


## Article

# Climate Change Effects on Hydropower in Mozambique

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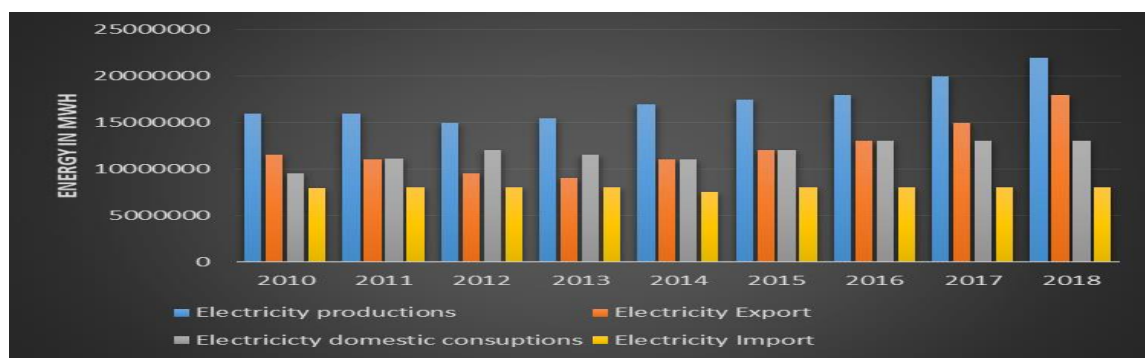
**Abstract:** The impact of climate change on the production of hydropower in Mozambique is reviewed and regression analysis is applied to evaluate future climate scenarios. The results show that climate change will cause increased variability of precipitation and create flooding that can damage infrastructure such as hydropower dams. Climate change can also cause drought that will decrease surface water and reduce hydroelectric generation in Mozambique. Electricity generation is to a major extent performed through large-scale hydropower in Mozambique. To fulfill the sustainable development goals (SDGs) and an increased demand for electricity, several large and many small hydropower projects are planned and were built in the country. The economic lifetime of a hydropower plant is typically 100 years, meaning that the hydrologic regimes for the plants should be evaluated for at least this period. Climate change effects are rarely included in present feasibility studies. Economic implications associated with climate change phenomena are higher in Mozambique than in neighboring countries as its future electricity demand to a large extent is forecasted to be met by hydropower. The large hydropower potential in Mozambique should as well be considered when investing in new power plants in southern Africa.

**Keywords:** renewable energy; hydropower; climate change effects; flow regimes

## 1. Introduction

Mozambique is a southern African country that possesses considerable water resources and hydropower potential through thirteen major river basins in the direction from south to north: Maputo, Umbeluzi, Incomati, Limpopo, Save, Buzi, Pungwe, Zambezi, Licungo, Ligonha, Lúrio, Messalo and Rovuma. Mozambique is a downstream country and nine of the fifteen major basins in the Southern African Development Community (SADC) region are shared with other countries. High river discharge and steep gradients provide a high potential for the development of hydropower schemes of all types, from pico- and mini- to small- and large-scale hydropower plants [1,2].

The current scenario of electricity access in Mozambique is not very favorable to eradicate poverty because the rural areas still have a low rate of electrification of 27%; in comparison in Sweden the rate is 100%. The rate of electrification in the urban areas in Mozambique is about 67% and the national electrification rate is 40%. With higher energy potential resources (coal, natural gas, renewable energy resources) Mozambique still has low electricity consumption per capita of about 443 kWh [2,3]. Figure 1 shows the electricity production and consumption over the last eighteen years. Today in Mozambique the average energy consumption is 12 billion kWh.



**Figure 1.** Current electricity scenarios in Mozambique: production, domestic consumption and import. Source: own illustration from information extracted from [1,3,4].

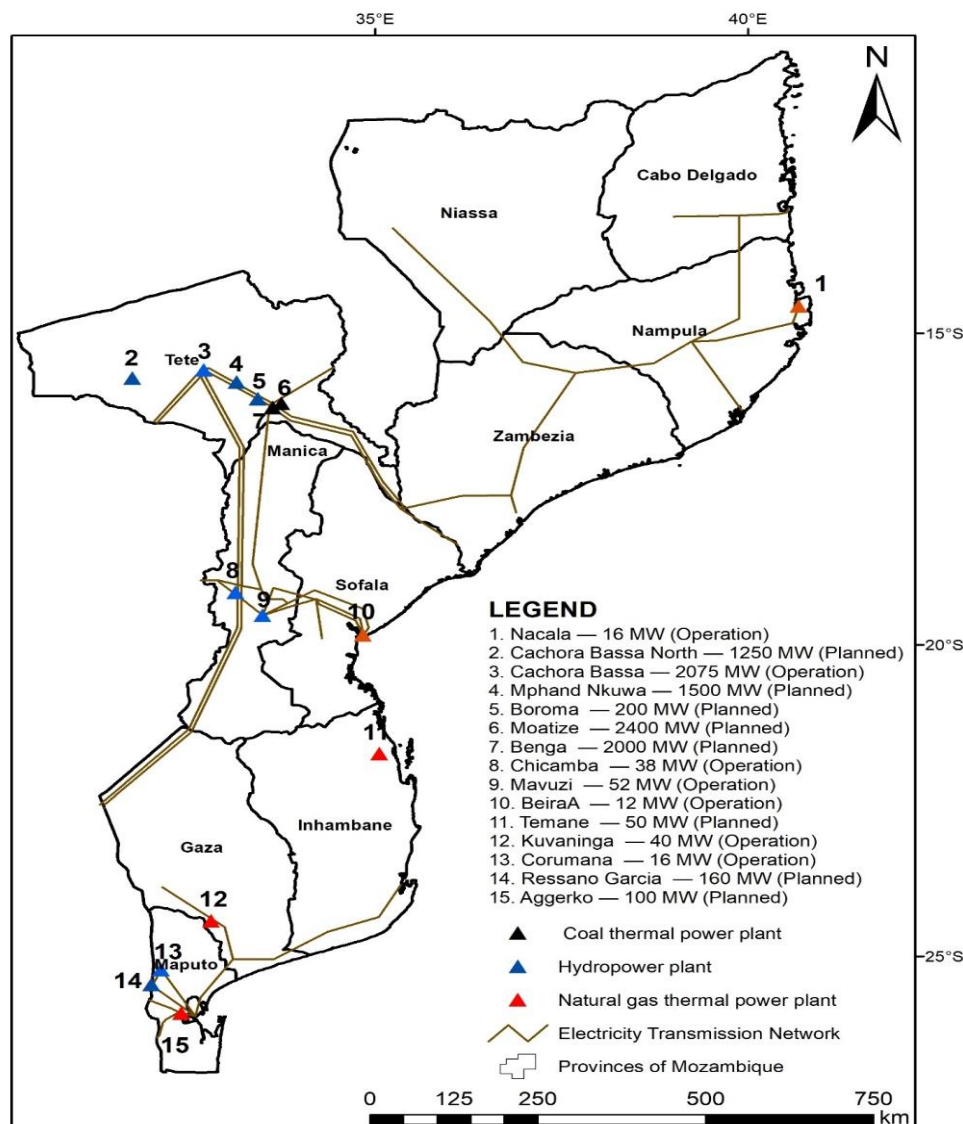
Hydropower is considered to be a very attractive form of electrical power generation for several reasons: it is one of largest sources of electricity in the world, the electrical power output takes only a short time to produce, it is always available since it represents renewable energy, and it is dependent upon water being available in large amounts. Hydropower represents one-sixth of the electricity generated globally and 97% of the total electricity generated in Mozambique [2]. Access to electricity is one of the instruments for achieving adequate social and industrial development in a society, yet about 1.3 billion people in the world are living without access to electricity. In Mozambique, there are around 20 million people living without electricity access and in poverty, out of which 85% live in rural areas [1,3,5].

The current figure regarding hydropower potential in Mozambique is highly attractive, being estimated to be at an 18,000 MW level, although only roughly 2200 MW of it has been developed in a manner providing it access to the national grid shown in Figure 1. To meet the needs that exist, the government of Mozambique has made rural electrification a major component of its development program. In addition, it has liberalized the energy sector of the country and an influx of direct foreign investments into hydro-projects within Mozambique has followed since 1997.

Rainfall and topography offer greatest hydropower potential in Mozambique to the Zambezi River basin, at sites such as Cahora Bassa and Manica (Mavuzi and Chicamba with 80 MW of power output) on the Revue River. Together these have a generating capacity of about 2200 MW, of which Cahora Bassa provides 95% of the total hydropower produced in Mozambique.

Figure 2 illustrates the total renewable energy including non-renewable energy such as coal and natural gas and good hydropower potential depending on the province in Mozambique. Rainfall and topography offer the greatest hydropower potential in the Zambezi River Basin at sites such as HCB and Manica (Mavuzi and Chicamba with 80 MW of power output) on the Revue River, as shown in Figure 3 [1–3,6].

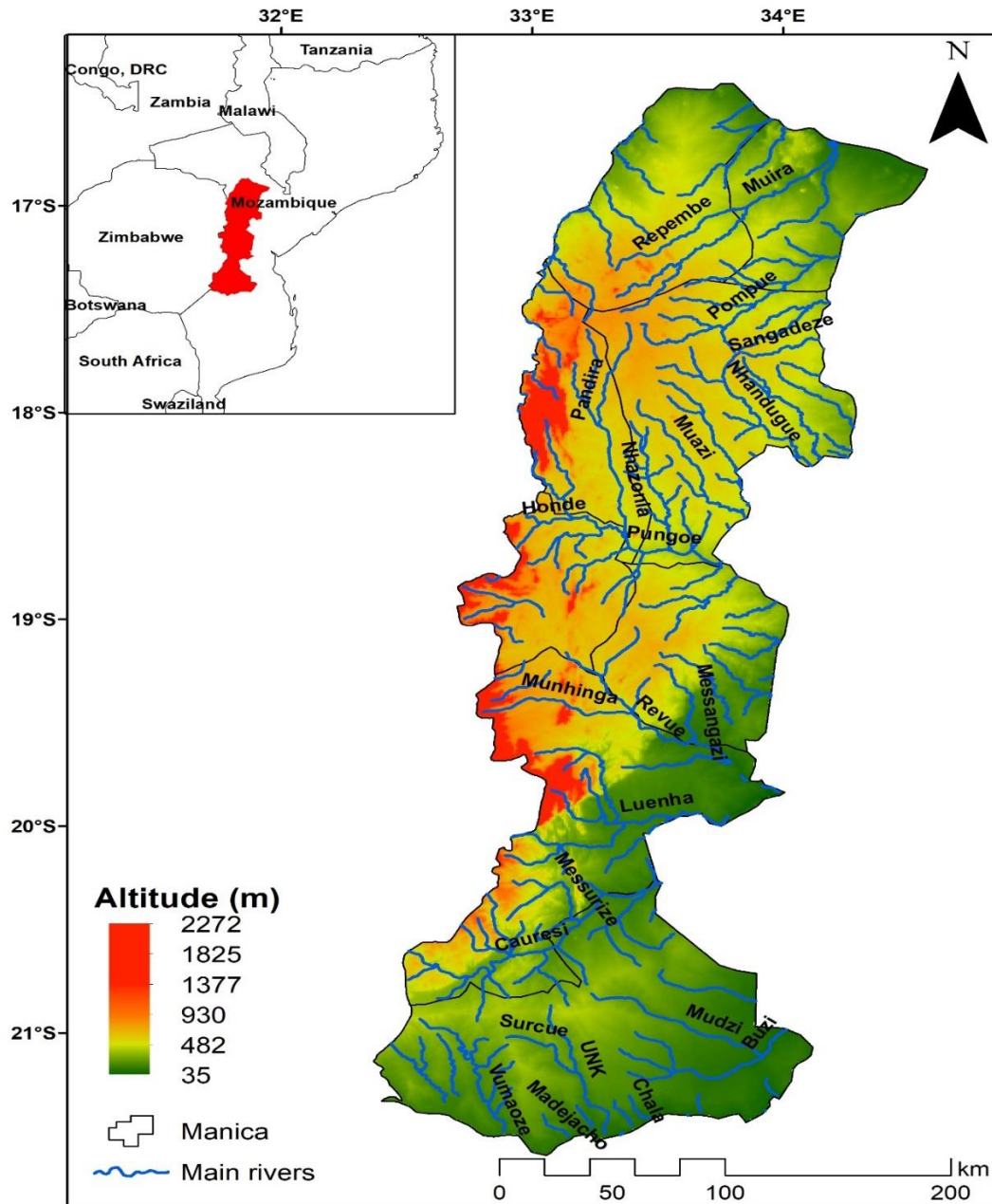
Climate variation impacts the use of hydropower and represents big challenges to the water resources sector in Mozambique. In Africa in general, and especially in Mozambique, water supply systems are poor and the government is already strained to deliver this resource to the population. Climate change will further complicate management of most of the systems in the future. In southern African nations where Mozambique is located, a decrease in annual discharge will significantly affect the amount of surface water in large parts of the south of the continent by the end of the century [3,7,8]. Hydropower is dependent on a predictably steady precipitation pattern. The use of hydropower plants in the country of Mozambique is therefore fraught with potential risks associated with its geographical location, as it is identified as being a vulnerable country in terms of climate change. Located along the coast of the Indian Ocean, being a downstream country and being associated with low technology, poverty and a weak capacity to adapt to societal changes, hydropower use in Mozambique is expected to be negatively affected by climate change in the future [4,9,10]. A change in the water resources availability will result in significant changes in electricity supply [5,8,11].



**Figure 2.** The three main grid systems in Mozambique with existing or planned large power plants.  
Source: author.

The historical records of rainfall and temperature from stations in Mozambique show that in general the mean annual temperature has increased by  $0.6\text{ }^{\circ}\text{C}$  between 1960 and 2006, equivalent to an average rate of  $0.13\text{ }^{\circ}\text{C}$  per decade [3,11,12]. This increase in temperature has been observed in the rainy season December, January and February (DJF), March, April and May (MAM), and June, July and August (JJA) only, at a rate of  $0.15\text{--}0.16\text{ }^{\circ}\text{C}$  per decade. According to future projections, temperatures are expected to increase up to  $+1.4\text{ }^{\circ}\text{C}$  by 2030 and  $+1.0$  to  $+2.8\text{ }^{\circ}\text{C}$  by 2060 (minimum ranging). A continued increase is expected of  $+2.2\text{ }^{\circ}\text{C}$  by 2070 and  $+1.4$  to  $+4.6\text{ }^{\circ}\text{C}$  up to the 2090s (maximum ranging) as shown in Figure 4 [3,8,11,13]. In addition, under a single emissions scenario, the projected changes from different models have shown that the temperature will be up by  $1.8\text{ }^{\circ}\text{C}$ . On the other hand, the mean annual rainfall over Mozambique has decreased at an average rate of  $2.5\text{ mm}$  per month ( $3.1\%$  per decade) between 1960 and 2006. This annual decrease is largely due to a reduction in DJF rainfall, which has decreased by  $6.3\text{ mm}$  per month, and  $3.4\%$  per decade. Rainfall projections show that the substantial change in total annual rainfall on the national level is projected to be between  $-8$  and  $+14\%$  from 1975 to 2100. Regional and seasonal changes are however more pronounced: A rainfall increase of  $1\text{--}8\%$  (2010–2090) is expected for the north of the country, mainly

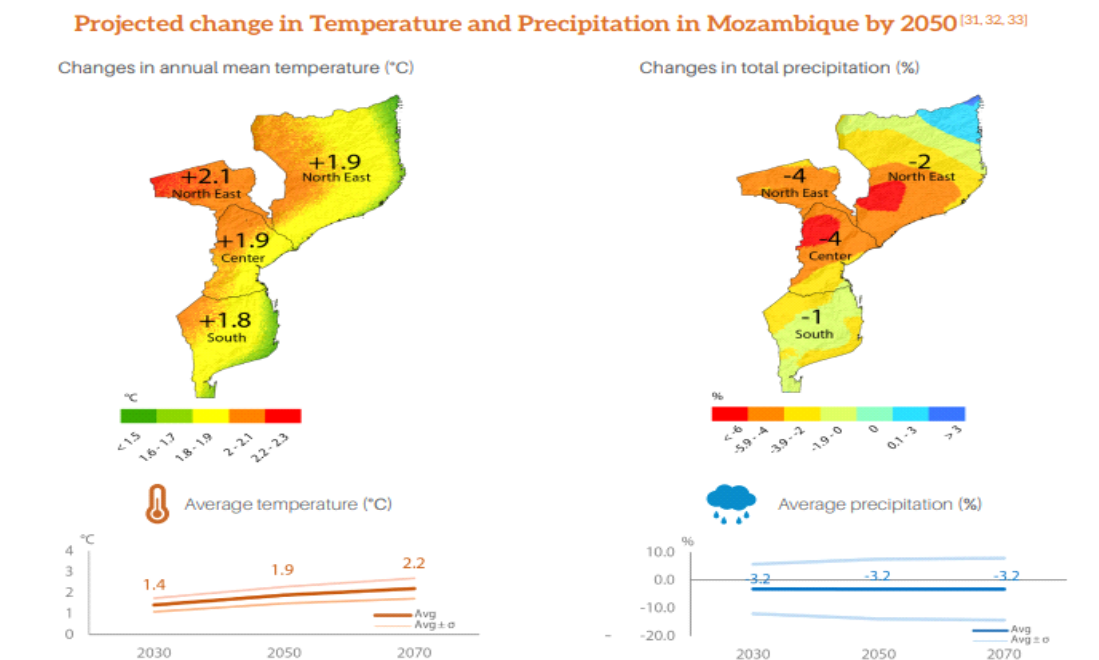
in the rainy season between December to February. A decrease is projected for the west, south and central regions of the country (including the Zambezi valley) during the onset of the rainy season, with a strong decrease of up to 31% projected for September and October. Another decrease for the south of the country is expected for the main rainy season [7,9,14].



**Figure 3.** Manica province at central Mozambique showing the altitude and the local river basin.

Climate change is projected to alter the frequency of precipitation, floods and drought events in Mozambique. Regional studies have been made for the Zambezi River, which has the largest river basin, where Spalding-Fecher estimates the output from major Zambezi hydropower plants to decline by 10–20% under a drying climate [6,9,11,15]. To mediate the potential reduction, Spalding-Fecher argues for an increased cooperative governance arrangement to manage shared water resources in the entire southern African region, which could be enhanced by targeted political initiatives.





**Figure 4.** Projected increase in temperature and precipitation in Mozambique by 2030–2070, from [3].

Temperature and evapotranspiration are projected to increase in Mozambique while precipitation is projected to decrease [7,8,14]. The Zambezi River has two of the biggest dams in the world, the Kariba and Cahora Bassa, which both will be affected substantially by increased evapotranspiration and decreased precipitation. The Kariba dam forms Lake Kariba, which extends for 280 km and holds 185 km<sup>3</sup> of water [8,14,15]. The Cahora Bassa dam forms the Cahora Bassa Lake, which extends for 292 km and holds 56 km<sup>3</sup> of water. The flow of the Zambezi River will decrease by 40% or more due to climate changes, according to [5,6,14]. It is estimated that precipitation will be reduced by 15% and the evaporative losses will increase up to 25%. The runoff could be reduced by 30–40%. This may to a large extent be applicable for all the major river basins in Mozambique. A decrease in runoff reduces the economic benefits of a hydropower plant fed by the river, increasing the need for careful investment analysis of new hydropower plants. The climate change projections show that average temperatures in Mozambique will rise up to 4.6 °C between 2010 and 2090 [6,9].

According to [1,2,16], the demand for electricity in Mozambique, where 15% more households have been connected to the grid the last 5 years, increases rapidly. In addition, the need for electricity in industry and public works further increases each year in Mozambique, meaning that the demand for electricity will continue to increase in the coming 30 years. According to [6,14,16] this implies a need for policy development in the energy sector, not only in Mozambique but within the entire region of southern Africa. A combination of excessive use of reservoirs and low precipitation directly reduces the electricity output from hydropower [8]. Future changes in climate could reduce the performance of power plants and reduce the economic output, as well as the power production [8,10,16]. This also decreases the economic growth in southern Africa, particularly in hydropower dependent countries like Zambia and Mozambique [5,6,13,14]. To mediate these risks from climate variability and long-term climate change, there is a need for strong and cooperative governance arrangements to manage shared water resources with the help of integrated water resource management tools. The probable expansion of irrigation and construction of new dams and hydropower stations will intensify the need for cooperative governance between the countries sharing the trans-boundary rivers. Not least of concern is an economically viable structure which can cover costs and support additional investments, such as larger storage of water and additional alternative power supply sources to guarantee the future

delivery of power. Until 2070, the electricity demand in Mozambique is forecasted to increase by 5–7% per year from 10.9 TWh in 2010 [7,8,11–14].

## 2. Climate Characteristic in Mozambique

The climate in Mozambique is semi-arid; it is subtropical in the south, tropical in the north, and it is moderated by the influence of mountainous topography in the north-west of the country. Seasonal variations in temperature of around 5 °C occur between the coolest months (June, July and August) and the warmest months (December, January and February) [3,9,11]. Geographically, temperatures are higher in proximity to the coastal areas, in the southern part of the country, and in lowland regions, compared with the inland regions of higher elevation. Average temperatures in the lowland areas of the country are around 25–27 °C in the summer compared to 20–25 °C in winter months [3,9,11]. The temperature is usually affected by seasonal air circulation of the Indian Ocean, characterized by one rainy and one dry season during the year. The southern part of the country is generally drier than the north and has the most variability in temperature and precipitation. The rainy season starts in October and lasts until March. The annual average precipitation in Mozambique is 1032 mm, but it varies between 1400 mm/year near the Zambezi basin and 300 mm/year in the lowlands of the inner part of the south. Up in the mountainous area, the rainfall can be over 2000 mm per year [11,12,14]. From 1960 to 2006 it has been observed that the rainy season starts later in October and that the dry period lasts longer. Since 1950, extreme weather events such as drought, heavy flooding and cyclones, have increased in frequency [10]. The climate change scenario in southern Africa projected using global climate models (GCMs) in IPCC report number four (AR4) shows the temperature will increase 1–2.8 °C until the 2060s and then 1.4–4.6 °C until the 2090s, while the precipitation will decrease. With higher temperature comes higher evaporation, and for Mozambique lower precipitation, which affects the potential for hydropower generation.

Mozambique is extremely vulnerable to climate variation because of its geography location; large areas of the country are exposed to tropical cyclones and droughts and every three to four years the phenomena repeat and river and coastal areas suffer from flooding. This vulnerability is heightened by the country's 2470 km of coastline and socioeconomic fragility. More than 60 percent of the population lives in low-lying coastal areas, where intense storms from the Indian Ocean and rising sea levels put infrastructure, coastal agriculture, key ecosystems and fisheries at risk. Forty-five percent of the population lives below the poverty line and 70 percent depends on climate-sensitive agricultural production for their food and livelihoods. Increased frequency and severity of intense storms, droughts and floods are likely to exacerbate these development challenges. For example, Idai Tropical Cyclone, which hurtled into the Mozambique's coastline on 14 March 2019, flooded 2515 km<sup>2</sup> of the low lying plain in the central part of the country. It caused more than 500 deaths, and the final figure will maybe never be known since many bodies were washed out to sea. In total the floods caused by Idai are thought to have affected the lives of some 1.8 million Mozambicans. 90% of Beira municipalities were devastated or destroyed by the cyclone. In 2000, large-scale flooding in the south-central part of Mozambique killed almost 700 persons [16].

## 3. Study Area

The study took place in the central region of Mozambique, namely in Sofala, Manica, Tete and Zambezia, which have high potential of hydropower use. The Sofala province is divided into 13 districts and has, since 2013, five municipalities: Beira, Dondo, Gorongosa, Marrromeu and Nhamatanda. The Manica Province is located in the central western part of Mozambique, along the border with Zimbabwe, between 21°34' and 16°24' latitude S and 34°01' and 32°42' longitude W. The province has an area of 61,661 km<sup>2</sup>, representing approximately 7.7% of the total area of Mozambique.

## 4. Methodology

### 4.1. Data Collections

The data collations concerning climate in the central region of Mozambique (Chimoio, Beira and Tete) were collected from Ara-Centro and provided by The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in Manica by February 2017. The data represent the mean average monthly data of temperature and precipitation. GIZ has worked with rural electrification in Mozambique with the objective to provide electricity access to rural households and promote a better quality of life for the rural poor people in the country.

### 4.2. Statistical Regressions Method

Temperature and precipitation data for the rainy season in Mozambique (October–March) were evaluated for linear trends using regression analysis based on ordinary least square fits for the time period 1902 to 2012 [14,17,18]. Analyses were done on both the full rainy season, as well as for each of the constituting months. The significances of the linear regressions were estimated based on the  $p$ -value from the author's  $t$ -test on the slope coefficients. Only linear regression with a  $p$ -value  $\leq 0.05$  for the slope coefficient was accepted as significant. Linear trends were further evaluated for three periods in the data, for 1902–1957, 1957–2012 and 1974–2012, to be able to capture whether the trends have been changing when entering a period when the global climate has been subject to climate change, generally accepted to have started around the early 1970s. The periods were selected and evaluated separately, which respectively represent 50, 50, and 25% of the full sample size. The data sets all give reliable sample sizes for ordinary least square regressions. For the time series where significant linear trends were established, projections were made based on these trends until 2050 and 2100 [3,5].

### 4.3. Future Projections Based on Gcms and Hydropower Capacity

Different African research communities such as Climate Systems Analysis Group (CSAG), the University of Cape Town (South Africa), [8,12,18] have developed comprehensive future climate projection scenarios for the southern African region with the objective to assess climate variation impact in the energy sector, mainly focused on hydropower. The projections of future climate scenarios used are uncertain. The total of the 121 global climate models simulations (GCM) were analyzed, including those used in the fourth report in the International Panel on Climate Change (IPCC-AR4), and recently those used in the IPCC—AR5 GCMs. The reason to use GCMs based on future emission scenarios is because those are presently the main tools used to efficiently develop and analyze future climate scenarios. Statistical downscaling is involved in the statistical regression between GCMs outputs and local observations, resulting in the projected future local climate for specific stations and [12–14,18].

In total at least 20 GCMs have been developed for the region of southern Africa [5,9,10,18]. These are relevant to use to assess climate variability for hydropower potential or water resources. Of these, five GCMs were selected: Coupled Global Climate Model (CGCM3.1), Commonwealth Scientific and Industrial Research Office (CSIRO3.0), Max Planck Institute for Meteorology Global Model, (ECHAM5), Community Climate System Model (CCSM3.0), and the Hadley Centre Coupled Model (HACDM3). Three scenarios were chosen for climate variability (A2, A1B and B2). These scenarios cover a wide range of emissions, from low (B2) to middle (A1B) and high (A2) [6,13,18].

## 5. Results

In Figure 4 the trends for the three chosen periods are presented. For the years 1902–1957 no clear trend can be seen from the linear regression analysis. For the years 1957–2012, a small increase in temperature can be detected. For the years 1973–2012, a significant temperature increase is present. Figure 4 shows that the average temperature during the rainy season for the first 10 years, 1974–1984, was 25.4 °C, while it increased to 26.3 °C during the last 10 years, 2002–2012. The temperature gradient

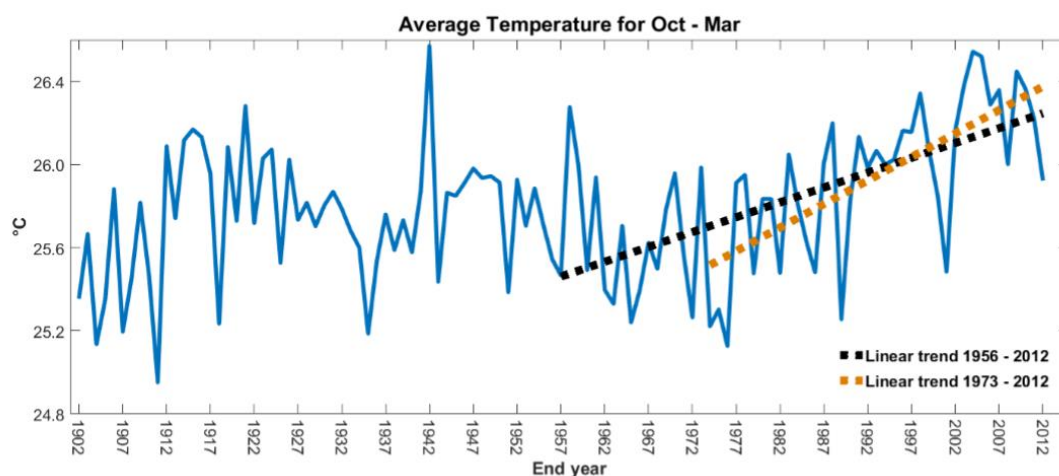
was +0.9 °C during this period. There is clear statistical data for a positive temperature trend during the last four decades from 1973 to 2012.

The positive trend in Figure 4 and in Table 1 show the historically recorded trend for the rainy season of October to March, which provides evidence for an approximately 3.6 °C increase in temperature that can be expected to occur up to the year 2100 according to Figure 5, the rainy season thus becoming hotter than it is today. The third period, that of 1974–2012, indicates an increase in both the observed temperature, along with the projected temperature, pointing to a situation of a continuing rise in temperature. These observations thus provide evidence for continuing climate change, with both the temperature and the evaporation of water increasing and the availability of water then decreasing; this very much presents a challenge to the hoped-for success of the hydropower project. There is uncertainty, however, regarding a decrease in precipitation, since the precipitation shows no significant trend in terms of results of the simulations, yet USAID and UNDP have studied this to some extent and have found that precipitation can be expected to increase in the country as whole.

**Table 1.** Trends and Projections of Monthly Average Temperatures for Rainy Season.

	Current Average (°C)	Annual Trend <sup>1</sup> (°C/y)	Annual Trend <sup>2</sup> (°C/y)	2100 Projected Average <sup>1</sup> (°C)	2100 Projected Average <sup>2</sup> (°C)
October	25.78	0.009	0.029	26.56	28.34
November	26.68	0.016	0.024	28.07	28.83
December	26.53	0.016	0.023	27.97	28.56
January	26.42	0.015	0.013	27.76	27.53
February	26.40	0.013	0.016	27.53	27.82
March	25.91	0.015	0.019	27.27	27.58

<sup>1</sup> Liner trend from 1956–2012. <sup>2</sup> Liner trend from 1973–2012.



**Figure 5.** Trends in average temperature for October to March in the Ara-Centro region.

For precipitation for October to March, there is no significant trend visible for the dataset. Climate change scenarios do suggest an increase in precipitation due to warmer climate, yet with a faster increase in temperature, the evapotranspiration will grow faster than the precipitation. Extrapolating data from Figure 5 indicates an increase in temperature of 3.6 °C in 2100, as presented in Table 1. The rainy season will become warmer and most probably shorter in the future. Comparing the data set for 1974–2012 with the projected temperatures in Table 1 and Figure 6 suggests that the observed temperatures have increased even faster than the projected ones. An interpretation is that climate change is already visible in Mozambique. The evaporation will continue to reduce the available water in the river basins and alter the runoff for the hydropower plants.



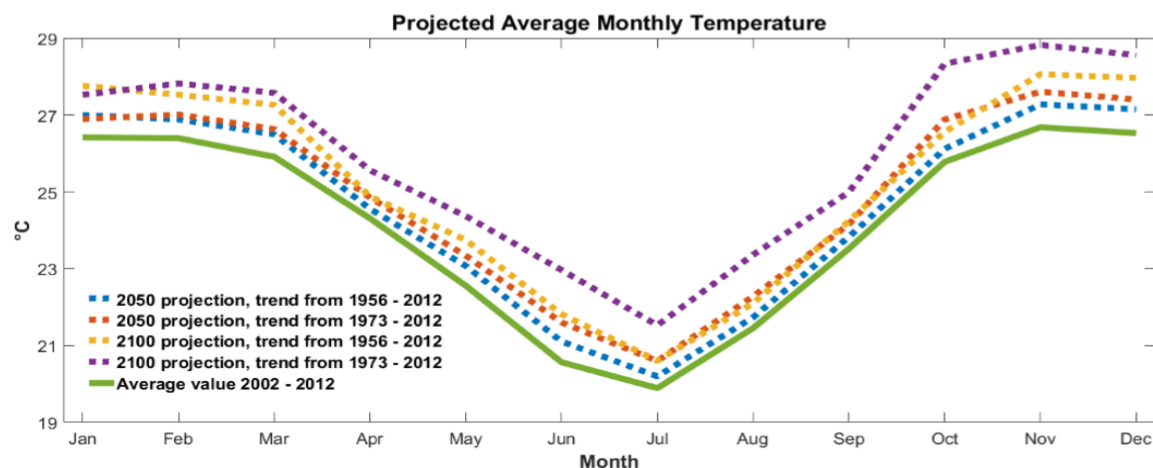


Figure 6. Projected average monthly temperature for the Ara-Centro region.

Extrapolating the results from Table 1 to the effects on precipitation in Mozambique, it is possible to calculate how the rainfall pattern will change until 2100. In the climate scenarios projected in GCM (CSIRO 3.0, CGCM3.1, ECHAM5, CCSM3.0, HACDM3), a 10% decrease in runoff during the rainy season and a 12% decrease during the dry season is estimated for the coming 10 years; until 2100 the runoff will decrease even further, down to −18% in the rainy season and −20% in the dry season. A lower runoff will immediately affect hydropower production. The total electricity generation will decrease in accordance with the available flow to the reservoirs. Taking Cahora Bassa as an example, the total capacity of the plant is at present 2075 MW and the yearly standard/normal generation of electricity for the plant is almost 19 TWh. The Zambezi River flow is however never that high all year round. For instance, the electricity generation in 2016 was 15.6 TWh and due to drought in 2017, the electricity generation decreased that year by 11.5%, down to 13.8 TWh. A further reduction in flow to the Cahora Bassa dam by 20% would decrease the electricity generation further, maybe down to 12.5 TWh per year. Assuming a steady growth of electricity consumption in Mozambique requires a continuous development of hydropower stations.

Mozambique has a large number of economically suitable rivers and gorges that could be exploited for hydropower generation. Table 2 lists some already existing and some planned hydropower plants in Mozambique which contribute to the electricity supply in the entire southern African region. What is notable from a power supply point of view is that with reduced runoff to the hydropower stations, their maximum capacities cannot be utilized all year round. Instead, the total power generation available during a year will be cut by 10–20% in the 21st century due to climate change, increased evapotranspiration and decreased runoff. The combined capacity for the hydropower stations in Table 2 is 4685 MW, which theoretically could produce 41 TWh electricity. A more realistic generation is 70–80% of the theoretical capacity which thus is reduced due to climate change.

Table 2. Major hydropower plants in Mozambique. Source: own illustrations. From [1,2,18].

Hydropower Plant	Project	Province	Capacity MW
Cahora Bassa	Operations	Tete	2075
Mpanda Nkuwa	Project Ongoing	Tete	1500
Boroma	Project Ongoing	Tete	400
Lupata	Project Ongoing	Tete	612
Mavuzi	Operations	Manica	42
Chicamba	Operations	Manica	38
Curumana	Operations	Maputo	16
Lichinga	Operations	Niassa	0.75
Cuamba	Operations	Niassa	1.1

## 6. Discussion

Statistical extrapolations should be made with some care. The data sets from Mozambique indicate a clear and steady temperature increase from 1974 and the extrapolation done in this paper coincided with models previously presented by IPCC, see for instance [18]. Temperature has a less clear effect on precipitation, but longer periods of drought have been observed in the watersheds of the major rivers in Mozambique, not least at Cahora Bassa.

The total hydropower potential for Mozambique is approximately 18,000 MW according to Electricidade de Moçambique (EDM) and hydrological studies of the large river basins in the country [1]. The hydropower plants presented in Table 2 are thus only a fraction of the potential hydropower plants available for electricity generation in the country. Mozambique and neighboring countries will need to develop electricity generation further to meet the needs of the population and the economy, as much as possible. The climate change effect, however, reduces the runoff in the rivers and thus the economic value of investment in hydropower plants. The substantial hydropower potential that could be exploited in Mozambique should be investigated. The dramatic growth in demand and supply until 2100 has geopolitical consequences for all countries in southern Africa. The South African share of regional capacity will decrease and hydropower from the Democratic Republic of Congo, Mozambique and Zambia is estimated to increase. The fuel mix will shift away from coal and towards hydropower. Depending on growth assumptions and the economy, the southern African regional power generation capacity will increase from 52 GW to about 1000 GW in 2070, a 20 fold increase [15]. This is approximately the same growth rate as for Mozambique itself. The capex cost for a large hydropower plant is in the range of US\$50 per MWh. To build a new plant like Cahora Bassa (with an annual generation of about 15 TWh) could be estimated to cost US\$750 million. Assuming that all the hydropower potential in Mozambique was utilized, the total investment cost for these additional 16,000 MW would be in the range of US\$8–10 billion. Capital is generally difficult to raise in southern Africa, yet the need for electricity and the willingness to pay for it is high in the region. Increased sustainable power generation will benefit all countries in the southern part of Africa. Therefore, one important step to facilitate an expansion of the hydropower generation in Mozambique is to increase the economic collaboration with the neighboring countries and increase the electricity transmission capacity within and between the countries. The joint European electricity market may possibly be one inspiration for the southern African countries on how to organize the supply and transmission. Central for the southern African countries is probably to continue collaboration and develop mutual organizations to utilize the important hydropower potential of the watersheds.

When investigating potential hydropower projects in Mozambique, it is necessary to take into account that the climate change effects on river runoff will decrease the annual capacity of a plant by 10–20% and reduce electricity generation. Particularly in the investment calculations the prolonged pay-off of investments should be considered. The need for sustainable and renewable electricity generation is however urgent in southern Africa and investment projects should therefore be considered carefully in the feasibility phase considering they may need to operate for a longer period before delivering profit to the owners.

## 7. Conclusions

The electricity consumption in Mozambique will increase by 5–7% per year until 2070 due to increased wealth, a larger population and higher investments in the manufacturing and mining industries. The main electricity generation source in Mozambique is hydropower. Climate change will affect the temperature and precipitation patterns of Mozambique substantially. There is a close correlation between climate change and hydropower generation. With higher temperatures, the evapotranspiration increases too and reduces water levels in reservoirs and reduces runoff in rivers. One example is the hydropower plant of Cahora Bassa, where the electricity output may be reduced by 20% until 2100. Economic implications associated with this climate change phenomenon is higher in Mozambique than in neighboring countries as a result of the future electricity demand to a large

extent is forecasted to be met by hydropower. The large hydropower potential in Mozambique should be considered when investing in new power plants in southern Africa. It is important the southern African countries continue collaboration and develop mutual organizations to utilize the hydropower potential of their watersheds.

A regression analysis model based on ordinary least square fits was used to evaluate the linear trends that can be expected to occur. Temperature and precipitation data for the rainy season in Mozambique (October–March) was employed for the climate change analyses that were carried out. In using this model, there were found to be close correlations between climate change and the generation of hydropower energy: with temperature increasing and evapotranspiration increasing as well, the water level in reservoirs and in the rivers are reduced.

Regarding the climate-change projections, there is evidence that precipitation will decrease, thereby reducing river flow, which will lead to a decrease in the hydropower energy production available. The vulnerability to climate change can be expected to increase poverty in Mozambique, due to energy of this kind being a major source of income for the local economies and for the government. In addition, projections regarding the growth of the population show that by the year 2050 the population in Mozambique can be expected to be about 66 million. It is thus important that the government take steps aimed at increasing the capacity so as be able to meet this challenge.

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