Journal of Materials and Environmental Science
ISSN: 2028-2508
e-ISSN: 2737-890X
CODEN: JMESCN

J. Mater. Environ. Sci., 2023, Volume 14, Issue 7, Page 785-795

http://www.jmaterenvironsci.com

Prediction of Pluviometry in the *OUM ER RABIA* Hydraulic Basin

Ram Allah NASSOH[1], Malika ECHAJIA[1], Brahim ZOUKENI[1], Mouad MOUHSIN[1], Mohamed MBARKI[1], Mustapha OUBENALI[1], Bouchaib HAKKANI[2], Abdelkrim BENSALEM[3] and Tarik EL OUAFY[4*]

1 Laboratory of Engineering in Chemistry and Physics of Matter, Department of Chemistry and Environment, Faculty of Sciences and Technics, Sultan Moulay Slimane University, Beni Mellal, Morocco
2 Oum Er-Rbia Hydraulic Basin Agency, Beni Mellal, Morocco
3 Research Center Plant and Microbial Biotechnologies, Biodiversity, and Environment, Faculty of Sciences, Mohammed V University in Rabat, Morocco
4 Laboratory of Engineering in Chemistry and Physics of Matter, Department of Physics and Chemistry, Polydisciplinary Faculty of Khouribga, Sultan Moulay Slimane University, Beni Mellal, Morocco
** Corresponding author. E-mail address: tarikelouafy@gmail.com*

Received: *15 April 2023*
Revised: *27 June 2023*
Accepted: *15 July 2023*

***Citation**: Nassoh R. A., Echajia M., Zoukeni B., Mouhsin M., Mbarki M., Oubenali M., Hakkani B., Bensalem A., EL Ouafy T. (2023) Prediction of Pluviometry in the OUM ER RABIA Hydraulic Basin, J. Mater. Environ. Sci., 14(7), 785 - 795.*

Abstract: The climate prediction offers an important and useful information for modern agriculture. Indeed, this form of agriculture is optimized because of unfavorable condition as low rainfall and climat changes. This work focuses on rainfall forecasting in the *Oum Er Rbia* basin in Morocco at the level of the Rhamna area, to optimize the yield of six durum wheat tested varieties. The pluviometry data for the years 1994/2020 have been collected at the *Bouchane* agro-meteorological station in Rhamna province and compared to data from three other stations: *El Massira* stations, *Bengrir* stations and *Zmemra* stations too. In order to determine similarities between years and an eventuel correlation between months to the principal component analysis (PCA) was applied. The first results show that the PCA has been able to classify the years and determine the correlations. To predict the mean annual precipitation (MAP), partial squares regression (PLS) was applied. This regression has allowed to confirm the similarities between years (1994/2020) as well as the correlations between months as determined by the PCA. The statistical parameters of the model in terms of the R^2 determination coefficient and the RMCE error are relatively satisfactory that the PLS model has been validated.

Keywords: *Rhamna*; *Rainfall; Oum Er Rabia Basin; Predictions; Climate Changes.*

1. Introduction

Morocco is a North-African country where the vulnerability of the populations to extreme hydrological events is high (Douglas *& al.* 2008, Di Baldassarre *& al.* 2010) However, semi-arid and *Mediterranean* areas are expected to be particularly vulnerable to climate change (Oueldkaddour *& al.* 2021). This could lead to an increased probability of occurrence of events inducing both floods and droughts (Gao *& al.*, 2006). According to the latest models, for 2050, global warming in progress, would in all likelihood lead to an increase in temperature between 2.3°C and 2.9°C and a decrease in rainfall between 13 and 30% (Ait Houssa *& al.*, 2016). This change intensifies the water cycle and brings more intense rainfall, with accompanying flooding and more intense droughts in many areas.

According to the press release of the 6th IPCC report, the climate change will increase in all areas in the forthcoming decades. This climatic effect modifies the distribution of rainfall and it is likely that this rainfall will increase at high latitudes, while a decrease is projected in a large part of the subtropics areas (Trenberth *& al.*, 2011).

The first rainfall map of Morocco was elaborated by the German geographer Theobald Fischer early 1900 (Horden *& al.*, 2006) It contains some errors due to lack of meteorological observations and to meager technical resources at that time. Many rainfall maps have been developed since then, with varied degree of accuracy (Richardson *& al.*, 1917). All these maps reveal high spatial heterogeneity of total annual rainfall in Morocco like in **Figure 1**, varying from 13 mm in the Sahara to above 1000 mm at Tangier. This heterogeneity had already been illustrated by the first global work on rainfall in Morocco done by Augustin Bernard (1921) (Balaghi *& al.*, 2013). The distribution of average annual rainfall received more attention of researchers to see its impact on the climate and agriculture as well as on the economic growth (Ejjiar & Arib, 2023; hakkou *& al.*, 2023; Mohamed *& al.*, 2019; Aabdousse *& al.*, 2021)

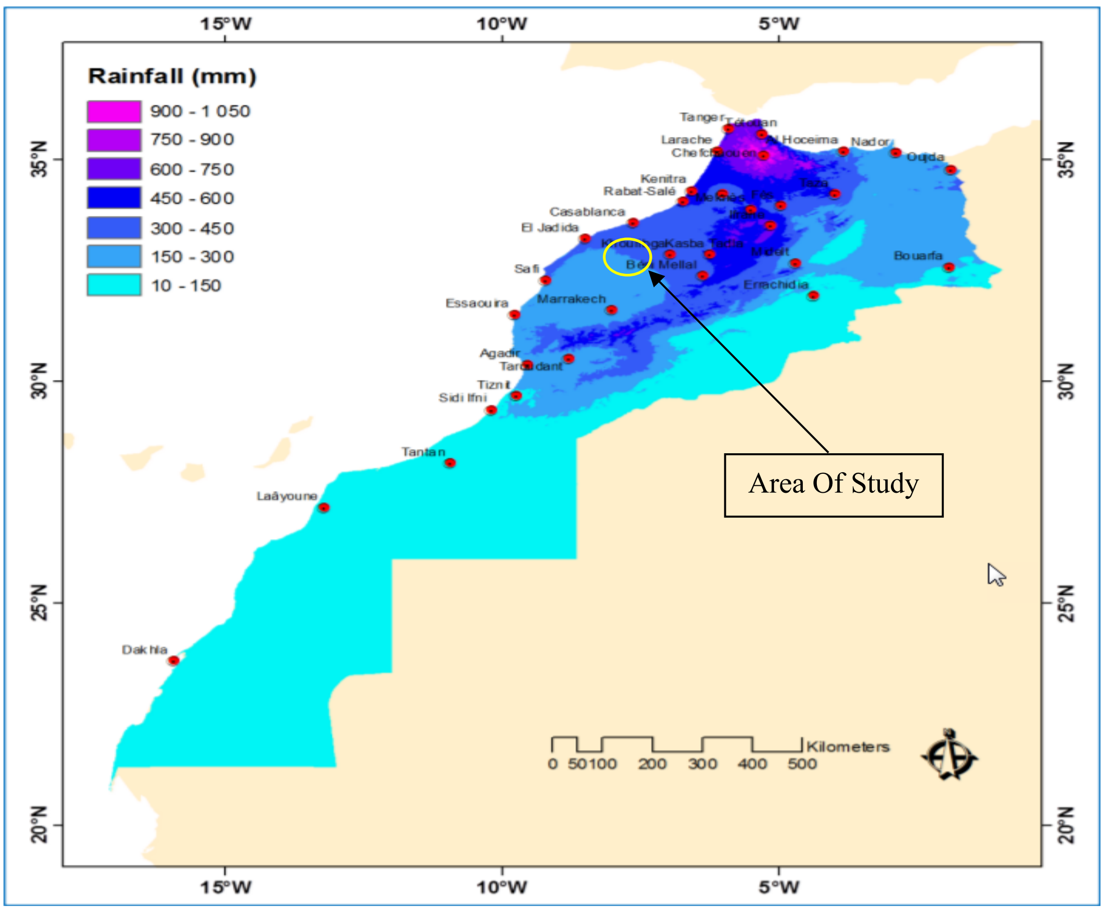

Figure 1. Cumulative average rainfall over Morocco between September and April (Hijmans *& al.*, 2005)

Otherwise, the rainfall distribution in Morocco did change during the (1961-2008) period. This change, consisting of a shift to drier conditions has coincided with an increase in the average temperature in all seasons (Driouech *& al.*, 2010). The area of study is part of this change, where rainfall is known to vary from year to year, thus affecting the yield of cereals that account for 92% of the area under diffuse crops (PDA, 2018; Zoukeni *& al.*, 2023). In this context, the present work is based on a statistical study of the rainfall data of the agro-meteorological *Bouchane* station, using the Principal Component Analysis PCA to predict rainfall and month/year relationships within and between years.

2. Data and Methods

The proposed method consists in processing and analyzing the annual rainfall data of the agro-meteorological stations; *Bouchane, El Massira, Bengrir* in the study area at *Rhamna* province and *Zmemra* station, using the data of *Bouchane* station, the closest to the test area that presents an interesting time period, for PCA, CAH and PLS, in order to correlate the results with the predictions.

3. Results and Discussion

3.1. Studying the annual precipitation trend

The **Figure 2** shows that the annual rainfall in the province of *Rhamna* and the area of *Zmemra* are very variable and irregular from one year to another. The interannual average is about 185.2 mm for El Massira dam, 206.7 mm for *Bouchane*, 147.25 mm for *Bengurir* and 292.3 mm for the *Zmemra* station. The observed values of each station show a variability of rainfall has the quantitative scale, thus, a remarkable downward trend of the annual height of precipitation with time for the four stations (ORRBA, 1993/2020 & 1984/2020, OADD, 2006/2020, ROAC, 2012/2020).

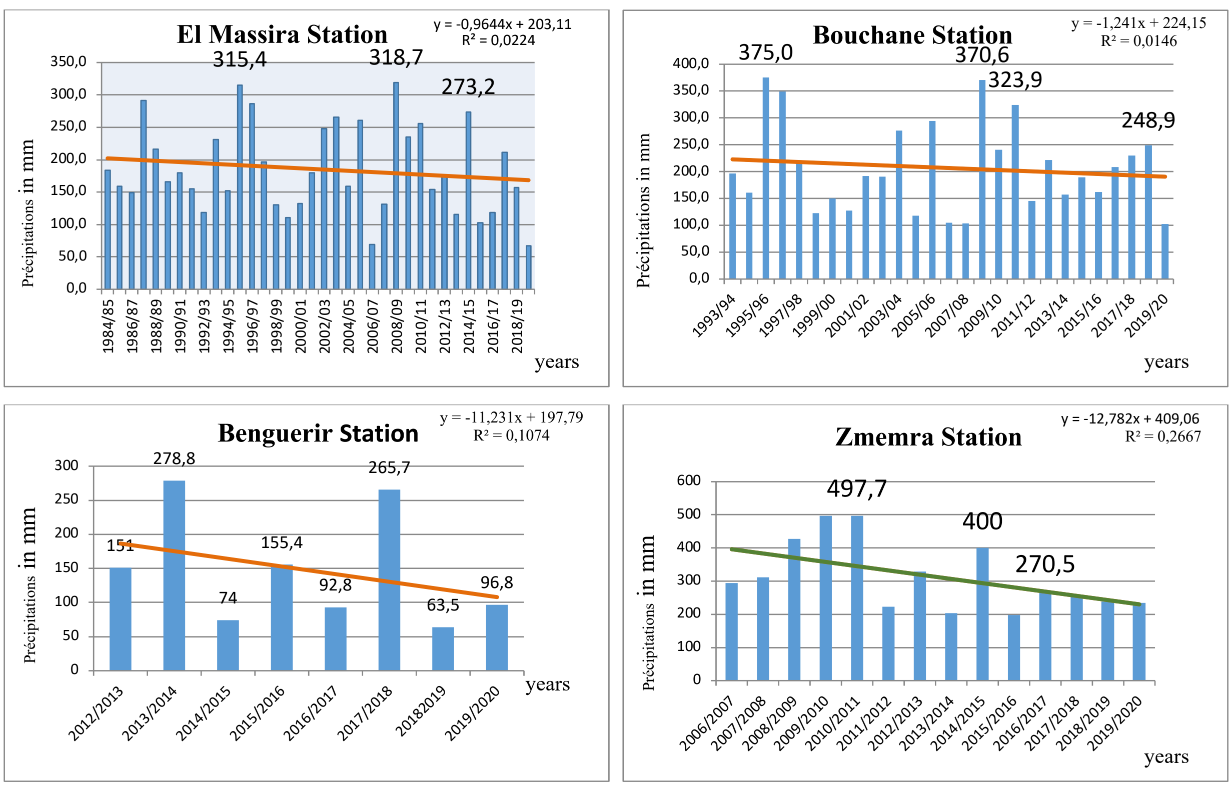

Figure 2. Annual precipitation trends at the four stations.

Also, the number of days of precipitation tends to decrease over time in **Figure 3**. In fact, this figure present Trend in number of days with rainfall greater than or equal to 1 mm.

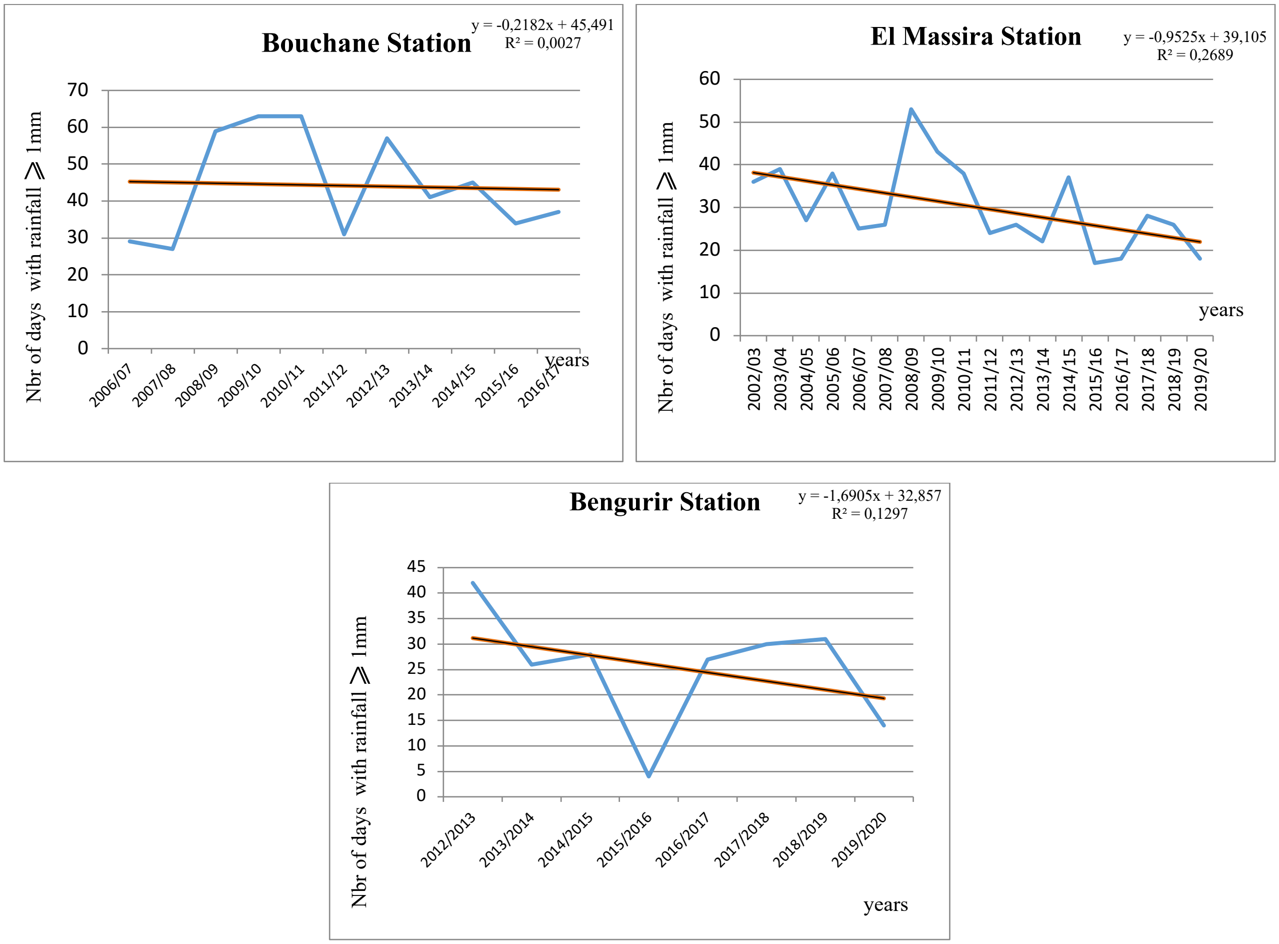

Figure 3. Trend in the number of rainy days at the three stations.

3.2. Classification and prediction of rainfall data

Statistical parameters in **Table 1** shows that the averages of the months in terms of rainfall are not close, hence the need for the centering step of the rainfall data in the initial table. Also, the standard deviations are not close, and that necessitates a reduction of the rainfall data in the initial table before the PCA is performed. Survey literature pointed out that the trend toward allowing direct delivery of objective guidance to users is a significant new development in the operational hydrologic forecasting community, and it could facilitate the increased transfer of research (i.e., new objective methods) into practice at operational agencies (Pagano *& al*., 2009; Canchala-Nastar *& al*., 2019 ; Jolliffe & Cadima *& al*., 2016). The information about the years of rainfall from the initial table of raw data is preserved only at 36.37% in two dimensions of the PCA in **Figure 4**.

Otherwise, the 3D factorial map in **Figure 5** has been able to illustrate the variables with a significant percentage of conservation that reached 68%.

However, at the level of the two dimensions PCA, it seems that they are three classes defined as follows:

- The first class contains relatively more similar years such as 2000, 2005, 2007, 2012, 2019 and others.

- The second class, possibly confused with the third, contains relatively more similar years such as: 1996, 1997, 2010, 2011, 2016 and others.

Table 1. statistical parameters for monthly rainfall in the (1994/2020) years

Month	Minimum	Maximum	Average	Standard deviation
September	0.000	97.500	7.874	20.365
October	0.000	88.400	21.963	22.526
November	0.000	187.500	41.211	40.154
December	0.000	148.500	33.252	32.347
January	0.000	102.900	28.389	25.620
February	0.000	93.300	26.133	24.823
March	0.000	83.400	26.548	19.834
April	0.000	61.900	17.463	20.240
May	0.000	54.400	9.374	14.514
June	0.000	17.500	1.533	3.826
July	0.000	2.000	0.081	0.385
August	0.000	6.300	0.374	1.286

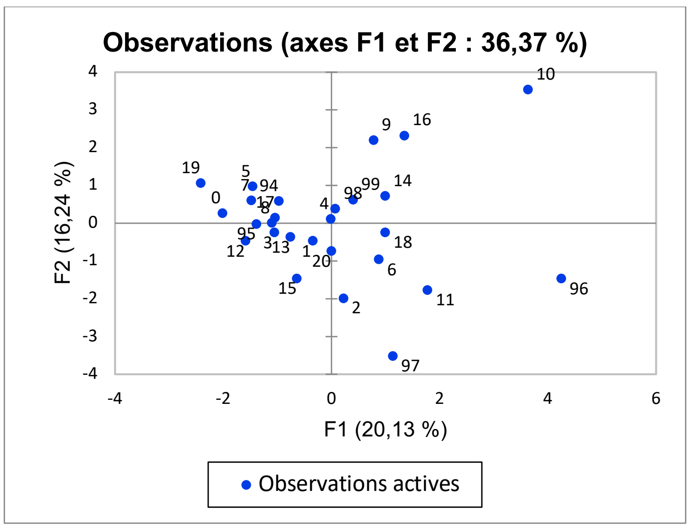

Figure 4. 2D factorial map of rainy years (1994/2020)

The presentation of the 3D maps shows perfectly the above-mentioned classification but this time with precision of one can notice the grouping of the rainy years such as 1996, 1997, 2009, 2010 and 2018 that does not appear in 2D, and that we know by a record yield of durum wheat. While the class of years with low rainfall appears the same with the year 1995. Fact a result did not appear with the group. In fact, it was known as the driest year. Apart from December, the eleven months seen to fall into four classes such as **Figure 6**:

- February, June, July and August
- January, March and May
- September and October
- November and April

In fact, there is a more or less strong positive correlation between the months within each group, with this trend disappearing as we move from one group to the next. Looking for the years that best increased the similarity between the months within each group, one can observe that years such as 2009, 2010, 2014 and 2016 have been so for the February, June, July and August group.

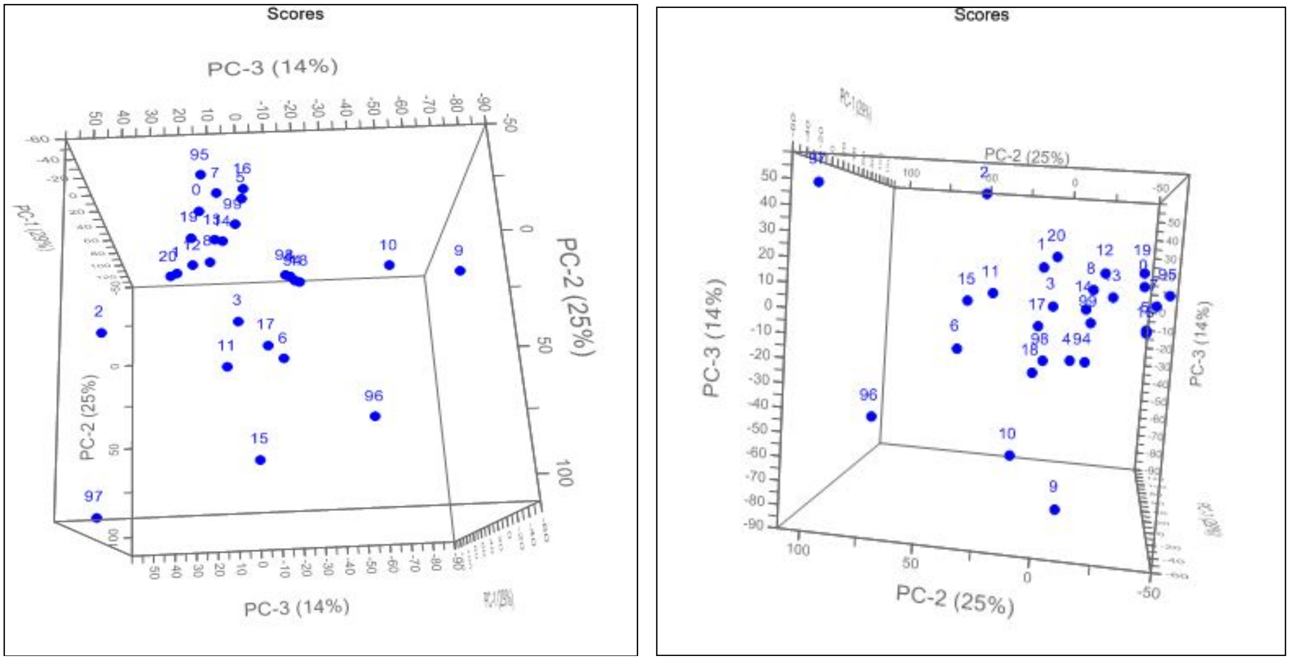

Figure 5. 3D factorial map of rainy years (1994/2020)

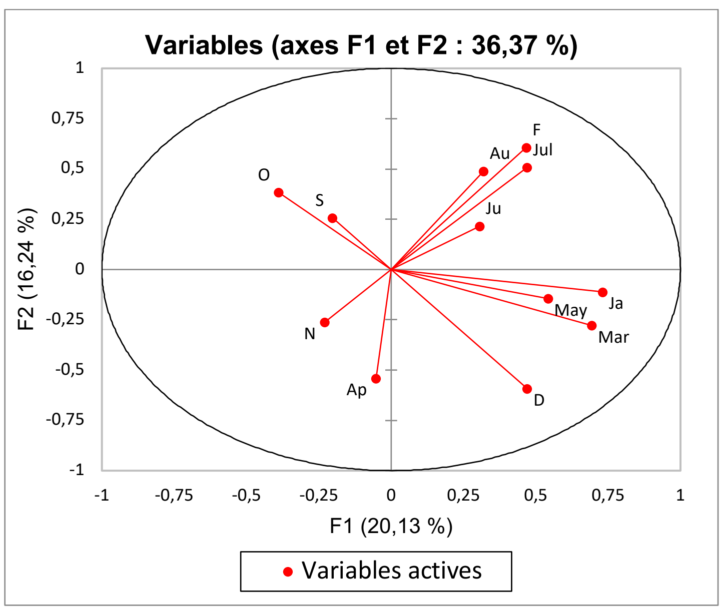

Figure 6. Correlation plot (loading) of rainfall months (1994/2020)

Years such as 1996 and 2018 have been so for the group of January, March and May, while the 1994, 2005 years have served for the group of September and October and the years such as 2002 and 2015 and for the group of November and April. This result concerning the obtained correlations between months and years and with the one noted by (Balaghi *& al.*, 2013), where cereal growth (from lifting to the tillering) extends from September until March in this geographic area. However, these two campaigns have known a record yield of grain that exceeds 103 million quintals for 2018 (Ministry of Agriculture, Maritime Fishing, Rural Development and Water and Forests, 2017/2018). On the other hand, the lack of rainfall in September, October, November and April correlates positively with dry years such as 1995, 2019 or cereal yields no longer exceed 32 million quintals for 2019 (Ministry of Agriculture, Maritime Fishing, Rural Development and Water and Forests, 2019), and correlates negatively with rainy years such as 1996, 2018 in **Figure 7**. Although the PCA showed two to three classes of years (Figure 4), the analysis of the classification results of the years confirmed that these classification results corroborate those of the PCA according to the following AHC dendrogram in **Figure 8**:

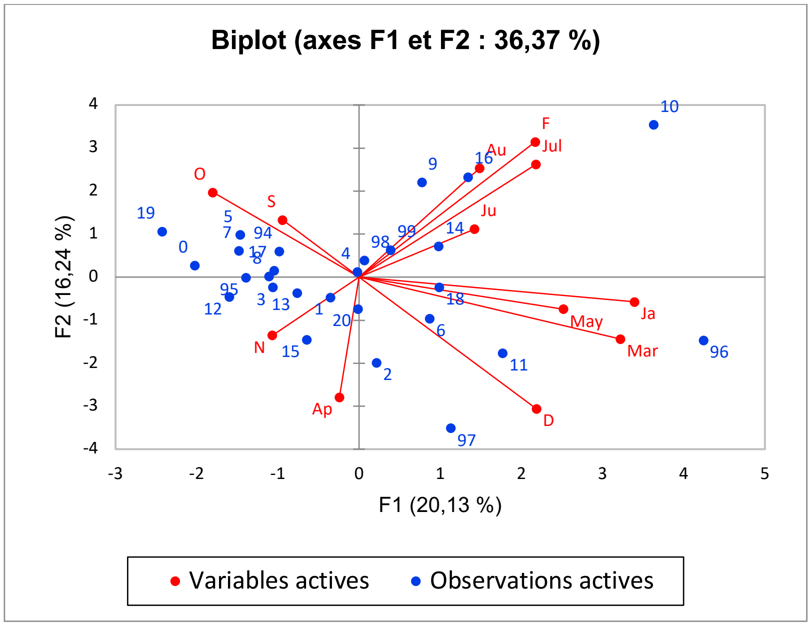

Figure 7. Map of variables

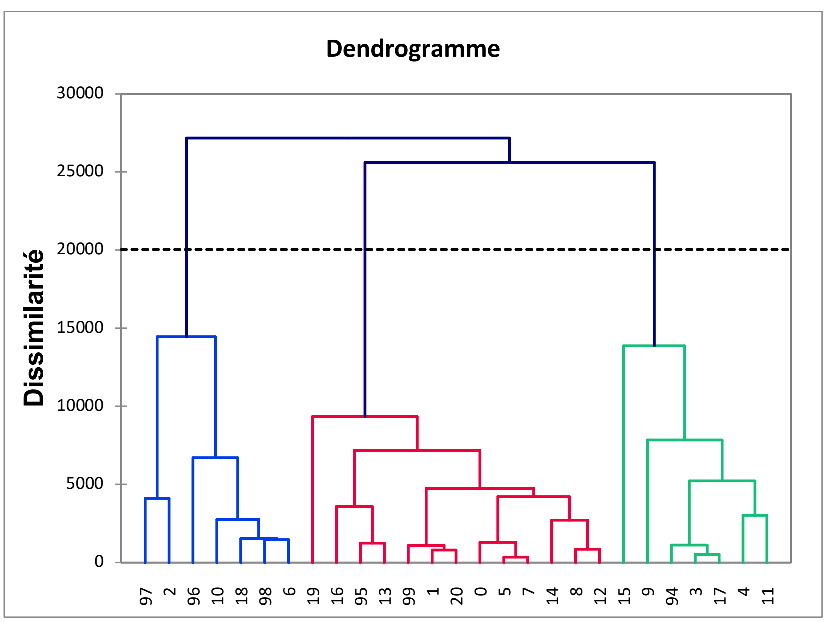

Figure 8. Hierarchical Ascending Classification (HAC) dendrogram of annual rainfall years from 1994 to 2020

The correlation matrix between the different pairs of months and pairs (month, MAP) is given in table 2. It is observed that the month of March correlates best with MAP (0.663) followed by December and January. This explains that overall, the study period (1994-2020) it is the month of March that recorded more rainfall in **Table 2**.

Table 2. correlations between different months and months/MAP

	S	O	N	D	Ja	F	Mar	Ap	May	Ju	Jul	Au	PAM
S	1.000	0.093	-0.027	-0.231	-0.178	-0.132	-0.015	0.018	-0.059	0.056	-0.028	0.255	0.071
O	0.093	1.000	0.017	-0.338	-0.286	0.311	-0.188	-0.032	-0.094	0.055	-0.200	-0.146	0.109
N	-0.027	0.017	1.000	-0.024	-0.120	-0.154	0.120	-0.131	-0.109	-0.019	-0.200	-0.267	0.369
D	-0.231	-0.338	-0.024	1.000	0.423	-0.039	0.327	0.260	0.059	-0.120	0.078	-0.169	0.504
Ja	-0.178	-0.286	-0.120	0.423	1.000	0.307	0.312	-0.071	0.185	0.362	0.252	-0.097	0.503
F	-0.132	0.311	-0.154	-0.039	0.307	1.000	0.174	-0.226	0.048	0.159	0.504	0.217	0.372
Mar	-0.015	-0.188	0.120	0.327	0.312	0.174	1.000	0.161	*0.663*	0.134	0.002	0.241	0.699
Ap	0.018	-0.032	-0.131	0.260	-0.071	-0.226	0.161	1.000	-0.026	-0.073	-0.172	-0.227	0.219
May	-0.059	-0.094	-0.109	0.059	0.185	0.048	*0.663*	-0.026	1.000	0.061	-0.125	0.273	0.344
Ju	0.056	0.055	-0.019	-0.120	0.362	0.159	0.134	-0.073	0.061	1.000	0.155	-0.071	0.208
Jul	-0.028	-0.200	-0.200	0.078	0.252	0.504	0.002	-0.172	-0.125	0.155	1.000	0.278	0.054
Au	0.255	-0.146	-0.267	-0.169	-0.097	0.217	0.241	-0.227	0.273	-0.071	0.278	1.000	-0.076
PAM	0.071	0.109	0.369	0.504	0.503	0.372	0.699	0.219	0.344	0.208	0.054	-0.076	1.000

The months considered to have been the most important for MAP prediction (VIP > 0.8) are the following in order of importance in **Figure 9**: March, December, January, February, November and May.

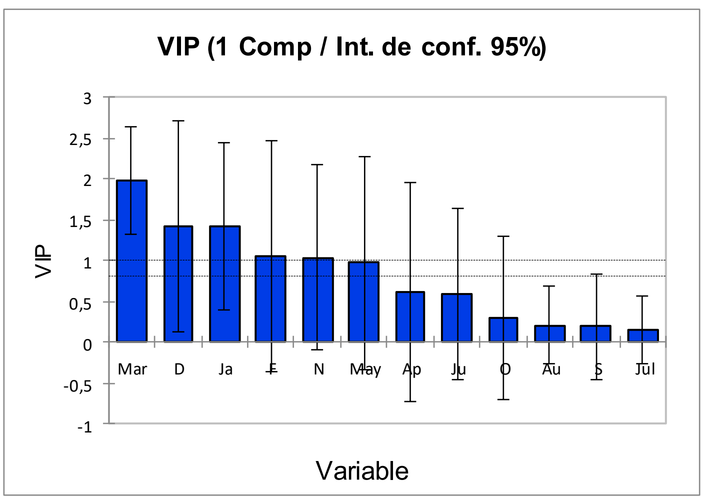

Figure 9. importance of hierarchical predictor variables (HPV)

The equation for the MAP prediction model using PLS regression is as follows:

MAP = 5,28 + 1,28E-02*S + 1,78E-02*O + 3,40E-02*N + 5,76E-02*D + 7,26E-02*Ja + 5,55E-02*F + 0,13*Mar + 4,00E-02*Ap + 8,75E-02*May + 0,20*Ju + 0,52*Jul -0,22*Au.

The Q^2cum term being greater than 0.5 in **Figure 10**, we consider that the prediction model is of acceptable quality. Also, the statistical parameters of the model validated by cross-validation show that the model is moderately robust since the R^2= 0,823(The correlation coefficients (R^2cum) and the cross-validation) is not very close to 1 and the error (RMCE = 2,796) is not close to 0.

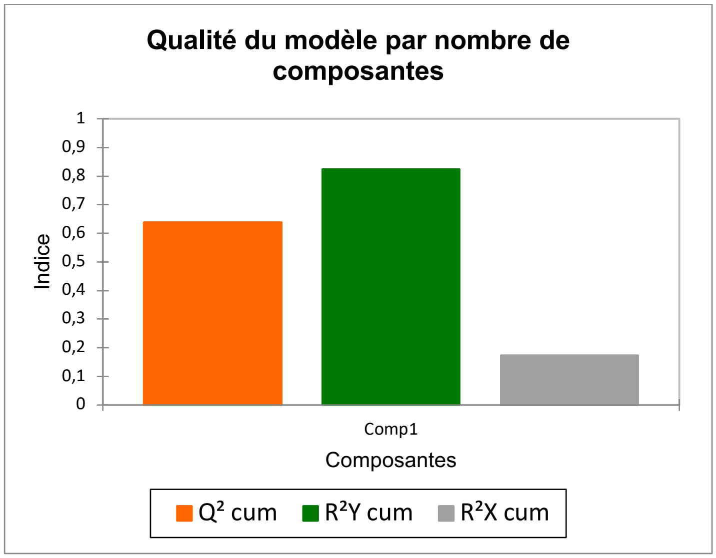

Figure 10. Quality of the prediction model

3. Conclusions

Data analysis methods such as descriptive statistics, PCA and AHC presented representations that facilitated both the understanding of similarities between rainfall years and correlations between months of the year. The PLS regression model for MAP prediction was found to be of acceptable quality and moderately robust. The PLS method would be a fast and robust tool capable of predicting MAP for all the years studied (1994/2020), where it was found that the recording of precipitation in the months of January, March and May leads to a fairly interesting campaign in terms of yield, even if they are absent in the periods of September, October, November and April. These results obtained showed that the loss of yields of durum wheat in our study area (south unfavorable Bour) is due not only to the irregularity of rainfall inter annual but also intra annual where the model studied to show that the period of study of rainfall (1994/2020) recorded more rainfall during the month of March, contrary to the needs of the varieties tested and wheat in general. Because this time of year for wheat is the end of the tillering phase and the beginning of the elongation phase, but it is still in the lifting stage. Therefore, it is concluded that the trends of climatic conditions will no longer be favorable for obtaining good yields of cereals with the exception of some special campaign resembling those recorded in 1996, 2010 and 2018. However, although our agriculture is climate-dependent, it is extremely important to think about alternative crops adaptable to climate change in the study area and other vulnerable areas in Morocco (unfavorable Bour), like most countries in the world, to the negative impacts of these changes, in particular, the disruption of the water cycle and increased temperatures.

Acknowledgements

Authors acknowledge Mr. Bouchaib HAKKANI for his help. We also express our sincere thanks to the Oum Er-Rbia Hydraulic Basin Agency for providing the hydro-climatic data.

References

Aabdousse J., Wahid N., Faida R., Karaoui I., Boulli A., Hassib A. (2021). Determination of the effect of biogeographic variability on myrtle ecology in Morocco using a combination of GIS and bioclimatic indices, *J. Mater. Environ. Sci.,* 12, Issue 9, 1209-1225

Ait Houssa A; Drissi, S.; Asehraou, A.; & al. (2016). Climate change in Morocco: which cropping systems and which biotechnologies to adapt to it? Rev Marocaine des Sci Agron Vétérinaires, 5(3), 210-221.

Aoubouazza M., Rajel R., & Essafi R. (2019). Impact des phénomènes climatiques extrêmes sur les ressources en eau et l'agriculture au Maroc. *Revue Marocaine des Sciences Agronomiques et Vétérinaires,* 7(2), 223-232

Balaghi R.; Jlibene, M.; Tychon, B.; & al. (2013). Agrometeorological Cereal Yield Forecasting in Morocco. Int J Water Resour Dev., 26(4), 157. doi:10.13140/RG.2.1.3645.6805.

Balaghi R.; Jlibene, M.; Tychon, B.; & al. (2013). Agrometeorological Cereal Yield Forecasting in Morocco. Int J Water Resour Dev., 26(4):157. doi:10.13140/RG.2.1.3645.6805

Canchala-Nastar T, Carvajal-Escobar Y, Alfonso-Morales W, Loaiza Cerón W, Caicedo E. (2019). Estimation of missing data of monthly rainfall in southwestern Colombia using artificial neural networks. *Data Brief.* 26, 104517. doi: 10.1016/j.dib.2019.104517

Di Baldassarre G.; Montanari, A.; Lins, H.; & al. (2010). Flood fatalities in Africa: from diagnosis to mitigation. *Geophys Res Lett.,* 37(22), L22402.

Douglas I.; Alam, K.; Maghenda, M.; & al. (2008). Unjust waters: climate change, flooding and the urban poor in Africa. Environ Urban., 20(1), 187-205.

Driouech F.; Déqué, M.; Sánchez-Gómez, E. (2010). Weather regimes—Moroccan precipitation link in a regional climate change simulation. *Glob Planet Change.*, 72(1-2), 1-10.

Ejjiar, A., & Arib, F. (2022). The Impact of Climate Change on Economic Growth in Developing Countries Case of Morocco. International Journal of Accounting, Finance, Auditing, Management and Economics, 3(4-1), 354-367. https://doi.org/10.5281/zenodo.6612549

Gao X.; Pal, JS.; Giorgi, F. (2006). Projected changes in mean and extreme precipitation over the Mediterranean region from a high resolution double nested RCM simulation. *Geophys Res Lett.,* 33(3).

Hakkou S., Sabir M., Machouri N. (2023) Contribution to the study of the production factors of Moroccan truffles (Soil, Climate, Vegetation), *J. Mater. Environ. Sci.,* 14(1), 13-30

Hijmans RJ. ; Cameron, SE. ; Parra, JL. ; & al. (2005). Very high resolution interpolated climate surfaces for global land areas. *Int J Climatol A J R Meteorol Soc*., 25(15), 1965-1978.

Horden, P.; Purcell, N. (2006). The Mediterranean and "the new thalassology.". *Am Hist Rev*., 111(3), 722-740.

Jolliffe I. T. and Cadima Jorge (2016). Principal component analysis: a review and recent developments, *Phil. Trans. R. Soc.* A.374(2065), 2015020220150202 http://doi.org/10.1098/rsta.2015.0202

Khaddor I., Achab M., Soumali M. R., Hafidi Alaou A. (2017). Rainfall-Runoff calibration for semi-arid ungauged basins based on the cumulative observed hyetograph and SCS Storm model: Application to the Boukhalef watershed (Tangier, North Western Morocco), *J. Mater. Environ. Sci.,* 8, Issue 10, 3795-380

Ministry of Agriculture, Maritime Fishing, Rural Development and Water and Forests. https://www.agriculture.gov.ma/fr/actualites/campagne-agricole-2017-2018-les-resultats-definitifs-font-etat-dune-recolte-de-103

Ministry of Agriculture, Maritime Fishing, Rural Development and Water and Forests. https://www.agriculture.gov.ma/index.php/fr/actualites/une-production-cerealiere-definitive-de-32-millions-de-quintaux-pour-la-campagne-2019.

Office of Agriculture Development Dokkala OADD. *Rainfall Data from the Meteorological Station of Khemiss Zmemra between (2006/2020)*.

Oueldkaddour FZE.; Wariaghli, F.; Brirhet, H.; & al. (2021). Hydrological modeling of rainfall-runoff of the semi-arid Aguibat Ezziar watershed through the GR4J model. *Limnol Rev.,* 21(3), 119-126.

Oum Er Rabia River Basin Agency ORRBA. *Rainfall Data from the Bouchane Meteorological Station between (1993/2020) & El Massira Meteorological Station between (1984/2020).*

Pagano T.C., David C. Garen, Tom R. Perkins, and Phillip A. Pasteris P.A. (2009), Daily updating of operational statistical seasonal water supply forecasts for the Western U.S., Journal of the American Water Resources Association, 45(3), 767-778

Provincial Directorate of Agriculture PDA. (2018). *Monograph of the Rhamna Province.*

Regional Office of the Agriculture Council *Marrakech Safi ROAC. Rainfall Data from the Ben Guerir Meteorological Station, between (2012/2020)*.

Richardson R. Morocco as a French protectorate. (1917). *Scott Geogr Mag*., 33(9), 392-400.

Trenberth KE. (2011). Changes in precipitation with climate change. *Clim Res*., 47(1-2), 123-138.

Zoukeni B., EL Orche A., Nassoh R. A., Oubenali M., Mahboub A., EL Ouafy T., Echajia M., Mbarki M. and Gamouh A. (2023) Prediction of the pluviometry in the Guir-Ziz-Rheris hydraulic basin, J. Mater. Environ. Sci., 14(4), 430-441

(2023) ; http://www.jmaterenvironsci.com