KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

PRECIPITATION PATTERNS AND ANALYSIS FOR MADAGASCAR

NAME: Pinkrah Nana Ofosuhene

PROGRAM: B.Sc. Meteorology and Climate Science

LEVEL 300

INDEX NUMBER: 4295120

DATE: 03rd MAY, 2023

INTRODUCTION

This report presents the findings of a study on the rainfall patterns in Madagascar over a period of 10 years, from 2001 to 2010. The main objectives is to assess the monthly and annual rainfall totals, their climatologies, and the number of dry and wet days in the region. The study also examines the extreme rainfall events with rainfall intensity greater than 10mm per month and 20mm per month, and also greater than 10mm/year, and 20mm per year.

Precipitation is one of the most important components of the Earth's water cycle. It is the process by which water is released from the atmosphere as rain, snow, sleet, and hail. In many parts of the world, precipitation is an essential part of the hydrological cycle and provides essential freshwater resources for many living beings. In particular, it is an essential factor in helping to sustain vegetation and protecting agricultural land. In regions like Madagascar, it is also particularly important due to its impact on food security and ecosystem health.

Madagascar is an island nation located in the Indian Ocean off the southeastern coast of Africa, and has coordinates of latitude -18.7793 and Longitude 46.8345 in the southern hemisphere, whose capital city is Antananarivo, Antananarivo is the largest city in Madagascar. It is the fifth largest island in the world and has a unique biodiversity, with many endemic species of plants and animals found nowhere else on Earth. The island was first settled by humans around 2,000 years ago, and has been influenced by various cultures, including African, Arab, European, and Asian. The official languages are Malagasy and French, and the economy is largely based on agriculture, fishing, and tourism. Madagascar is known for its beautiful beaches, tropical forests, and diverse wildlife, including lemurs, chameleons, and baobab trees.

Madagascar has a tropical climate with two distinct seasons: a rainy season from November to April and a dry season from May to October. The amount of precipitation varies greatly across the island, with the eastern side receiving much more rain than the western side.

The eastern coast of Madagascar is known for its high rainfall, with some areas receiving over 4,000 mm of rain per year. This is due to the prevailing winds, which brings moisture-laden air from the Indian Ocean and cause it to rise and cool, resulting in heavy rainfall.

In contrast, the western side of Madagascar is much drier, with some areas receiving less than 500 mm of rain per year. This is due to the rain shadow effect caused by the central highlands, which block the moist air from the east and cause it to drop its moisture before reaching the western coast.

The variation in precipitation across Madagascar has a significant impact on the country's ecosystems, with the eastern rainforests supporting a rich diversity of plant and animal life, while the western dry forests are adapted to survive in arid conditions. However, deforestation and climate change are threatening both ecosystems, highlighting the need for sustainable conservation efforts.

MAIN OBJECTIVES

To assess the monthly and Annual rainfall patterns, variations, trends and impact of climate extremes in Madagascar over a period of 10years from 2001 to 2010.

SPECIFIC OBJECTIVES

1. To identify the monthly variation and trends in rainfall patterns in Madagascar.

2. To establish the average annual rainfall, which is helpful for agriculture and water management planning.

3. To establish the dry and wet days per month and per year

4. To identify areas that are at risk of flooding during extreme rainfall events of about 10mm and 20mm.

RESEARCH QUESTIONS

1. What are the monthly and annual rainfall patterns in Madagascar from 2001 to 2010?
2. How do the rainfall patterns vary across different regions in Madagascar?
3. What is the number of dry and wet days in Madagascar, and how has it changed over time?
4. What is the frequency and intensity of extreme rainfall events in Madagascar in the year 2001 to 2010, and how has it changed over time?

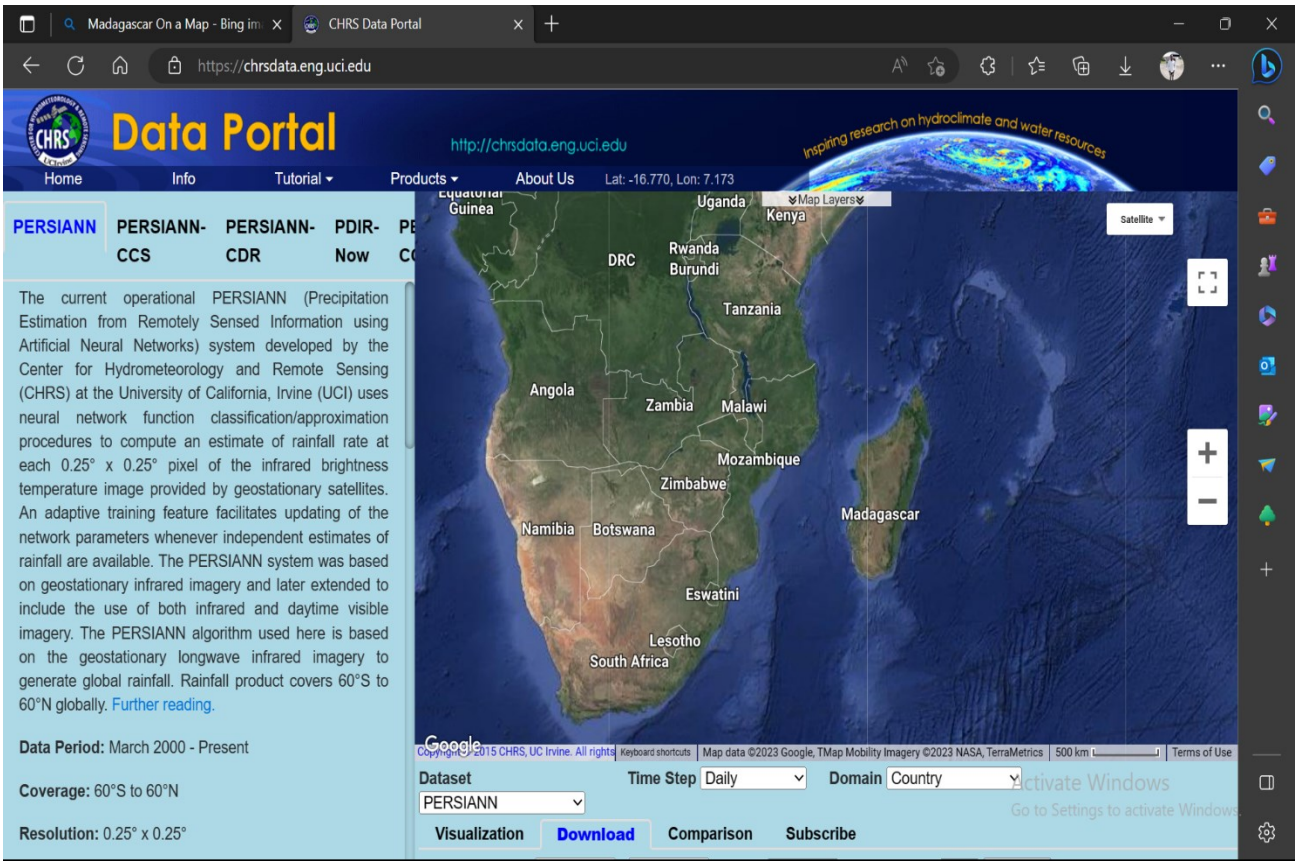
DESCRIPTION OF MADAGASCAR AND DATASETS

Madagascar is an island nation located in the Indian Ocean off the southeastern coast of Africa, and has coordinates of latitude -18.7793 and Longitude 46.8345 in the southern hemisphere, whose capital city is Antananarivo, Antananarivo is the largest city in Madagascar. It is the fifth largest island in the world and has a unique biodiversity, with many endemic species of plants and animals found nowhere else on Earth. Madagascar has a tropical climate with two distinct seasons: a rainy season from November to April and a dry season from May to October. The amount of precipitation varies greatly across the island, with the eastern side receiving much more rain than the western side.

The daily datasets of Madagascar was downloaded from the Climate Hazards Group Infrared Precipitation with Station data (CHIRPS) dataset in netcdf file and a decade from 2001 to 2010 was selected and the datasets was sent to a mail provided, after downloading the datasets it came in a zip file and was extracted, which contains 16 files of which 10 are the actual data which contains the precipitation data of years selected, and one also contains information about the file

example: units, number of rows, number of columns, missing values and coordinates. The eastern coast of Madagascar is known for its high rainfall, with some areas receiving over 4,000 mm of rain per year. This is due to the prevailing winds, which brings moisture-laden air from the Indian Ocean and cause it to rise and cool, resulting in heavy rainfall.

The CHIRPS dataset provides an opportunity to better understand the spatiotemporal patterns of rainfall in Madagascar and their long-term trends and variability. The dataset covers the period from 2001 to 2010, which encompasses a decade of significant climate variability.



METHODOLOGY USED TO PERFORM THE ANNUAL AND MONTHLY RAINFALL PATTERNS IN MADAGASCAR

The daily rainfall datasets for Madagascar from 2001 to 2010, was obtained from the Climate Hazards Group Infrared Precipitation with Station data (CHIRPS) dataset. The data was processed using Python Xarray, a library for working with labeled multi-dimensional arrays. The following assessments are performed:

1. The daily datasets of precipitation in mm/day was merged together using Climate Data Operators (CDO), where all time in individual netcdf files from 2001 to 2010 were merged together in one netcdf file
2. Monthly rainfall totals and their long-term climatologies were computed for each month of the decades. The climatology was computed by averaging the monthly totals over the years 2001 to 2002.
3. Annual totals was computed across Madagascar, by summing all years of the decades, and averages were also obtained by finding the mean of the decades 2001 to 2010 and a time series plot was produced to show year-to-year changes and trends.
3. The number of dry and wet days (per month) was computed by finding the sum of the decades and were grouped into 12 months, afterwards, precipitation less than one(1) was selected to be dry and precipitation greater than or equal to 1 (RR>=1) was also selected to be wet, for the number of dry and wet days (per year), it was computed by finding the sum of the decades and were grouped into 10 various years, afterwards, precipitation less than one(1) was selected to be dry and precipitation greater than or equal to 1 (RR>=1) was also selected to be wet , and spatial and time-series plot for visualizations were produced.
4. The number of extreme rainfall in days (per month) was computed by finding the sum of the decades and were grouped into 12 months, afterwards, precipitation greater than 10 (RR>10) was selected to be extreme rainfall, and precipitation greater than 20 (RR>=20) was also selected extreme rainfall for the 12 months, and for the number of extreme rainfall in days (per year), was also computed by finding the sum of the decades and were grouped into 10 various years, afterwards, precipitation greater than 10 (RR>10) was selected to be extreme rainfall, and precipitation greater than 20 (RR>=20) was also selected extreme rainfall for the 10 selected decades(2001 to 2010)

RESULTS AND DISCUSSION

QUESTION 1

MONTHLY RAINFALL TOTALS FOR EACH MONTH

MONTHLY RAINFALL TOTALS FOR EACH MONTH FOR EACH MONTH

MONTHS	YEARS									
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	2010
	MONTHLY PRECIPITATION(mm/day)									
January	385.9	212.9	447.2	350.4	262.22	221.2	526.0	175.4	267.9	312.9
February	202.3	319.1	85.4	225.6	183.52	164.1	392.4	228.8	72.8	136.1
March	220.3	225.3	252.9	353.4	155.9	152.6	103.6	56.1	318.5	190.4
April	34.0	15.9	21.4	42.7	13.82	37.5	56.3	22.3	70.0	17.4
May	0.24	79..6	33.1	0.00	12.5	13.4	0.00	0.42	0.00	4.5
June	0.00	0.00	0.00	0.00	0.2	0.00	0.00	0.00	0.00	4.2
July	0.00	0.00	0.00	0.00	14.21	1.23	0.00	0.00	0.2	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.7	0.2	0.00
September	0.00	1.71	0.92	0.00	0.00	0.00	2.4	7.7	0.00	0.00
October	32.23	34.4	32.6	62.5	1.30	16.4	33.4	50.4	28.9	79.2
November	101.4	168.8	137.4	93.9	160.47	203.5	194.6	243.9	39.2	135.5
December	195.0	233.3	188.9	501	493.45	325.4	227.5	268.6	163.2	282.8

For monthly rainfall totals of Madagascar in the years 2001 to 2010 the highest amount of rainfall was recorded in January, 2007 of an amount of 526.010010mm/day, and the least amount of rainfall was recorded was mostly recorded in (June, July, August, September).

From the results above, it is clear that precipitation patterns in Madagascar vary greatly over the course of the year. The amount of precipitation is much higher during the wet season, which lasts from November to April. The highest amount of monthly precipitation occurs in December, followed by February, November, and March. Whilst, from May to October, Madagascar experiences its dry season, with very little precipitation and the lowest monthly amounts of precipitation occurring in May, June, and July.

This is indicative of a strong natural variability in precipitation patterns, due to weather patterns such as the Indian Ocean Dipole and El Niño.

Extreme rainfall events and extended periods of dryness can occur in Madagascar during both the wet and dry seasons. During the wet season, especially in the months of December and January, extreme rainfall events can lead to significant flooding and damage, particularly in agricultural or low-lying areas. During the dry season, extended periods of dryness can increase the risk of drought and crop failure, leading to food insecurity and other negative impacts.

THEIR LONG TERM CLIMATOLOGY

MONTHS	PRECIP/**(mm)**
January	316.2
February	201.0
March	202.9
April	33.1
May	14.4
June	0.43
July	1.56
August	0.09
September	1.27
October	37.14
November	147.9
December	287.9

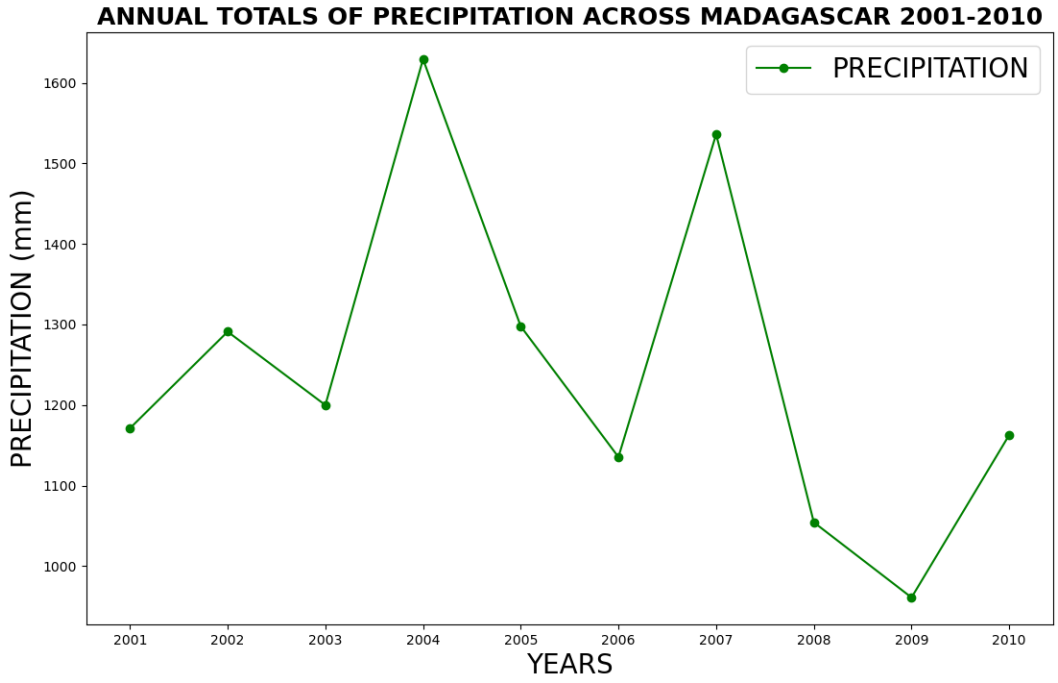
The long-term climatology of precipitation for Madagascar shows that it has a seasonal pattern, with the wet season being from November to March and the dry season from April to October. During the wet season, precipitation totals are much higher, especially in December and January. During the dry season, less rainfall is expected, with the lowest amounts in June and July.
From the table it appears that Madagascar's wet season occurs from December to March, with rainfall totals reaching a maximum of 316.2mm in January. This is followed by a period of moderate precipitation from April to October, with a minimum of 0.43mm in June. The dry season is from November to May, with a maximum total of 287.9mm in December and a minimum of 0.09mm in August. The data indicate that some areas of Madagascar may experience extreme precipitation events and extended dry periods during both the wet and dry seasons.

These patterns can lead to a variety of events, both during the wet and dry seasons. During the wet season, extreme precipitation events can lead to flooding, landslides, and other natural disasters. During the dry season, extended periods of dryness can increase the risk of drought, leading to water shortages and crop failure. Both of these events can have severe and long-term impacts on ecosystems, food security, and sustainable development in the region.

QUESTION TWO

ANNUAL TOTALS OF PRECIPITATION ACROSS MADAGASCAR

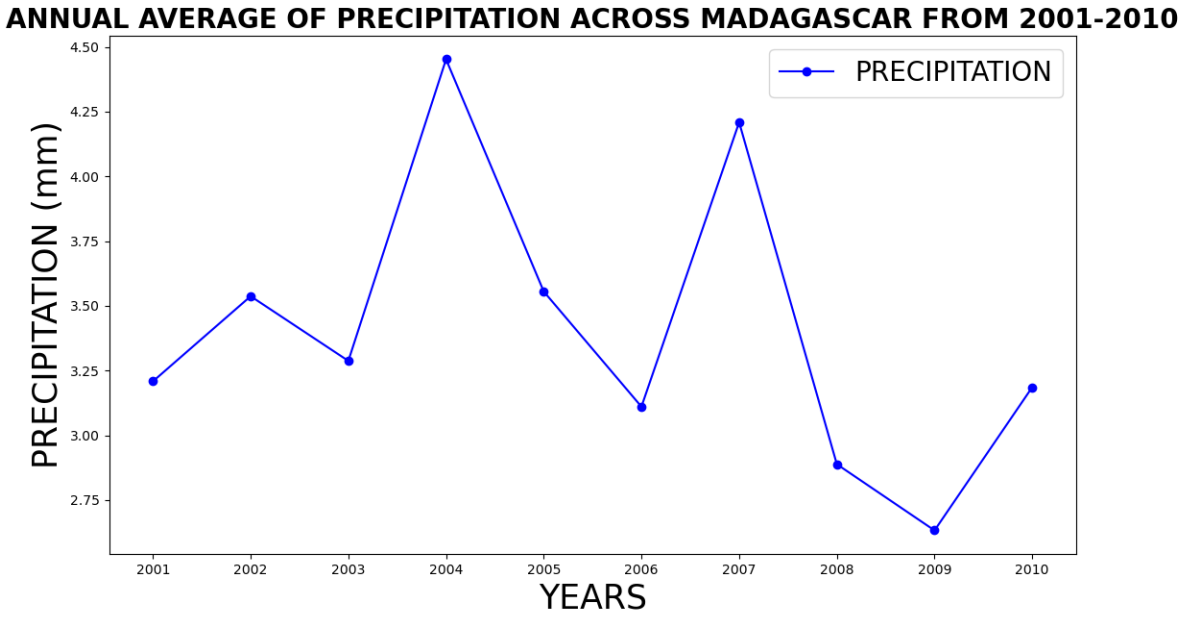
YEARS	PRECIP/(mm)
2001	1171.1
2002	1291.0
2003	1199.9
2004	1629.4
2005	1297.7
2006	1135.4
2007	1536.1
2008	1054.3
2009	961.0
2010	1162.8



This data indicates that Madagascar has experienced variations in average annual precipitation levels between the years 2001 and 2010. When graphed as a timeseries plot, this dataset reveals that the highest amount of rainfall occurred in 2004 with 1629.4mm and that the lowest amount of rainfall was recorded in 2009 with 961mm. In general, this data also shows that precipitation in Madagascar has been in a state of flux over the past decade, with the lowest amounts of rainfall occurring during 2003 and 2009. Their peaks are bimodal.

ANNUAL AVERAGES ACROSS MADAGASCAR

YEARS	PRECIP/(mm)
2001	3.21
2002	3.54
2003	3.29
2004	4.45
2005	3.56
2006	3.11
2007	4.21
2008	2.89
2009	2.63
2010	3.19



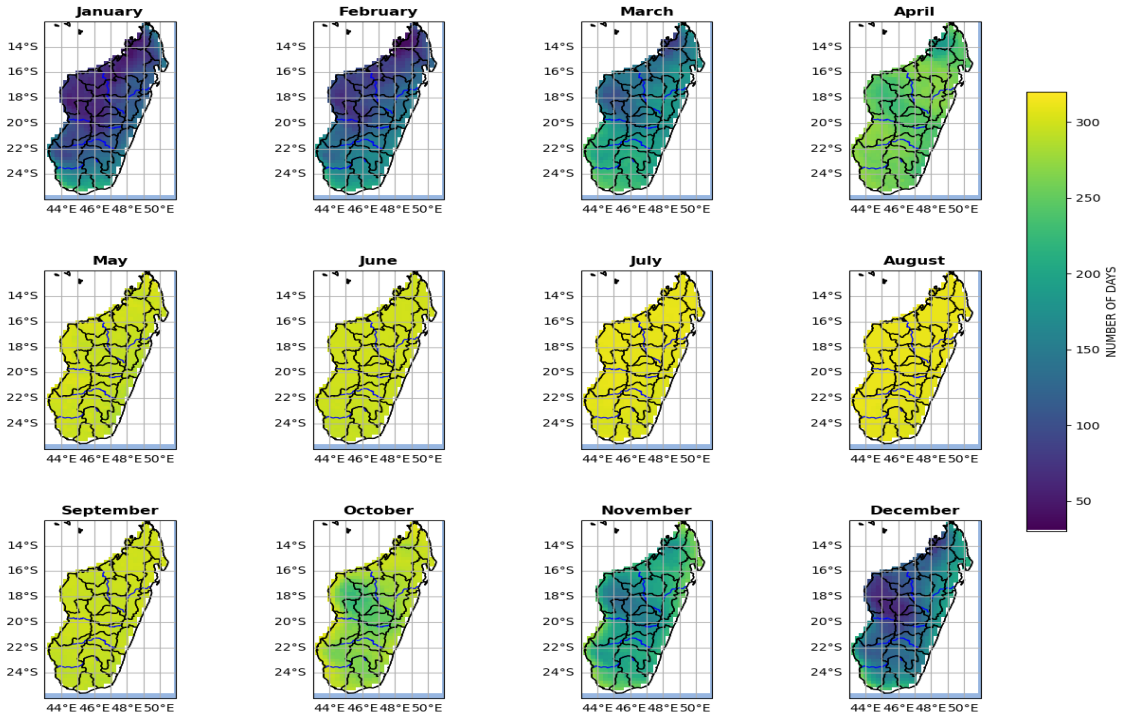
Annual average of precipitation across Madagascar, from the years 2001-2010, From the table and timeseries plot are the same, this data reveals that the highest amount of rainfall occurred in 2004 with 4.45mm and that the lowest amount of rainfall was recorded in 2009 with 2.63mm. On an average the data also shows that annual mean precipitation in Madagascar has generally remained relatively stable over this timespan. From the peaks it can be concluded that they are bimodal. The data suggests that Madagascar experiences both wet and dry seasons, which contributes to the bimodal pattern as seen in the timeseries plot

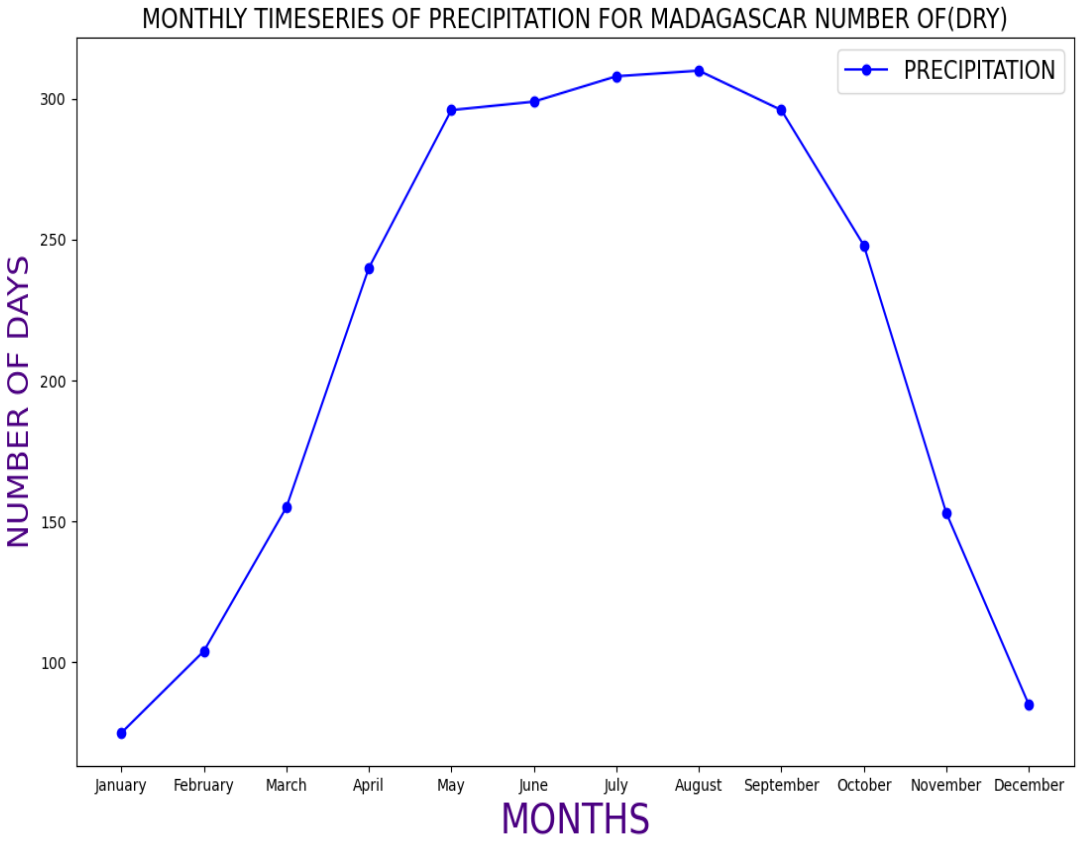
QUESTION 3

NUMBER OF DRY (RR<1) DAYS PER MONTH

MONTHS	NUMBER OF DAYS
January	75
February	104
March	155
April	240
May	296
June	299
July	308
August	310
September	296
October	248
November	153
December	85

THE NUMBER OF DRY (RR<1) MONTHLY PRECIPITATION ACROSS MADAGASCAR FROM YEAR 2001-2010)



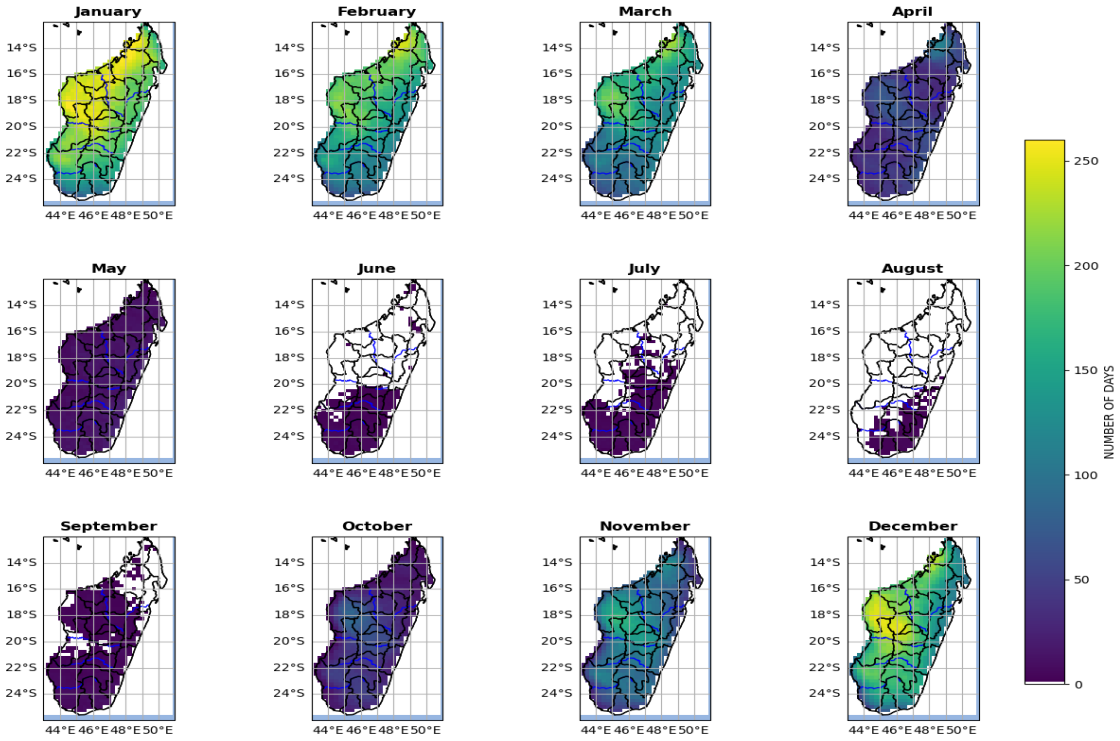


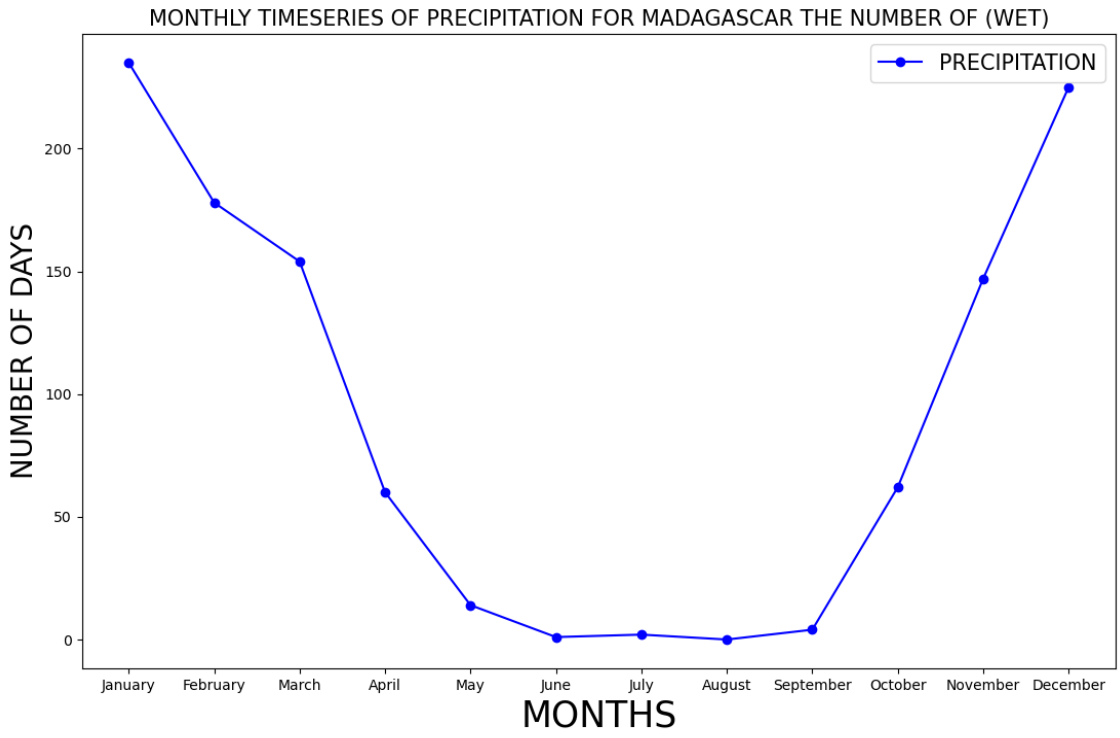
From the table, spatial plot and timeseries for the number of dry days per month are the same for the understanding of climate variability in Madagasar. It can be observed from both the table, spatial and timeseries plots that the dry season in Madagascar from 2001 to 2002, mostly starts from April, May, June, July,August, September and October. It also indicates that Madagascar experiences a wet season from December to March, with the highest amount of rainfall occurring in January. During the dry season, which occurs from April to October, the amount of rainfall decreases significantly. From the plots provided, some areas of Madagascar may experience extreme precipitation events and extended dry periods during both the wet and dry seasons. This could adversely impact food security, ecosystems, and sustainable development in the region.

THE NUMBER OF WET (RR>=1) DAYS PER MONTH

MONTHS	NUMBER OF DAYS
January	235
February	178
March	154
April	60
May	14
June	1
July	2
August	0
September	4
October	62
November	147
December	225

UMBER OF WET (RR>1) MONTHLY PRECIPITATION ACROSS MADAGASCAR FROM YEAR 2001-2010 WE



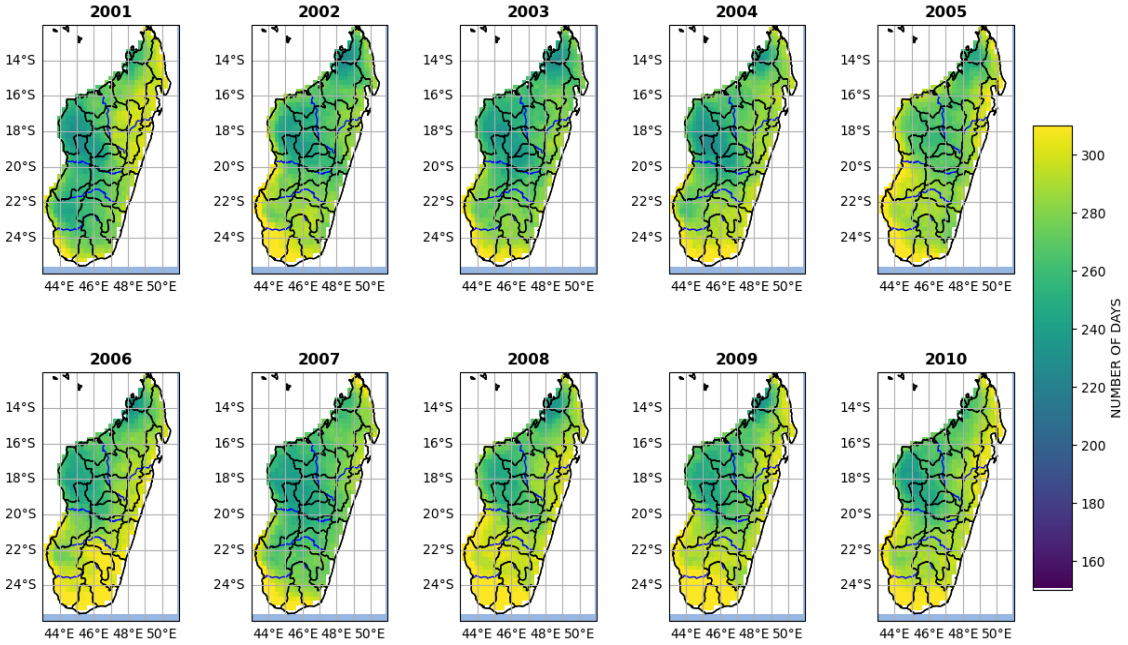


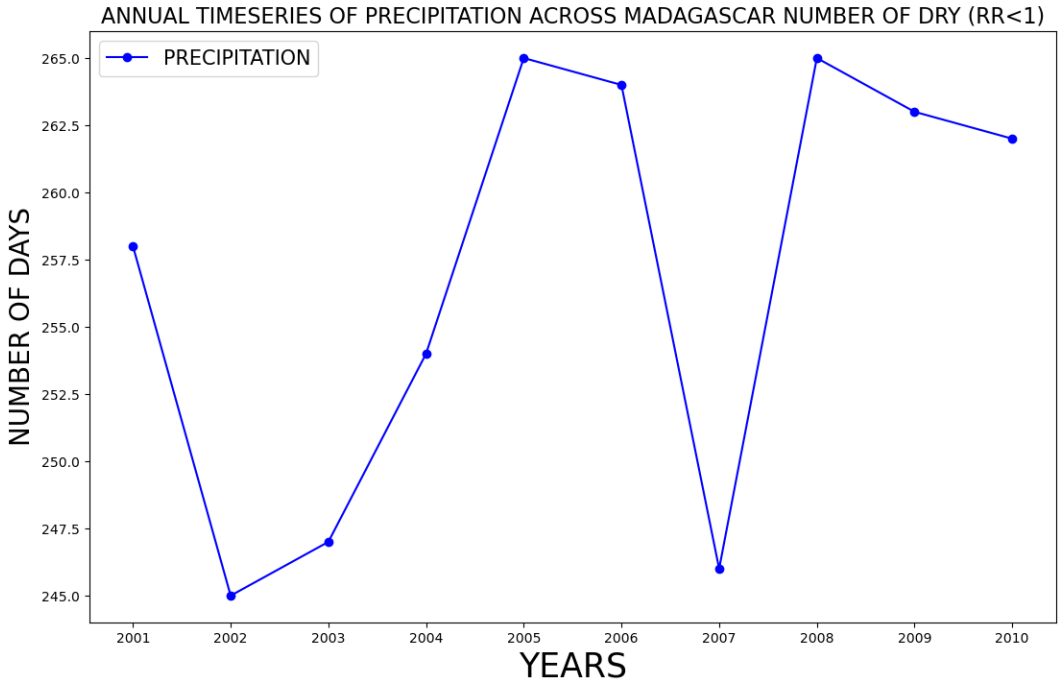
The results above are the same for both table, spatial, and timeseries plots, From this, we can observe that Madagascar has a very wet season which starts from December to March, with the most rainfall in January, and followed by December and a dry season which occurs from April to November. The results indicates that January had the highest number of precipitation in 235days, followed by December with 225 days. The months with the lowest number of days of precipitation were recorded in August with 0 days, followed by June with 1 day, and May with 14days. From the spatial plot the uncovered areas didn't experience the wet season, areas like Antananarivo, Antsohiny did not experience the wet season or precipitation greater than one in both June, July and August. During the wet season that is from December to March, precipitation were higher in the Northern parts of the country and low in the Southern part of the country.

THE NUMBER OF DRY (RR<1) DAYS PER YEAR

YEARS	NUMBER OF DAYS
2001	258
2002	245
2003	247
2004	254
2005	265
2006	264
2007	246
2008	265
2009	263
2010	262

THE NUMBER OF DRY (RR<1) ANNUAL PRECIPITATION ACROSS MADAGASCAR FROM YEAR 2001-2010



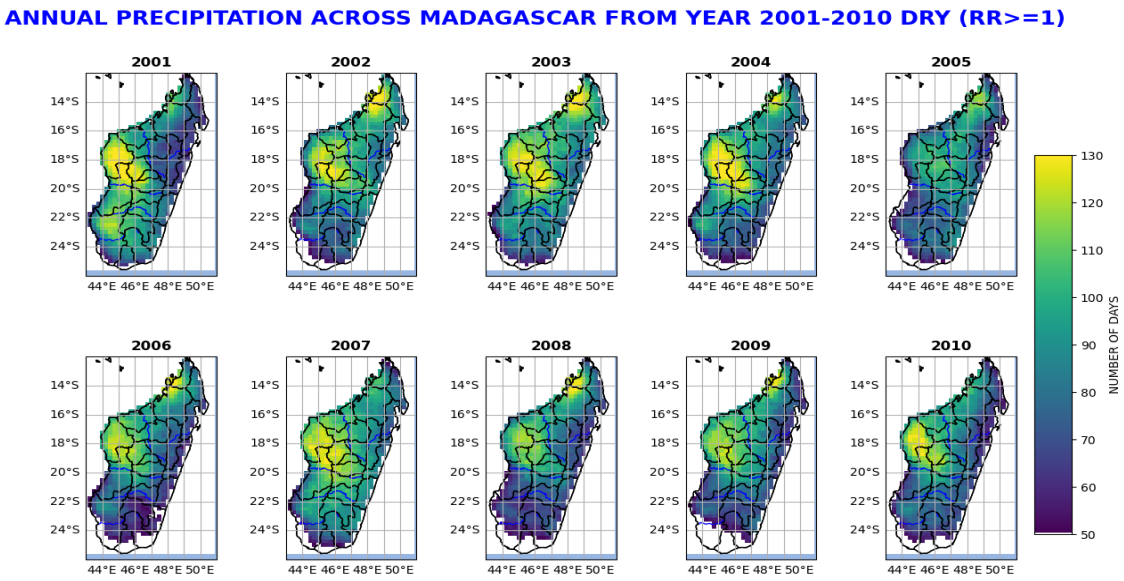


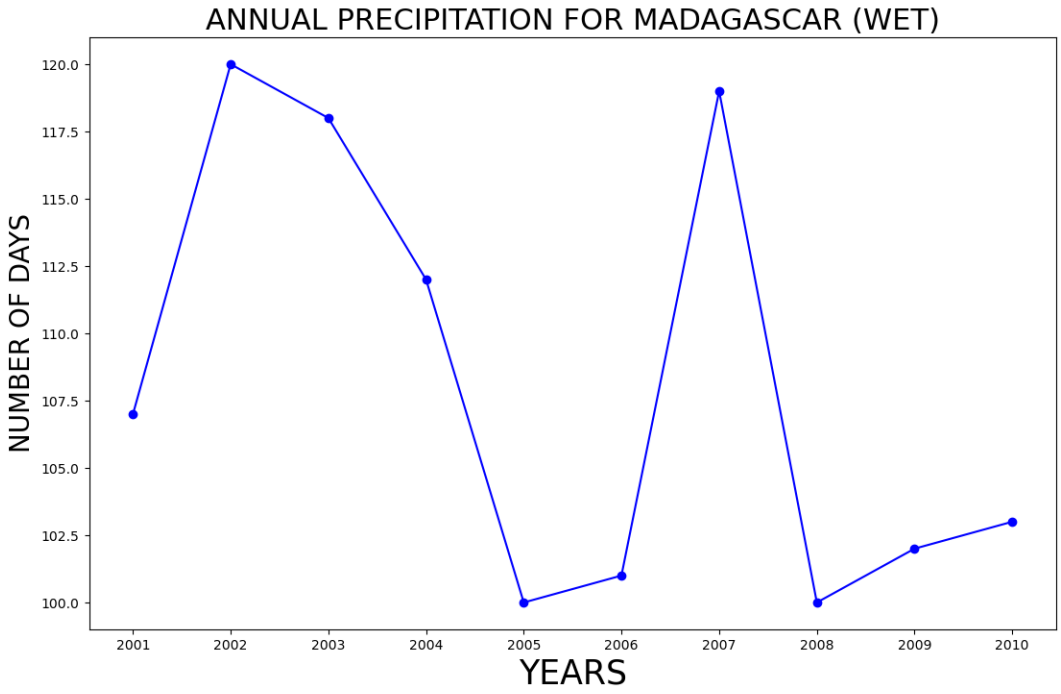
From the spatial plots the number of dry days were higher in the Southern part of the country than the Northern part of the country through the decades 2001 to 2010

From the results provided, it appears that there is some variability in the number of dry days per year. The range of the data is from 245 to 265 days, with an average of approximately 257 days per year. The highest number of dry days from the plots was recorded in 2008 and the least amount of the number of dry days was recorded in 2002, which shows there were some climate variabilities in the year 2001 to 2010 in Madagascar.

THE NUMBER OF WET (RR>=1) DAYS PER YEAR

YEARS	NUMBER OF DAYS
2001	107
2002	120
2003	118
2004	112
2005	100
2006	101
2007	119
2008	100
2009	102
2010	103



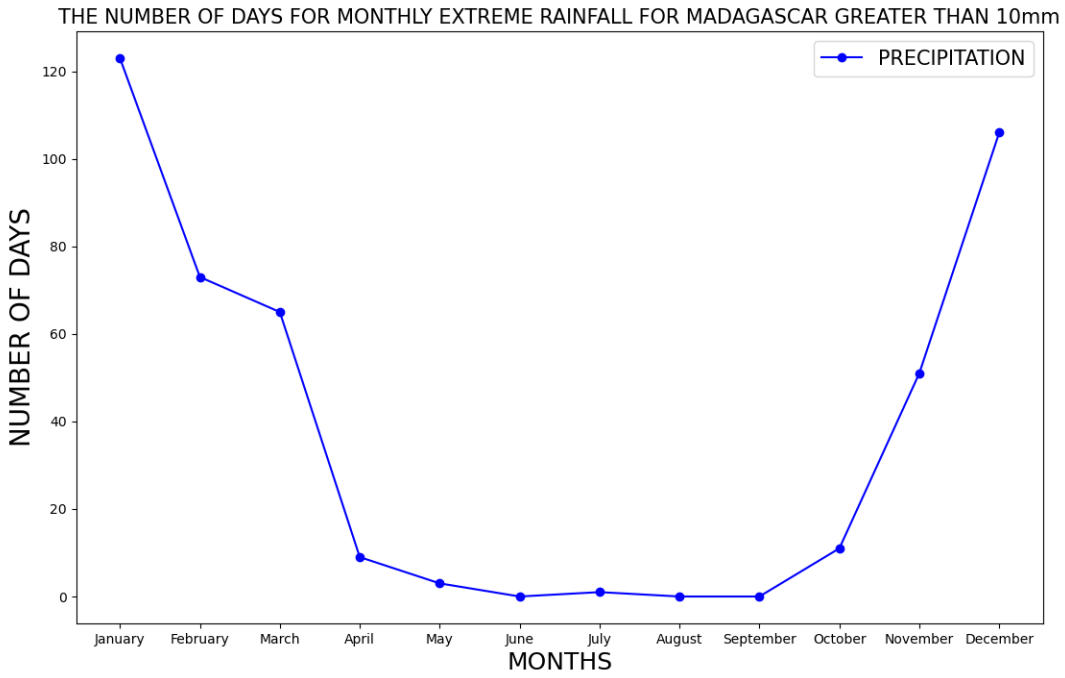


Based on the plots, from the number of wet days per year in Madagascar, there is some variation in the number of wet days per year in Madagascar over the 10-year period. The highest number of wet days was recorded in 2002 with 120 days, while the lowest number of days was recorded in 2005 with only 100 days. Overall, the result suggests that Madagascar experiences a relatively consistent number of wet days per year, with most years falling within the range of 100-120 days. For the spatial some Southern parts of Country didn't record any value as a result of they didn't experience wet season, but they experience dry seasons

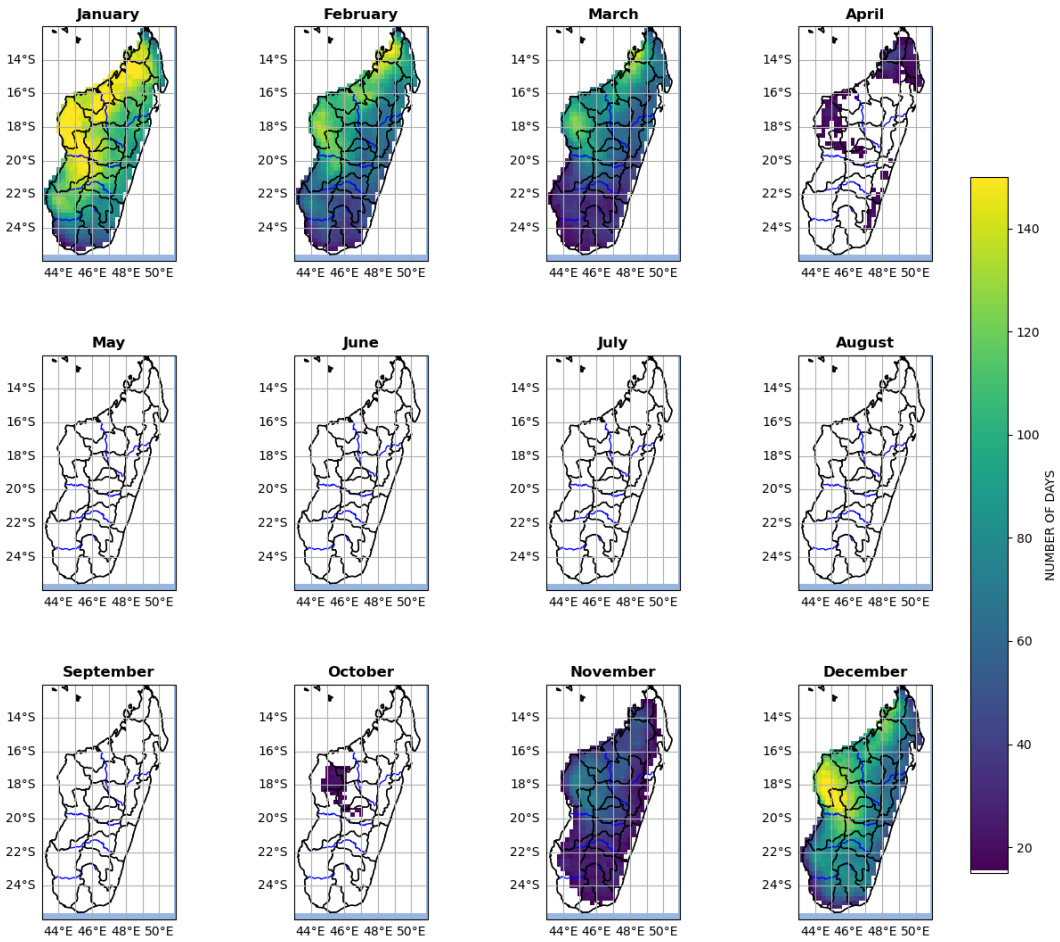
QUESTION 4

NUMBER OF EXTREME RAINFALL (RR>10) DAYS PER MONTH

MONTHS	NUMBER OF DAYS
January	123
February	73
March	65
April	9
May	3
June	0
July	1
August	0
September	0
October	11
November	51
December	106



NUMBER OF DAYS FOR EXTREME PRECIPITATION(RR>10) PER MONTH ACROSS MADAGASCAR 2001-2010

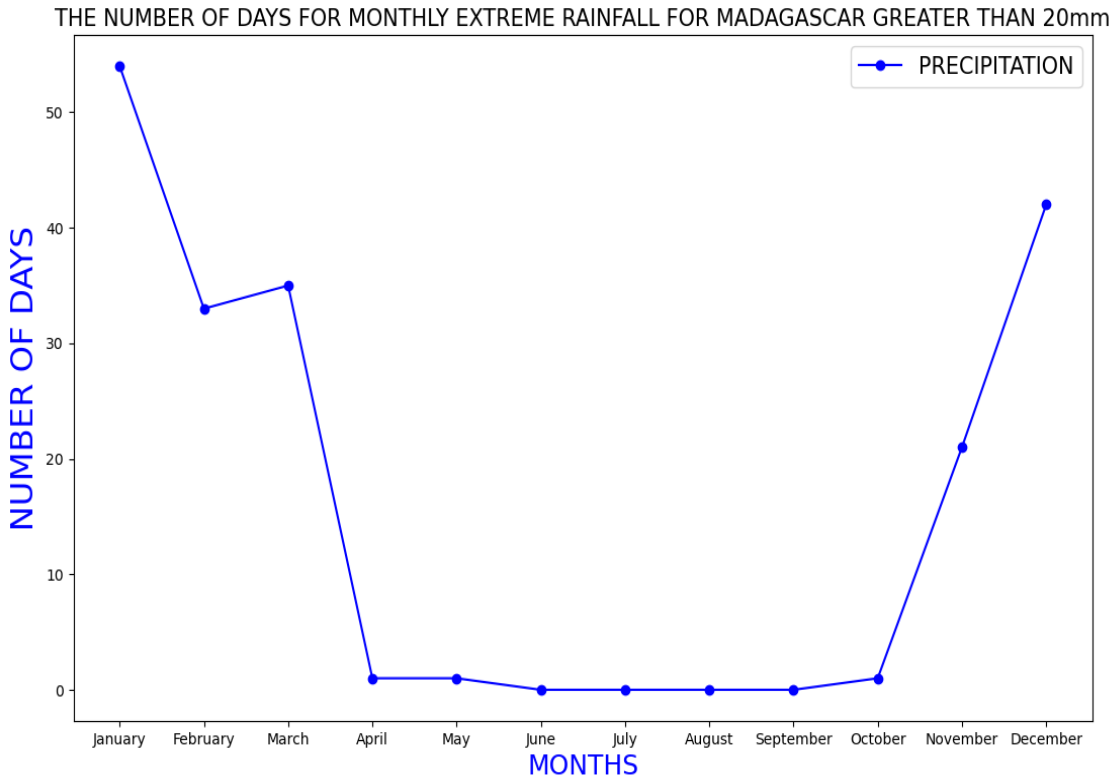


The results presented shows the number of extreme rainfall days per month in Madagascar, with January having the highest number at 123 days and July, and August andSeptember having no extreme rainfall days. This highlights the variability of extreme weather events in the region and the potential impacts on agriculture, infrastructure, and human livelihoods. From the spatial plots areas with no extreme precipitation are the dry season in Madagascar and areas of extreme rainfall are the wet season in Madagascar.

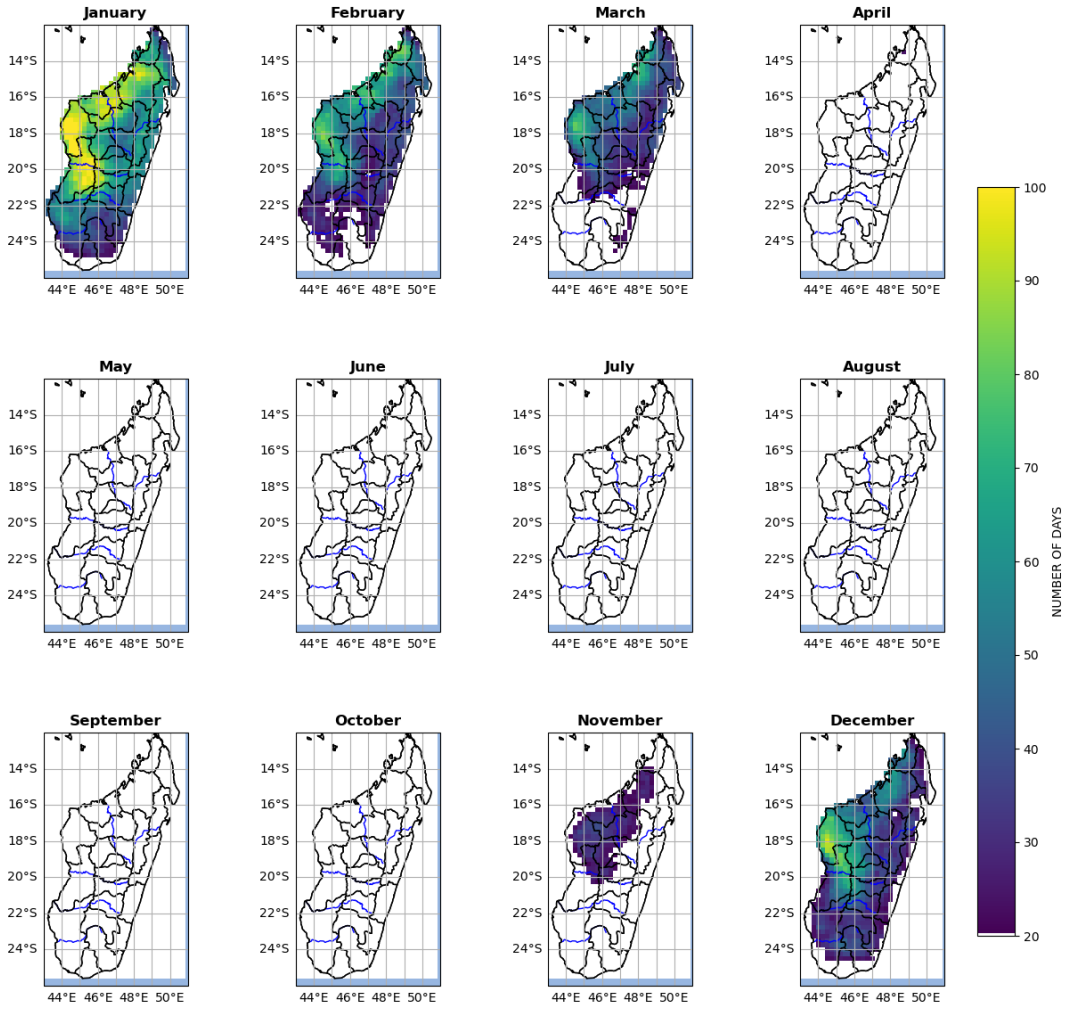
The high number of extreme rainfall days in January, November, and December could lead to flooding and damage to crops and infrastructure. On the other hand, the low number of extreme rainfall days in June, July, and August could lead to droughts and water scarcity, which can also have significant impacts on agriculture and human livelihoods.

NUMBER OF EXTREME RAINFALL (RR>20) DAYS PER MONTH

MONTHS	NUMBER OF DAYS
January	54
February	33
March	35
April	1
May	1
June	0
July	0
August	0
September	0
October	1
November	21
December	42



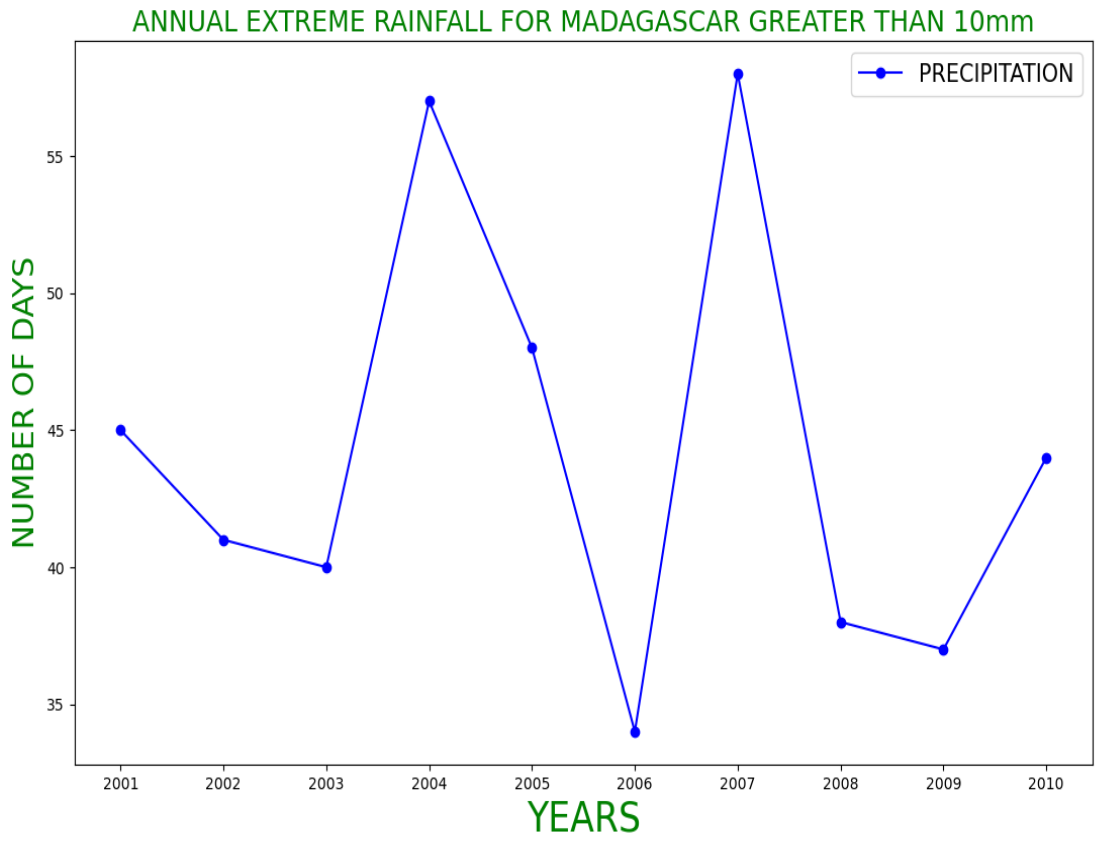
NUMBER OF DAYS FOR EXTREME RAINFALL(RR>20) PER MONTH ACROSS MADAGASCAR 2001-2010

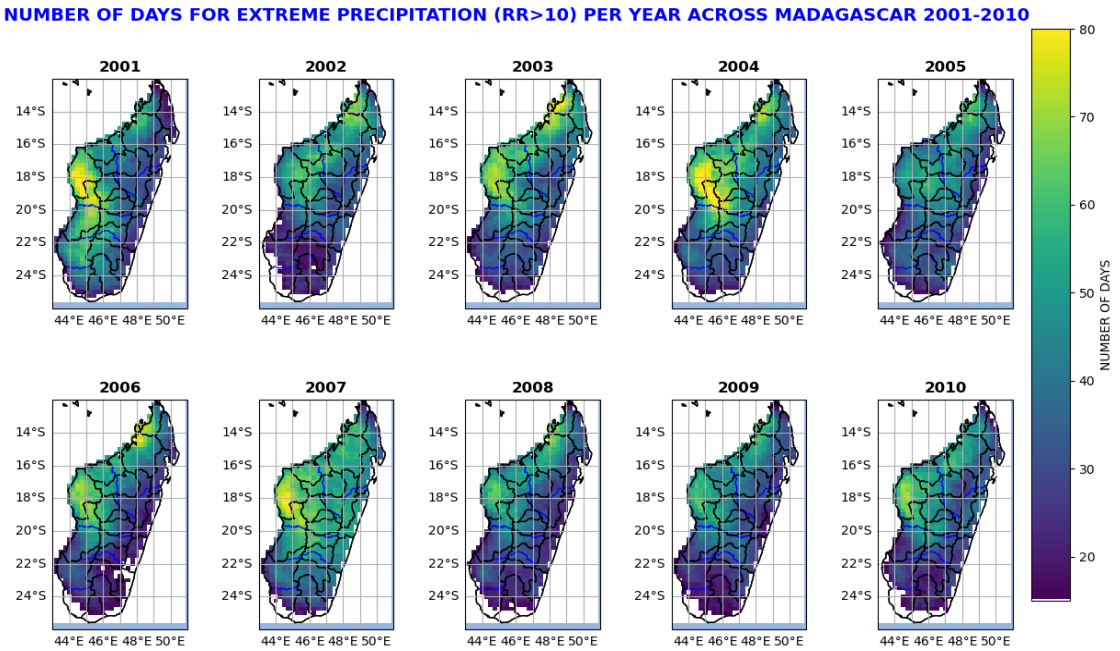


The high number of extreme rainfall days in January, November, and December suggests that these months are particularly vulnerable to flooding and damage to crops and infrastructure. On the other hand, the low number of extreme rainfall days in June, July, and August highlights the risk of droughts and water scarcity during these months, which can also have significant impacts on agriculture and human livelihoods, climate change is expected to exacerbate these risks, making it crucial to continue monitoring and adapting to these extreme weather events. This could involve implementing measures such as improving drainage systems to mitigate flooding or investing in water storage and irrigation systems to combat droughts.

NUMBER OF EXTREME RAINFALL (RR>10) DAYS PER (YEAR)

YEARS	NUMBER OF DAYS
2001	45
2002	41
2003	40
2004	57
2005	48
2006	34
2007	58
2008	38
2009	37
2010	44

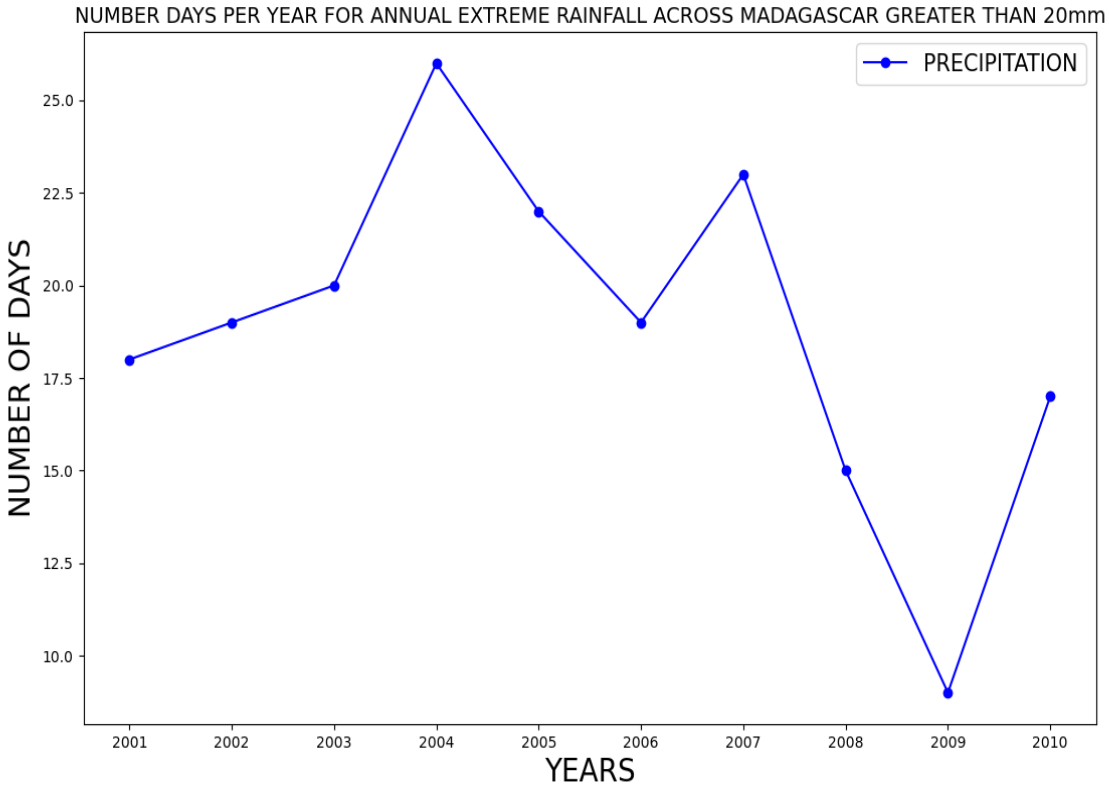


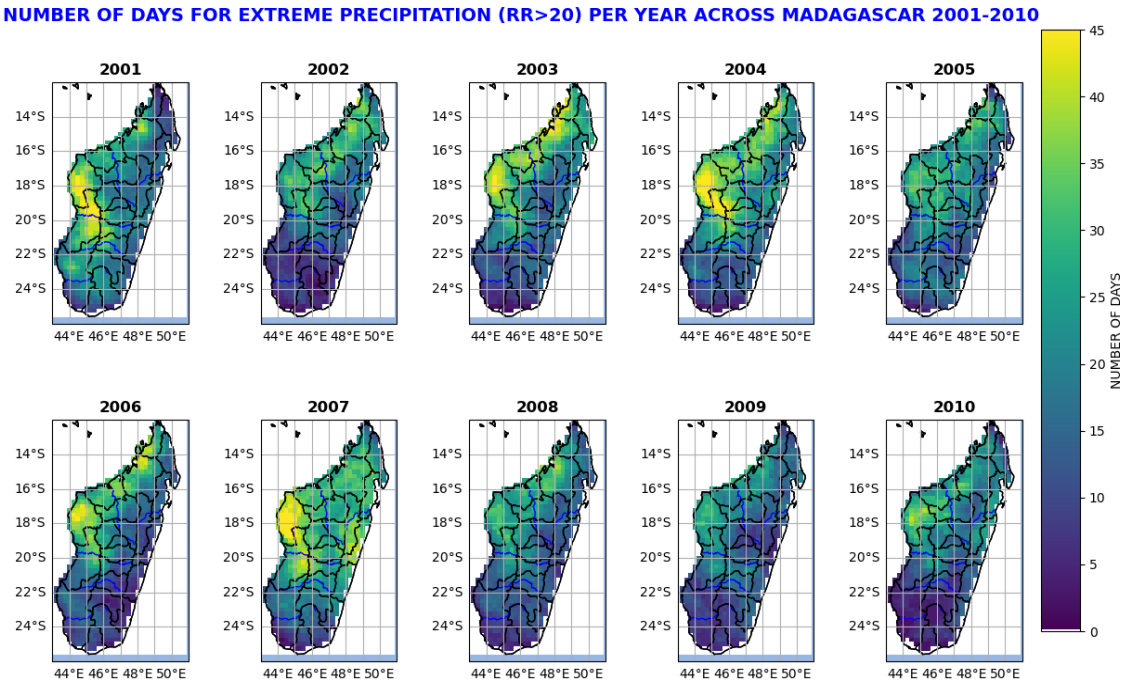


The result presented shows the number of extreme rainfall days in Madagascar per year from 2001 to 2010. Extreme rainfall events are defined as days with rainfall greater than 10mm. The data provides insights into the frequency of extreme weather events in Madagascar and highlights the potential risks and impacts of these events on agriculture, infrastructure, and human livelihoods.The data shows that the number of extreme rainfall days varies from year to year, with a high of 58 days in 2007 and a low of 34 days in 2006. However, there is a clear pattern in the distribution of extreme rainfall days throughout the year. The months of January, November, and December have the highest number of extreme rainfall days, while June, July, and August have the lowest number.The high number of extreme rainfall days in January, November, and December suggests that these months are particularly vulnerable to flooding and damage to crops and infrastructure. This highlights the importance of implementing measures such as improving drainage systems to mitigate flooding and investing in infrastructure that can withstand extreme weather events. On the other hand, the low number of extreme rainfall days in June, July, and August highlights the risk of droughts and water scarcity during these months. This can have significant impacts on agriculture and human livelihoods, particularly in rural areas where agriculture is the primary source of income. It is important to invest in water storage and irrigation systems to combat droughts and ensure the sustainability of agriculture and human livelihoods.

NUMBER OF EXTREME RAINFALL (RR>20) DAYS PER (YEAR)

YEARS	NUMBER OF DAYS
2001	18
2002	19
2003	20
2004	26
2005	22
2006	19
2007	23
2008	15
2009	9
2010	17





The results presented shows the number of extreme rainfall days in Madagascar per year from 2001 to 2010. The number of extreme rainfall days varies from year to year, with a high of 26 days in 2004 and a low of 9 days in 2009. Looking at each individual year, the number of extreme rainfall days ranged from 9 days in 2009 to 26 days in 2004. In general, there does not appear to be a clear trend in the number of extreme rainfall days over the 10-year period. However, it is important to note that extreme rainfall events can have significant impacts on agriculture, infrastructure, and human livelihoods, regardless of the overall trend in the number of days. It is also important to consider the distribution of extreme rainfall days throughout the year, as some months may be more vulnerable to flooding or drought than others.

CONCLUSION

In conclusion, the analysis of daily rainfall data for a 10-year period in Madagascar revealed several key findings

Firstly, we computed the monthly rainfall totals and their long-term climatologies for each month. We found that the months of January, February, and March had the highest average monthly rainfall totals, while the months of June, July, and August had the lowest average monthly rainfall totals. This suggests that measures such as water storage and irrigation systems may be particularly important during the dry season months to mitigate the risks associated with drought.

Secondly, we computed the annual rainfall totals and their averages across Madagascar. We produced a time series that provided information on the year-to-year changes and trends. We found that there was no clear trend in the annual rainfall totals over the 10-year period. However, there were some years with significantly higher or lower rainfall totals than the average. This suggests that extreme weather events can have significant impacts on agriculture, infrastructure, and human livelihoods.

Thirdly, we computed the number of dry (RR<1mm) and wet (RR>=1mm) days per month and per year for our case study region. We presented spatial and time series visualizations of the output. We found that there were more wet days than dry days in Madagascar, with the highest number of wet days occurring in January and the lowest number of wet days occurring in August. This suggests that measures such as improving drainage systems may be particularly important during the wet season months to mitigate the risks associated with flooding.

Finally, we performed similar analysis for extreme rainfall indices (RR>10mm; RR>20mm). We found that there were more extreme rainfall events in our case study region than extreme dry events. The highest number of extreme rainfall events occurred in January, while the lowest number occurred in August. This suggests that measures such as improving drainage systems and investing in water storage and irrigation systems may be particularly important during the wet season months to mitigate the risks associated with extreme weather events.

Overall, our findings suggest that extreme weather events can have significant impacts on agriculture, infrastructure, and human livelihoods in our case study country. Measures such as improving drainage systems, investing in water storage and irrigation systems, and implementing early warning systems may be particularly important to mitigate the risks associated with extreme weather events.

APPENDIX

https://github.com/PinkrahNanaOfosuhene/PINKRAH.git