International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
SCHOLAR AI Be Smart
Vol. 50 No. 1 April 2025, pp. 397-415

Forecasting Study Of The Start, End And Duration Date Of The Tiomena Wind Season In Southern Madagascar By Artificial Neural Networks

Honoré RAZAFIMANDIMBY[1],Jean Eugène RANDRIANANTENAINA[2],
Jacques Chrysologue RATSIMAVO[3],Adolphe Andriamanga RATIARISON [4]

[1,2,3], Laboratory of Atmospheric, Climate and Ocean Dynamics-Doctoral School :≪Physico-Chemistry Geosciences of the Environment and High Pathogenic Systems≫; University of Toliara)

[4], Laboratory of Atmospheric, Climate and Ocean Dynamics-Doctoral School :≪Physics and Applications Doctoral School:≫:University of Antananarivo)

Abstract: Tiomena is a wind phenomenon that generally occurs after a long period of rain in southern Madagascar. But currently it is changing its behavior due to climate change. According to the results of analysis made on the fast Fourier transform and the maximum entropy method, we note that tiomena repeats twice in a year with two different periods, of different length and especially of different intensity.

Keywords: Tiomena, Start, End, Length.

I-Introduction

Southern Madagascar is highly vulnerable to the impacts of climate change. Recently, the Tiomena has been added to the list of meteorological phenomena facing this region. The Tiomena wind is one of the factors causing aridity in the southern part of Madagascar, with an average daily speed of 46 km/h (28 mph), equivalent to 12 m/s (32 mph), and a central pressure of 1000 hPa. Over the past two or three years, we have noticed that the Tiomena wind is intensifying.

I.1-Presentation of the study area

Our study area is delimited between 26°S to 20°S and 42°E to 46°E, with 35 individuals ranging from A1 to A7 vertically and A1 to E1 horizontally. We chose a 1-degree increment, which is equivalent to a distance of 111 km.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

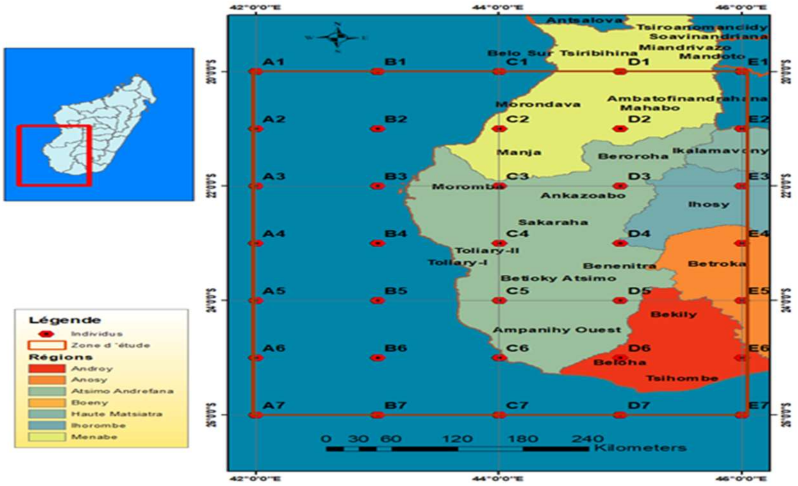

Figure 1: Study area

II-Methodology

II.1-Fast Fourier Transform Method

Harmonic analysis is based on expanding the cylindrical components of the series into a sum of periodic terms involving a combination of sines and cosines. It leads to the construction of a periodogram defined from the data fit using the Fourier series least squares method (G. Baudoïn and J.-F. Bercher, 2001):

μ(t) = $a_0 + \sum_{n-1}^{N}(a_n cosnt + \ b_n sinnt)$

$$a_n = \frac{2}{T}\int_0^T u(t)\cos\left(\frac{2\pi nt}{T}\right)dt$$

$$b_n = \frac{2}{T}\int_0^T u(t)\sin\left(\frac{2\pi nt}{T}\right)dt$$

II.2-Liebmann's "Anomalous Accumulation" Method

The anomalous accumulation model is a method proposed by Liebmann in 2006 to determine the spatiotemporal variability of the rainy season date. In this research, however, we used this method to determine the start date and the Tiomena wind. This method is given by the following relationship:

AA = $\sum_{n-1}^{t} x(n) - \ \bar{x} * t$ avec x(n) : Daily wind and $\tilde{X}$: the average daily wind.

II.3-Artificial Neural Network (ANN)

An artificial neural network is a system whose design was originally schematically inspired by the functioning of biological neurons, and subsequently moved closer to statistical methods. Neural networks are generally optimized using probabilistic learning methods, particularly Bayesian learning. Different types of neurons are distinguished by the nature, f, of their activation function. The main activation functions are:

- Linear: f(x) = x
- Sigmoid: f(x) = $\frac{1}{(1+e^{x})}$
- Threshold: f(x) = $1_{[0,+\infty[}(x)$
- Radial f(x) = $\sqrt{\frac{1}{2\pi e^{\frac{-x^2}{2}}}}$

III-Results 1

III.1-Periodicity of the Tiomena Wind

For the frequency study of the Tiomena wind time series, we used a fast Fourier transform and the maximum entropy method. The results of the first process are represented as a periodicity, which indicates that in southern Madagascar, the Tiomena wind occurs twice a year with different intensities.

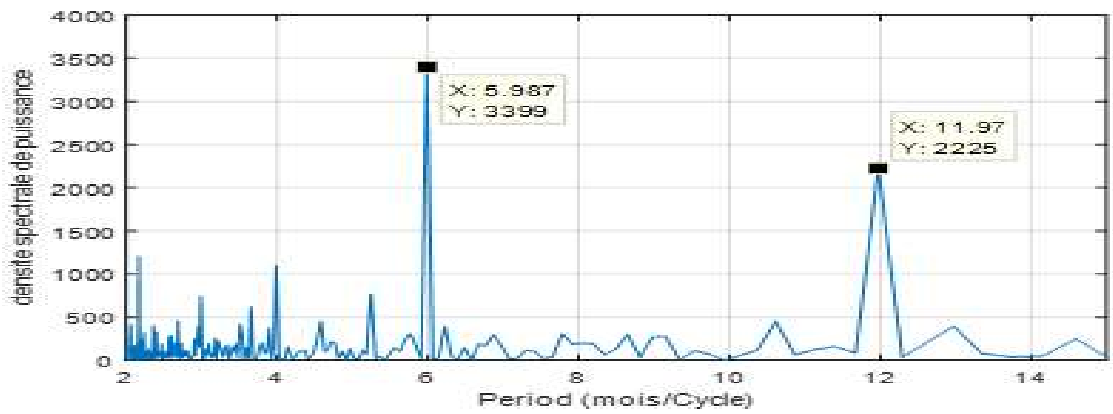

Figure 2: Tiomena Periodicity in Southern Madagascar

According to the results of the Fast Fourier Transform, we found two significant peaks with a period of 5.98 corresponding to the month of July and 11.97 corresponding to the month of December. These two peaks clearly prove that Tiomena occurs twice a year in southern Madagascar. The Maximum Entropy Method (MEM) is then adopted to verify the decomposition of the wind signal. A statistical significance test was also performed at the 5% threshold on the resulting cycles.

From the figure below, we see that the spectral signature evolves as follows:

- The first is between 7.9 and 11.52 months

- The second between 4.76 and 6.1 months.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

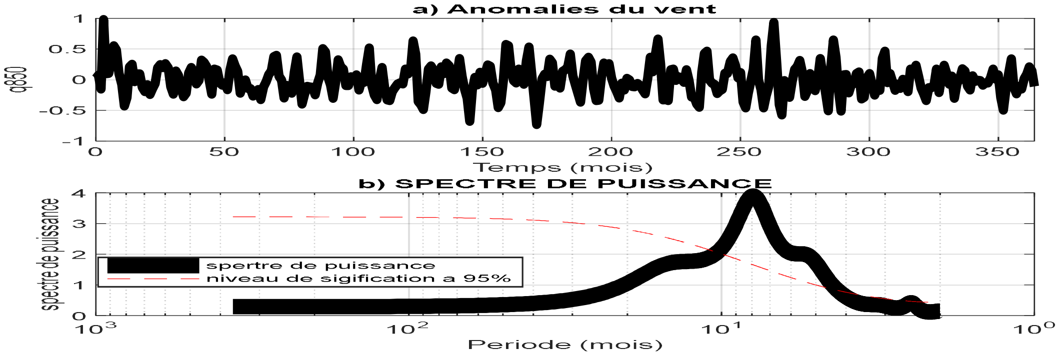

Figure 3: Power spectrum of Tiomena

III.2- Study of Tiomena in the first period P = 5.98 MONTHS

To determine the start and end dates of the Tiomena wind, we used the Anomalous Accumulation (AA) method. For each year, minimum and maximum speeds were observed.

The results of the Anomalous Accumulation on the Tiomena wind are represented by the following figure, which is none other than the start and end dates for the year 1983. The same method was used for the remaining years.

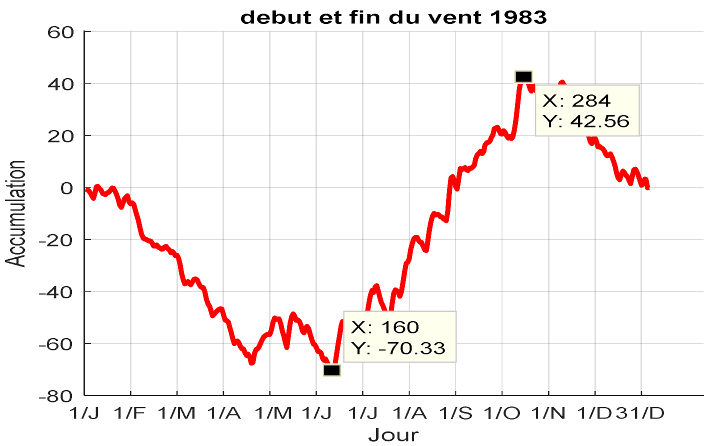

Figure 4: Some illustration of Tiomena AA curve in 1983

Based on the results obtained by the AA method, we summarize in Table 21 the start and end dates of Tiomena in the 1st period. Years Rank Start Rank End Duration

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
SCHOLAR AI Be Smart
Vol. 50 No. 1 April 2025, pp. 397-415

Table 1: Beginnings and endings of Tiomena in the 1st period

Years	Rank	Start	Rank	End	Duration
1979	163	12 June	255	12 September	92
1980	179	27 June	288	14 October	109
1981	89	30 March	296	23 October	207
1982	28	28 January	96	06 April	68
1983	161	10 June	284	11 October	123
1984	19	19 January	122	01 May	103
1985	40	09 February	59	28 February	19
1986	44	13 February	79	20 March	35
1987	101	11 April	320	16 November	219
1988	26	26 January	103	13 April	77
1989	54	23 Fefruary	103	13 April	49
1990	130	10 May	314	10 November	184
1991	44	13 February	118	28 April	74
1992	157	05 June	285	11 October	128
1993	57	26 February	79	20 March	22
1994	29	29 January	68	09 March	39
1995	20	20 January	161	10 June	141
1996	22	22 January	123	02 May	101
1997	21	21 January	46	15 February	25
1998	35	04 February	58	27 February	23
1999	176	25 June	305	01 November	129
2000	33	02 February	68	08 March	35
2001	67	08 March	220	08 August	153
2002	82	23 March	343	09 Décember	261
2003	160	09 June	260	17 September	100
2004	20	20 January	179	27 June	159
2005	72	13 March	100	10 April	28

2006	174	23 June	314	10 November	140
2007	51	20 February	76	17 March	25
2008	30	30 January	84	24 March	54
2009	81	22 March	115	25 April	34
2010	168	17 June	281	08 October	113
2011	29	29 January	52	21 February	23
2012	05	05 January	64	04 March	59
2013	21	21 January	57	26 February	36
2014	79	20 March	104	14 April	25
2015	03	03 January	75	16 March	72
2016	82	22 March	246	02 September	164
2017	65	06 March	320	16 November	255

Figures 5 and 6 show the results of the plot of the start and end date of Tiomena for the period of 5.98 months. The wind generally starts between January and February and ends between February and May. But we also noticed years where the wind started in June and ended in November, such as the following:

- 1979: the wind started on June 12 and ended on September 12
- 1980: the wind started on June 27 and ended on October 15
- 1983: the wind started on June 10 and ended on October 11
- 1992: the wind started on June 5 and ended on October 11
- 1999: the wind started on June 25 and ended on November 1
- 2003: the wind started on June 9 and ended on September 17
- 2006: the wind started on June 23 and ended on November 10
- 2010: the wind started on June 17 and ended on October 8

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

III.3- Beginnings and ends of Tiomena for the 1st period

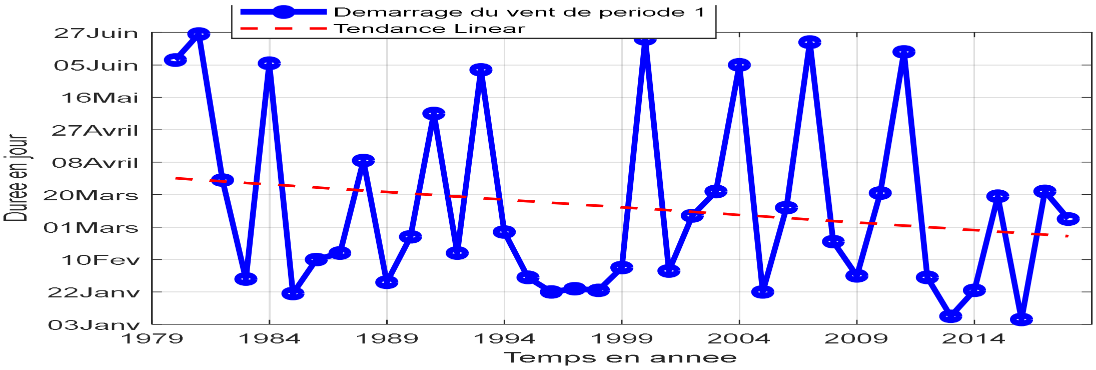

Figure 5: Interannual variability of Tiomena season start dates

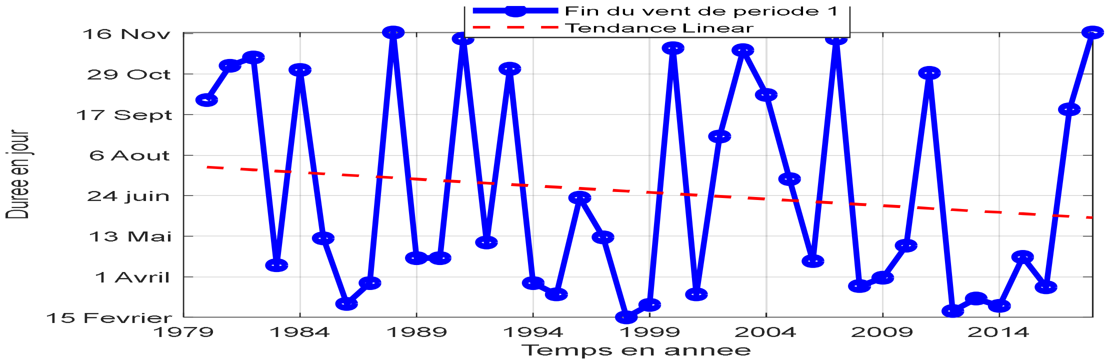

Figure 6: Interannual variability of Tiomena season end dates

III.4- Tiomena Season Length for the 1st Period

Figure 7 below displays the length or duration of the Tiomena season over the study period from 1979 to 2017. We see that the shortest season is 1986, which is 19 days. The longest season is 2003, which is 261 days, and 2017, which is 279 days. On average, the season lasts 100 days, but we also see a trend toward a decreasing season length, meaning that the period when Tiomena blows strongly tends to decrease.

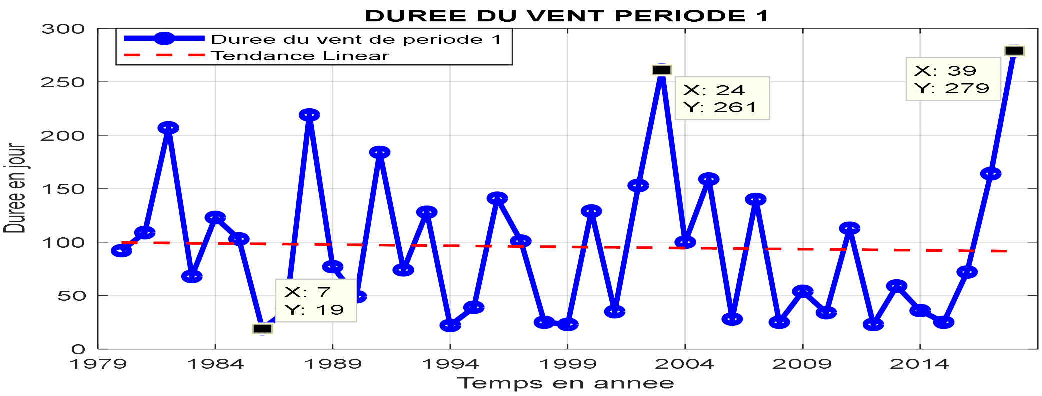

Figure 7: Length of Tiomena from the 1st period

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

IV-Results 2

IV.1- Prediction of the start date, end date, and duration of the Tiomena season for the first period using an artificial neural network.

IV.1.1- Prediction of the start date of the Tiomena season from 2017 to 2028

For the prediction of the dates of the beginning of Tiomena, we did not use any other variable except the data of the date of the beginning of the wind. The architecture of the neural network is illustrated in Figure 8.

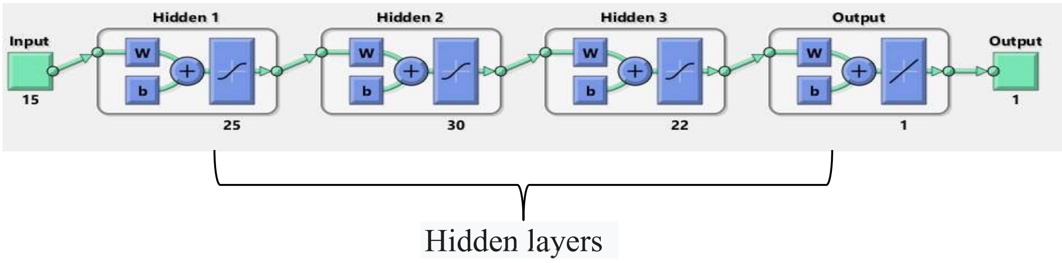

Figure 8: Neural architecture of the Tiomena wind onset model

The neural architecture is composed of:

- An input layer with 15 neurons.

- Three hidden layers, the first of which contains 25 neurons, the second 30 neurons, and the third 22 neurons.

- And at the output, one layer contains 1 neuron.

IV.1.2- Model Validation

Model validation depends on the correlation coefficient between the desired output (Target) and the calculated output (Output). In our present case, the value of this correlation is 0.84, or 84%, which means that the model for the onset of the Tiomena wind is excellent (Fig. IV.17).

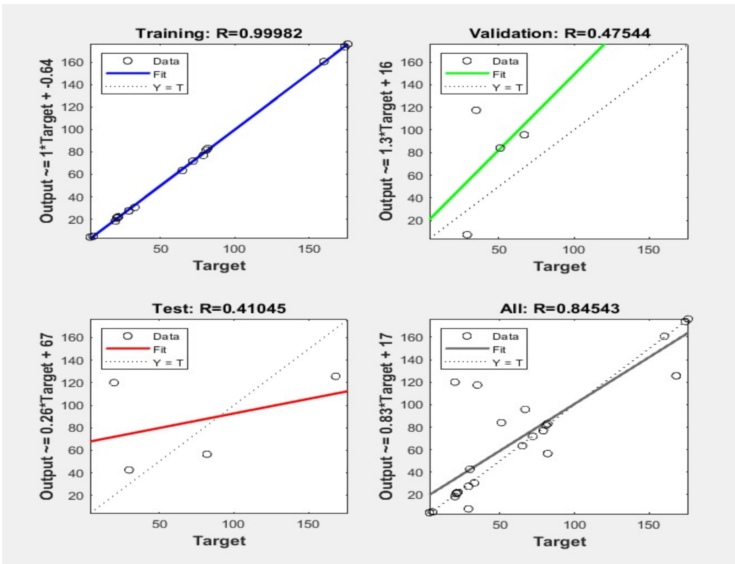

Figure 9: Correlation between calculated and desired output of the Tiomena wind starts

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

IV.1.3- Forecast Results

The forecast based on the Tiomena wind onset data is then performed in Figure IV.18 below. We see a very remarkable change in 2021 and 2026. In 2021, the wind season will start very early, while in 2026, the wind onset will be too late, i.e., on October 1, 2026.

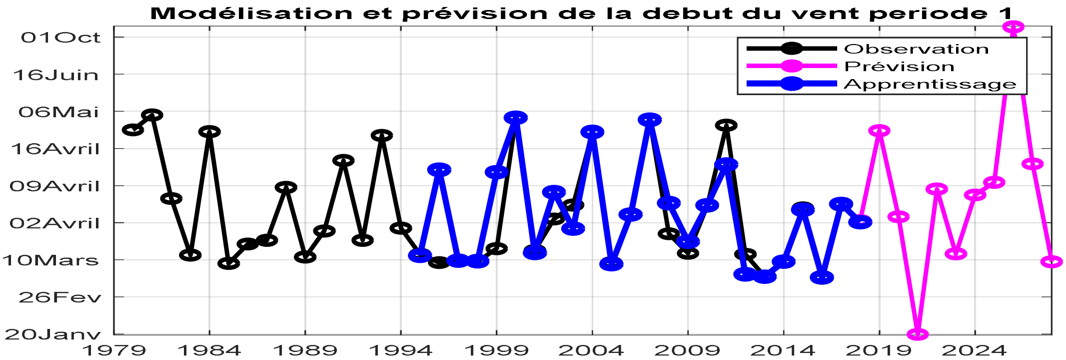

Figure 10: Forecast of Tiomena wind start dates from 2018 to 2028

The trend in Tiomena wind start dates in Figure IV.19 shows us that the start of Tiomena wind seasons for the coming year tends to be brought forward.

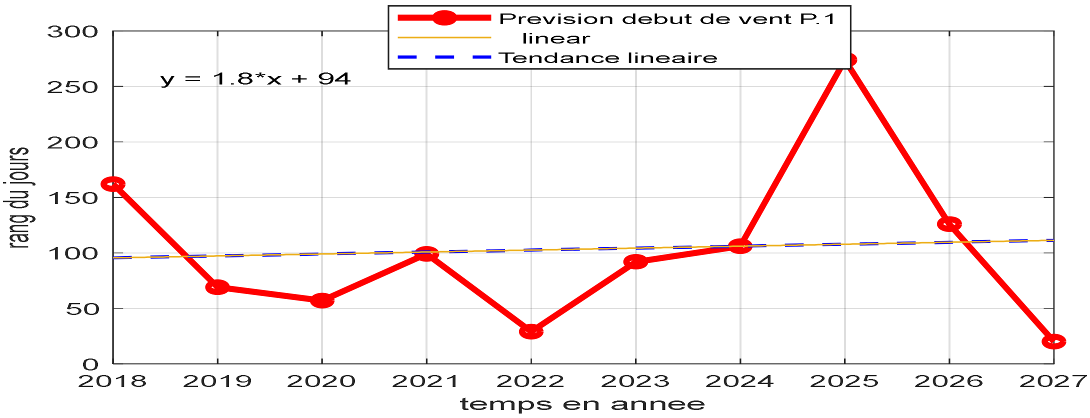

Figure 11: Trend of future dates of the start of the Tiomena wind seasons from the 1st period from 2018 to 2028

IV.1.4- Forecast of the end dates of Tiomena from 2018 to 2028

For the prediction of the end dates of the Tiomena wind, we did not use any other input variable except the data of the end date of the Tiomena wind. The architecture of the network of neuron is illustrated in Figure 12.

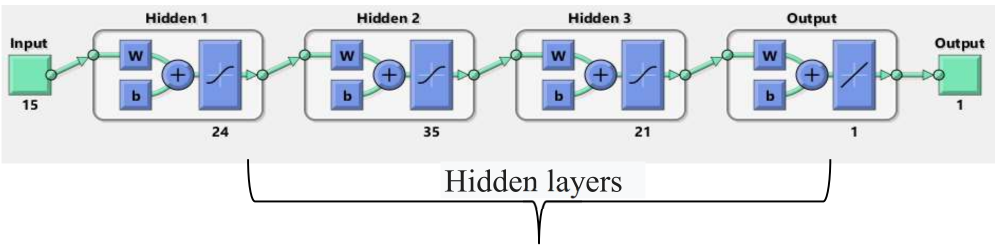

Figure 12: Neural architecture of the Tiomena wind end model

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

The neural architecture is composed of:

- An input layer with 15 neurons.

- Three hidden layers: the first with 25 neurons, the second with 35 neurons, and the third with 21 neurons.

- And at the output, one layer has 1 neuron.

IV1.5- Model Validation

The correlation between the desired output and the calculated output is 0.88, or 83%, which allows us to say that the model for the Tiomena wind's end for the first period is excellent.

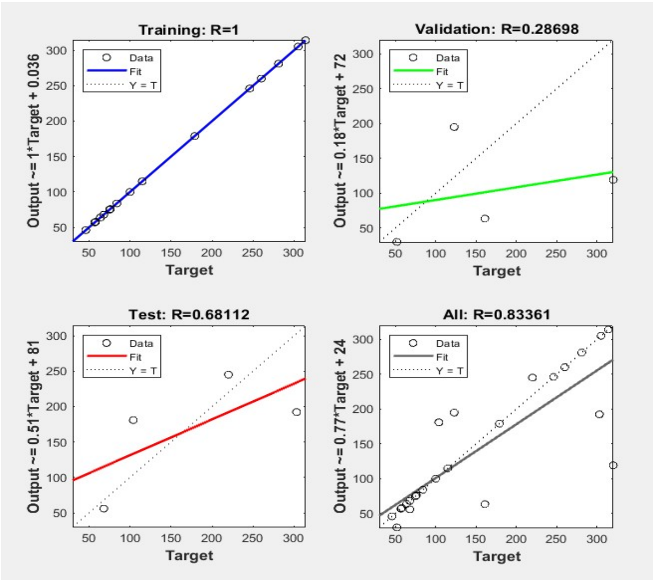

Figure 13: Correlation between desired output and calculated output of Tiomena wind ends

IV1.6- Forecast Results

The forecast of the end date of the Tiomena wind shows that, in general, there is no significant change in the coming years, but its trend shows that the end dates of the wind's arrival are tending to advance.

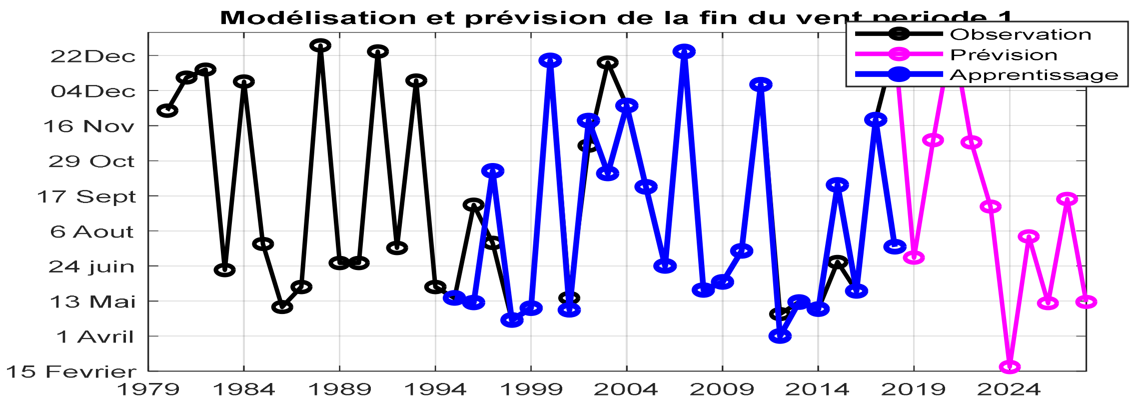

Figure 14: Forecast of the end dates of the Tiomena wind from 2018 to 2027.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

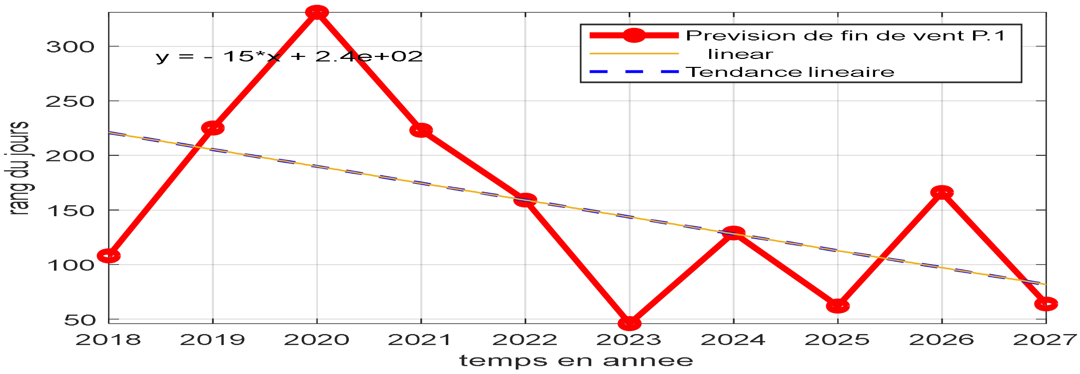

Figure 15: Trend in future dates of the end of the Tiomena wind of the 1st period.

The predicted durations of the Tiomena wind seasons are shown in Figure 16 below. The longest season is 2020 with 274 windy days. 2024 is the shortest season with 23 windy days. The trend shows that the number of windy days will decrease in the coming year.

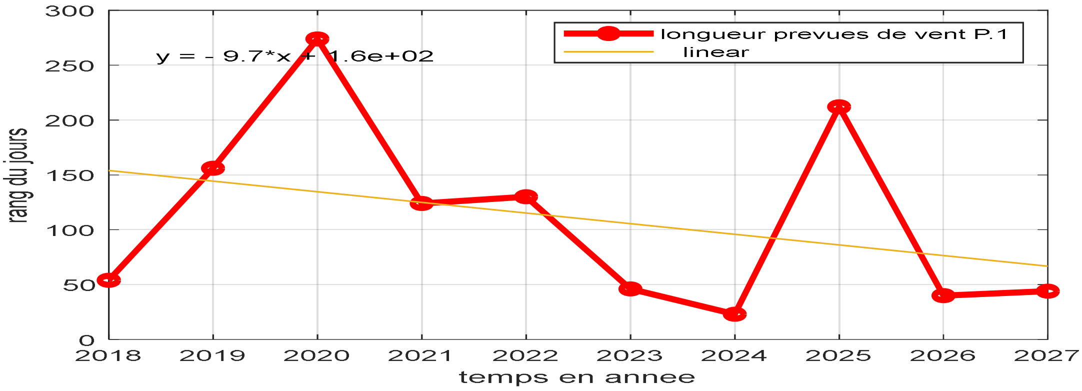

Figure 16: Predicted length of the Tiomena wind end seasons of the 1st period.

V- Results 3

V.1- Wind Study of the 2nd Period

The start and end dates of the 2nd period Tiomena wind season are shown in Table 2.

Table 2: Start and End Times of the 2nd Period Tiomena Wind

Years	Rank	Start	Rank	End	Duration
1979	163	12 June	255	12 September	92
1980	179	27 June	288	14 October	109
1981	89	30 March	296	23 October	207
1982	170	19 June	303	30 October	133
1983	161	10 June	284	11 October	123

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

1984	140	19 May	283	09 October	143
1985	227	15 August	326	22 November	99
1986	152	01 June	189	08 July	37
1987	101	11 April	320	16 November	219
1988	222	09 August	329	24 November	107
1989	195	14 July	288	15 October	93
1990	130	10 May	314	10 November	184
1991	148	28 May	246	03 September	98
1992	157	05 June	285	11 October	128
1993	155	04 June	295	22 October	140
1994	132	12 May	308	04 November	176
1995	182	01 July	229	17August	47
1996	170	18 June	208	26 July	38
1997	180	29 June	309	05 November	129
1998	158	07 June	297	24 October	139
1999	176	25 June	305	01 November	129
2000	178	26 June	297	23 October	119
2001	67	08 March	220	08 August	153
2002	82	23 March	343	09 Décember	261
2003	160	09 June	260	17 September	100
2004	264	20 September	299	25 October	35
2005	232	20 August	318	06 November	86
2006	174	23 June	314	10 November	140
2007	166	15 June	308	04 November	142
2008	192	10 July	301	27 October	109
2009	177	26 June	330	26 November	153
2010	168	17 June	281	08 October	113
2011	185	04 July	284	11 October	99
2012	247	03 September	309	04 November	62

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

2013	185	04 July	305	01 November	120
2014	157	06 June	341	07 October	184
2015	236	24 August	311	07 November	75
2016	82	22 March	246	02 September	164
2017	67	08March	344	10 Décember	279

V.2- Starts and Ends of the Second Period Tiomena

Figures 17 and 18 shows the evolution of the start and end dates of the second period Tiomena wind. Generally, the second period Tiomena begins in June and July and ends between October and November.

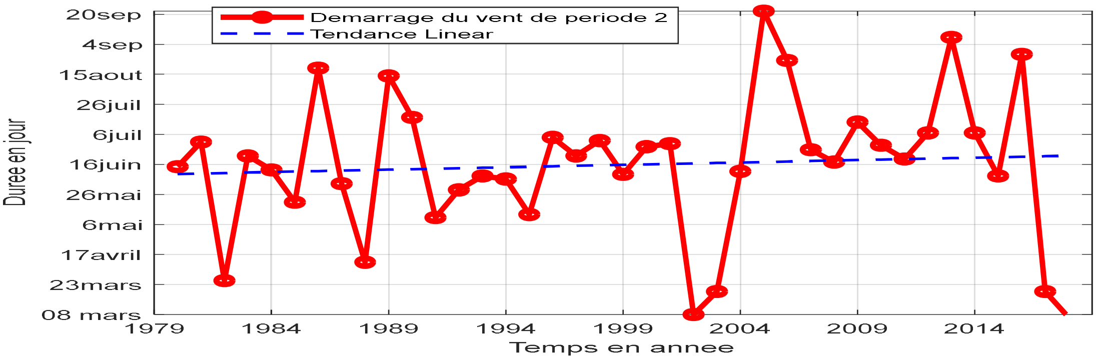

Figure 17: Interannual variability of the start date of Tiomena 2nd period

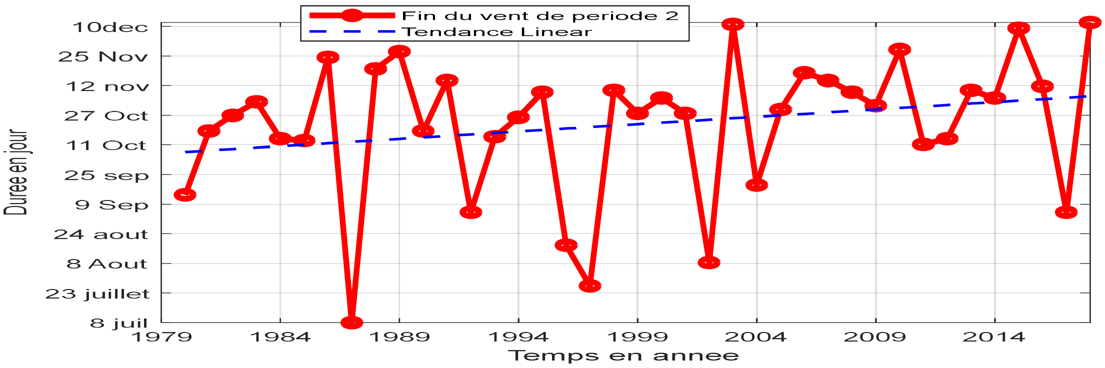

Figure 18: Interannual variability of the date of the end of Tiomena

V.3- Length of the Tiomena Wind Seasons in the 2nd Period

The graphical representation in Figure 20 serves to visualize the different variations in the length of the Tiomena season in the 2nd period. The curve clearly shows the succession of short and fairly long wind seasons that evolve around the average. The shortest wind season was in 1986, which was 37 days, and the longest was in 2002, which was 261 days, and in 2017, which was 279 days. In general, the average length of the Tiomena wind season in the 2nd period is 120 days, with an increasing trend in the length of the season, meaning that periods with strong winds tend to become longer.

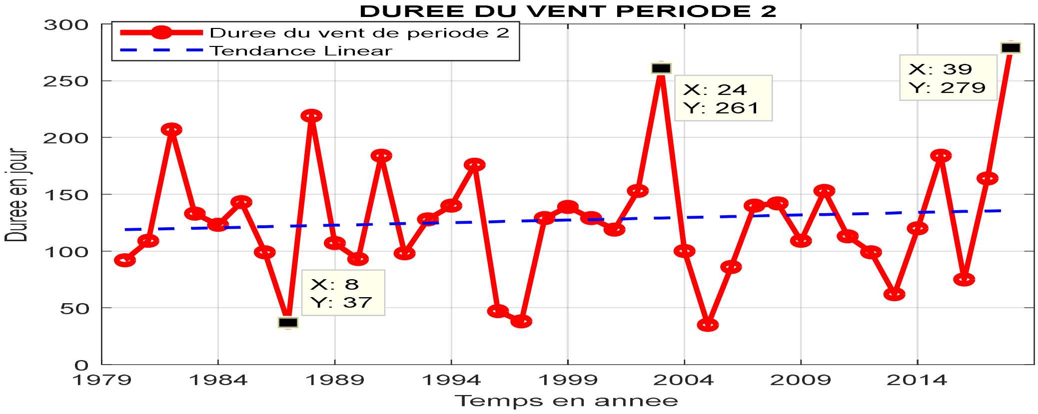

Figure 19: Length of the Tiomena wind of the 2nd period

V.4- Prediction of the start date, end date, and duration of the second-period Tiomena season using an artificial neural network

V.4.1- Prediction of the start date of the second-period Tiomena season from 2018 to 2028

For the prediction of the dates of the beginnings of Tiomena of the 2nd period, we did not use any other input variable except the data of the date of the ends of the Tiomena wind. The architecture of the neural network is illustrated in Figure 20.

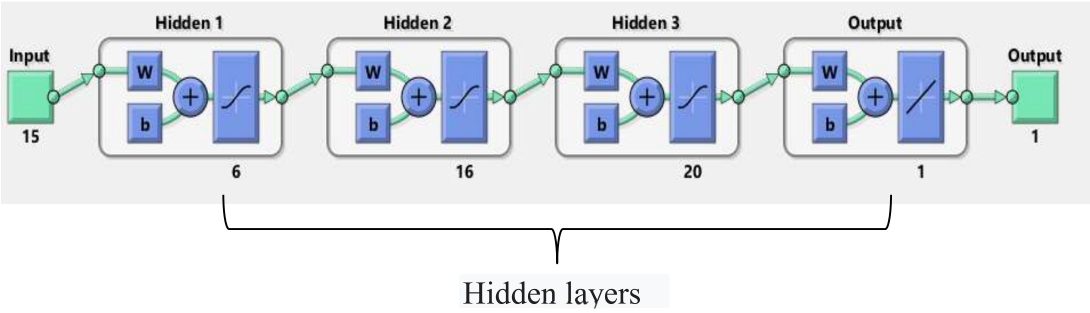

Figure 20: Neural architecture of the early Tiomena model of the 2nd period.

The neural architecture is composed of:

- An input layer with 15 neurons.

- Three hidden layers: the first with 6 neurons, the second with 16 neurons, and the third with 20 neurons.

- And at the output, one layer has 1 neuron.

It is with this characteristic of the neural architecture that we will validate the model.

V.4.2- Model Validation

For model validation, we see that their correlation coefficient is 0.85, or 85%, indicating that the model is excellent.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

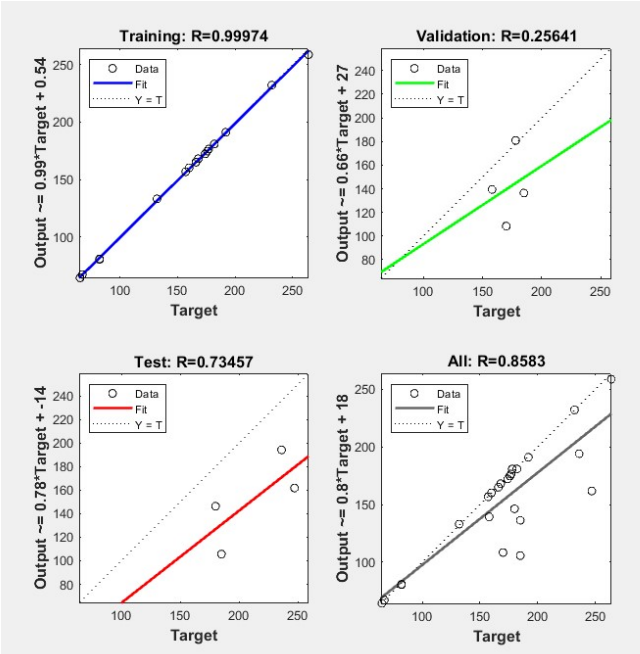

Figure 21: Correlation between the desired output and the calculated output at the start of Tiomena 2nd period from 2018 to 2028

V.4.3-Forecast Results

The forecast of the start date of Tiomena for the second period shows that, in general, there is no significant change in the start date of the wind for the coming year. The trend line shows that the start of the wind seasons for the coming year tends to be delayed.

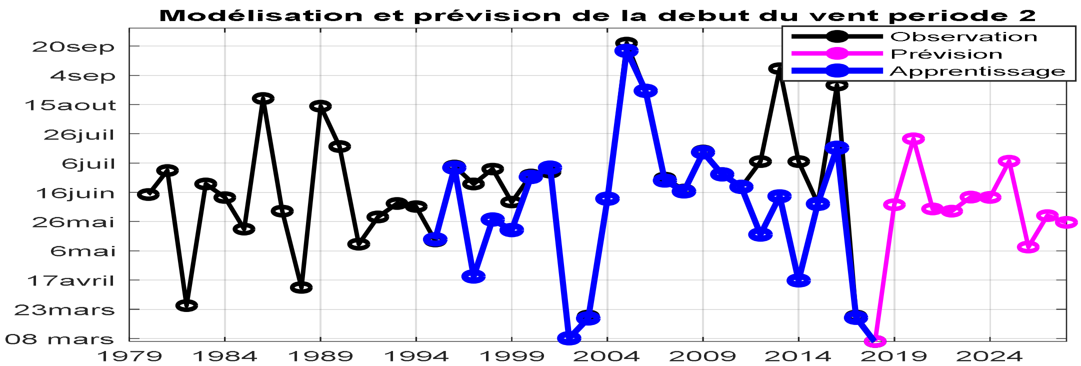

Figure 22: Forecast of the start date of the 2nd period Tiomena season

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

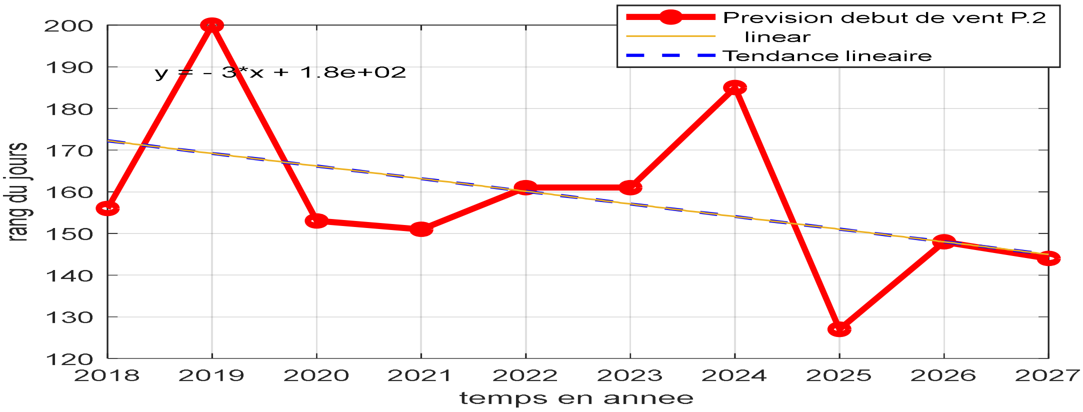

Figure 23: Trend in the start date of the Tiomena wind from the 2nd period from 2018 to 2027

V.4.4- Forecast of the dates of the end of Tiomena 2nd period in the South of Madagascar

For the prediction of the end dates of the 2nd period Tiomena wind, we did not use any other input variable except the data of the end date of the 2nd period wind. The architecture of the neural network is illustrated in Figure 24.

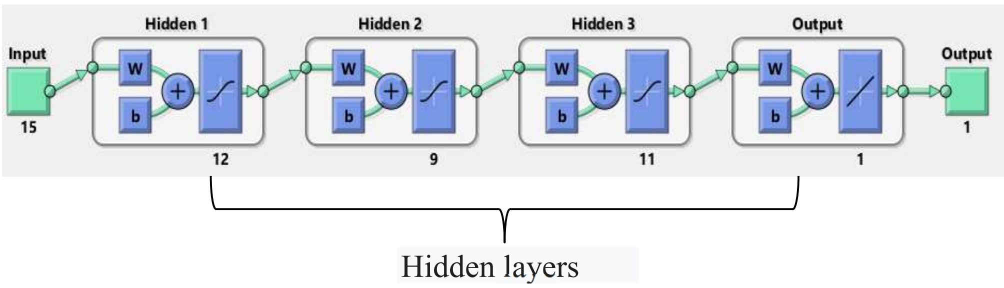

Figure 24: Neural architecture of the late Tiomena model of the 2nd period.

The neural architecture is composed of:

- An input layer with 15 neurons.

- Three hidden layers, the first of which contains 12 neurons, the second of which contains 9 neurons, and the third of which contains 11 neurons.

- And at the output, one layer contains 1 neuron.

V.4.5- Model Validation

For model validation, the intercorrelation between the desired and calculated output is 0.74, or 74%, meaning that the model is good and acceptable.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

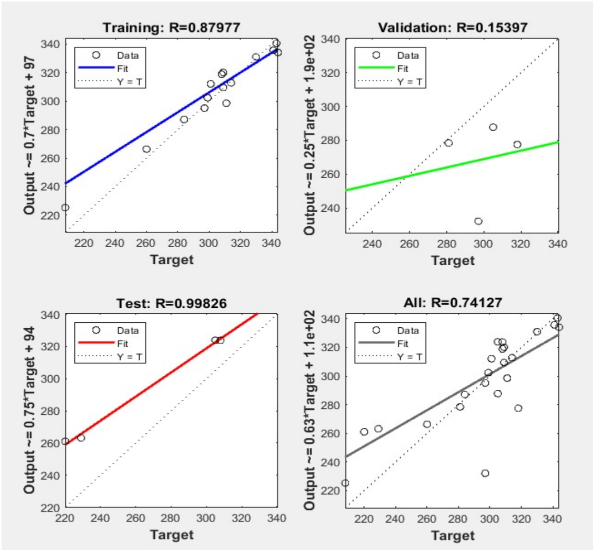

Figure 25: Correlation between the calculated output and the desired output at the end of the 2nd period wind

V.4.6- Forecast results

The forecast of the end date of Tiomena in the 2nd period shows that there is no significant change in the end date of Tiomena, with a slightly decreasing trend.

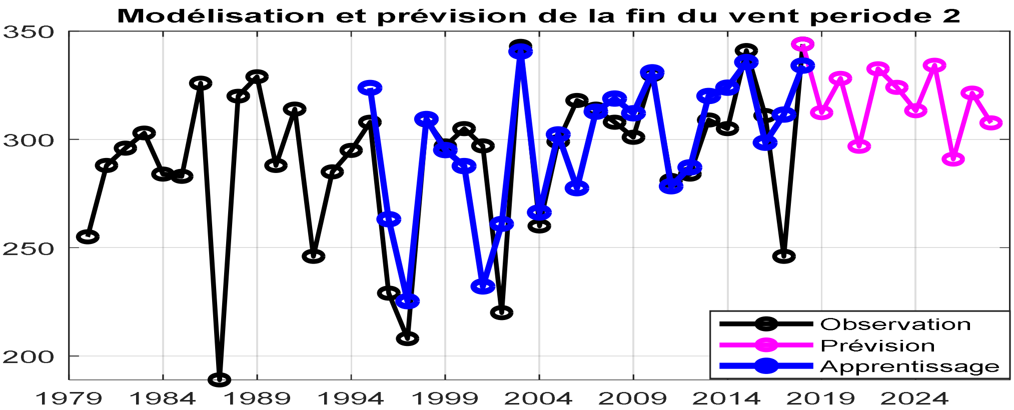

Figure 26: Forecast of the end dates of Tiomena 2nd period from 2018 to 2027

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

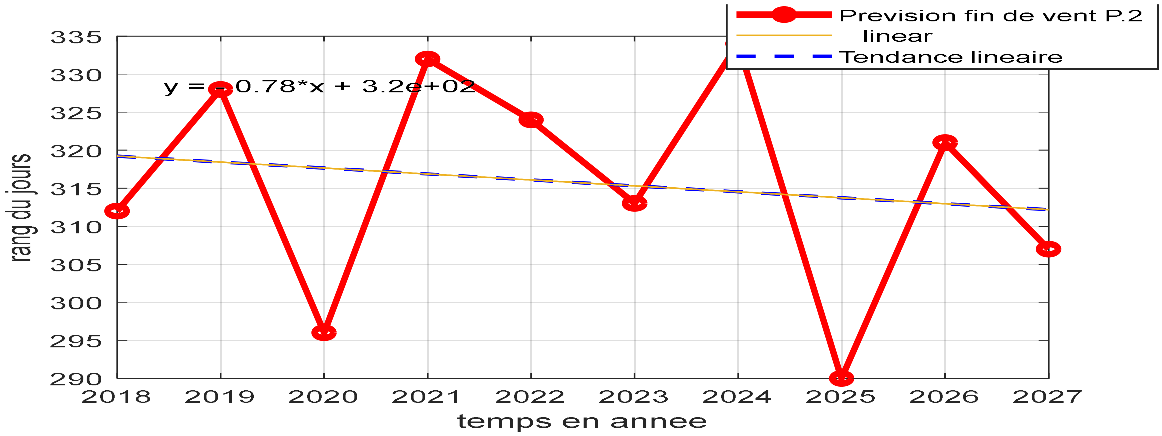

Figure 27: Trend in Tiomena End Dates for the Second Period, 2018–2027

The predicted lengths of Tiomena seasons from 2018 to 2028 are shown in Figure 28 below. We see that the longest season is in 2021, with 181 windy days. The trend (blue dotted line) indicates that there will be a significant increase in the number of windy days from 2018 to 2028.

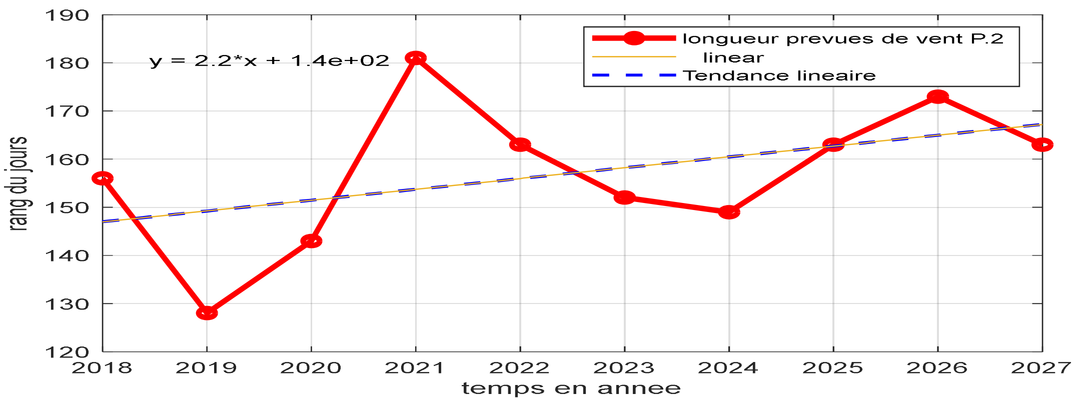

Figure 28: Projected season length of Tiomena from 2nd period from 2018 to 2027

VI-Conclusion:

The Fast Fourier Transform analysis of Tiomena led us to see that in southern Madagascar, the Tiomena wind occurs twice a year with different intensities over periods of 5.98 months and 11.97 months. The Liebmann method is often used to determine the beginning, end, and duration of a given climatic parameter. In our work, we used it to determine the beginning, duration, and end of Tiomena in southern Madagascar.

According to the artificial neural network, we observe that the duration of Tiomena in the first period tends to decrease, while that of the second period increases until 2028. This proves that changes in Tiomena will occur in the coming year. The general objective of this research is to understand the two Tiomena wind phenomena by calculating the wind power provided and finally to be able to know the type of wind turbine which is adapted to these two types of wind speed.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 397-415

Références

[1] ALLAOUI Charani Youssouf, 2004. Mémoire de DEA. Intitulé : « Etude du vent dans la partie sud de Madagascar »

[2] CLAUDE TOUZET, 1992. Cours : les réseaux des neurones artificiels introduction au connexionnisme.

[3] Fabrice GAMBOA, numéro d'ordre : 1141. Thèse intitulée : « Méthode du maximum d'entropie sur la moyenne et application ». Université de PARIS SUD

[4] G. BAUDOIN et J-F. BERCHER, 2001. Transformée de Fourier discrète. Ecole Supérieure d'ingénieurs en Electrotechnique et Electronique-version 0.1

[5] M.G. DONQUE, 1974. Les types de temps d'alize actif à Madagascar. Bull.Assoc.Geoge.franc

[6] Pr ABDALLAOUI Abdelaziz, 2011. Utilisation des réseaux de neurones artificiels pour l'analyse des données. Université de MOULAY ISMAIL Faculté de Sciences Meknes.

[7] RAZAFINDRAKOTO NY Hasina Irina, 2014. Mémoire de DEA. Intitulé : « La circulation du vent zonal à Madagascar ». Université d'ANTANANARIVO

[8] TAMO Andy, 2020. Thèse de Doctorat intitulé : « Modélisation a différentes échelles spatio-temporelles du vent « VARATRAZA » au nord de Madagascar ». Université de Toliara

Webographies

(Moov.Mg https://www.moov.mg « Tiomena dans le Sud de Madagascar »)