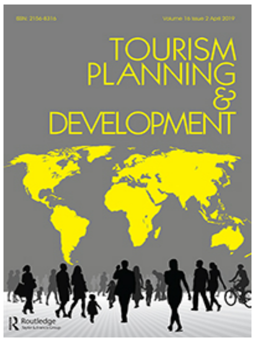

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Forty Years of Climate and Land-Cover Change and its Effects on Tourism Resources in Kilimanjaro National Park

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ABSTRACT

This study explores the effects of observed changes in rainfall, temperature and land cover on the physical and sightseeing aspects of trekking in Kilimanjaro National Park. The impact analysis is organised around hazard-activity pairs approach, combinations of environmental change aspects (such as higher temperatures) and tourism activities (such as trekking and sightseeing). The results suggest that higher temperatures and reduced rainfall have lowered the risks of landslides, rock fall and mountain sickness, improving physical trekking conditions. Changes in land cover have affected sightseeing: there now are more flowers and groundsels to admire and less wildlife, waterfalls and snow. In the short term, the disappearing snow may give rise to "last chance tourism", increasing visitation, but eventually, the loss of snow and forest cover will likely decrease the number of tourists. The paper concludes that effective management of the attractions in the expanding heathlands is the most promising option to limit the losses.

KEYWORDS

Kilimanjaro; tourism; attractions; climate; land-cover; last chance tourism

1. Introduction

Mount Kilimanjaro is the highest mountain in Africa, rising 5895 metres above sea level. The ancient volcano with three peaks (Shira, Mawenzi, and Kibo) is an iconic tourism feature in Tanzania and one of the UNESCO world heritage sites in Tanzania. The snow-capped Kibo peak, rare plants and animals, and favourable microclimates have attracted tourists to Mount Kilimanjaro since its "discovery" in 1889 by Western explorers. Kilimanjaro National Park (KINAPA) is the second biggest earner of Tanzania's national park system after Serengeti National Park. KINAPA manages the part of Mount Kilimanjaro above 1800 metres.

According to the most recent visitor statistics available, the total number of KINAPA visitors reached almost 60,000 in 2013 (https://web.archive.org/web/20151220102029/http://www.tanzaniaparks.com/corporate_information.html), close to a threefold increase since

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2000. Trekking is the key tourism activity, performed by adventure tourists who aim to reach the summit. Day-trip visitors, in contrast, are mostly drawn to attractions at lower altitudes (park warden M. Mombo, personal communication, 13 February 2013). Traditionally, the majority (78%) of visits made by both adventure tourists and day-trip visitors occur in two distinct seasons: June to October and December to February. These timeframes coincide with the summer and Christmas holidays in the major source markets. They also coincide with the traditional dry seasons.

As a nature-based tourism destination, Mount Kilimanjaro is dependent on favourable environmental and climatological conditions. Over the past decades, climate change has started to affect Mount Kilimanjaro. Higher temperatures and changes in precipitation patterns have been reported (Appelhans et al., 2015; Hemp, 2005, 2009). These climatic changes, in combination with other forms of environmental change, have reduced Mount Kilimanjaro's snow cover (Thompson et al., 2002; Thompson, Brecher, Thompson, Hardy, & Mark, 2009), increased the incidence of wildfire (Hemp, 2005) and altered vegetation patterns (Hemp, 2006, 2009).

Climate change and its induced effects are likely to have substantial implications for trekking and other forms of tourism, but these implications have so far remained under-researched. Our literature study revealed only one dedicated study. Minja (2014) analysed local people's perceptions of tourism's vulnerability to climate variability and change on Mount Kilimanjaro. Using survey and key informant methods, he found that local people perceived increased temperature, decreased annual rainfall, dry riverbeds, water shortage, increased frequency of forest fire, and decreased snowfall as key threats to the mountain's tourist attractions, including its snow, forests, waterfalls, springs and wildlife. No resource-based assessment exists for Mount Kilimanjaro. In fact, such assessments are scarce for African destinations in general (Scott et al., 2008).

Recent years have seen a surge of scientific publications on the impacts of climate change and tourism in Africa. A large share of these studies, however, are general literature reviews, whose coverage ranges from the whole of Africa (e.g. Hoogendoorn & Fitchett, 2018; Sifolo & Henama, 2017), to Sub-Saharan Africa (e.g. Mutana, 2016; Pandy, 2017; Preston-Whyte & Watson, 2005) and to the individual country of South Africa (e.g. Amusan & Olutola, 2017; Fitchett, Robinson, & Hoogendoorn, 2017; Rogerson, 2016; van de Bank & van de Bank, 2018). These studies reveal that the dearth of empirical studies that Scott et al. (2008) observed ten years ago still persists, and repeat the urgent call for such studies in Africa. The impacts of climate change on tourism are site-specific (Hoogendoorn & Fitchett, 2018) and destinations require site-specific studies to inform adaptation. Recently, a few empirical and site-specific studies have been published, notably the study on Botswana's Okavango Delta by Hambira, Saarinen, Manwa, and Atlhopheng (2013), the study on the desert town of Uis, Namibia by Tervo-Kankare, Saarinen, Kimaro, and Moswete (2017), and the studies by Dube and Nhamo on the Zambian (2018b) and Zimbabwean (2018a) sides of the Victoria Falls and the study in the Serengeti National Park in Tanzania by Kilungu, Leemans, Munishi, and Amelung (2017). Whereas the first two of these studies are based on tourism stakeholders' perceptions, the latter three explore the implications for tourism of observed climatic trends. This paper follows a similar research-based approach; the first application to a mountainous destination in Africa.

Resource-based assessments do exist for mountainous destinations in North America, Europe and Asia. Pederson, Gray, Fagre, and Graumlich (2006), for example, report how climate-induced glacier retreat threatens the sustainability of tourism in Montana's Glacier National Park in Montana. Serquet and Rebetez (2011) show that summer heat waves in the European Alps have resulted in more visitor nights. With respect to the Himalayas in Asia, Moore and Semple (2009) found that increases in temperature have improved trekking condition on Mount Everest while Nepal (2011) and Nyaupane and Chhetri (2009) conclude that nature-based tourism in the Himalayas is threatened by more avalanches, debris flows and glacial lake outburst floods.

Impact assessments typically make a distinction between direct and indirect effects. Direct effects influence tourist activities. They interfere with the timing and duration of tourism activities or influence the quality of tourism experiences (Scott, Jones, & Konopek, 2007). A hiking experience in warm and sunny conditions, for example, is qualitatively different from one in cold, rainy or extremely hot conditions. Indirect effects influence tourist attractions. They include changes in mountain landscapes, snow cover and wildlife biodiversity (Beniston, 2003).

Tourism activities vary widely in terms of their climatic and environmental requirements and they respond to environmental change in very different ways. Careful activity-by-activity assessments are therefore required. Systematically connecting the wide range of climate change impacts to specific tourism activities is a formidable challenge. In the context of coastal tourism, Moreno and Becken (2009) developed a vulnerability framework based on hazard-activity pairs. From mapping the vulnerability of key hazard-activity pairs, a relatively complete assessment of a destination's overall vulnerability can be put together. This study identifies the hazard-activity pairs that are most relevant for trekking, Mount Kilimanjaro's main tourism activity. The aim of this study is to make a first-order assessment of the effects on tourism of the recent climate and land-cover changes observed on Mount Kilimanjaro.

The study has two objectives: (1) to assess the effects of observed changes in rainfall and temperature on trekking conditions in Mount Kilimanjaro, and (2) to assess the effects of observed changes in land-cover on the extent and distribution of tourist attractions for sightseeing. Future projections of change are not considered in the analysis, but an outlook of what continued changes in climate and land cover may bring is given in the discussion section.

The study relates to at least three policy processes that are currently ongoing in Tanzania. First, in April 2018 Tanzania ratified the Paris climate agreement, which not only covers mitigation but also adaptation. Paragraph 7.9 of the agreement states that, "each Party shall, as appropriate, engage in adaptation planning processes and the implementation of actions, including the development or enhancement of relevant plans, policies and/or contributions". Tourism-specific adaptation plans may be part of Tanzania's efforts. Secondly, Tanzania is working on an update of its almost twenty year old tourism policy (Melubo, 2017), and may pay attention to the effects of environmental change. Thirdly, KINAPA is reviewing its general management plan (current version: 2005–2015) and may account for the impacts of environmental change on tourist visitation.

This paper is organised as follows. The next section introduces the major tourism activities on Mount Kilimanjaro including their specific physical and environmental requirements. The following section outlines the methods and data used to determine climatic and environmental change. The results section presents the developments in the climate and environmental change indicators relevant for trekking and sightseeing, and discusses their implications for tourism. The discussion reflects on the study's approach and findings and puts these findings in a broader context. The final section concludes.

2. Mount Kilimanjaro's key tourism activities and their environmental requirements

Trekking, the key tourism activity on Mount Kilimanjaro, has two main aspects: (1) the physical challenge of reaching the summit and (2) sightseeing along the way. Both aspects are described in more detail below, highlighting their dependence on the mountain's physical conditions and aesthetic features.

Reaching the mountain's summit is the primary goal for most tourists. A range of environmental factors makes it a challenging endeavour: supposedly, almost half of the trekkers never reach the summit (https://www.climbkilimanjaroguide.com/kilimanjaro-success-rate/). On the lower parts of Mount Kilimanjaro, trekkers often have to endure rainfall. The mountain receives more rain than other high east African mountains (Hemp, 2006). Apart from being a nuisance in its own right, heavy rainfall makes surfaces slippery, reduces visibility and can cause landslides and rock fall (de Freitas, 2003; Kanungo & Sharma, 2014; Owen & Slaymaker, 2014). Landslides are already occurring after short bursts of intense precipitation. In 1970, a downpour of 100mm in less than 3-hours caused landslides in the Uluguru Mountains, a few hundred kilometres to the South of Kilimanjaro (Temple & Rapp, 1972). On Mount Kilimanjaro itself, twenty people were killed in 2009 by a landslide that occurred after four days of heavy rain (CNN, 2009). Landslides are a challenge for mountain tourism development in the whole of East Africa, but few studies have so far been devoted to the issue. Jacobs et al. (2016) and Komu (2017) reported on the increasing incidence of landslides in the Rwenzori Mountains in Uganda and on Mount Kenya in Kenya respectively, but did not discuss the implications for tourism.

Annual precipitation on Mount Kilimanjaro increases upslope, reaches its maximum in the mid-montane forest zone, located between 1800 and 2400 metres on the southern slope, and gradually decreases again at higher elevations (Hemp, 2005). Most precipitation occurs in two distinct rain seasons: the long rains from March to May, and the short rains from October to November. The short rains are less intense than the long rains (Chan, Vuille, Hardy, & Bradley, 2008) and are also less predictable. In some years, there is no rain at all in October and November.

Nearer to the summit, extreme cold and altitude sickness take their toll. Mount Kilimanjaro's summit is at 5895 metres above sea level, and most climbers reach it at night, when temperatures can be as low as −20°C (Hemp, 2005). The combination of high altitude and low temperature creates conditions of low barometric pressure, which limits oxygen uptake in the lungs. Consequently, the ability to perform work (e.g. walking or trekking) diminishes greatly (Grocott et al., 2009). Altitude sickness is a major source of unsuccessful summiting on Mount Kilimanjaro (Eigenberger et al., 2014; Karinen, Peltonen, & Tikkanen, 2008; Lawrence & Reid, 2016). According to Karinen et al. (2008), trekkers on Mount Kilimanjaro start to experience the first symptoms of altitude sickness at an altitude of around 2700m. At altitudes above 3700, some trekkers suffer potentially fatal forms of altitude sickness, namely High Altitude Pulmonary Oedema and High Altitude Cerebral Oedema.

A trekking journey on Mount Kilimanjaro takes about six days (Lawrence & Reid, 2016). Only one of these days is devoted to finally reaching the summit, which leaves plenty of time for sightseeing. The peaks and snow of Kilimanjaro are the most famous sights, but there are more. Kilungu, Leemans, Munishi, and Amelung (2018) made an inventory of attractions and their evaluation by tourists in Serengeti National Park and Kilimanjaro National Park (KINAPA). For KINAPA, 306 tourists completed a survey on the park's attractions and their importance. Respondents were asked to rate the importance of each of the listed attractions and to indicate KINAPA's main attraction. Importance was denoted on a discrete scale ranging from 1 (extremely important) to 5 (least important).

According to the study by Kilungu et al., each altitudinal zone has its own unique type of attractions, brought about by elevation-based differences in temperature and precipitation. Tourist attractions change from plants and animals in the montane forests (1800–3000m) and heathlands (3001–4000m) to rocks in the alpine desert (4001–5000m) and snow in the arctic zone (>5000m). The Kilungu study suggests that the Kibo summit/Uhuru peak is the most important attraction in KINAPA, with a mean importance rating of 1.4. The second most important attraction is snow, with a mean importance rating of 2.2. The wildlife, forest flowers and waterfalls of the montane forest are in third place (mean rating of 3.0), followed by the flowers and giant groundsels (i.e. senecio and lobelia plant species) of the heathland (3.3) and the rocks and other abiotic attractions of the alpine desert (3.6). Table 1 gives an overview of the results.

Interestingly, all vegetation zones, except for the alpine desert, were considered to be home to "main attractions" by three quarters or more of respondents. Fewer respondents, albeit a sizeable minority, considered the inanimate attractions of the alpine desert zone "main attractions". In summary, on their way up, trekkers first pass through two zones of considerable interest (montane forest and heathland) and one zone of more limited importance, after which they reach the two main attractions: snow and the mountain peak.

Table 1. Attractions on Mount Kilimanjaro organised by land-cover zone and their importance as perceived by tourists.

Location of tourist attractions based on land cover/altitude zone	Description of attractions in each zone	Designation as "main attraction"		Importance of attraction	
		[a]Count	%	[b]Mean score	Std. Deviation
Snow/ice and gravel (>5000m)	the Kibo summit/Uhuru peak (i.e. Mountains' high altitude)	301	98	1.4	0.9
	Snow	242	79	2.2	1.1
Alpine desert zone (4001–5000m)	Zebra rocks, Great Barranco wall, lava tower, turtle-like rocks, mushroom-like rocks, church-like rock and rock pinnacles	117	38	3.6	1.2
Heath/moorland (3001–4000m)	Patches of groundsels (i.e. giant senecio and lobelia trees), flowers of the genus Helichrysum (e.g. everlasting and stoebes), protea, Maundi crater, and underground waterfall	233	76	3.3	1.0
Montane forest (1800–3000m)	Wildlife, waterfalls, forest flowers (e.g. red-hot pokers, fireball lilies, wilderness) etc.	264	86	3.0	1.0

Total number of respondents (*N* = 306).
[a]Count = Number of respondents who indicated this was the/a main attraction.
[b]Mean score based on scale: 1 extremely important: 2 very important: 3 important: 4 less important: 5-least important.
Source: Kilungu et al. (2018).

The overview shows that temperature and precipitation influence the trekkers' experience in all stages of the climb. Temperature and precipitation patterns are changing because of climate change, affecting trekking tourism on Mount Kilimanjaro in at least three main ways. (1) changes in rainfall patterns affect the trekking conditions on the lower parts of the mountain; (2) changes in temperature affect the trekking conditions near the summit; and (3) changes in temperature and precipitation alter the distribution of the various land cover types (i.e. snow and vegetation zones) and the tourist attractions associated with them. Environmental change is likely to impact trekking tourism via each of these three ways. This paper assesses the impacts that occurred over the past few decades. The following section presents the methods used.

3. Methods and data

Our study approaches the effects of environmental change on tourism from an environmental suitability perspective. It concentrates on the environmental side rather than the tourism side of the topic, because of the very limited availability of tourism statistics. The only available dataset, provided by KINAPA, contains monthly visitor numbers for the 2000–2013.

The main links between environmental change and trekking tourism that were described in section 2 are interpreted as hazard-activity pairs. Hazard-activity pairs were proposed by Moreno and Becken (2009) as a way to structure the analysis of the often complex interactions between climate change and tourism in a particular destination. Rather than considering all aspects of climate change and all tourism activities at the same time, they concentrated on the links between one relevant aspect of climate change (the hazard) and one important tourism activity at a time. Afterwards, these partial analyses were integrated into a vulnerability profile for the destination as a whole.

This paper uses the hazard-activity approach to structure our analysis of the interactions between environmental change and tourism activities on Mount Kilimanjaro. Four pairs: three related to the physical aspects of trekking and one related to sightseeing in the various land-cover zones.

The first pair combines rainfall and trekkers' comfort. Trekkers' comfort is assumed to decrease linearly with rainfall amounts. The observed trend in annual rainfall for Tanzania were available at a resolution of ~5km for 1981–2016 (FCFA, 2017). Complementary to this source, rainfall trends were estimated from local weather station data, using linear regression. In addition, monthly trends were estimated in view of the strong seasonality in visitation patterns. Annual and monthly data from the weather station at Kilimanjaro International Airport (KIA; 896m ASL), covering the 40-year period between 1973 and 2013, were purchased from the Tanzania Meteorological Agency. The KIA weather station is located outside KINAPA. Additional data were obtained from the Nyati weather station, located within KINAPA at 3250m altitude. This dataset covers a shorter period: 2000–2013. No other datasets were available to sample the heterogeneity of rainfall patterns within the park.

Hazard-activity pair two represents the relationship between the intensity of rainfall events and the risk of landslides and rock-fall. Exploring the intensity of rainfall events and the frequency of intense rainfall events requires very high-resolution precipitation data. This kind of data is not available for KINAPA. Instead, monthly data were used as very rough proxy data, under the assumption that rainfall intensity and the frequency of intense rainfall are positively correlated with rainfall totals. The same data were used as for the rainfall-comfort pair.

Hazard-activity pair three pertains to the relationship between temperature, air pressure and altitude disease. To explore this hazard-activity pair, the trend in temperature at the top of Mount Kilimanjaro over the past decades is estimated. Observed weather data for Kilimanjaro's mountaintop are limited to two years of daily measurements by an automatic weather station in 2000 and 2001, which had been temporarily placed there in the context of a research project. These data provide a reference point but not a trend. That is not a problem, however, since we do have time-series data on temperature at the mountain's foot, yielding information on temperature change. This is a good estimate for temperature change at the mountaintop, given the rather stable temperature gradient between a mountain's foot and top. Monthly temperature data were obtained from the KIA station, located at the foot of the mountain, for 1973–2013. The trends obtained from these weather station data were compared with those reported in (FCFA, 2017); this is a useful check, since temperature is generally much less variable in time and space than rainfall.

Hazard-activity pair four relates to the effects of climate change on the quality of the attractions tourists pass while trekking. The quality of an attraction is understood here as the importance tourists attach to it, in this case according to a study by Kilungu et al. (2018). Attractions on Mount Kilimanjaro are uniquely connected to specific land-cover zones, with some land-cover zones harbouring more important attractions than other zones. In this study, we assume that the sightseeing attractiveness of the mountain as a whole depends on the distribution of the total mountain area over the various land-cover types (e.g. snow, heathlands and montane forest). Our analysis consists of tracking the shares of Mount Kilimanjaro's mountain area that each of the land-cover types occupies over time. The land-cover maps needed for this analysis were derived from Landsat TM7 satellite images, which are available free of charge from www.glovis.usgs.gov The Landsat images were transformed into land-cover maps using the Normalised Difference Vegetation Index (NDVI), following Pettorelli et al. (2005) and Zurlini et al. (2006). Images were selected based on three criteria. First, the level of cloud cover on the images had to be limited to allow processing. Second, the period covered by the set of images had to be at least a decade to allow detection of slow changes. Third, all images had to be taken in the same season of the year to avoid interference of inter-seasonal changes. The final selection contained three images, which were taken in February 1993, February 2000 and February 2013.

4. Results

FCFA's climate policy brief for Tanzania (FCFA, 2017) clearly shows that rainfall amounts for the Mount Kilimanjaro region (around 1500mm per year) are among the highest in the country. The report indicates slight to moderate reductions of up to 6mm/year in rainfall for the Kilimanjaro region in the 1981–2016 period. The KINAPA and KIA weather station data reveal that annual rainfall on and near Mount Kilimanjaro is highly variable (see Figure 1). For both stations, trends in annual rainfall are negative, albeit not significant at the 95% confidence level.

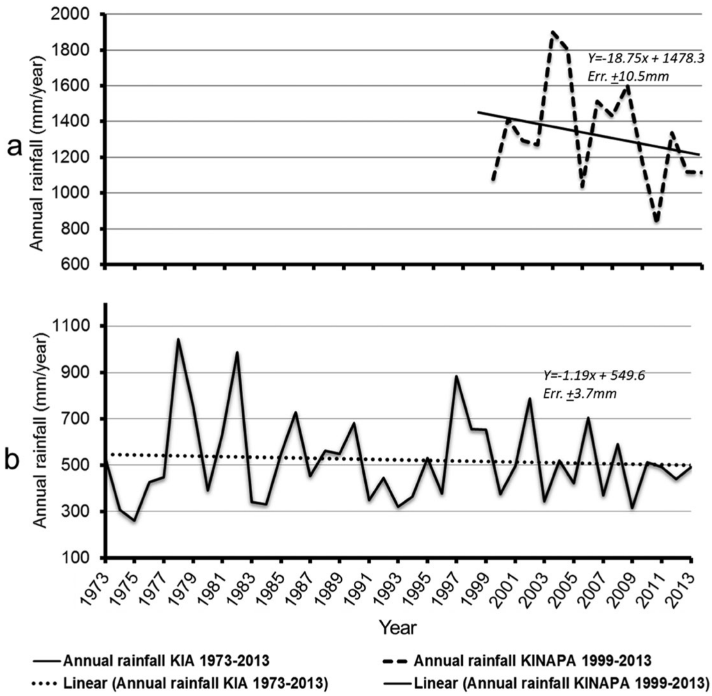

Figure 1. Annual rainfall totals and trend for (a) Kilimanjaro National Park, 1999–2013 and (b) Kilimanjaro International Airport, 1973–2013.
Data source: Kilimanjaro National Park and Kilimanjaro International Airport.

On a monthly level, significant changes in rainfall seasonality were found for March and April. March's share in annual rainfall increased by 15 ± 1.4% points, at the expense of April that lost 14 ± 1.6% points (see Figure 2). This shift signals an earlier start of the long rains season. No significant trend was detected for the rainfall shares of the other months. The earlier onset of the rainy season has had no discernible impact on the tourism seasonality pattern. This pattern remained fairly stable between 2000 and 2013, with considerable inter-annual variability. June appears to be gaining importance at the expense of August, but the data series is too short to conclude if this is a significant trend.

In view of the decreasing trends in annual precipitation, general climbing conditions are likely to have improved. The risk of landslides may have decreased as well, under the assumption that the general decrease in precipitation has corresponded to a decrease in heavy precipitation. The analysis suggests that March and April have been subject to most changes, with climbing conditions in March deteriorating and conditions in April improving.

In 2000 and 2001, the temporary weather station at the mountaintop registered an annual mean temperature of −7.1°C, with daily temperature fluctuating slightly around that mean and never exceeding −2°C (Thompson et al., 2002). At the foot of the mountain, as represented by the KIA weather station, the annual temperature increased by 1.3 ± 0.06°C (p-value <0.05) between 1973 and 2013 (see Figure 3). Taking the annual mean temperature of the year 2000, measured at −7.1°C, as a reference point, the observed temperature change at the foot of the mountain corresponds to a temperature change at the top

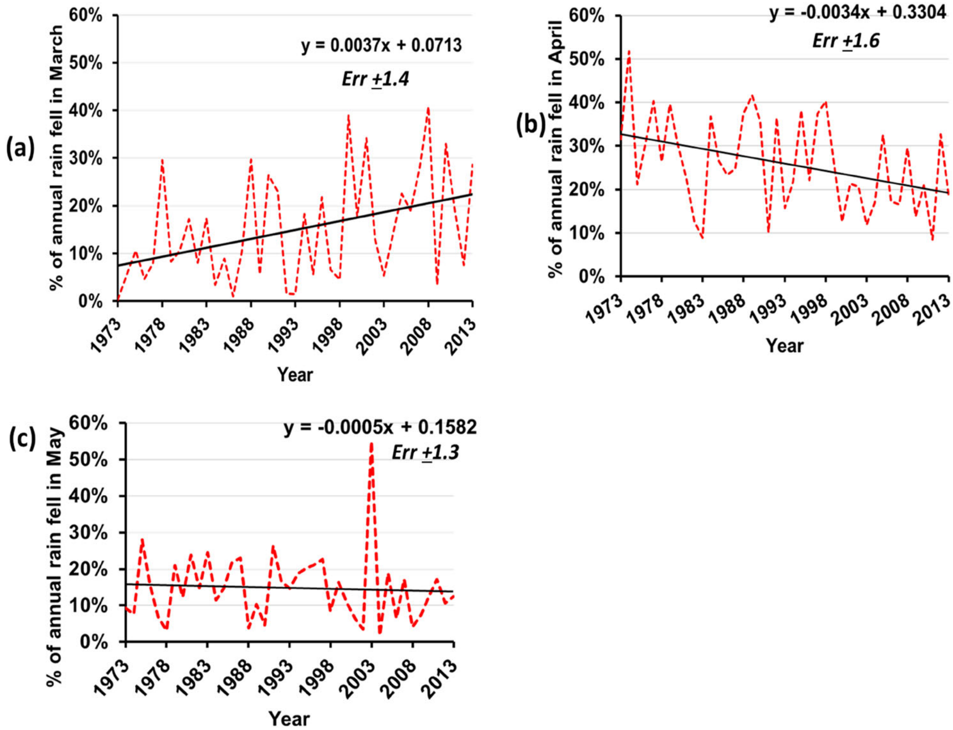

Figure 2. Shares in annual rainfall at Kilimanjaro International Airport and trend for March (a), April (b) and May (c), 1973–2013, plus trends.
Data source: Kilimanjaro International Airport.

from an estimated −8.0°C in 1973 to an estimated −6.7°C in 2013. This temperature change translates into an increase in barometric pressure of around 200Pa, which, at the mountaintop, is equivalent to a descent of around 28 metres. Whereas this change

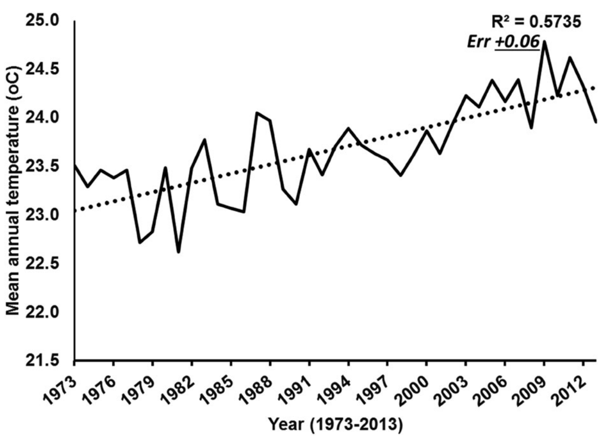

Figure 3. Mean annual temperature at Kilimanjaro International Airport (KIA) from 1973 to 2013.
Data Source: Kilimanjaro International Airport.

seems small, in a study for Mount Everest a similar change in pressure of 200–300Pa was found to be physiologically relevant for climbers (Moore & Semple, 2009). Besides affecting the risk of altitude sickness, the increasing temperatures at higher altitudes also cause permafrost soils to thaw. This can destabilise infrastructure, such as climbing trails, airstrips and campsites and increase the risk of landslides and rock fall.

At the start of our study period in 1993, changes in land-cover were already well underway, in particular with respect to forests (see Hemp, 2005) and ice cover (see Cullen et al., 2013; Thompson et al., 2002, 2009). In 1912, ice cover on Mount Kilimanjaro amounted to 11.40 square kilometres, of which only 3.8 remained in 1993 and 1.76 square kilometres in 2011 (Cullen et al., 2013) and we assumed a negligible change between 2011 and 2013. That is, ice lost 2.04 square kilometres, 54% of its 1993 area. Our study indicates that between 1993 and 2013, land cover patterns on Mount Kilimanjaro showed substantial further change (see Table 2). Montane forest lost 169.5 square kilometres, 15% of the initial area. The area of alpine desert increased by 9.5 square kilometres (8%) and that of heathland by 166.1 square kilometres (38%). The analysis further suggests that most of this change occurred prior to 2000. Afterwards, the rate of change levelled off; the trend in ice cover even reversed.

Figure 4 shows how the changes in land-cover played out spatially. The alpine desert expanded upslope as a result of snow melt, but also downslope into areas previously home to heathland vegetation. In its turn, heathland vegetation shifted further downslope, in particular towards the Shira plateau in the West and northeast. Replacing montane forest cover, heathlands now occur under 3000 metres. The possible reasons for these changes are discussed in the discussion section.

The loss of montane forest has likely increased pressure on wildlife species, including those of tourism potential. Prior studies (e.g. Agrawala et al., 2003; Newmak, Foley, Grimshaw, Chambegga, & Rutazaa, 1991) associate change in forests with loss of wildlife. Grey duikers and Elands have become endangered, while Black Rhinos are now extinct (Newmak et al., 1991). Local residents report that Black and White Colobus monkeys, which were previously spotted year-round, are now only seen in specific seasons and that the spatial distribution of many bird species has changed (Minja, 2014). The abundance and diversity of forest flowers have probably also diminished.

Table 2. Land-cover change in Kilimanjaro National Park between 1993 and 2000/2013.

Land cover	Area (sq. km) 1993	Land cover change 1993–2000 Area change	%	Land cover change 1993–2013 Area change	%
Snow/ice (5001–5895m ASL)	3.8 as per Cullen et al. (2013)			−2.0	−54
Boulders/sand -alpine desert (4001–5000m ASL)	128.1	+9.5	+7	+10.6	+8
Heathland/moorland vegetation (3001–4000m ASL)	431.7	+118.6	+27	+166.1	+38
Montane forest vegetation (1800–3000m ASL)	1096.7	−120.5	−11	−169.5	−15
Total	1668.0	0	0	0	0

Note: Cullen et al., 2013 reported 1.76 square kilometres remained in 2011. We assumed a negligible change between 2011 and 2013.

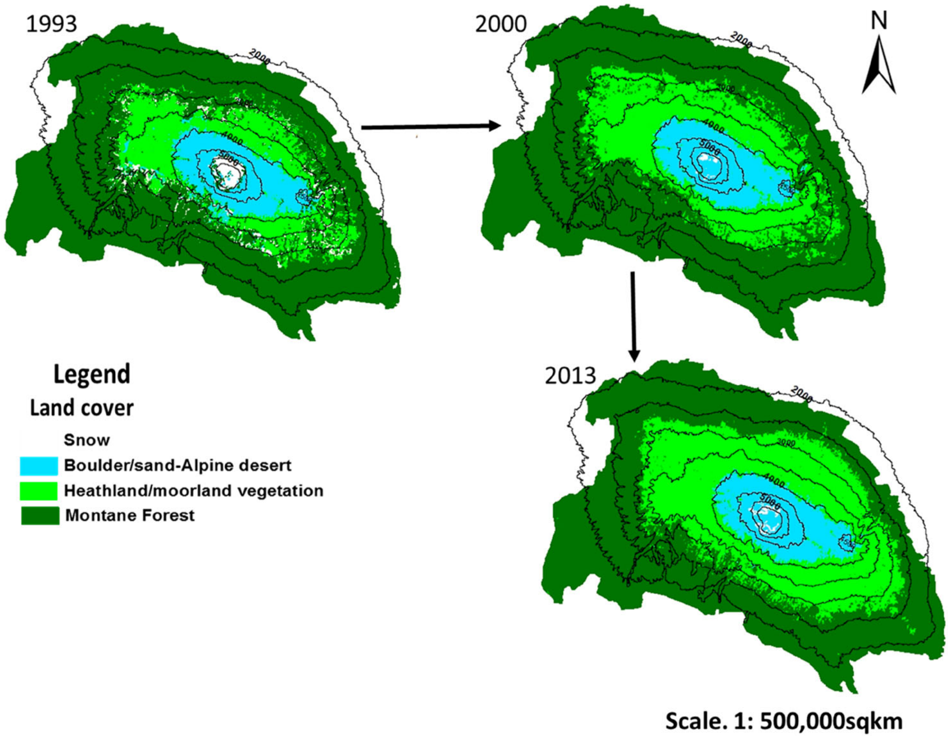

Figure 4. Land-cover in February 1993, February 2000 and February 2013.
Data Source: Landsat TM7, www.glovis.usgs.gov.

The downslope shift of heathland vegetation has resulted in the presence at lower altitudes of flowers with substantial tourism potential, such as Helichrysum. Changes are particularly noticeable at the Shira plateau. The plateau, which offers good views of the snow on top of Mount Kilimanjaro and Mount Meru, was largely covered by Erica bush (Beck, Scheibe, & Senser, 1983), but is now being colonised by Helichrysum and other flowering species. The area is within easy reach of day visitors.

5. Discussion

This paper's main purpose is to draw attention to the main impacts of observed environmental change on trekking in Kilimanjaro National Park, also in view of the projected acceleration of climate change and other forms of environmental change. The results suggest that the indirect impacts of environmental change have likely had a much bigger impact on tourism in KINAPA than the direct impacts. Since the 1970s, sightseeing opportunities have changed substantially as a result of land-cover change supporting key attractions. The land-cover changes reported here resonate with those reported by other authors such as Hemp (2005, 2006, 2009) and Newmak et al. (1991). Snow, which is KINAPA's second most important attraction, lost most of its coverage and may even disappear completely in the near future (Helama, 2015; Thompson, 2010; Thompson et al., 2009). Simultaneously, large areas of montane forest, home to attractions such as widlife, flowers and waterfalls, have given way to heathlands, radically changing the vegetation and wildlife.

The transformation from forest to heathlands is remarkable, since it represents a downward shift in vegetation, whereas climate change is typically associated with upward shifts. Deforestation and a change in the wildfire regime have been put forward as explanations (Hemp, 2005, 2009). Drier and warmer conditions have made Erica trees, which dominate the cloud forest at the high end of the montane forest belt, more susceptible to fire. Fire caused the loss of nearly one-third of the forest cover between 1906 and 1976 (Hemp, 2009), 300 hectares of Erica forest between 2001 and 2004 (Madoffe & Munishi, 2005; URT, 2013), and 40 hectares in 2014 alone (Jenman East Africa, 2013). The Erica forests are replaced by Erica bush, a pioneering species characteristic of the heathlands that thrives in the new conditions. Erica bush, however, is also susceptible to wildfire. At higher altitudes, it is in its turn replaced by Helichrysum, the heathlands' climax vegetation. Assuming that the usual uphill shift in vegetation is still taking place, the Erica forest is actually squeezed between the uphill expansion of the lower montane forest and the downslope expansion of Erica bush. The precarious position of the Erica forest will further deteriorate as climate change continues. The developments within the montane forests and their implications for tourist attractions are an important topic for further study.

The reported slowdown of land-cover change after 2000 may be related to the introduction by the Kilimanjaro regional administration of stringent bylaws in 2000 to control cutting trees. These bylaws control tree cut and forest harvests. In addition, illegal logging is limited to occasional incidents (ecologist warden, E. Kikoti, personal communication, 28 February 2017).

Our findings on the loss of snow cover confirm earlier studies such as Thompson et al. (2009) and Cullen et al. (2013). Snowless Mount Kilimanjaro will very likely be less attractive to tourists, given the position of snow as the mountain's second-most important attraction after the mountain's high altitude. Therefore, the long-term impacts of snow loss will be negative. In the short term, however, as long as snow is melting but has not completely vanished, visitor numbers may actually increase through a phenomenon called "last-chance tourism". Last-chance tourism refers to visits to destinations or attractions that are expected to disappear (Lemelin, Dawson, & Stewart, 2011).

The direct impacts of environmental change, those affecting trekking conditions, are less clear. Mean temperature has gone up by an estimated 1.3±.06°C. The downward trend in our annual precipitation was not significant at the 95% level, which may be due to the limited time series. Based on a much longer dataset (1911–2004) for two stations located at 1430 metres altitude on Mount Kilimanjaro's southern slope, Hemp (2009) also reported a decrease in annual rainfall. In contrast to ours, Hemp's results were statistically significant. For Tanzania as a whole, Future Climate for Africa (FCFA, 2017) report a negative trend in rainfall, albeit not a statistically significant one because of the large interannual variability in rainfall. A combination of higher temperatures and less precipitation create more favourable climbing conditions on the lower parts of the mountain. Higher up on the mountain, the temperature increase may have caused permafrost to melt and destabilised trails and infrastructure. The same temperature increase has likely reduced the risk of altitude sickness, albeit to a limited extent. Air pressure increased by 200Pa, which is equivalent to a descent of just 28 metres. This may seem a marginal effect, but Moore and Semple (2009) found similar increases in pressure (200–300Pa) to be of physiological relevance for climbers on Mount Everest, as it increased the maximum oxygen consumption at the summit by 10%. The effects on Mount Kilimanjaro are likely to be noticeable as well, albeit smaller than on Mount Everest, given the difference in altitude between the mountains.

Due to a general lack of data, both on the environmental and on the tourism side, many assumptions had to be made, with varying effects on the reliability and plausibility of the results. To start with, the strong spatial and temporal variation in temperatures and rainfall amounts on Mount Kilimanjaro could not be adequately captured, since climate data were available from only a few weather stations, and for relatively limited periods of time. To compensate for the lack of a long series of temperature data at the summit, we used the few years of available data to create a reference point and combined this with the temperature trend, observed at the mountain foot. This method yields reasonably accurate results as long as the temperature at the top shows little interannual variability and the temperature gradient between the foot and top of the mountain is stable, both of which conditions are met. Daily or hourly data are required to analyse the high-intensity rains that can trigger landslides and rock fall, but monthly data were the best available. Our suggestion that the risk of landslides and rock fall may have diminished because of decreasing rainfall totals is therefore the most speculative of our study. FCFA (2017), for example, point in the opposite direction, projecting an increase in rainfall intensity on rainy days, despite a general reduction in rainfall. Our analysis of land-cover change was based on freely available satellite images. The limited number of images studied were enough to draw some general conclusions about long-term changes, but insufficient to deliver insights on developments in the rate of change. In addition, the limited number of land-cover categories identified may hide dynamics within each of the categories, as in the case of the Erica forest being squeezed from two sides in the montane forest area. Future impact assessments would greatly benefit from more, longer and higher-resolution datasets of climate and environmental change.

Data are also lacking on the tourism side. Records of monthly visitor numbers for most parks in Tanzania, including KINAPA, do not go back further than the year 2000 (also see, Kilungu et al., 2017; Mitchell, Keane, & Laidlaw, 2009). Before 2000, the parks' tourist visits were not properly documented. In 2005, TANAPA decided to gather and ditigitise these data from 2000 onwards (park warden M. Mombo, Personal communication, 13 February 2013) This dataset sufficed to establish a clear link between the seasonality patterns in rainfall and visitation, with visitation peaks in the dry seasons. However, shifts in visitation, as a result of shifts in rainfall, could not be established. Longer datasets with daily resolution are needed for that. Information about the spatial patterns of tourism behaviour is also scarce. Our study compensated for this knowledge gap by using survey data about tourists' preferences for the various sightseeing attractions on Mount Kilimanjaro. Spatial data on tourists' whereabouts would, however, help to complement this self-reported data, in particular if it was a product of continuous monitoring programme.

Our study has important implications for management and policy. In the short term, park managers should account for potential last-chance tourism to Kilimanjaro. They should, however, be aware that almost by definition any increase in visitor numbers associated with last-chance tourism is temporary, in particular if Kilimanjaro were to be completely snowless by 2020 as has been projected (Helama, 2015; Thompson et al., 2009). Making structural investments to accommodate this temporary growth may not be warranted. A more structural change that park managers can try to capitalise on is the increased attractiveness of the Shira plateau. They can do so by providing facilities such as picnic sites and campsites. Such facilities are likely to be of particular interest for day visitors and domestic tourists and can thus help to diversify the park's visitor profile. This insight is a good example of the study's broad scope that goes beyond the traditional focus on the ice cap and reaching the summit. For many visitors, sightseeing in the various landscapes, either as part of a mountain climbing expedition or as part of a daytrip, is an important aspect of visiting Mount Kilimanjaro. Just like snow and ice, sightseeing attractions are tourism resources that merit monitoring and management.

Mountain tourism destinations are highly susceptible to the impacts of climate change (Beniston, 2003). Our study shows that Kilimanjaro is no exception. It is increasingly important for mountain tourism-destination managers to understand their susceptibility to climate change and to devise appropriate adaptation strategies to warrant sustainable tourism. Nevertheless, KINAPA's current general management plan (2005 2015) does not yet identify climate change as an issue of concern. KINAPA's new 10-year general management plan, which is currently being developed, provides an excellent opportunity to introduce climate and environmental change as major drivers of change. The general management plans of other parks are revised or replaced as well, and our study can inform those plans by showing the variety of ways in which climate and environmental change can affect nature-based tourism.

The policy relevance of our study extends beyond Tanzania's park system. Tanzania is currently revising its tourism policy (current version dated 1999) and is committed to developing adaptation plans as part of the Paris agreement. Our study draws attention to the importance of climate and environmental change for tourism, and the importance of tourism for adaptation. The tourism sector has long taken climate and weather for granted (Scott, Wall, & McBoyle, 2005; Tervo, 2008), which has hindered the mainstreaming of climate change adaptation in tourism management, planning and policy, particularly in Africa (Hoogendoorn & Fitchett, 2018; UNWTO/UNEP, 2008). Our study adds to the growing body of literature on climate change impacts on tourism in Africa that reminds the sector of its depence on climate and environmental resources, and of its vulnerability to environmental change. Mount Kilimanjaro's rapid loss of snow is a powerful signal.

Similarly, our study reminds the adaptation community of the relevance of tourism. This is particularly important now that Tanzania has committed to developing adaptation plans as part of the Paris Agreement. Tourism is a major economic sector in Tanzania, accounting for 13% of Tanzania's GDP, compared to 29% for both agriculture and industry (https://www.indexmundi.com/tanzania/gdp_composition_by_sector.html) Tourism in Tanzania is primarily nature-based and thus susceptible to environmental change, as our study on Mount Kilimanjaro shows. Whereas climate change impact assessments and adaptation plans have been produced for sectors such as agriculture (FAO, 2015) and forestry (FAO, 2009; Hall, 2009), no such assessments and plans exist for tourism. Our study responds to the call for tourism-focused studies and policies (see e.g. Hoogendoorn & Fitchett, 2018) and adds further urgency to it.

Tanzania may come to experience tension between adaptation and mitigation policies with respect to tourism. Its adaptation policies may be directed at projecting the tourism sector as a key economic sector and an important source of foreign currency. Most tourists, however, are foreigners, most of whom arrive in Tanzania after long-haul flights. Aviation is tourism's largest and most problematic source of greenhouse gas emissions and, in the absence of viable technological solutions in the short and medium term, may face restrictions and/or much higher fuel prices in the not-so-distant future (Peeters & Eijgelaar, 2014). Restrictions and higher prices are likely to have the largest impact on long-haul tourist flows, thus potentially hurting destinations that depend on such flows, such as Tanzania. The study by Peeters and Eijgelaar (2014), however, suggests that for most countries, the negative impacts will be limited, as long-haul visitors will be replaced in part by short-haul visitors from neighbouring countries.

6. Conclusion

This study is a first-order assessment of the changes in climate and land-cover on Mount Kilimanjaro over the past 20–40 years and the impacts thereof on trekking and tourist attractions. The study's primary focus is on trekking, the dominant tourism activity on Mount Kilimanjaro. Trekking has two main aspects: the physical performance of climbing and sightseeing. Change in rainfall at lower altitudes, temperature change at high altitudes and land-cover change were identified as the aspects of environmental change that are most relevant for trekking and sightseeing.

Land-cover change has arguably had the largest impact on tourism. The montane forests, home to Black and White Colobus monkeys, birds and other animals appreciated by tourists, became 166km^2 (15%) smaller in the past two decades. The area of heathlands, known for its many attractive flowers and giant groundsels, increased by almost the same amount (170km^2, 38%) and now covers most of the Shira plateau. Since the Shira plateau is within the reach of day visitors, this development provides an opportunity for market diversification. Increased use by day visitors and domestic tourists, however, probably requires a higher standard of facilities than is currently provided. The most alarming development has been the loss of snow cover. Mount Kilimanjaro's snow-cap, one of the mountain's main attractions, lost half of its extent in the last two decades. Ironically, in the short run, this rapid decline is likely to add to the mountain's appeal through an increase in "last-chance tourism": tourism to disappearing destinations. Park managers should be aware that this positive effect on visitor numbers will likely be short-lived. In the long run, the absence of snow will make the mountain less attractive. This effect can be partly mitigated by carefully managing the mountain's forest cover and maintaining and further developing attractions in the expanding heathlands.

Reaching the top of Mount Kilimanjaro has probably become somewhat easier over the past 40 years. Mean temperature at the mountaintop increased by 1.3 ± 0.06°C, which resulted in an estimated 200Pa (2mb) rise in barometric pressure, making breathing easier and reducing the risk of altitude disease. Although an increase of 200Pa is equivalent to a descent of just 28 metres, previous studies suggest that such change has physiological significance. With respect to rainfall, trekking conditions at lower altitudes appear to have remained largely unchanged over the past 40 years. The downward trend in annual rainfall, though not statistically significant at the 95% confidence level, confirmed the results of earlier studies. Our study did reveal a statistically significant shift in rainfall from April to March, signalling an earlier start of the short rains period. The relevance of this shift for tourism is limited, however, as March and April belong to the low season. This study found substantial impacts of environmental change on tourism in Kilimanjaro National Park, and the acceleration in climate change suggests that more is yet to come. Adequate anticipation and adaptation by park managers require detailed assessments. More complete and extensive datasets on tourist arrivals, attractions, temperature, rainfall, and land-cover are a pre-requisite.

Our assessment coincides with the revision of KINAPA's general management plan, the revision of Tanzania's tourism policy, and the development of adaptation policies in response to the Paris Agreement on climate change that Tanzania signed earlier this year. The current versions of the general management plan and the tourism policy do not yet identify climate change and environmental change as major factors. Current adaptation plans do not yet identify tourism as an important sector. Our study emphasises the need to acknowledge and act on the strong links between the phenomena of environmental change and tourism.

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