A STUDY OF RAINFALL FOR A BETTER OFFER OF VISITS ON 23 TOURIST SITES IN MADAGASCAR

Mohamed SOILIHI[1], Jean Gabriel RANDRIANARISON[2], Hasina Nirina RANDRIANALY[3]

[1] *PhD student, Public Law and Political Science (Catholic University of Madagascar), Geotourism, Ecotourism and Geohazards (University of Antananarivo), Madagascar*
[2] *Senior Lecturer, Statistics and Economics, Catholic University of Madagascar, Madagascar*
[3] *Professor, Geotourism, Ecotourism and Geohazards, University of Antananarivo, Madagascar*

ABSTRACT

The rainfall is one of the climatic constraints that prevent tourist visits. This research focuses on 23 tourist sites in Madagascar that are popular for their fascinating biodiversity all over the world. They are relatively dispersed geographically in the island. This dispersion gives an overview of the national situation on green tourism. The aim of this work is to study the monthly rainfall of these 23 tourist sites in order to determine which are the least rainy and therefore the most accessible during each of the 12 months of the year. As such, we download the daily cumulative rain height data with a resolution of 0.125° x0.125° that have been provided by the ECMWF (European Centre for Medium-Range Weather Forecasts) for the period from 1979 to 2018. The result is a wide divergence in monthly rainfall conditions between the 23 tourist sites that can allow the development of green tourism throughout the year. The 23 tourist sites can still be visited in the same period of the year, but preferably from the least rainy month to the most rainy month, respectively from September, August, June, July, October, May, November, April, December, March, February and finally January.

Keyword: - *Green tourism, Rainfall, Tourist site, and Tourist visit*

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1. INTRODUCTION

Tourism is inescapable for economic growth in developing countries like the Republic of Madagascar [1 - 5]. According to a study conducted by World Bank, Madagascar's international tourism receipts are estimated at US$ 951.500 million in 2019, an increase of 8.25% over 2018 [6]. The attractiveness of green tourism in Madagascar is explained by its terrestrial potential, evaluated at 95% endemicity of animal and plant species. The island also has a marine potential composed of coastal ecosystems, covering almost 5 000 kilometers of coastline and a continental shelf representing 20% of land areas [7]. In this context, Madagascar has become a wonder for many tourists who like to visit nature. It is well known that a link exists between tourism and climate conditioning most of the tourist activities and resources [8]. It appears that, rainy conditions are among the main climatic factors in the organization of visits for green tourism. However, to this day, there is not enough scientific study on the subject. It is in this regard that the study of rainfall in 23 popular tourist sites for green tourism remains important and original.

It is a question of adopting a new look at green tourism in order to support the permanent securing of tourist jobs, the improvement of socio-economic conditions, especially for local communities, and the increase in tax revenues. In other words, the primacy is imposed to mitigate essentially the traditional seasons for green tourism, that is to say to welcome tourists all year long without interruption. The objective of this research consists of determining the least rainy frequencies in all 23 sites for green tourism on each of the 12 months of the year. While some tourist sites appear to be difficult to access in any month in the rainy reasons, it is wise to know other sites that may be more accessible in a process of developing green tourism throughout the year.

2. METHODOLOGY

2.1 Study zone

Our study area concerns 23 popular tourist sites for green tourism and gives a brief overview of green tourism in Madagascar (Fig -1).

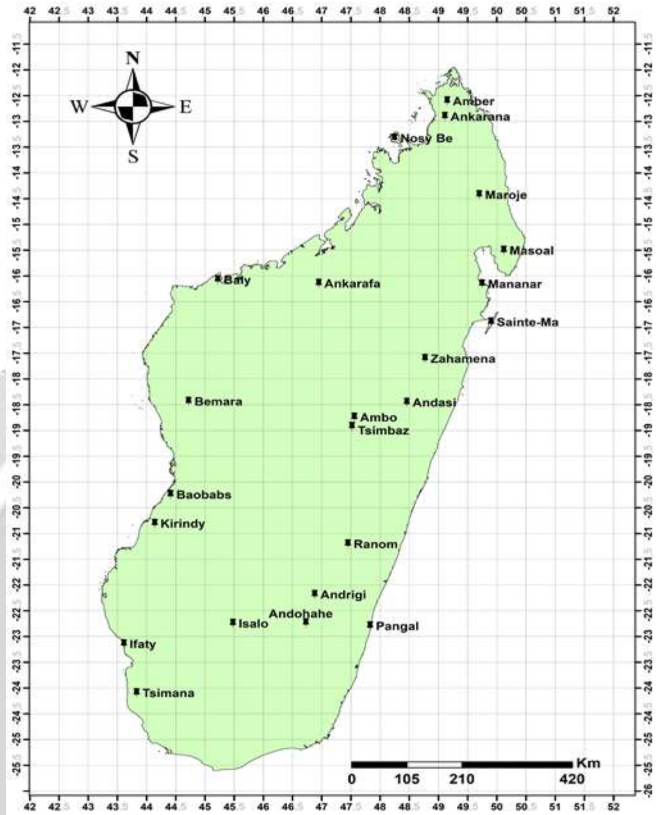


Fig -1: Geographical positions of the 23 tourist sites of the study

2.2 Observation Data

The observed data are of climatological type and concern the height of cumulative precipitation with a unit expressed in meters, at daily step on a series going from 1979 to 2018. They were provided by the ECMWF (European Centre for Medium-Range Weather Forecasts) with a resolution of 0.125° x 0.125°. They have been checked for quality and reliability. It is considered that the rainfall data of the sites correspond approximately to those of the closest points of the 0.125° x 0.125° grid as illustrated in the table below (Table -1).

Table -1: Considered geographical locations in decimal degrees of the 23 tourist sites of the study

Tourist sites of the study	Considered long	Considered lat
Sainte-Marie Island (Sainte-Ma)	49.87	-16.87
Isalo National Park (Isalo)	45.25	-22.50
Bemaraha Tsingy National Park (Bemara)	44.75	-18.87
Waterfall of Nosy Be Island (Nosy Be)	48.25	-13.37

Avenue of the baobabs in Morondavo (Baobabs)	44.37	-20.25
Ifaty Baobob Tree or Reniala Reserve (Ifaty)	43.5	-23.12
Rovan' Ambohimanga (Ambo)	47.5	-18.75
Andasibe Mantadia National Park (Andasi)	48.5	-18.87
Masoala National Park (Masoal)	50.12	-15.62
Ranomafana National Park (Ranom)	47.37	-21.25
Marojejy National Park (Maroje)	49.75	-14.50
Amber Mountain National Park or Alan Ambohitra (Amber)	49.12	-12.62
Botanical and Zoological Park of Tsimbazaza (Tsimbaz)	47.5	-18.87
Andrigitra National Park (Andrigi)	46.87	-22.25
Narodowy Ankarafantsika Park (Ankarafa)	47	-16.25
Pangalanes Canal or Manakara South (Pangal)	48.00	-22.00
Kirindy Mitea National Park (Kirindy)	44.12	-20.75
Tsimanampetsotsa Nature Reserve (Tsimana)	43.87	-24.12
Ankarana Special Reserve (Ankarana)	49.12	-12.87
Zahemana National Park (Zahamena)	48.75	-17.62
Andohahela National Park (Andohahe)	46.87	-24.25
Baly Bay National Park (Baly)	45.25	-16.00
Mananara North National Park (Mananar)	49.75	-16.50

2.3 Climatological average

The climatological average of a tourist site represents the amount of monthly cumulative rain height data from the period 1979 to 2018. It is determined for each of the 12 months of the year by taking the arithmetic mean of 480 monthly cumulative rain height during this reference period [9 - 10]. It is calculated as follows:

$$\bar{x} = \frac{1}{T}\sum_{i=1}^{T} x_i \qquad (1)$$

where i is the value of the i-th term in the climatological series; T is the number of months that constitute the climatological series [11]. In addition, the monthly climatological averages of all 23 tourist sites are previously centered and reduced in order to avoid differences in results, which could be generated by their change of measurement unit. They are expressed in milli-meters (mm).

2.4 Overall average

The overall average is the average of all observations, as opposed to the average of individual groups. It is the average determined over all 23 tourist visits [11]. It is then represented by a horizontal line parallel to the x-axis, called the center line.

2.4. Classification of the 23 tourist sites by rainfall similarity clusters

2.4.1 Classification method

The classification of the tourist sites is performed by the dynamic clustering algorithm of the XLSTAT software. The sites are groups into K distinct non-hierarchical clusters based on their similarity [12]. In other words, this process in optimizes the homogeneity of the clusters by minimizing the common intra-class inertia matrix, called Trace (W). This amounts to systematically minimizing the intra-class variance, which is the sum of the Euclidean distances between the observations of a class and their centroid [13]. If G designates the objective function to be minimized, then it is defined by the formula:

$$G = \sum_{j=1}^{n}\sum_{i=1}^{c} u_{i,j} \cdot d_{i,j} \qquad (2)$$

where $u_{i,j} \in \{0, 1\}$ encodes the partition, ($u_{i,j}$ = 1 iff records j is assigned to cluster/ prototype i) and $d_{i,j}$ represents a the distance between record j and prototype i [14]. And the Euclidean distance is calculated as follows:

$$d_{ij} = \sqrt{\sum_{v=1}^{P} \left(x_{iv} - x_{jv}\right)^2} \qquad (3)$$

where x_{iv} represents the characteristics of the individual i; x_{jv} represents the characteristics of the individual j; P is the number of portions in the sample and v is the number of individuals in the sample [15].

2.4.2 Choice of the optimal number of clusters

According to the Elbow method [16], the optimal number of K-classes to retain is represented by the elbow point on the curve, showing the evolution of the number of K-classes as a function of the intra-class variance. This is here the point from which the intra-class variance no longer decreases significantly [16 - 17] and can also be detected in the evolution of the number of K classes as a function of the envelope coefficient, calculated as follows:

$$S_{(i)} = \frac{b(i) - a(i)}{max\left(a(i), b(i)\right)} \qquad (4)$$

where a is the average distance between the observation and its cluster; b is the average distance between the observation and the neighboring class [18]. Note that the envelope coefficient varies between the values -1 and +1. It allows to judge the place of an observation in a class, but also to compare the homogeneity among the classes. Indeed, the observation is well classified if this coefficient is close to +1 whereas it is badly classified if it tends towards -1 [18]. However, an envelope coefficient representative of all clusters average allows to compare their homogeneities. When the envelope coefficient of a class tends to the value of +1, then the class becomes more homogeneous [19].

2.4.3 Method used to guide the visit of the 23 tourist sites of the study

In the present research, two methods, based essentially on rainfall trends, are used to guide tourist visits to Madagascar throughout the year. The first, which is intra-monthly, consists of directing tourist flows towards sites with low rainfall, located below the overall average cumulative rain height of the 23 sites, in each of the 12 months of the year. The second, which is inter-monthly, concerns the possibility of directing tourists to all 23 sites, preferably from the least rainy month to the wettest. These are determined in relation to the overall average of the monthly averages of the cumulative rain height of the 23 sites in each of the 12 months of the year.

3. RESULTS AND DISCUSSION

3.1 The 23 tourist sites in the study by rainfall similarity clusters

The optimal number of classes over which the intra-class variance no longer varies significantly is fixed at 2. It is illustrated by the representation of the evolution of the number of clusters K as a function of the intra-class variance (Fig -2) or of the number of clusters K as a function of the envelope coefficient (Fig -3).

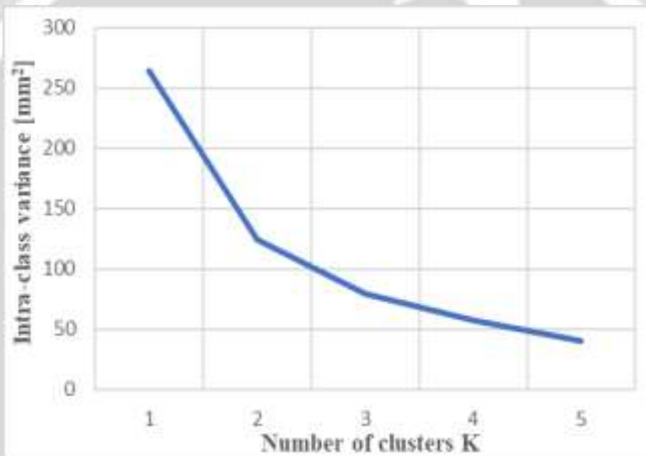


Fig -2: Evolution of the intra-class variance as function of the classification of monthly average cumulative rainfall from 1979-2018 of the 23 tourist attractions

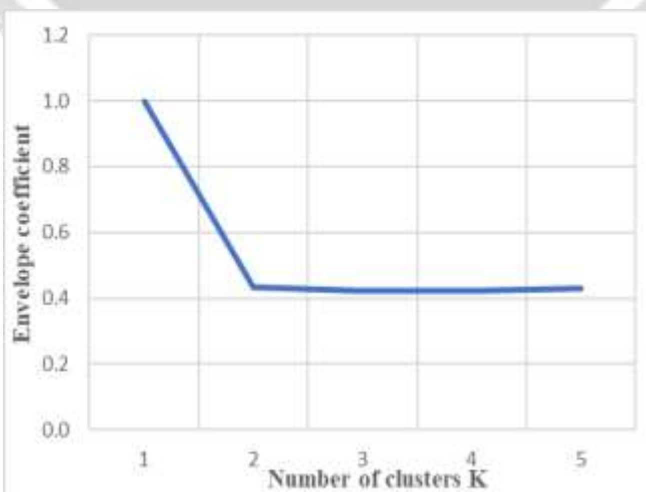


Fig -3: Evolution of the envelope coefficient as function of the classification of the monthly average cumulative rainfall from 1979-2018 of the 23 tourist attractions

In addition, it is observed that all the tourist sites are as-sociated with the good classes of distribution with the ex-ception of the Andrigitra National Park located in class 2, which has a negative coefficient of silhouette (Table -2). It is important to point out that class 1 is more homogeneous with an average envelope coefficient of 0.483 than class 2 where it is 0.403 (Fig -4).

Table -2: Classification of monthly average cumulative rain height from 1979-2018 of 23 tourist attractions by K-means

Site	Cluster	Intra-class variance	Envelope coefficient
Sainte-Ma	1	13030.32	0.59
Andasi	1	13030.32	0.39
Masoal	1	13030.32	0.55
Ranom	1	13030.32	0.58
Maroje	1	13030.32	0.38
Pangal	1	13030.32	0.43
Zahamena	1	13030.32	0.35
Andohahe	1	13030.32	0.51
Mananar	1	13030.32	0.56
Isalo	2	15618.18	0.50
Bemara	2	15618.18	0.24
Nosy Be	2	15618.18	0.19
Baobabs	2	15618.18	0.56
Ifaty	2	15618.18	0.51
Ambo	2	15618.18	0.49
Amber	2	15618.18	0.45
Tsimbaz	2	15618.18	0.45
Andrigi	2	15618.18	-0.01
Ankarafa	2	15618.18	0.47
Kirindy	2	15618.18	0.56
Tsimana	2	15618.18	0.49
Ankarana	2	15618.18	0.46
Baly	2	15618.18	0.29

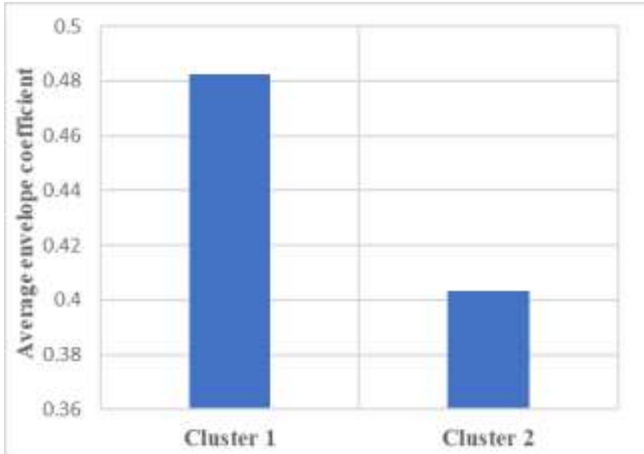


Fig -4: Average envelope coefficient by cluster of the monthly average cumulative rain height from 1979-2018 of the 23 tourist attractions

It is observed that the average monthly cumulative rain height (A_CRH) of tourist sites in class 1 varies from 64.211 mm to 291.389 mm while, that of class 2 from 9.052 mm to 284.406 mm. This would mean that the tourist sites included in class 1 are more rainy than those groupped in class 2 in each of the 12 months of the year (Fig -5). Therefore, in relation to rainfall, the tourist sites in class 2 are more accessible for visits throughout the year than those included in class 1.

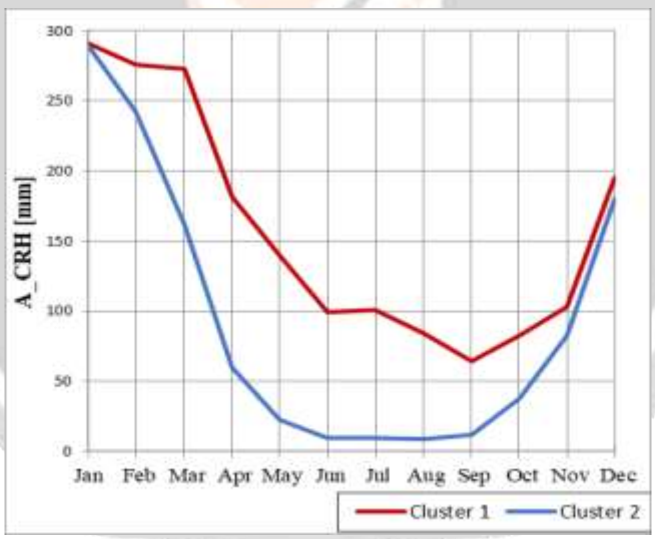
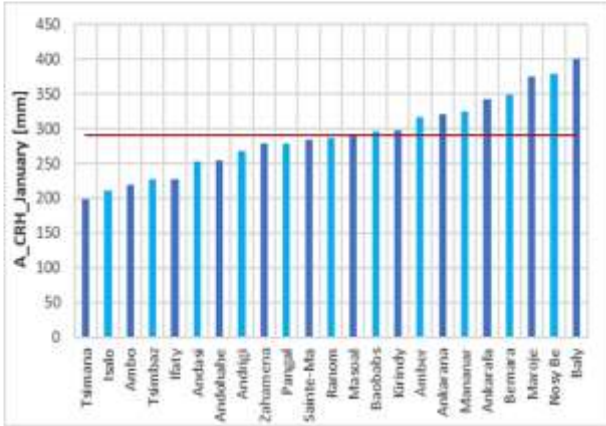
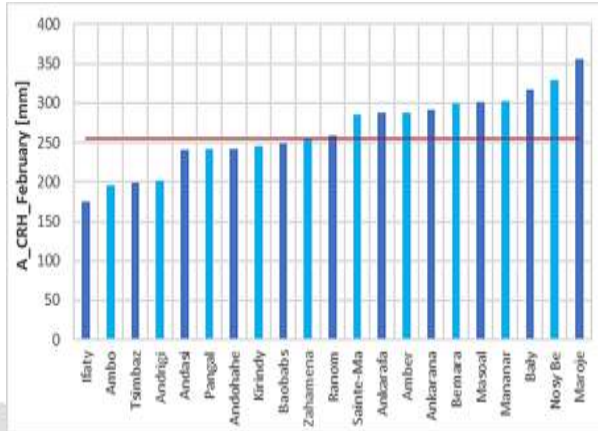


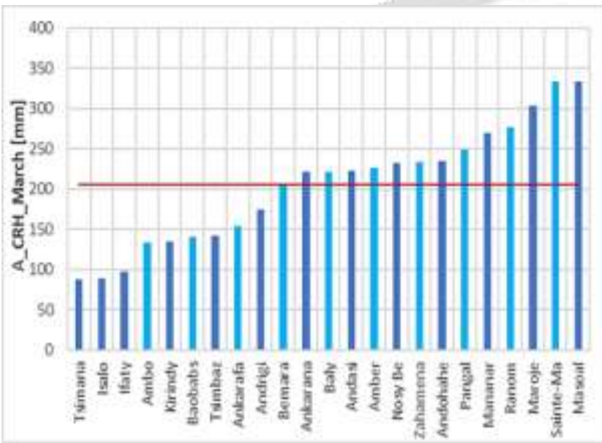
Fig -5: Evolution of the envelope coefficient as function of the classification of the monthly average cumulative rain height from 1979-2018 of the 23 tourist attractions

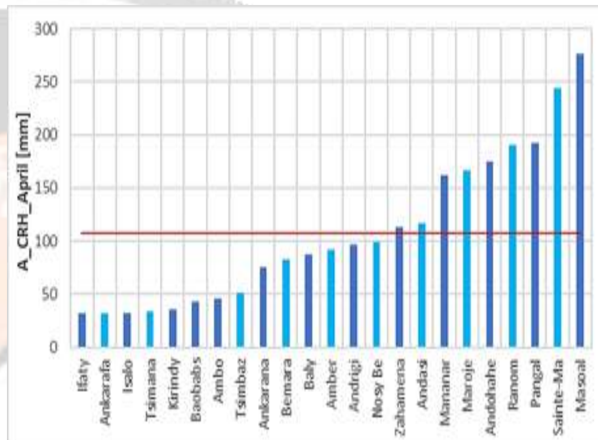
3.2 Orientation of monthly visits to the 23 tourist sites of the study

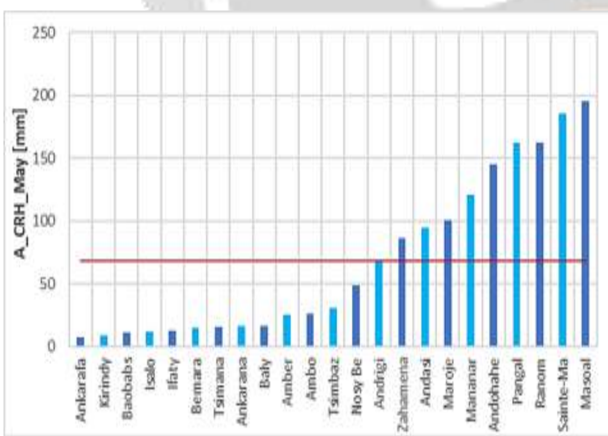
The tourist sites below the overall average have the least rainfall of all in each of the 12 months of the year (Fig -6). Therefore, these sites are the most accessible in relation to the others, making them the best offer for tourist visits.

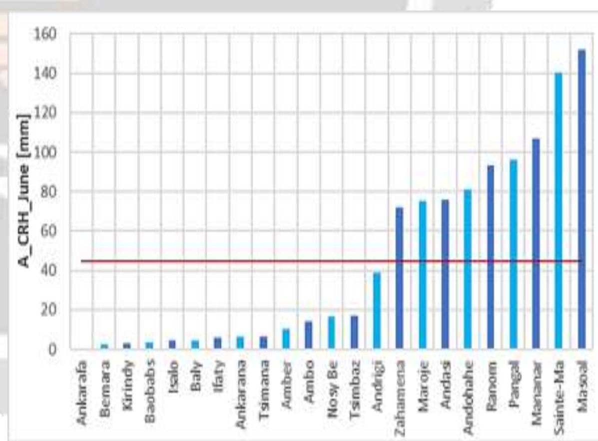

A_CRH_January [mm]
450
400
350
300
250
200
150
100
50
0
Tsimana
Isalo
Ambo
Tsimbaz
Ifaty
Andasi
Andohahe
Andrigi
Zahamena
Pangal
Sainte-Ma
Ranom
Masoal
Baobabs
Kirindy
Amber
Ankarana
Mananar
Ankarafa
Bemara
Maroje
Nosy Be
Baly


A_CRH_February [mm]
400
350
300
250
200
150
100
50
0
Ifaty
Ambo
Tsimbaz
Andrigi
Andasi
Pangal
Andohahe
Kirindy
Baobabs
Zahamena
Ranom
Sainte-Ma
Ankarafa
Amber
Ankarana
Bemara
Masoal
Mananar
Baly
Nosy Be
Maroje


A_CRH_March [mm]
400
350
300
250
200
150
100
50
0
Tsimana
Isalo
Ifaty
Ambo
Kirindy
Baobabs
Tsimbaz
Ankarafa
Andrigi
Bemara
Ankarana
Baly
Andasi
Amber
Nosy Be
Zahamena
Andohahe
Pangal
Mananar
Ranom
Maroje
Sainte-Ma
Masoal


A_CRH_April [mm]
300
250
200
150
100
50
0
Ifaty
Ankarafa
Isalo
Tsimana
Kirindy
Baobabs
Ambo
Tsimbaz
Ankarana
Bemara
Baly
Amber
Andrigi
Nosy Be
Zahamena
Andasi
Mananar
Maroje
Andohahe
Ranom
Pangal
Sainte-Ma
Masoal


A_CRH_May [mm]
250
200
150
100
50
0
Ankarafa
Kirindy
Baobabs
Isalo
Ifaty
Bemara
Tsimana
Ankarana
Baly
Amber
Ambo
Tsimbaz
Nosy Be
Andrigi
Zahamena
Andasi
Maroje
Mananar
Andohahe
Pangal
Ranom
Sainte-Ma
Masoal


A_CRH_June [mm]
160
140
120
100
80
60
40
20
0
Ankarafa
Bemara
Kirindy
Baobabs
Isalo
Baly
Ifaty
Ankarana
Tsimana
Amber
Ambo
Nosy Be
Tsimbaz
Andrigi
Zahamena
Maroje
Andasi
Andohahe
Ranom
Pangal
Mananar
Sainte-Ma
Masoal

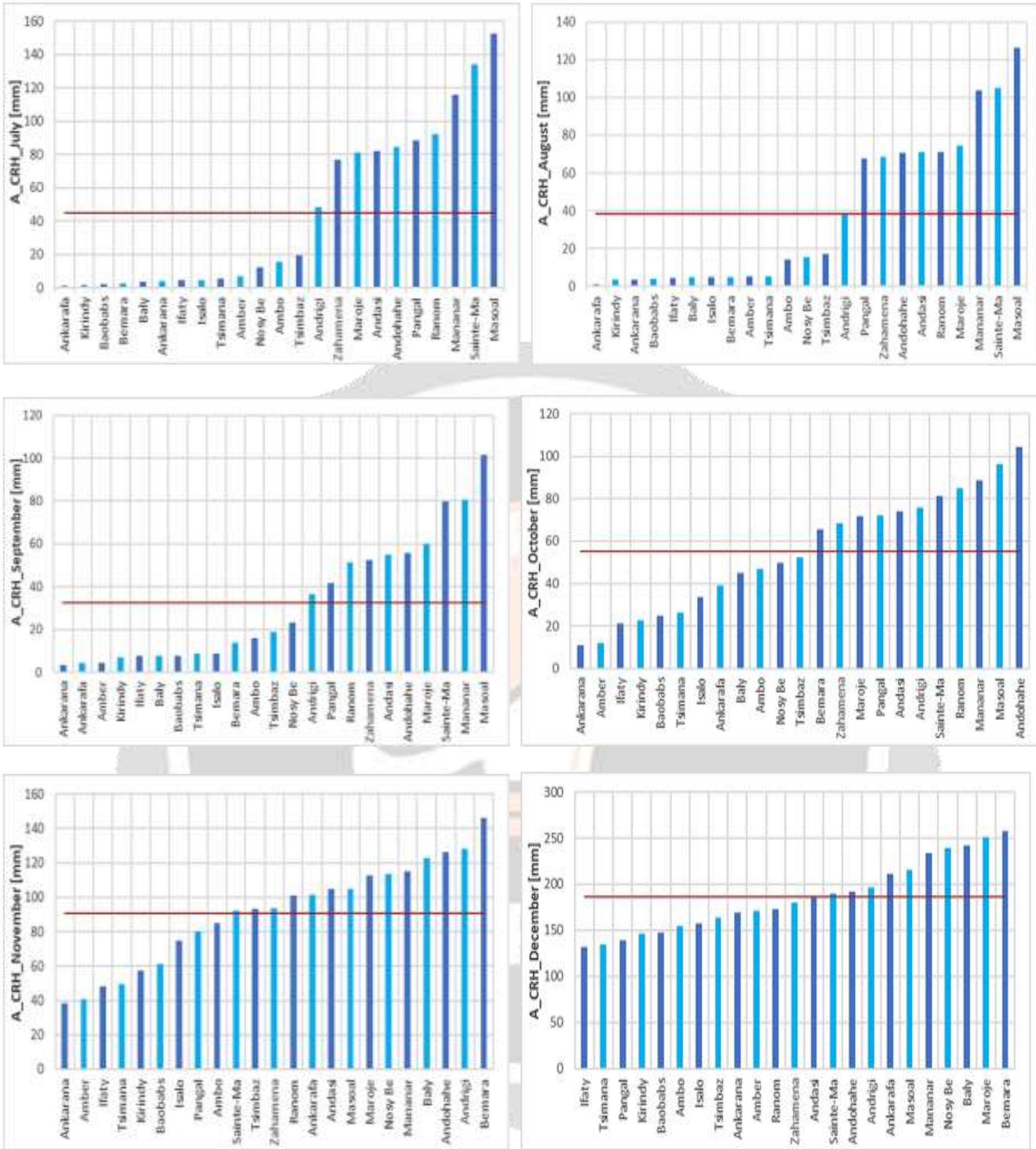


Fig -6: Overall average monthly cumulative rain height in millimeters at each of the 23 tourist attractions for the 12 months of the year from 1979-2018

The overall average of the monthly cumulative rain height for the 23 tourist sites in the study for each of the 12 months of the year is used to rank the months from least rainy to rainiest. This categorizes the month as: September, August, June, July, October, May, November, April, December, March, February and finally January (Table -3). So the best offer of visits for all 23 tourist sites of the study would be preferably in September. However, it should be noted that the ranking of the best offers of visits for the 23 sites concerning green tourism can be done by following the order of the ranking of the least rainy months towards the rainiest.

Table -3: Overall average monthly cumulative rain height for the 23 attractions sites from the least rainy month to the wettest month of the year

Month of the year	**Overall average of monthly cumulative rain height for the 23 sites expressed in millimeters**
September	32.38
August	38.49
June	44.55
July	45.10
October	55.05
May	68.11
November	90.92
April	107.47
December	185.98
March	205.20
February	255.20
January	290.18

4. CONCLUSIONS

As demonstrated by this research, some sites are very rainy in any given month, others are less rainy and therefore re-main favorable for visits. Therefore, knowledge and com-parison of rainfall behavior among the 23 tourist sites in the study can serve as a support for the development of year-round green tourism in Madagascar. Nevertheless, in further work, some parameters such as temperature, wind or cyclones can be studied to better guide tourist visits to Madagascar with more climatic precision. Moreover, it would be judicious to deepen the research with other sites concerning green tourism. In addition, the development of national tourism requires to examine also the factors of attraction determining for the business tourism, the family tourism or the cultural tourism.

5. DATA AVAILABILITY STATE-MENT

The raw data provided by the ECMWF (European Centre for Medium-Range Weather Forecasts), leading to the results of this article, will be made available to the readers, without reservation.

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