RAINWATER CAPTURE PROJECTIONS FOR THE UNIVERSITY OF ANTANANARIVO ROOFTOPS

A STUDY PROJECTS

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Abstract

The analysis of rainfall estimation is crucial when aiming to optimize rainwater capture methods. This projection facilitates the sizing of the equipment that will be deployed. Merely assuming the quantity of rainfall or relying on unfounded estimates could lead to either an over or underestimation of the capture system's capacity. The analyzed data also provides an insight into the efficiency of the system. Within our Rainwater Management Study, estimation stands as a pivotal element, serving as a solid foundation for project initiation. It is imperative to ensure accurate estimation methodologies to drive the success of rainwater harvesting initiatives.

For data analysis, we will leverage multiple sources to establish a robust foundation for our estimation. Primarily, we will utilize official data from the APIPA (The Authority for Flood Protection of the Antananarivo Plain) spanning 20 years across various zones in Antananarivo. Our estimation will not solely focus on the total annual rainfall quantity but will encompass an analysis of the water quantity supplied throughout the year, considering different scenarios (wet and dry years) to provide insight into all possible eventualities. This approach ensures a comprehensive understanding of rainfall dynamics and water availability, thereby enhancing the effectiveness of our assessment.

1- Presentation of the climate in Madagascar and description of the case of

Antananarivo:

Madagascar experiences two main seasons : a hot and humid season (summer) from November to April, and a dry and cool season (winter) from May to October. Two short inter-seasons separate these main seasons, each lasting approximately one month.

For the central highlands, the climate is rather cool, with average annual temperatures ranging between 15°C and 22°C. This region experiences the lowest average temperatures in Madagascar, dipping below 14°C. It receives significant rainfall, with annual precipitation ranging from 1 000 to 2 000 mm. Approximately 90 to 95% of the total annual precipitation occurs from November to April. Precipitation is relatively low during the months of September and October. [1] [2] [3]

2- Estimation of precipitation in Antananarivo:

The data collected from various sources [1] [6] [7] appear to converge towards an estimation of rainfall in Antananarivo averaging 1000 mm per year. According to the estimation provided by our specialist in the journal, this value is approximately valid for the Antananarivo region. However, the sources did not specify how they collected their data or arrived at the result of this estimation. Furthermore, we also need to investigate the daily rainfall history to provide more specific and useful data for the rainwater harvesting project, as storage and other elements will be sized according to the amount of water that will be available daily to make them more efficient. The data provided in [4] by APIPA and in [5] dataset seems to suggest a high resolution of precipitation for two decades *(2000-2022),* which is highly relevant for our study.

3- Data Analysis According to Various Sources Two types of data collected from websites providing access to meteorological data for Antananarivo provide precipitation statistics for the region. One, sourced from [7], appears to provide approximately the same values as those sourced from [6].

Antananarivo -Précipitation moyennes		
Mois	Quantité(mm)	Jour de pluie
Janvier	270	18
Février	255	17
Mars	185	17
Avril	50	9
Mai	20	6
Juin	7	6
Juillet	10	8
Août	15	9
Septembre	10	4
Octobre	65	8
Novembre	170	14
Décembre	305	20
An	1365	136

Figure 1 : Antananarivo precipitation, source : [7]

Actually, both of them indicated that their data had been analyzed for the period from *1991 to 2021*, but their analyse appear to not converge into one result. However, they gave an estimation around 1000 mm of precipitation per year. The table emphasize also the fact that there are two season in Antananarivo and it is confirmed by the number of rainy day.

Antananarivo -Précipitation moyennes		
Mois	Quantité(mm)	Jour de pluie
Janvier	289	17
Février	256	15
Mars	147	12
Avril	40	6
Mai	16	2
Juin	7	1
Juillet	8	1
Août	6	1
Septembre	8	1
Octobre	31	4
Novembre	87	8
Décembre	189	13
An	1084	81

Figure 2 : Antananarivo precipitation, source : [6]

Some data from [9] provide a history of rainfall for the past four years that we can also take into consideration for our analysis. They also reflect the current situation due to recent climate change and the trend of rainfall reduction even the 2019 is not complete.

mm	2019	2020	2021	2022	2023	2024
Jan	-	414, 8	86,4	338, 8	235, 2	194
Fev	-	182, 2	174	132, 4	118	239, 8
Mar	-	149, 6	123, 2	139, 8	205, 6	48
Avr	-	29,2	19,2	2,6	61,2	-
Mai	-	0	5,4	0,8	24,2	-
Jun	-	6,4	8	1	1	-
Jul	-	1,8	0,8	3,2	0,8	-
Aou	-	0	2,8	0,6	17,2	-
Sep	-	1	1,4	1,8	0,8	-
Oct	-	64	23,2	17,2	124,6	-
Nov	2,2	21,2	113, 2	67,8	60	-
Dec	129	94,4	97	181, 8	129,2	-
AN	131, 2	964, 6	654, 6	887, 8	977, 8	481, 8

Figure 3: Antananarivo Precipitation 2019-2024 in millimeters, source [9]

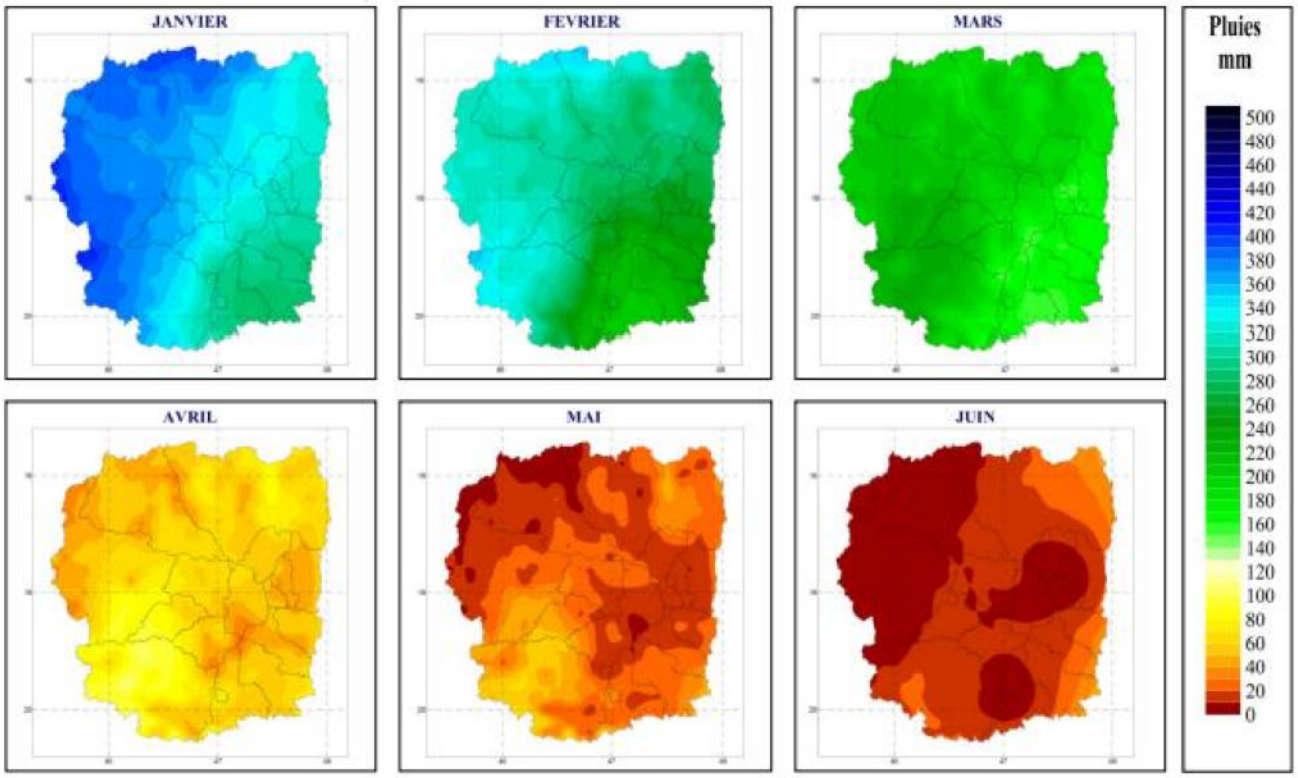
On the other hand, we can also observe a decrease in the number of rainy days over the past few years, as depicted in the following figure, where an average of 70 rainy days is shown.

Days	2019	2020	2021	2022	2023	2024
Jan	-	17	8	18	18	17
Fev	-	10	13	11	10	15
Mar	-	7	12	11	18	5
Avr	-	6	6	1	8	
Mai	-	0	2	0	-	
Jun	-	3	2	0	3	
Jul	-	1	0	0	-	
Aou	-	0	1	0	0	
Sep	-	0	0	1	-	
Oct	-	6	2	3	0	
Nov	1	6	8	8	-	
Dec	9	10	7	13	3	
An	10	66	61	66	12--	37
					87	
					0	
					8	
					-	
					7	
					-	

Figure 4 number of rainy day in Antananarivo 2019-2024 [9]

In addition to those data, we have this Rainfall map of Antananarivo from [1] that indicate the amount of rain during each months of the year, it also shows that there is not a really significant variation of the amount of precipitation in the region of Antananarivo. It also shows the two season of year that reflect the amount of precipitation.

ANTANANARIVO
MOYENNES MENSUELLES DES PLUIES



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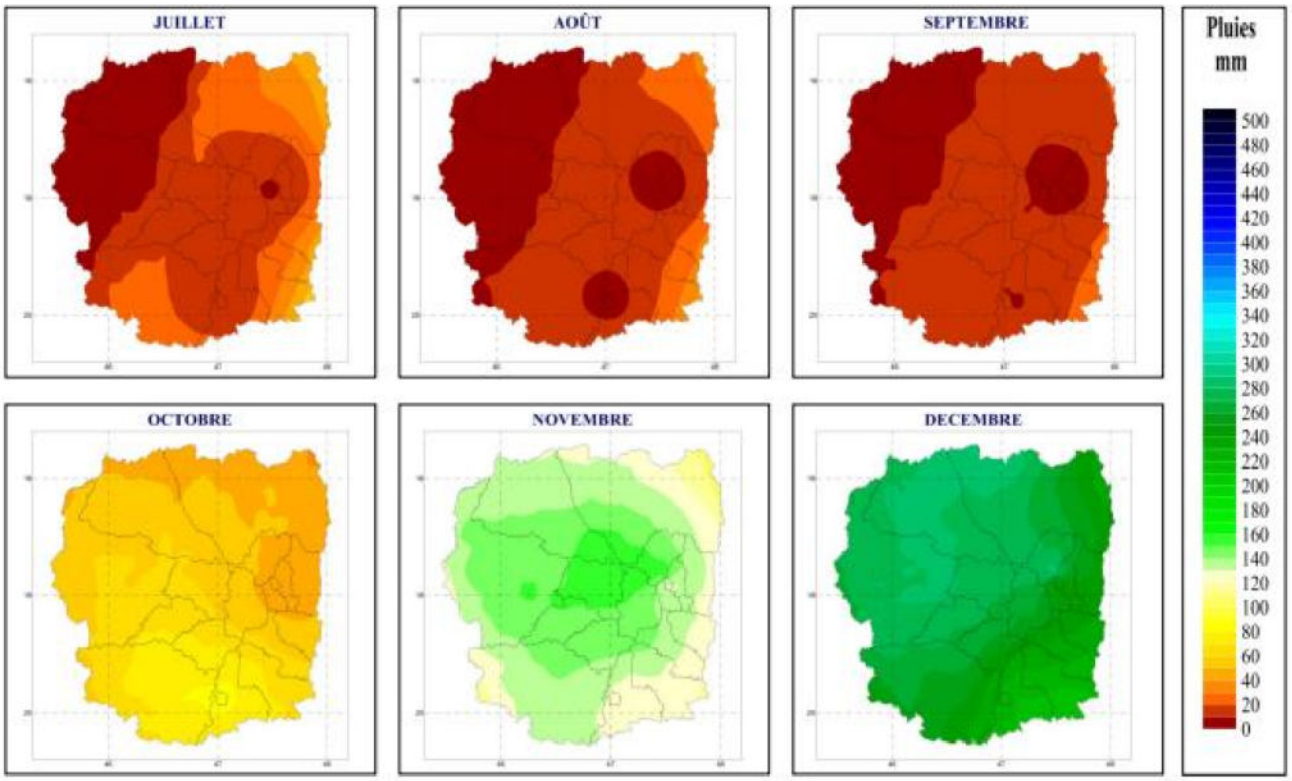

4- Data Analysis According to APIPA station data Those previous data can be used to validate the result of our Analysis based on the measurement made in the APIPA Station. Actually, the APIPA provide a large dataset of hourly measurement from 2000 to 2022 from its nine (9) stations around Antananarivo. The localisation of these Station will be detailed in later section of this document. We had to fill the missing data which we can not always know if it is a null value or should take a special value. By converting the daily data to a monthly data for a better visualisation, we get the next result that show the rainfall data of each station. Given the necessity of capturing both short and long-term relationships within the dataset, we have opted to examine three distinct time periods (2000-2022 / 2010-2022 / 2019-2022). These are actualy derivated by monthly average.

	Al arobi a	Anosi be	Anosizatom	bohimanam	Mbanjakandrian	Ambatofotsy	Antelomita	Be he nj y	Anj e va	Moye nne
Jan	297, 1	323, 7	302,5	343,2	299,4	295,0	337,8	304, 5	323, 7	314, 1
Feb	217, 0	264, 9	203,4	230,4	236,4	215,5	243,3	220, 4	229, 0	228, 9
Mar	161, 0	180, 9	164,7	203,6	221,1	184,0	153,9	170, 1	182, 9	180, 3
Apr	42,5	82,0	61,4	68,2	61,1	60,7	48,1	54,1	50,0	58,7
May	24,4	32,5	19,7	17,7	35,5	38,8	14,8	19,6	17,9	24,5
Jun	14,9	18,3	12,8	8,9	37,8	7,1	12,6	10,0	6,2	14,3
Jul	12,5	43,8	1,7	5,5	33,3	11,9	10,3	4,6	5,1	14,3
Aug	11,3	27,5	4,1	10,7	27,3	1,8	8,6	6,1	6,8	11,6
Sep	12,5	19,3	5,1	9,2	21,2	29,3	10,4	9,6	12,8	14,4
Oct	36,1	45,9	26,8	39,2	47,5	47,9	71,5	53,7	42,2	45,7
Nov	102, 8	132, 0	115,6	118,7	112,3	158,6	134,8	121, 0	121, 0	124, 1
Dec	221, 6	273, 5	214,6	235,8	249,5	222,7	210,0	232, 8	246, 6	234, 1
Tot a l	1153, 7	1444, 4	1132,3	1291,1	1382,3	1273,2	1256,2	1206, 6	1244, 3	1264, 9

Figure 5 APIPA monthly average rainfall for 2000-2022

	Al arobi a	Anosi be	Anosizatom	bohimanam	Mbanjakandrian	Ambatofotsy	Antelomita	Be he nj y	Anj e va	Moye nne
Jan	232, 8	255, 8	294,3	319,4	250,5	263,1	280,3	273, 9	258, 3	269, 8
Feb	197, 6	265, 8	193,1	216,2	202,5	203,9	226,5	191, 7	173, 3	207, 8
Mar	139, 4	162, 7	177,5	218,6	186,2	192,2	128,0	168, 9	162, 7	170, 7
Apr	36,2	71,9	58,2	51,7	43,1	55,1	36,9	41,2	30,9	47,2
May	13,0	29,2	13,9	14,5	30,2	50,7	10,2	16,5	13,2	21,3
Jun	9,9	11,4	20,4	10,5	30,1	8,5	11,9	12,0	2,9	13,1
Jul	7,3	95,7	1,3	3,1	27,5	13,2	9,1	1,3	0,6	17,7
Aug	6,6	38,6	1,2	11,1	22,6	0,8	6,1	2,2	0,5	10,0
Sep	3,9	7,7	0,2	4,3	12,8	38,2	9,9	0,9	7,9	9,5
Oct	42,1	44,7	35,8	41,9	51,5	60,3	89,2	56,7	57,3	53,3
Nov	77,8	80,2	106,3	92,6	94,2	131,8	106,2	78,7	98,8	96,3
Dec	128, 7	258, 2	200,8	181,0	186,7	165,0	172,8	210, 5	179, 3	187, 0
Tot a l	895, 3	1321, 8	1103,0	1164,8	1137,6	1182,8	1087,2	1054, 3	985, 7	1103, 6

Figure 6 APIPA monthly average rainfall for 2010-2022

	Al arobi a	Anosizatom	bohimanam	Mbanjakandrian	Ambatofotsy	Antelomita	Be he nj y	Anj e va	moye nne
Jan	130, 5	385,9	294,4	246,6	300,4	272,2	334, 5	264, 5	299, 8
Feb	172, 4	172,6	178,4	189,7	174,7	155,6	151, 1	178, 4	171, 5
Mar	116, 2	163,0	204,1	176,5	169,0	118,8	158, 0	144, 4	162, 0
Apr	13,2	32,5	32,6	36,4	23,1	30,7	35,9	4,6	27,9
May	13,7	9,0	17,3	23,2	22,8	6,6	0,1	5,0	12,0
Jun	17,1	68,7	22,5	42,8	18,5	16,3	6,2	7,5	26,1
Jul	5,1	0,0	7,9	34,2	29,4	7,7	2,1	1,9	11,9
Aug	4,1	0,0	37,3	12,1	1,4	4,7	6,9	0,0	8,9
Sep	3,4	0,1	21,0	12,3	118,4	18,5	0,0	20,2	27,2
Oct	43,7	34,1	83,3	44,2	73,8	132,8	43,8	75,5	69,6
Nov	64,2	181,1	126,0	52,7	87,2	114,2	66,3	91,4	102, 7
Dec	107, 0	132,6	86,0	167,4	131,8	122,3	163, 5	80,8	126, 3
Tot a l	690, 5	1179,4	1110,7	1038,1	1150,2	1000,4	968, 4	874, 3	1045, 9

Figure 7 APIPA monthly average rainfall for 2019-2022

Remark: The Alarobia data was biased by missing values, so we did not include it in the calculation of the mean value in the table for 2019-2022.

We have the following illustration for different range of data that we have analyzed from

the dataset where we used the average min and max value of total yearly precipitation per station:

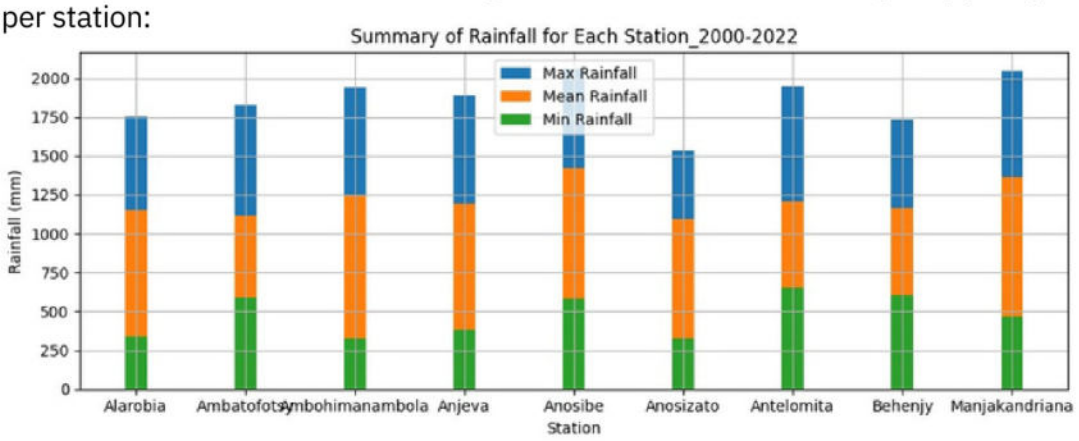

Figure 8 Min/Max/Average rainfall Data 2000-2022

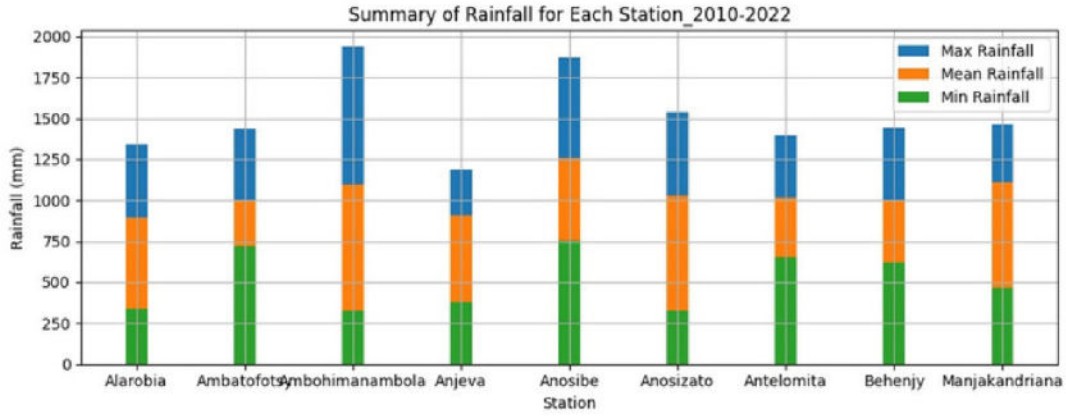

Figure 9 Min/Max/Average rainfall Data 2010-2022

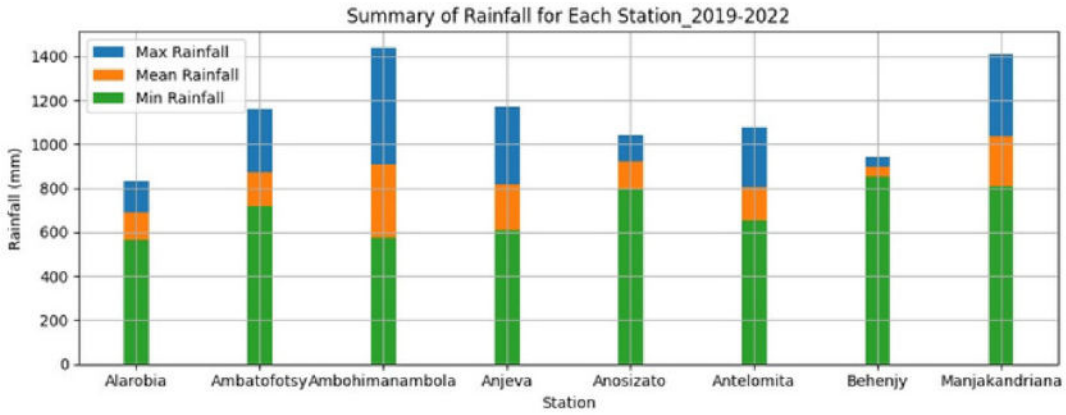

Figure 10 Min/Max/Average rainfall Data 2019-2022

We can observe that the rainfall measured at the station tends to decrease over the year. The more recent the data we analyze, the lower the values are. However, *we can still rely on the fact that over the past 10 years, the average rainfall was estimated to fluctuate around 1000 mm per year.*

The repartition of the average precipitation during the year is illustrate in the figure bellow for the periode between 2019 to 2022 and 2010-2022.

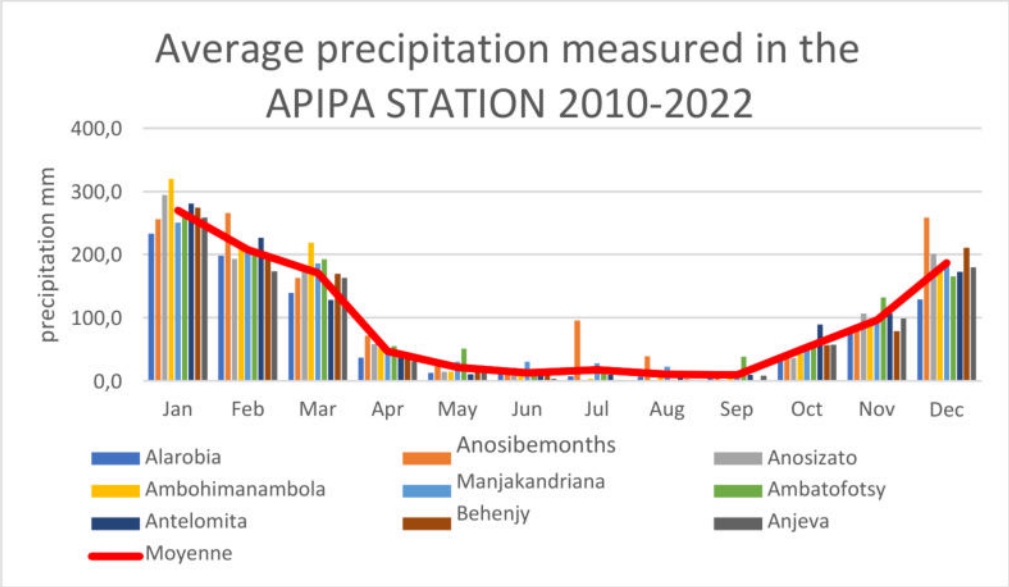

Figure 11 Average precipitation 2010-2022

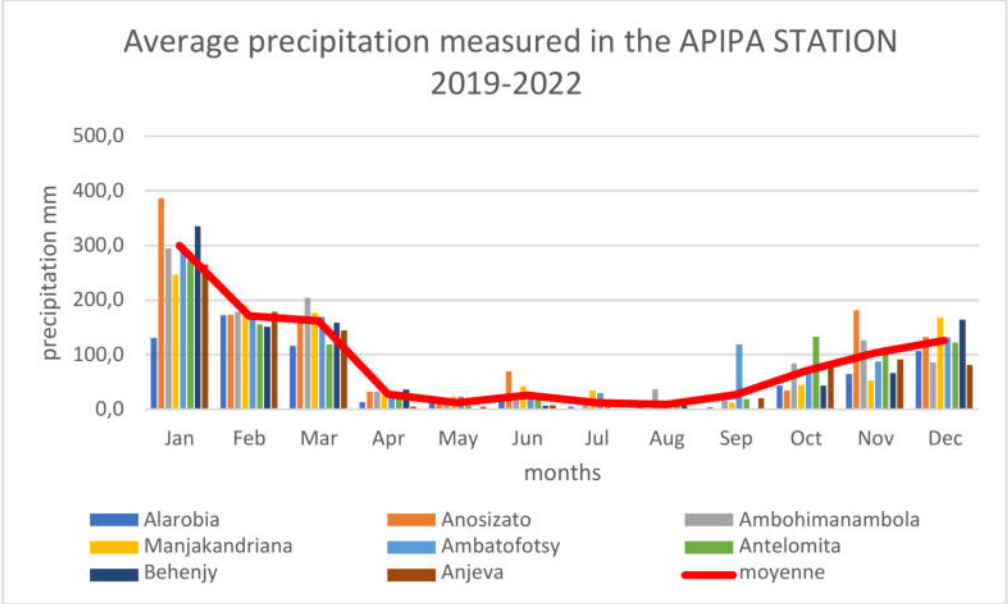

Figure 12 Average precipitation 2019-2022

The assertions posited in [1] and [2] are readily affirmed by the visual representation, wherein the two distinct seasons of Madagascar are discernible. Antananarivo is not exempt from this validation.

5- Analysis of the past Scenario from APIPA data

The following table will show the number of rainy days as the amount of precipitation during these days for the 2019-2022 period:

Tableau 1 rainfall Scénario 2019-2022 Source APIPA

	Average Annual Rain mm	Max Rain mm	Average Number of Rainy day	Rainy day > 1mm	Rainy day > 5mm	Rainy day > 10mm	Rainy day > 25mm	Rainy day > 50mm	daily max rain [mm]
Anosizato	921,6	1044,0	58	51	36	26	12	4	119
Ambohimanambola	909,8	1440,1	69	52	35	24	8	3	142
Manjakandriana	1038,1	1408,0	133	101	53	29	10	2	120
Ambatofotsy	871,6	1161,3	72	57	36	27	10	3	131
Antelomita	804,9	1078,5	114	70	36	23	9	2	135
Behenjy	896,2	943,8	73	58	39	28	13	3	83
Anjeva	820,4	1169,4	52	51	37	25	10	2	113
Antananarivo	894,6	1178	82	63	39	26	10	3	120

This table demonstrates the following key findings:

- The average number of rainy days varies considerably, ranging from 52 to 133 days across the stations with an average of 82
- Precipitation events exceeding 25 mm occur within a range of 8 to 13 days.
- The highest recorded daily rainfall spans from 83 mm to 142 mm.
- Notably, there are instances of significant rainfall, with some days experiencing precipitation of up to 10 mm, and a few days even reaching 50 mm.

This indicates that occasionally, there are instances of minimal precipitation (1 mm), where the losses during capture may outweigh the volume collected. For instance, each system requires a minimum threshold of precipitation to effectively collect and store water. Additionally, it is noteworthy that during periods of heavy precipitation, undersized storage facilities may result in a significant portion of the rainfall being lost. These are important parameters to consider in the analysis.

The following illustration depicts a duration curve, a graphical representation illustrating the cumulative distribution of rainfall intensity throughout the year. This curve offers valuable insights into the distribution of rainfall intensity over time. Through analysis of
the curve, patterns such as periods of heavy rainfall, dry spells, and overall variability in rainfall intensity become evident. The duration curve serves as a crucial tool for rainwater harvesting endeavors. It guides the sizing and design of rainwater harvesting systems by indicating the necessary storage capacity required to efficiently capture rainfall. For the 2021 data, we can easily see how the precipitation is distributed for Antananarivo. It gives a continuous curve of the discrete description on the table 1.

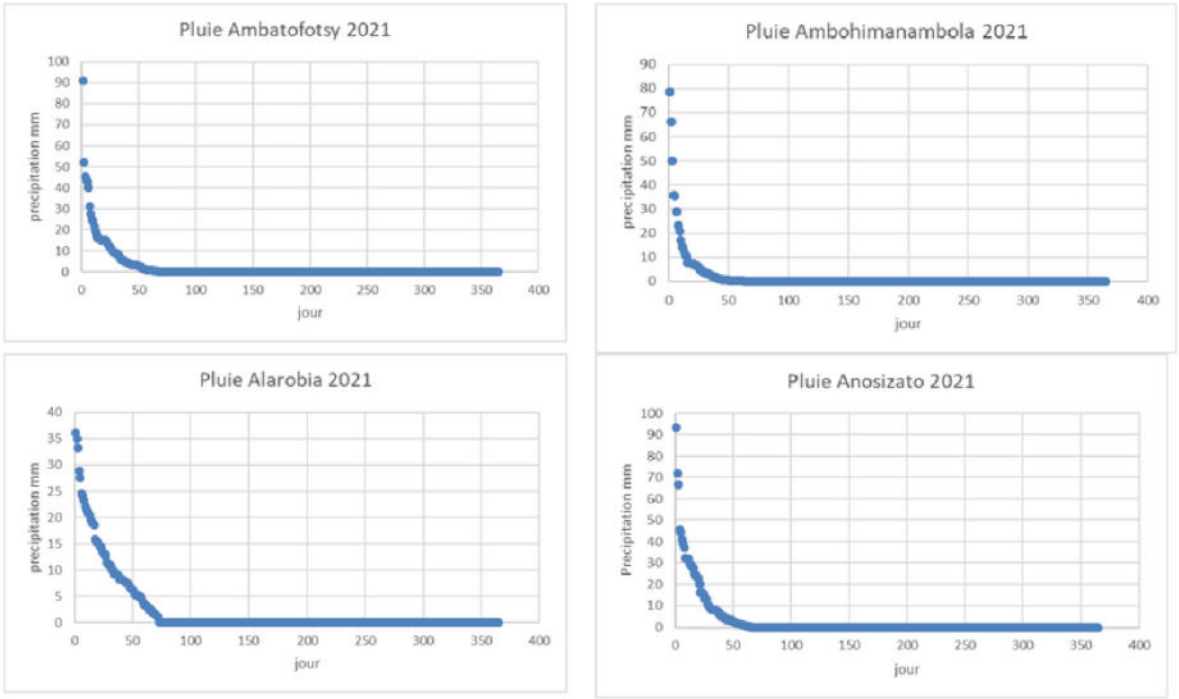

Figure 13 duration curve of precipitation in APIPA STATION 2021

The processed data from APIPA will be appended to this document to verify the basis of all analyses conducted for rainfall estimation.

6- RAINFALL MAP

Based on the rainfall data collected from the APIPA Station Measurement, we have developed a rainfall map of the Antananarivo City region, where the university is located. The Inverse Distance Weighting (IDW) method was employed in creating this map, a widely utilized technique for constructing rainfall maps based on weighted data. The map was generated using QGIS software. The data utilized for this purpose were derived from the average rainfall records spanning the period from 2000 to 2022 and the 2019-2022.

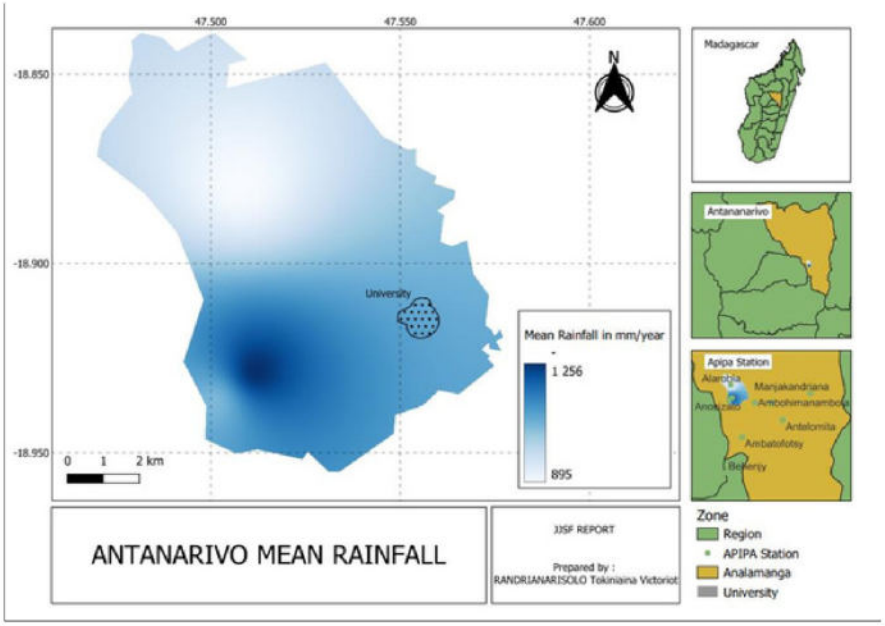

Figure 14 : Rainfall map based on APIPA data 2000-2022

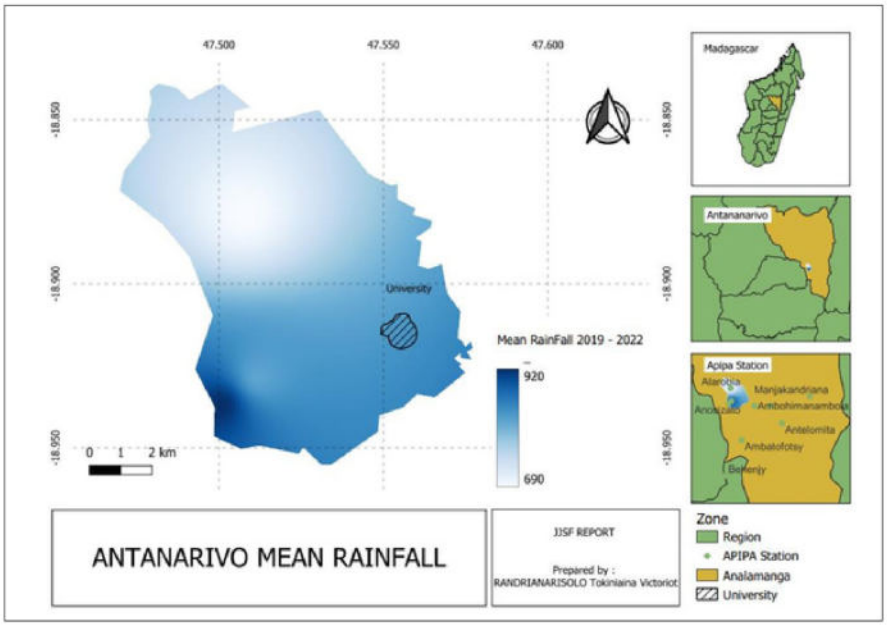

Figure 15: Rainfall map based on APIPA data 2019-2022

Based on Figures 9 and 10, we can infer that the estimated precipitation at the University of Antananarivo fluctuates around 800 mm/year from 2012 to 2022. However, considering the average data from the period 2000-2022 leads to an estimated value of 1000 mm/year for precipitation at the University of Antananarivo.

7- BUILDING ROOFTOP AREA For the subsequent calculations, it will be necessary to ascertain the surface area of the buildings within the University of Antananarivo. The surface area of each building will subsequently allow us to deduce the volume of water that can be captured, as the captured rainfall volume is expressed as follows:

$$V=A*p*c$$

Where:

- V is the Volume of rain harvested [m3]
- A is the Area of the Roof [m2]
- p is precipitation [m]
- c is the coefficient related to the type of the roof

Tableau 2 type of catchement, source pacey,Arnold 1989,Rainwater Harevesting : the collecion of rainfall runoff in rural areas,ITP,London

Type of Catchement	Tyles	Corrugated metal sheet	Concrete	Brick pavement	Soil on slopes less than 10%	Rocky natural catchements
Coefficient	0.8-0.9	0.7-0.9	0.6-0.8	0.5-0.6	0.0-0.3	0.2-0.5

From the Volume harvested, we can evaluate the type of stockage we will need. The roof area will be determined utilizing GIS software QGIS, which applies spatial analysis techniques to compute the surface area of rooftops within the designated region. This software facilitates precise measurements of geographical features, including building footprints, thereby enabling the extraction of accurate roof area data for further analysis. Each building is subsequently assigned a unique ID and labeled with corresponding
attributes, such as the roof area, department affiliation, and building name. Following this, buildings will be categorized based on their roof area dimensions. This classification will offer initial insights into which buildings may yield the highest volume of captured rainfall. It is noteworthy, however, that roof area alone does not exclusively inform our selection process, as the needs of occupants also warrant consideration.

The findings indicate that there are 168 structures within the university, with surface areas ranging from 36 to 2726 m².

We actually got:

- *2 structures that have an area exceeding 2188 m²*
- *7 stuctures with an area from 1650 to 2188 m²*
- *2 structures with an area from 1381 to 1650 m²*
- *12 structures with an area from 843 to 1381 m²*

Those Building are actually the Conaco DEGS, Conaco Medecine, Conaco Lettre, Primature, Conaco Science, NAS, Library, Gymnase, DT_DEGS, DT_Medecine, Bloc Tech Polytechnique, Departement Mathematique, Departement lettre, Science Q1, Présidence ...

Tableau 3 : List of the building in the university of Antananarivo

ID	Building name	Departement	Roof Area [m²]
68	CONACO	FLSH	2726
94	CONACO	DEGS	2679
66		Gymnase	2033
96	CONACO	Medecine	2029
34	Département	Science	1907
81	Conaco3	Science	1873
60		Library	1751
62	DT	DEGS	1731
97		Primature	1653
69	NAS	Science	1385
1	AEDECOUA	DEGS	1347
105		AdminUA	1337
61	DT	Medecine	1336
13	Département	FLSH	1196
98		AdminUA	1059
30		Science	1024
102		AdminUA	1010
32	Q1Q2	Science	997
106	Atelier	Agro	925
117		Agro	921
77	Bloc tech	POLY	913
11		Présidence	901
67	Département	Sport	843
10	Département	Médecine	774
4	DSC	DEGS	758
2	DSC	DEGS	751
7	Amphi DEGS	DEGS	724
9		Labo CM	700

The table above presents the key buildings with roof areas exceeding 700 m². To provide a visual representation of their placement within the university premises, a map displaying these buildings alongside their respective IDs is included below. Despite the relatively modest roof areas of many structures, their central positioning within the campus facilitates effective rainwater harvesting. The close proximity of these buildings allows for the consolidation of collected rainfall, potentially mitigating the limitations posed by individual roof areas. Consequently, while the roof areas may be individually small, their combined contribution to rainwater harvesting remains significant due to their strategic positioning within the campus. Moreover, the relevance of these structures is underscored by their central location, which aligns with the pertinent needs of the university community.

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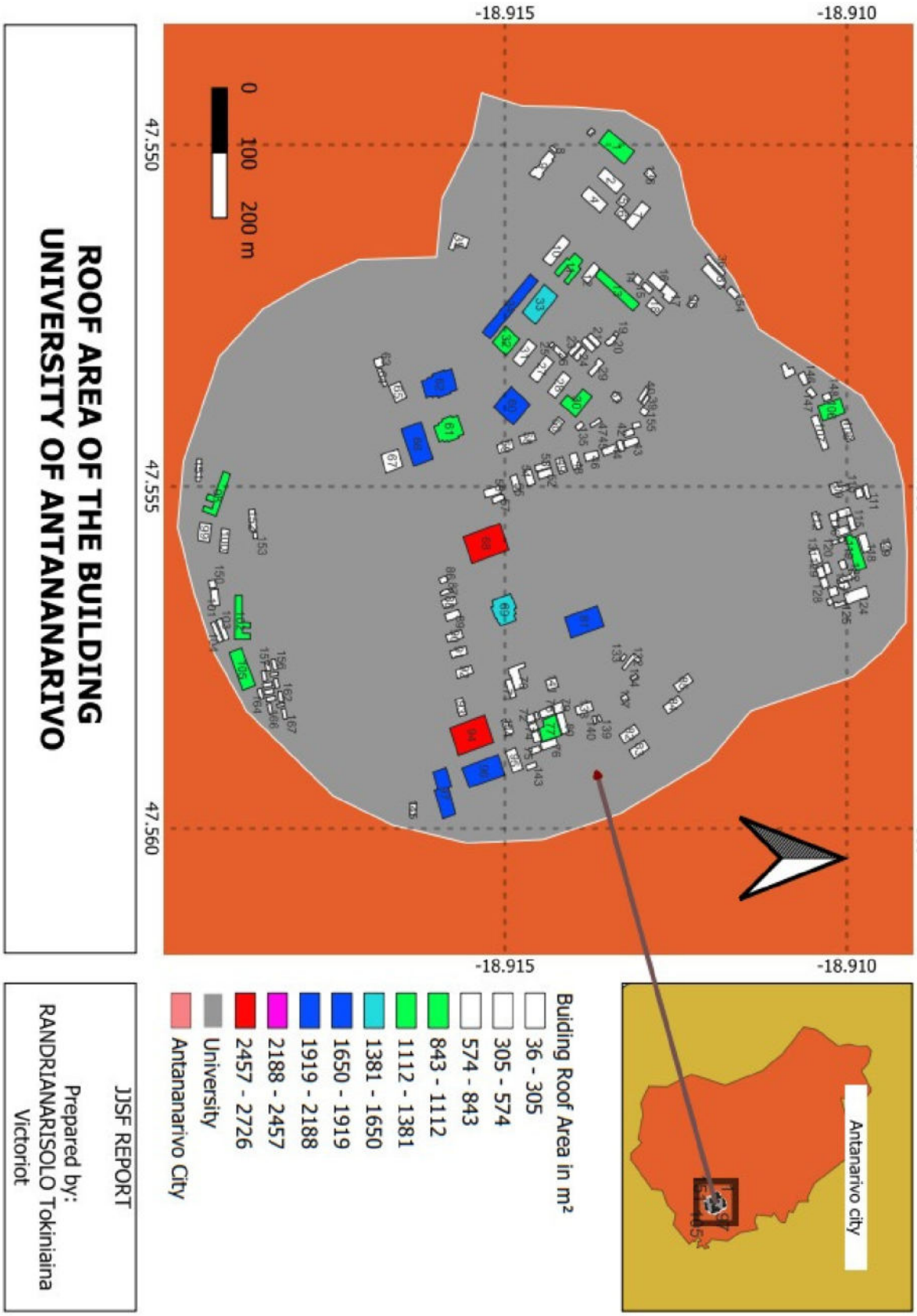
ROOF AREA OF THE BUILDING
UNIVERSITY OF ANTANANARIVO
0 100 200 m
-18.915
-18.910
47.550
47.555
47.560
Antanarivo city
Buiding Roof Area in m²
36 - 305
305 - 574
574 - 843
843 - 1112
1112 - 1381
1381 - 1650
1650 - 1919
1919 - 2188
2188 - 2457
2457 - 2726
University
Antananarivo City
JJSF REPORT
Prepared by:
RANDRIANARISOLO Tokiniaina
Victoriot

8- Analysis of Scenario from APIPA data based on the roof Area The following table based on the formula $V=A*p*c$ and an average rainfall of *894.6* mm from the APIPA data (2019-2022) is stored on the excel file that gives all the foundation of our study. We choosed a *max daily rainfall as 120* from the table 1.

id	Buisfing name	Departement	Roof Area [m²]	Type of roof	Volume from Total RainFall [m3/year]	Volume for daily max rainfall	Volume for 25 mm of precipitation [m3/day]	Volume for 10 mm of precipitation [m3/day]	Volume for 5 mm of precipitation [m3/day]
68	CONACO	FLSH	2726	0,8	1 951,0	262,6	54,5	21,8	10,9
94	CONACO	DEGS	2679	0,8	1 917,4	258,1	53,6	21,4	10,7
66		Gymnase	2033	0,8	1 455,0	195,9	40,7	16,3	8,1
96	CONACO	Médecine	2029	0,8	1 452,2	195,5	40,6	16,2	8,1
34	Département	Science	1907	0,7	1 194,2	160,8	33,4	13,3	6,7
81	Conaco3	Science	1873	0,8	1 340,5	180,5	37,5	15,0	7,5
60		Library	1751	0,7	1 096,6	147,6	30,6	12,3	6,1
62	DT	DEGS	1731	0,8	1 238,9	166,8	34,6	13,8	6,9
97		Primature	1653	0,7	1 035,2	139,3	28,9	11,6	5,8
69	NAS	Science	1385	0,8	991,3	133,4	27,7	11,1	5,5
1	AEDECOUA	DEGS	1347	0,7	843,6	113,6	23,6	9,4	4,7
105		AdminUA	1337	0,7	837,3	112,7	23,4	9,4	4,7
61	DT	Médecine	1336	0,8	956,2	128,7	26,7	10,7	5,3
13	Départementt	FLSH	1196	0,7	749,0	100,8	20,9	8,4	4,2
98		AdminUA	1059	0,7	663,2	89,3	18,5	7,4	3,7
30		Science	1024	0,7	641,3	86,3	17,9	7,2	3,6
102		AdminUA	1010	0,7	632,5	85,1	17,7	7,1	3,5
32	Q1Q2	Science	997	0,7	624,4	84,0	17,4	7,0	3,5
106	Atelier	Agro	925	0,7	579,3	78,0	16,2	6,5	3,2
117		Agro	921	0,7	576,8	77,6	16,1	6,4	3,2

id	Buisfing name	Departement	Roof Area [m²]	Type of roof	Volume from Total RainFall [m3/year]	Volume for daily max rainfall	Volume for 25 mm of precipitation [m3/day]	Volume for 10 mm of precipitation [m3/day]	Volume for 5 mm of precipitation [m3/day]
77	Bloc tech	POLY	913	0,7	571,8	77,0	16,0	6,4	3,2
11		Présidence	901	0,8	644,9	86,8	18,0	7,2	3,6
67	Département	Sport	843	0,7	527,9	71,1	14,8	5,9	3,0
10	Département	Médecine	774	0,7	484,7	65,2	13,5	5,4	2,7
4	DSC	DEGS	758	0,7	474,7	63,9	13,3	5,3	2,7
2	DSC	DEGS	751	0,7	470,3	63,3	13,1	5,3	2,6
7	Amphi DEGS	DEGS	724	0,7	453,4	61,0	12,7	5,1	2,5
9		Labo CM	700	0,8	501,0	67,4	14,0	5,6	2,8
TOTAL		**29 building**	**38870**		**24 904**	**3 352**	**695**	**278**	**139**

9- Estimation of the rainwater drained to the pipe to the rice field:

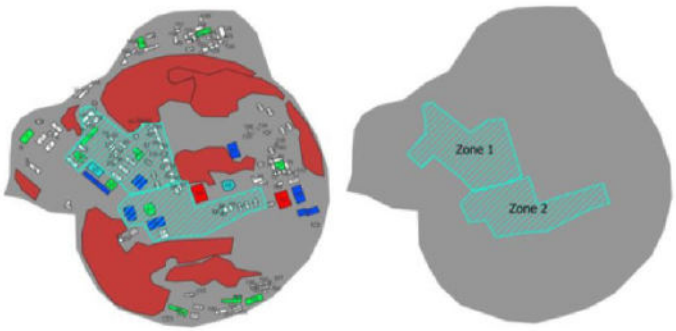

Figure 16 Zone existing infrastructure channes rainwater

Through investigations conducted during the fellowship workshop, it has come to our attention that certain existing infrastructure channels rainwater towards the adjacent rice fields.

id	Area	Coefficient	Total rain capture [m3/year]	Volume for Daily MAX Précipitation [m3/day]	Volume for Daily 25mm précipitation [m3/day]	Volume for Daily 10mm précipitation [m3/day]	Volume for Daily 5mm précipitation [m3/day]
1	72 674	0,3	19 513	2 616	545	218	109
2	64 625	0,3	17 352	2 327	485	194	97

These estimations are derived from the analysis of Zones 1 and 2, which feature rainwater drainage systems leading to the rice fields. Utilizing coefficients of rainwater

catchment and previous rainfall data scenario, we have arrived at the aforementioned results.

10- Key Results:

From the previous study, we came to some considerable results:

- Wet Season: the graph from figure 11-12 and the table on the figure 5-6-7 has shown that there is a rainy season of 5 - 6 months from October to April where the precipitation is significant for Antananarivo. It confirms what is said on many literature

Total Rainfall: the amount of precipitation for Antananarivo average 1000 mm/ year from 1991-2022 but as we move to the recent year, it tend to fluctuate around 900 to 800 mm/year (table 1)

- Number of rainy days: The average number of rainy days exhibits significant variation, ranging from 52 to 133 days across the stations, with an overall average of 82 days.

	Average Total Rain [mm/year] 894,6	Average Max Rain [mm/year]	Average Number of Rainy days	Rainy day > 1mm 63	Rainy day > 5mm	Rainy day > 10mm	Rainy day > 25mm	Rainy day > 50mm	daily max rain [mm]
Antananarivo		1178	82		39	26	10	3	120

- Area of the building: Building area breakdown:
  - 4 structures with an area exceeding 2000 m²
  - 13 structures with an area ranging from 1000 m² to 2000 m²
  - 11 structures with an area ranging from 700 m² to 1000 m²

- Amount of Rainwater harvested: The extreme value of rainfall harvested are between this table for roof Area from 2726 to 700 m²

Roof Area [m²]	Type of roof	Volume from Total RainFall [m3/year]	Volume for daily max Rainfall [m3/day]	Volume for daily precipitation of 25 mm	Volume for daily precipitation of 10 mm	Volume for daily precipitation of 5 mm
2726	0,8	1 951,0	262,6	54,5	21,8	10,9
700	0,8	501,0	67,4	14,0	5,6	2,8

11- Discussion:

- On the method:

calculating the average of data without considering missing values, one common approach is to simply exclude the missing values from the calculation and then divide the sum of the remaining values by the number of non-missing values. This method provides a straightforward way to compute the average based only on available data points. However, it will lead to a

nonconvergent estimation of the total rainfall in yearly average and total monthly average like we can see on the table 1 and figure 7. But they gave an estimated value that fluctuate between 900 to 1000 mm/year. Relevant result: Although, based on the similarity of the results we have observed from many other sources, we can conclude that the analysis of rainfall from the APIPA station measurements provides robust and relevant data that we can rely on to draw firm conclusions. Suggestion: It is advisable to consider the lower range of precipitation values from the total rainfall dataset, reflecting the observed trend of annual precipitation. However, when sizing equipment, it's crucial to also account for daily rainfall data. Both the analysis of monthly and yearly average totals should be factored in when making decisions based on the dataset.

Conclusion:

This document presents a comprehensive analysis of a substantial dataset aimed at corroborating information obtained from diverse sources regarding precipitation in Antananarivo. Specifically, it delves into an examination of the wet season in Antananarivo and provides estimations of the total annual rainfall for the University of Antananarivo. These data were subsequently utilized to gauge the potential harvestable rainwater for a year based on the roof area of existing buildings. Furthermore, various scenarios for rainwater collection were analyzed in detail. Indeed, these results and analyses serve as a foundational framework for future studies, particularly for the JJSF Water Management Project. They provide valuable insights into precipitation patterns, rainfall estimation, and potential rainwater harvesting opportunities, laying a solid groundwork for further exploration and implementation within the project's scope.

References :

[1] -Atlas Climatologique de madagascar – météo Malagasy [2]- Météo Madagascar,

2023: Tendances Climatiques Observées et Futurs
Changements Climatiques à Madagascar 2023. Kotomangazafy Stephason F., Nirivololona Raholijao, Zo A. Rakotomavo, M. D. Leroux, F. Bonnardot]. Direction Générale de la Météorologie de Madagascar & Direction Interrégionales de la Météo-France pour l'Océan Indien, La Réunion. [3]- https://www.chauffeur-guide-madagascar-lga.com/decouvrir-madagascar/presentation/climat-et-saisons/

[4]- Donnée Station APIPA 2000-2022

[5]https://www.meteoblue.com/fr/meteo/historyclimate/weatherarchive/antananarivo_ madagascar_1070940

[6] - https://fr.climate-data.org/afrique/madagascar/tananarive/tananarive-548/#climate-graph

[7] – https://www.climatsetvoyages.com/climat/madagascar/antananarivo

[8] – JJSF Spring Journal 2024 (https://jacquelynsandersfoundation.org/sustainable-vision-journal-spring-2024-edition/)

[9] - http://obs.meteor-oi.re/TAN1270/history.html

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