the food-web, ultimately changing ecological communities at the landscape level. Predicting the consequences for humans and other species is essential if measures are to be taken in time, either to prevent these changes or adapt to them.

Coasts

Coastal wetlands are among the most productive of all natural ecosystems (Day *et al.*, 1989) and so the impacts of climate change will be extremely important in coastal regions and have ramifications far beyond them. In addition to the effects of rising temperatures and changes in rainfall, animals and plants in coastal habitats face another threat from climate change: rising sea level. This is due to a combination of melting polar ice caps, ice sheets and montane glaciers coupled with thermal expansion, wherein warm water occupies a greater volume than cold water. The IPCC predicts that in the next century, average sea level will rise by 0.18–0.59 m compared to the 1980–1999 levels (Parry *et al.*, 2007). Other climate models go even further, with estimates of 0.5–1.4 m – a rise that would inundate many low-lying areas. Human population and development pressure is in many cases likely to prevent coastal habitats from moving inland, thus leading to net habitat loss. Such changes will have immediate impacts on many wildlife species (Michener *et al.*, 1997). Sea turtle populations are likely to be hit as their nesting beaches are inundated. It is predicted that a rise in sea level of 0.5 m will result in the loss of 32 percent of sea turtle nesting grounds (Fischlin *et al.,* 2007). Tidal mudflats, low-lying coastal and intertidal areas may cease to be exposed, affecting the feeding grounds of many species of birds, such as ducks, geese, swans and waders. If their feeding success is reduced, migratory birds may be prevented from building up sufficient stores of energy to allow their annual migration to reeding grounds (Galbraith *et al.*, 2002).

Low-lying coastal forests and wetlands will suffer increasing salination as high tides and storm surges bring saltwater inland, causing the death of plants that cannot tolerate brackish water and, subsequently, of the animals that depend on those plants. This salination will affect not only coastal biodiversity, but also ecological processes and primary and secondary productivity – with adverse impacts likely for local communities, whether dependent on agriculture or fishing. Location specific coastal inundation models have been developed and found to match known flooding patterns, but these have been primarily motivated by the desire to minimize the loss of life in coastal communities (Dube *et al.*, 2000 for the Andhra and Orissa coasts of India). There is a need for more detailed research on the likely effects of flooding on natural systems and measures to mitigate ensuing changes. Mangrove forests would seem to be preadapted to inundation, as they thrive in coastal locations below the high tide where their stilt roots are submergedin saline water on a daily basis. They cannot, however, survive permanentsubmersion due to rising sea levels, and mangrove die-off has been reported from several locations (Ellison, 1993). FAO estimates that there are 15.2 million ha of mangrove worldwide, mainly in the tropics, but also in a few warm temperate locations (FAO, 2007). Yet mangroves have been badly affected by unsustainable development activities, particularly aquaculture, and have already declined to less than half their original area (Valiela, Bowen and York, 2001). Their distribution is likely to move further into the temperate zones as global average temperatures rise and further inland as sea levels rise. There is geological and contemporary evidence that mangroves have expanded and contracted quite rapidly in the past and they are likely to be early indicators of the effects of climate change (Field, 1995).

Mountains

Mountain ecosystems cover close to 24 percent of the earth's land surface and, with their steep and varied topography and distinct altitudinal zones, they support a high variety of species and habitats and a high degree of endemism. Mountains also provide essential resources to human communities, both at the local level and beyond. They are, however, particularly sensitive to changes in temperature and precipitation because of their geographical and orographic nature. Climate change is exposing alpine and subalpine areas to increasing temperatures, with the projected result of a slow migration of ecosystems towards higher elevations. This is, however, not always the case: on Mount Kilimanjaro the opposite has been observed, with climate-induced fires causing a downward shift of the upper tree line and a consequent reduction in important cloud-forest habitat (Hemp, 2009).

Alpine plants, which are usually long-lived and slow growing, may have particular problems in adapting to a rapidly changing climatic environment and alpine vegetation will likely reflect this lack of capacity to adapt. Many plants will respond to the changes in climate with a considerable time lag (Pauli, Gottfried and Brabherr, 2003), thus monitoring such changes must be planned as a longterm objective. The expected migrations will cause a disintegration of current vegetation patterns, seriously impacting the stability of alpine ecosystems by, for example, creating unstable transition zones with largely unpredictable behavior (Gottfried *et al.*, 1999).

Mountain ecosystems are often located in small and isolated areas, surrounded by environments with warmer temperature regimes and often with fertile soils that can be used for agricultural purposes. As a result, species will be forced to try to adapt to changing conditions within the ecosystem. Migrating upwards, plants and animals will be faced with reduced areas of habitat and, in some cases, no suitable habitat will remain. Cold-adapted alpine species are stressed by climate warming and must compete with species from lower elevations extending their ranges upward. Extinctions are predicted to occur at higher rates in mountainous areas than in other ecosystems. Among the species reported to be at highest risk are the mountain pygmy possum (*Burramys parvus*) in Australia, the ptarmigan (*Lagopus muta*) and snow bunting (*Plectrophenax nivalis*) in the United Kingdom of Great Britain and Northern Ireland, the marmot (*Marmota* spp.) and pika (*Ochotona* spp.) in the United States of America, the gelada baboon (*Theropithecus gelada*) in Ethiopia (see Box 4) and the monarch butterfly (*Danaus plexippus*) in Mexico (Malcolm and Markham, 2000).

Higher temperatures will mean more rain than snow, raising the risk of flooding for mountains and down-stream lowland ecosystems. Changes in permafrost and hydrology are being widely recorded, for example in Alaska, the United States of America (Hinzman *et al.*, 2005), while snowpacks are declining throughout western North America, melting 1–4 weeks earlier than they did 50 years ago (Mote *et al.*, 2005; Westerling *et al.*, 2006). Warmer temperatures will also have an impact on the depth of mountain snowpacks and glaciers, changing their seasonal melts and affecting large downhill areas that rely on them as a freshwater supply (see Box 10). Glacial lake outburst flooding can have immediate and dramatic impacts on local ecosystems (Bajracharya, Mool and Shrestha, 2007). Shifts in seasons will affect the timing of ice and snow melts and consequent water runoff, in turn affecting the timing of processes and activities that depend on water, including agriculture. Changes in stream and river flow will affect the microfauna living in aquatic ecosystems, thus having an impact on fish and waterfowl species.

Forests

The impact of climate change on forests will vary from region to region according to the extent of change in local conditions. Among the effects already being reported, increased atmospheric carbon dioxide (CO_2) levels are thought to be stimulating growth and increasing the sequestration rate of forest carbon in areas with sufficient rainfall (DeLucia *et al.*, 1999). However, any potential growth increases are being countered by the negative effects of rising temperatures, higher evaporation rates and lower rainfall, with longer and more frequent droughts. This is leading to higher tree mortality, greater risk of forest fires, increases in insect attacks and a change in species composition (Eliasch, 2008).

Unfortunately, these negative impacts on forests are likely to outweigh any positive effects and will create a negative feedback loop where burning or decaying vegetation make forests a source of CO_2 rather than a sink, thereby increasing greenhouse gas levels and exacerbating climate change and its effects (Phillips *et al.*, 2009). Initially, this will be most apparent in drier forests. Tropical moist forests consist predominantly of evergreen trees and form under conditions of constant high temperature (a yearly average of 18 °C or higher) and high rainfall (more than 2 m per year; Peel, Finlayson and McMahon, 2007; WWF, 2011) where there are no prolonged dry spells (Whitmore, 1990). Tropical dry forests receive less rainfall and shelter a very different suite of species, including many deciduous species that can shed leaves during dry periods. The two forest types have very different distributions. Thus a reduction in rainfall will not simply turn a tropical moist forest into a tropical dry forest. Drastic changes in forest ecosystem structure and functioning will likewise have major impacts on associated wildlife, with specialized species likely to rapid flash floods, known as 'glacial lake outburst floods', that inundate surrounding areas with water, boulders, and sediment" (da Costa, 2009).

3. Problem statement

The ecosystems around Bwindi are under disturbance and it is unclear which factors are responsible for such disturbances. It is presumed change in rainfall patterns and temperature are influencing ecosystems. This is exacerbated through indirect drivers such as intensive agriculture, population pressure, poverty and deforestation among other factors. Change in ecosystems characters seem to have led to alterations in feeding habits, habitats and change in phenology of some organisms. It is against this background that the researcher was prompted to carry out this study.

Objectives

The main aim is to establish the effects of climate change on ecosystems sustainability around the park.

Specific objectives:

i) To establish the effects of climate changes on ecosystems sustainability.

ii) To find out how climatic variations affect ecosystems structure and functioning.

iii) To ascertain the mitigation measures that can be used to achieve sustainable ecosystems.

Research questions

- What are the effects of climate change on ecosystems sustainability?
- What the impacts of climate change ecosystems structure and functioning?
- What are the mitigation measures that can be used to achieve sustainable ecosystems?

4. Research methods

This section focused on the research design, area of study, population and sample, instruments and analysis of data.

Research design

This involved use of qualitative that was be majorly explanations and discussions with the respondents and quantitative data which included the statistic about the trends in numbers of, tourists, animals, plants cover, areas of forest cover as well as frequencies in how events have unfolded. The study utilized the primary data that was obtained from the field especially the feedback from the respondents and secondary sources that yielded data on aspects like past and present tourist numbers, population (of animals and people), national park area and policies in place. The study considered a period of 17 years (1995-2012).

Study area

Volcanoes National park lies at the latitude of 1.47^0S $1^0 28' 0''$S longitude of 29.492^0E $29^0 29' 30''$E of the republic of Congo and Rwanda. After several excisions, the PNV portion comprises 160 km^2 of higher altitude forest. The landscape in this area is rugged and steep and ends up abruptly in the crops of the local communities. It consists of mainly tropical vegetation. The area has extremely high human population pressures with an average of 300 people per square kilometer (Lanjouw et al. 2001), with some rural areas attaining 820 people per square kilometer (Waller 1996).

Population and sample of study

The population of study included the community leaders, RDB staff, conservation staff on ground, the leaders of tourism associations, cultural groups. The study used findings from a population of 105 People and samples of 30 respondents as a sample to get the picture on the ground. Purposive random sampling was used because the researcher selected the respondents that were deemed to be knowledgeable and with experience about the problem under question. Slovin's formula $n= N/1+(Ne^2)$ was used to get the sample.

The sample in the field comprised of 4 staff at the RDB headquarters, 12 RDB staff in the park, 4 district officers in the section of environment education, 6 community representatives, 2staff from Dian Fossey International and 2 student researchers on the ground.

Instruments

The instruments included the use of interview guide, oral interviews and observation. The researcher however used interview guide, orals and observation for the collection of data by visiting the area of study and interacting with the respondents. This gave the researcher the opportunity to get the first hand perception of the participants about the problem under study and through observation was able to get clear view of the situation. The combination of these tools enabled the researcher to generate the reasonable data.

Sample questions

- What are the different land use practices in this area?
- How are these land use practices affecting the ecosystems?
- How are they affecting the eco-tourism activities?
- What is being done to stop land-use effects from affecting both ecosystems and ecotourism?

5. The findings and analysis

Results from the field were collected from respondents by use of interview guides, oral interviews and observation. Interviews with the staff of RDB, showed that the majority of respondents 75% pointed out that climate variability is happening slow but surely. According to the respondents seasons are nowadays not predictable as compared to the past years. The respondents argued that its natural but part of the problem may be attributed to man's activities.

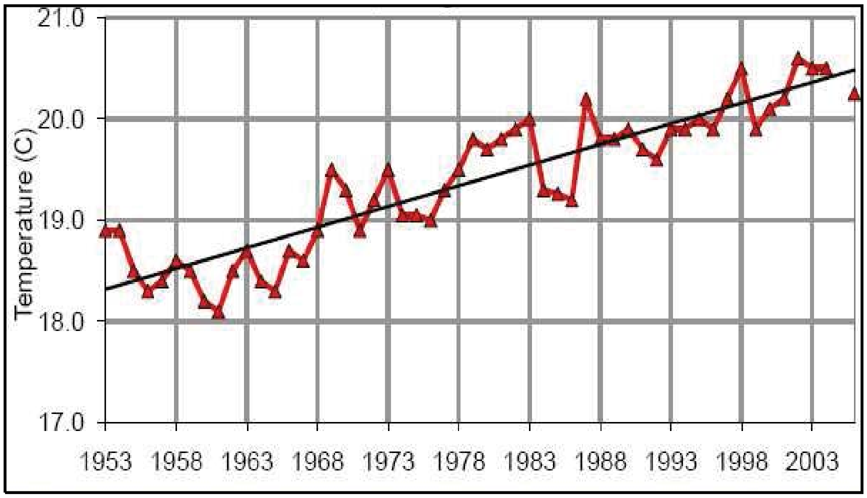

Figure 1.Temperature trends in western Albertine Rift Lwiro, Congo 1953-2006 (Seimon and Picton Phillipps, 2010)

So 25% 0f the respondents said it is not new for seasons to vary because it has been the case for several years. According to the deputy director in charge of conservation at RDB Kigali offices, the local climatic variations have been recorded over time and there are fears they will have an Impact on the conservation activities and thus sustainability.

The tourism manager on the ground emphasized that climate variability is becoming a challenge especially to the sustainability of the natural resources. He argued that some of the plant species and animal species are gradually disappearing and this to him is a sign that climate is impacting on the resources in the park. The reason he gave was rainfall is erratic in some months and temperature as well as sunshine hours are increasing.

The findings indicate that 90% respondents pointed out that the local communities lack awareness about climate variability issues. This exposes them to unpredictable aspects like change in seasons for planting since most of them depend on agriculture. The findings there point to the case that it is critical for the local communities to understand and get sensitized about the variability of climate. They added that the some of the local communities still have the perception that the park or forest is a gift from God so should be allowed to enjoy the resources when their crops are affected by season changes. During the interaction with the respondents further indicated that high population pressure is another factor that is a threat to the conservation of the park. Many local communities rely on agriculture and so demand for land to carry out agriculture in the end do deforestation which in turn affect ecosystems around the park. On the other hand it was revealed by 10% of the respondents that those that have no land have resorted to handcrafts by harvesting from wetlands.

On interacting with one the respondents from Dian Fossey International the director in charge of biodiversity, pointed out that a lot is changing due to climate variability. The officer put it clear that some of the water bodies in the park are disappearing and this he said has been going on for the last decade. This implies that ecosystems have started experiencing change in temperature and reduction in rainfall amounts. The disappearance of the ecosystems (water bodies) means the birds and other organisms that use these areas as habitats will be in danger of elimination or exposure to hash conditions. This was also echoed by the tourism manager who added that water from rivers that drain in these water bodies have dropped over time and yet the endemic species rely on these resources.

The study also established from the park staff that the communities around the park carry out different land use practices. According to the respondents 10% said the community members plant trees 70% argued that the local communities do subsistence farming mainly irish potatoes, 20% indulge in businesses. The staff argued that these activities impact on ecosystems because farmers use fertilizers and pesticide sprays which end up in water body bodies and soil and this means they affect these ecosystems that in turn affect tourism activities in the area.

According to the respondents in the field, 75% pointed out that one of the fascinating observations is the change in the feeding habits of some animals. The respondents pointed out that gorillas have now started feeding on foreign species like eucalyptus and this is believed that the plants that were feeding on should be beyond vicinity or are becoming rare due to climate variability. Another example was that the monkeys feel more comfortable resting on the eucalyptus than it was in the past. This attributed to the fact that the habituation and climatic conditions out the park may seem more comfortable. This implies that ecotourism activities are being impacted on since the main attractions are shifting their positions to other locations and therefore will to adjusting the trails in future.

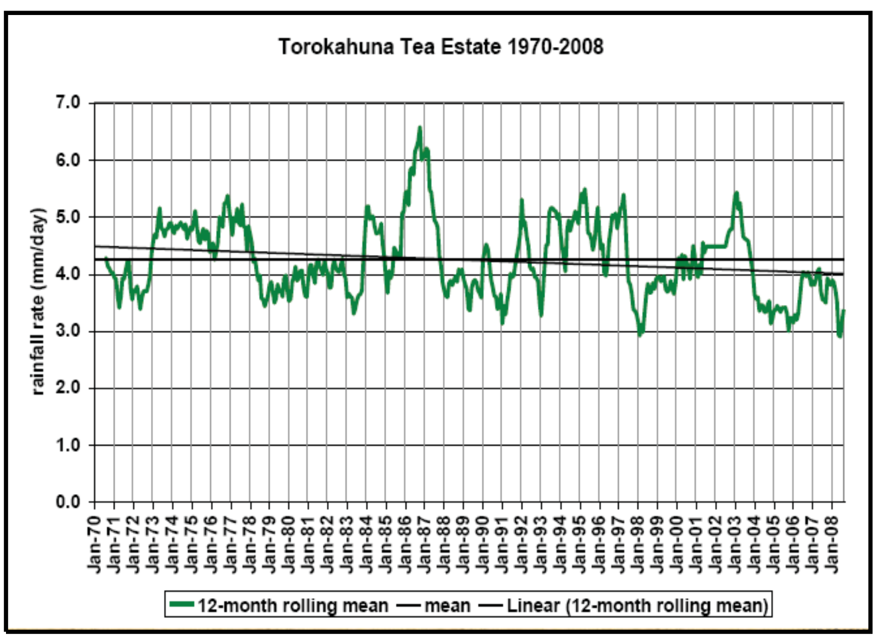

Figure 2: Precipitation trends in the Bwindi and Virunga volcanos region

Further respondents argued that variability in climate is also exhibited in the breeding periods among birds, butterflies and the expanded territories in some of the species especially the predators and this was voiced by 20% of the respondents and 5% indicated that migrations have become more frequent among certain species like birds and apes. Community leaders emphasized that the problem of climate variability is being experienced especially in the wetlands in and around the parks. An example pointed out was Genzi swamp the biggest in the park has reduced in size due to the increased temperatures that have led to growth of trees toward the center. This is because the edges are drying and this is exacerbated in the reduction of the endemic species like birds and some snakes in this swamp which negatively affects ecotourism activities. The other example pointed was the construction in the park to karisimbi peak of the power lines and fiber optics that led to cutting down the trees that accelerated the soil runoff down to the swamps which led to the siltation of the ecosystems. This is in turn is observed to have an affect the quality of the ecotourism activities in the park. In addition to that 60% of the respondents concurred that sustainability is critical because the ecosystems in this area experience stress due to population pressure which is another big problem that needs to look into and avoid putting pressure on the resources used for ecotourism activities. However 35% of the respondents argued that activities such as tree planting have to some degree reduced the pressure on the ecosystem which enables the park mangers to the attain their conservation goals but economic projects like road construction led to destruction of part the forest and habitat for certain animals which in turn affect ecotourism activities especially the aesthetic appeal of the area.

The 5% of the respondents said that deforestation is another factor that is still going on around the park which implies carbon sinks are threatened. Also the respondents argued that deforestation is one other factor that will drive the ecosystems to extremes since many locals believe it's a quicker way of earning income.

The researcher posed a question on the effects of climate variations especially cloud cover and sunshine hours on ecotourism and 50% of the respondents argued that one of the challenges is the variation in sunshine times that have been growing longer over years just as the cloud cover that keeps fluctuating and this influences the feeding times and rain intensity in certain areas which implies the eco-tourism activities need reprogramming and planning because it affects the visitor satisfaction. More to that 40% argued that due to tourists presence in the area, many communities are changing their economic activities due to demand for commodities that has increased and this further exert pressure on natural resources by the local people around the park. However 10% of the respondents the mindset of the locals that sill believe in free access to natural resources which means eco-tourism activities are affect.

6. Conclusion

From the results it can be concluded that climate variability is influencing ecosystems that are used for ecotourism activities. The results indicate that in both parks the signals about climate variability are already showing. This is exacerbated in feeding habits, reproduction cycles and change in ecosystem characteristics especially as reflected in water bodies especially the swamps. The findings showed that eco-tourism attractions are influenced by variation in rainfall and temperature fluctuations and unpredictability. Even if the parks experience these variations the degree of influence is different with Volcanoes National Park showing more signs than Bwindi Impenetrable National Park basing on what the respondents views. The results however indicated that authorities are trying to monitor the situation using their metrology centers and sensitizing that local communities and officials in charge of conservation.

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