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(Research Article)

Effects of climate change on the evolution of climatic parameters for a typical climate in Guinea: Case of the Upper Guinea region

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Abstract

This study analyzes the effects of climate change on the evolution of climatic parameters in a Sudano-Sahelian climate zone in Guinea, using the Upper Guinea region, specifically the prefectures of Kouroussa, Mandiana, and Siguiri, as a case study. The meteorological data used, covering the period 2000–2022, were collected from the Guinean National Meteorological Directorate and include precipitation, temperature, relative humidity, and solar irradiation. The methodology employed is based on a descriptive and comparative statistical analysis of climate time series to identify spatiotemporal trends. The results show marked interannual variability in rainfall, with similar profiles across the three locations, but a dominance of rainfall in Kouroussa, where a maximum of 2582 mm was recorded in 2021. Temperatures also show consistent trends, with higher values in Siguiri (average maximum of 28.5°C), reflecting an intensification of thermal conditions linked in particular to the degradation of vegetation cover. Relative humidity follows the same dynamic, with higher levels in Kouroussa (up to 70%) and lower levels observed in Siguiri (42%), reflecting drier conditions in the latter location. Furthermore, solar irradiation is higher in Siguiri, reaching a peak in 2013, which is consistent with the decrease in rainfall and the increase in temperatures. These results highlight a general trend towards progressive aridification of the climate in Upper Guinea, characterized by rising temperatures, a relative decrease in humidity and an increase in solar irradiation, with significant implications for natural resources and socio-economic systems.

Keywords: Climate Change; Evolution; Meteorological Parameters; Typical Climate; Upper Guinea.

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1. Introduction

The current climate crisis, characterized by global warming and altered rainfall patterns, represents one of the most serious threats to global ecosystems and socio-economic systems. Recent decades have been marked by record increases in global temperatures, with the last few years consistently being the warmest ever recorded since instrumental observations began [1–3]. Global warming intensifies the hydrological cycle, leading to an increase in the frequency and severity of extreme rainfall events [4]. The African continent is experiencing undeniable signs of anthropogenic climate change. The warming observed throughout the 20th century provides compelling evidence of anthropogenic forcing at the continental scale [5–10]. Observed frequencies of average annual surface temperature show a rapid increase in Africa between 1961 and 2015, with significant warming of 0.1 to 0.2 °C per decade, or even more, in all regions [3].

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Projections from high-emission scenarios, such as RCP8.5, indicate that warming in Africa could exceed 4°C by the end of the century, thus exceeding the global average [11,12].

Within this continental context, West Africa appears as a particularly vulnerable region, with warming rates above the African average. The region has already warmed by approximately 0.5°C in recent decades, with minimum temperatures rising faster than maximum temperatures [13-15]. There has also been an increased frequency of extreme events, including fewer cold nights, more frequent hot days, and more intense heat waves [16-18].

West African countries have experienced a significant increase in average annual rainfall since 2000 [21]. Climate models predict that West Africa could experience 2°C of warming 10 to 20 years earlier than other regions [5, 14, 25, 26]. According to the RCP8.5 scenario, West Africa could see the greatest long-term decrease in the number of rainy days, by 30% [27]. Models from the NASANEX-GDDP project predict increases in temperature and rainfall in West Africa [28], particularly pronounced in the SSP5-8.5 scenario compared to the SSP2-4.5 scenario. Projected changes in the position and intensity of the West African monsoon, the African jet stream, and the African easterly waves are expected to significantly reduce average summer rainfall in West Africa by the end of the 21st century, with primarily negative changes observed in the Sahelian savanna region [29]. However, these projections remain uncertain due to conflicting results from different climate models [30].

Located in West Africa, the Republic of Guinea exemplifies these regional challenges, while also exhibiting unique geographical and climatic characteristics that explain its particular vulnerability. The country has a sub-equatorial climate with distinct dry and wet seasons, and its diverse topography includes coastal plains, mountainous plateaus (Fouta Djallon , Northern Guinea Highlands), and savannas bordering the Sahel. These factors contribute to a complex spatial distribution of climate change, requiring detailed analysis of observed trends and future projections. The Republic of Guinea falls within a humid tropical climate regime, where relatively low natural climate variability creates narrow climatic thresholds that can be easily exceeded by anthropogenic forcing [5]. While the Guinean coast is expected to become wetter, the western Sahel could experience aridification [20].

The Republic of Guinea remains exposed to the threats facing West Africa: decreased annual rainfall, shorter rainy seasons, increased droughts during these seasons, irregular rainfall patterns, and rising temperatures [31,32]. The observed climate changes are already significantly affecting key sectors in Guinea (agriculture, water resources, energy, and public health), making the development of science-based adaptation strategies essential [33–40].

Changes in rainfall patterns and rising temperatures threaten food security, reduce maize yields, and necessitate the selection of climate-resilient crops [34–37]. The increased frequency of droughts and floods disrupts water supplies and limits their availability for agriculture [38]. According to climate model projections, Guinea is expected to experience the greatest decline in water availability among West African countries by the end of the 21st century [38]. Droughts induced by climate change are estimated to have reduced African agricultural production by 21%, resulting in a 9.7% drop in GDP [41]. Irregular rainfall reduces irrigation potential and makes hydroelectric power generation less predictable [33, 39]. Intensified heat waves negatively affect human health and natural ecosystems [40]. In the spring of 2010, many Sahel countries experienced an unprecedented heat wave, with temperatures exceeding 45°C [42]. The African continent has seen the greatest increase in its vulnerability to extreme heat globally (more than 10% since 1990), alongside a greater climatic suitability for the transmission of infectious diseases, notably due to a 38.7% increase in the potential for malaria transmission in mountainous regions since the mid-20th century [43].

This study aims to assess current and future trends in climate change in the Upper Guinea region, more specifically in the prefectures of Kouroussa, Mandiana and Siguiri, based on certain climate parameters.

2. Materials and Methods

2.1. Equipment

2.1.1. Presentation of the study area

Guinea is a country in West Africa, bordered to the north by Senegal, to the northeast by Mali, to the northwest by Guinea-Bissau, to the west by the Atlantic Ocean, to the south by Sierra Leone and Liberia, to the east by Côte d'Ivoire and part of Mali (Figure 1). It has an area of 245,857 km2 [44, 45].

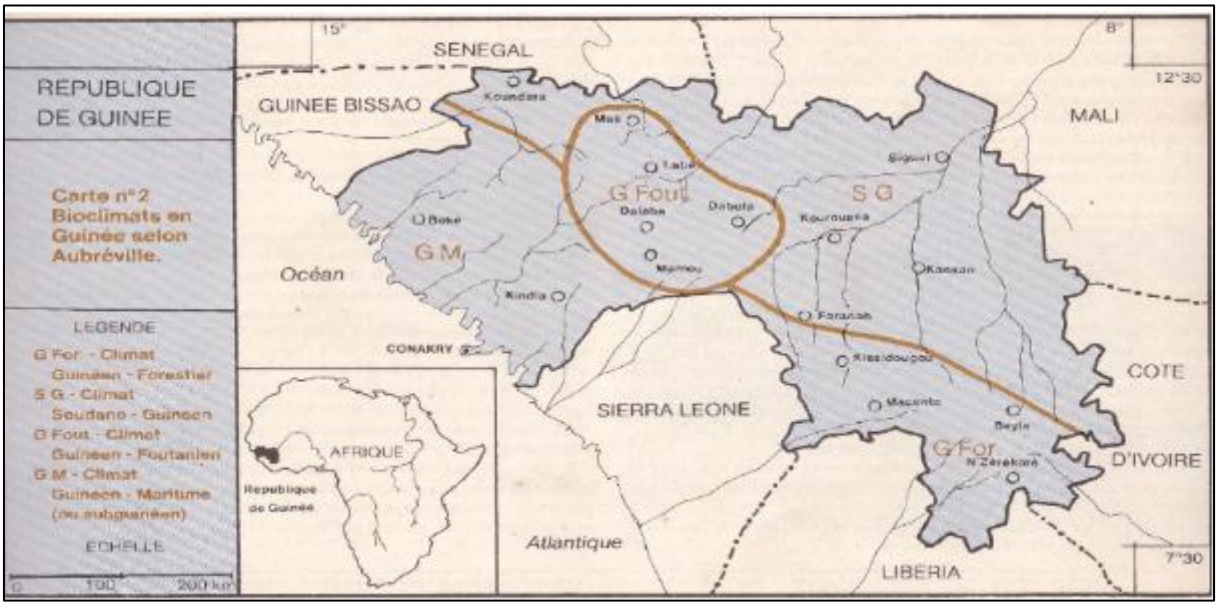

Figure 1 Climate map of the Republic of Guinea [46]

The climate is divided into two zones: tropical and subequatorial. Each of the four regions has its own distinct weather patterns due to the diverse topography. The tropical climate is itself divided into:

Tropical maritime climate in Lower Guinea

The coastal plain experiences the heaviest rainfall and most consistent temperatures. The single rainy season lasts six months with abundant precipitation (an average of 5000 mm), peaking in August. Temperatures range between 23°C and 35°C. Conakry, the capital, receives 4267 mm of rain annually, with an average temperature of 27°C.

Tropical mountain climate in Middle Guinea

This area has a five-month rainy season. Rainfall is less significant, ranging between 1600 mm and 2000 mm, with milder temperatures varying from 20°C to 25°C during the day and from 5°C to 10°C at night in winter.

Sub-Sudanian climate in Upper Guinea

This area has a dry climate, and the rainy season lasts between three and four months, with an annual average of 1500 mm, which is lower on the Mandingo plateau. Temperatures are high almost all year round, except for December and February (15°C instead of 40°C) due to the harmattan wind .

Sub-equatorial climate in Forest Guinea

It is characterized by two rainy seasons, separated by a short dry season (2 to 3 months) which is tending to disappear. During the rainy season, rainfall ranges from 1500 to 2600 mm. The temperature (24°C to 28°C) and humidity remain constant throughout the year.

2.1.2. Tools

As part of this research, we collected meteorological data from the Guinean National Meteorological Directorate for a 23-year observation period (2000–2022). This data covers the following parameters: precipitation, temperature, solar irradiance, and humidity for the prefectures of Kouroussa, Mandiana, and Siguiri in Upper Guinea.

2.2. Method

The methodology adopted in this research consists of analyzing climate data from the prefectures of Kouroussa, Mandiana and Siguiri in the Upper Guinea region, in order to determine trends in order to draw a conclusion regarding climate change and propose mitigation solutions.

3. Results and Discussion

This research has allowed us to obtain several which are presented as follows: the evolution of precipitation, the evolution of temperatures, the evolution of humidity, the evolution of irradiation and the evolution of maximum and minimum temperatures of the three prefectures chosen in Upper Guinea.

Figure 2 shows the rainfall patterns in the prefectures of Kouroussa, Mandiana, and Siguiri. As this figure illustrates, rainfall patterns are similar. Rainfall is higher in the Kouroussa area compared to the other two prefectures, with a peak of 2582 mm observed in 2021. Rainfall was almost identical in 2001, 2002, 2006, and 2007, with average rainfall of around 500 mm.

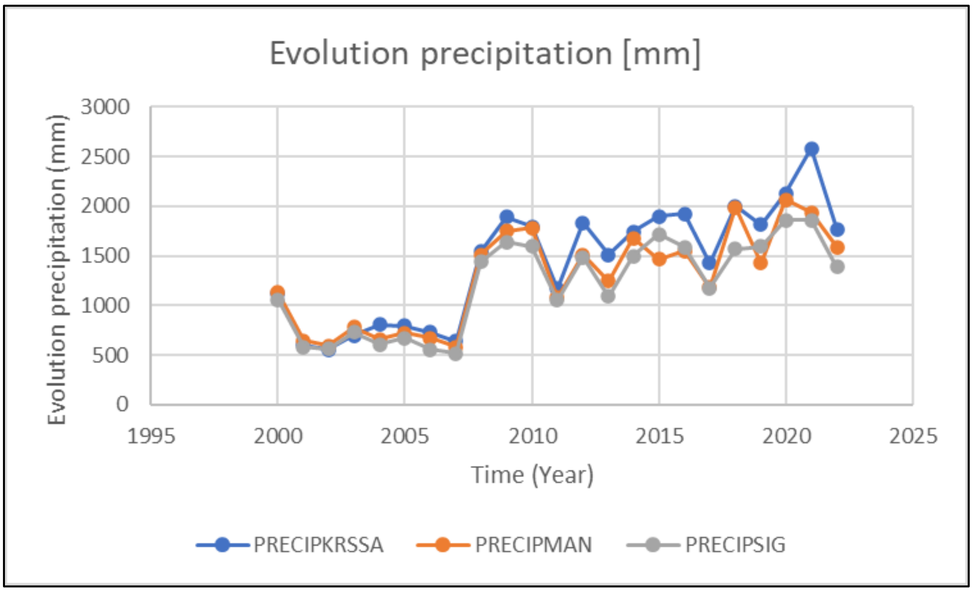

Figure 2 Rainfall trends in the three (3) prefectures

Figure 3 shows the evolution of the average monthly temperature in Kouroussa, Mandiana, and Siguiri. As shown in Figure 3, the temperature curves follow a similar pattern. It appears that throughout all the years of observation shown in this figure, temperatures are higher in Siguiri compared to Kouroussa and Mandiana, with a maximum average temperature of approximately 28.5°C observed in 2002. Based on our analysis of this graph, we note that it is cooler in Kouroussa compared to Siguiri and Mandiana. This is due to the destruction of vegetation cover by mining and the cutting of trees for brickmaking and charcoal production.

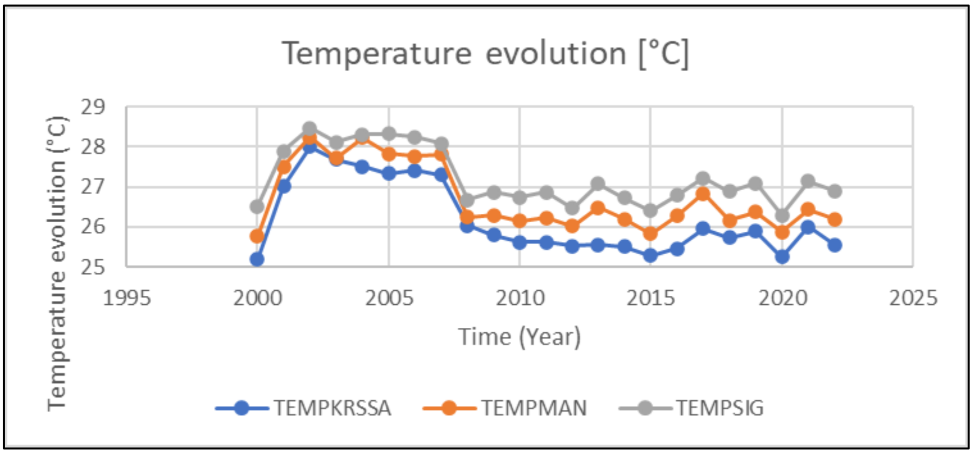

Figure 3 Temperature trends in the three (3) prefectures

Figure 4 shows the evolution of average monthly relative humidity in Kouroussa, Mandiana, and Siguiri. As we can see in this figure, the relative humidity curves have similar shapes. Humidity levels are higher in the Kouroussa prefecture than in Mandiana and Siguiri. Maximum relative humidity levels reach approximately 70% in the Kouroussa area, while the lowest level was observed in Siguiri in 2003, at around 42%.

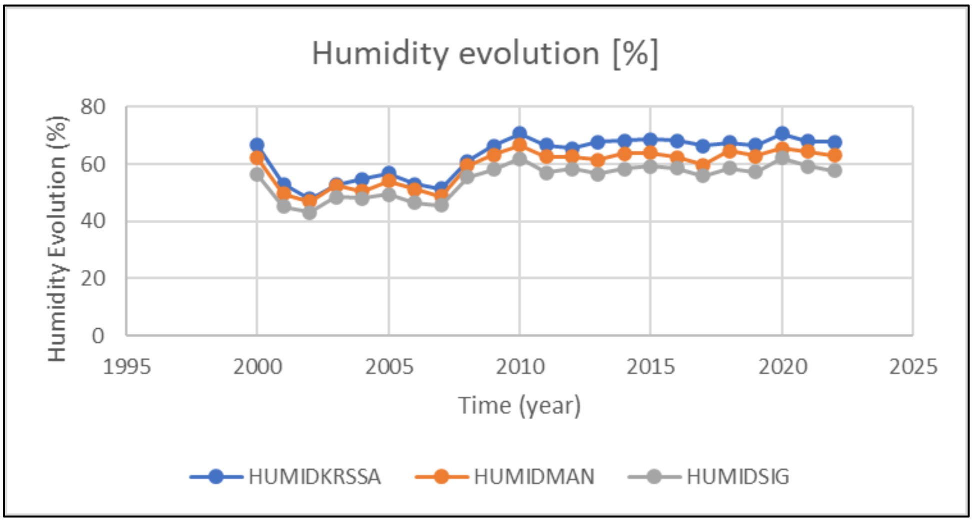

Figure 4 Evolution of humidity in the three (3) prefectures

Figure 5 shows the annual solar irradiance trends in the prefectures of Kouroussa, Mandiana, and Siguiri from 2000 to 2022. This figure reveals that irradiance is significantly higher in Siguiri compared to the other two prefectures (Kouroussa and Mandiana), and the curves maintain a consistent shape throughout all observation periods. The highest irradiance value was observed in 2013 in Siguiri, reaching approximately 5 W/m^2 . This can be attributed to low rainfall throughout the year and a rapid increase in temperatures.

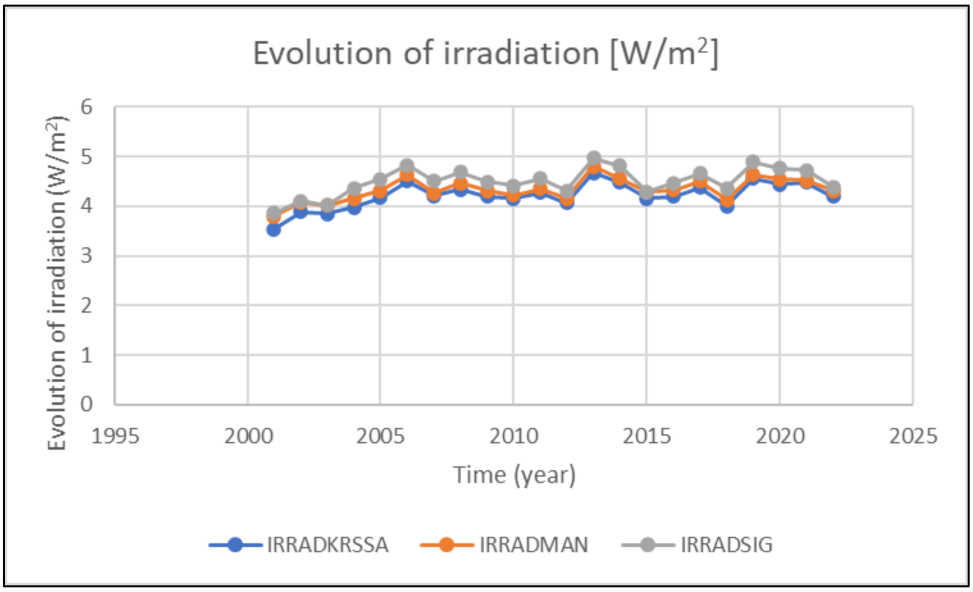

Figure 5 Evolution of solar irradiance in the three (3) prefectures

4. Conclusion

Analysis of climate parameters over a 23-year period (2000–2022) in the prefectures of Kouroussa, Mandiana, and Siguiri reveals significant changes reflecting the influence of climate change in Upper Guinea. The results show consistency in the evolution of the studied climate variables, although spatial disparities remain.

Rainfall exhibits significant interannual variability, with a tendency for precipitation to concentrate in certain years, reflecting an instability in the rainfall pattern. Temperatures, generally high, are more pronounced in heavily human-modified areas such as Siguiri, where mining activities and deforestation contribute to local temperature increases. Relative humidity, meanwhile, decreases in areas most exposed to these environmental pressures, thus exacerbating drought conditions. Solar irradiation, more intense in areas with sparse vegetation cover, confirms this trend toward aridification.

Overall, these changes reflect a gradual shift in the regional climate towards warmer and drier conditions. This trend poses a threat to agricultural systems, water resources, and the region's ecological balance. It also underscores the exacerbating role of human activities in amplifying the effects of climate change at the local level.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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