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Fuzzy Inference Modeling of Rain's Beginning and Ending in Coastal Areas of South East Madagascar

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ABSTRACT: *This research is based on the method of artificial intelligence including fuzzy logic. The objective is to model the dates of the beginning and the ending of rain during the period from 1980 to 2017. We have as study area the coastal areas of South-East Madagascar. It is delimited between 22° to 28° South latitude and 48° to 49° East longitude. The rainy season in this area is between December 1st and April 2nd. The model obtained is combined with the observation data. Also, the calculated MAPE is less than 10%. Therefore, our model is excellent.*

Keywords: *Artificial Intelligence, modeling, fuzzy inference, rain's beginning and ending*

I. INTRODUCTION

Fishing occupies an important place in the economic activity of Malagasy people. Nevertheless, it is undergoing serious consequences in the face of the current climate change such as the increase of salinity sea water caused by the lack of rain. It is for this optic our study is focused on the modeling of the dates of the beginning and the ending of rain in the coastal zones in order to improve the contribution on the economy of Madagascar.

II. METHOLOGIES

2.1. Study area

The study area is delimited between 22°S to 28°S South latitude and 48°E to 49°E East longitude as shown in Figure 1.

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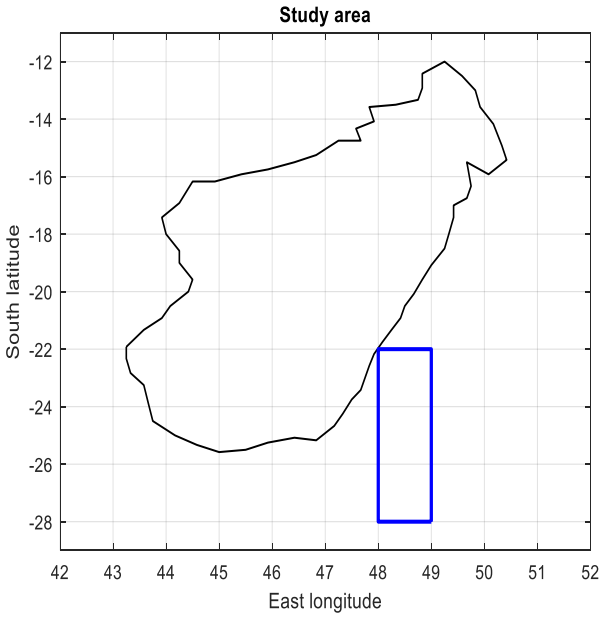

Figure 1: Study area

2.2. Data

Our data used are rain's beginning and ending dates calculated from the Anomalous Accumulation method for the entire period from 1980 to 2017 [1].

2.3. Fuzzy Inference System (FIS) [2][3][4][5]

This method is part of artificial intelligence which is able to formalize approximated situations, non-exact situations as well as, to treat imprecise data in order to approximate human reasoning. It also uses linguistic rules to establish relationships between input and output variables.

In fuzzy logic, there are three main steps to follow:

Fuzzification aims to transform the non-fuzzy inputs to a fuzzy variable.

Fuzzy Inference constitutes rules of the type "If...Then". It computes the consequence of each fuzzy rule of the input vector and aggregates the conclusions of all those rules activated on this vector.

Defuzzification is the inverse transformation of the first. It allows to determinate the numerical values to this command.

III. RESULTS

The variables to be modeled are time series of rain's beginning and ending dates over the 38 years of study. These dates are used as the input and output of the model.

3.1. Discourse universe

The discourse universe and the number of partitions for the beginning and the ending of rain are showed on this Table 1:

Beginning and Ending of rain	Discourse universe	Partition numbers
Start	U_d= [312 161]	50 partitions (A1, A2, ……A50)
End	U_f= [66 131]	34 partitions (a1, a2, ……a34)

Table 1: Discourse universe and number of partitions in the beginning and the ending of rain

3.2. Membership function

The model adopted for the rain's beginning is of order 2. Therefore, we have three similar membership functions (two for the input and one for the output). As for the end of rain, we have four similar membership functions (three for the input and one for the output) because the adopted model is of order 3.

Figure 2 represents an example of those membership functions for the rain's beginning and Figure 3 for the rain's ending.

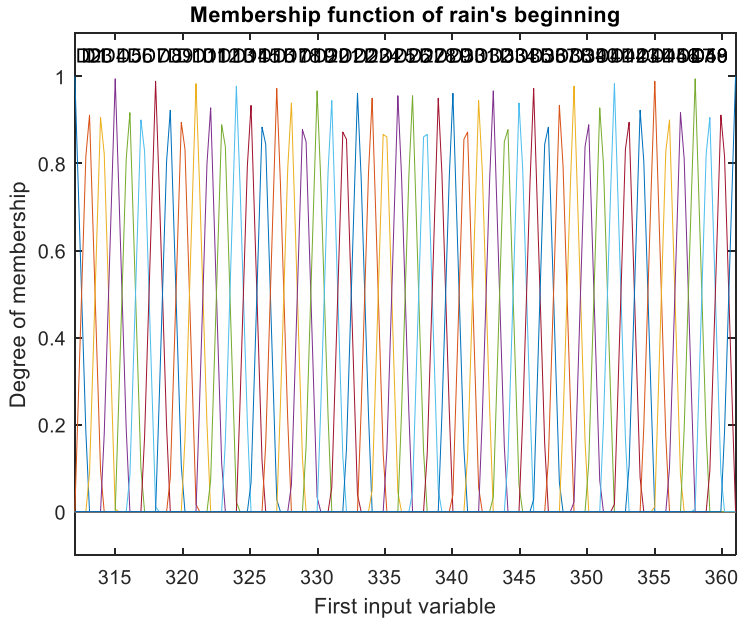

Figure 2: Membership function of rain's beginning

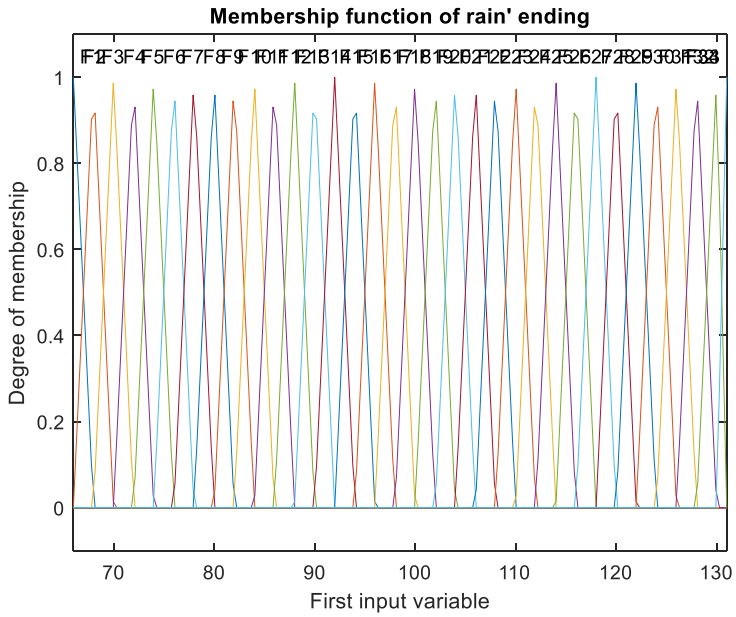

Figure 3: Membership function of rain's ending

3.3. Fuzzification

Table 2 recapitulates the numerical values and the fuzzy values of the rain's beginning and rain's ending dates during the study period (1980-2017).

YEAR	RAIN'S BEGINNING		RAIN'S ENDING	
	REAL VALUE	**FUZZY VALUE**	REAL VALUE	**FUZZY VALUE**
1981	333	**A22**	113	**a24**
1982	330	**A19**	80	**a8**
1983	330	**A19**	81	**a8**
1984	320	**A9**	109	**a22**
1985	312	**A1**	89	**a12**
1986	326	**A15**	77	**a6**
1987	332	**A21**	110	**a23**
1988	361	**A50**	90	**a13**
1989	349	**A38**	92	**a14**
1990	337	**A26**	112	**a24**
1991	325	**A14**	116	**a26**
1992	346	**A35**	105	**a20**
1993	356	**A45**	97	**a16**
1994	356	**A45**	84	**a10**
1995	335	**A24**	106	**a21**
1996	329	**A18**	88	**a12**
1997	335	**A24**	77	**a6**
1998	321	**A10**	66	**a1**
1999	338	**A27**	86	**a11**
2000	344	**A33**	94	**a15**
2001	335	**A24**	85	**a10**
2002	341	**A30**	131	**a34**
2003	344	**A33**	100	**a18**
2004	343	**A32**	73	**a4**
2005	350	**A39**	110	**a23**
2006	344	**A33**	81	**a8**
2007	322	**A11**	77	**a6**
2008	351	**A40**	69	**a2**
2009	314	**A3**	96	**a16**
2010	320	**A9**	78	**a7**
2011	348	**A37**	106	**a21**
2012	336	**A25**	112	**a24**
2013	344	**A33**	105	**a20**
2014	327	**A16**	84	**a9**
2015	350	**A39**	72	**a4**
2016	326	**A15**	95	**a15**
2017	332	**A21**	101	**a18**

Table 2: Fuzzification of rain's beginning and ending dates

3.4. Creation of fuzzy rules

The adopted fuzzy rules take the form on Table 3. The numbered letters are linguistic terms used for the beginning and ending dates of rains during the study period.

For an order 2 model (rain's beginning), it is two antecedent years for an output. For example, in the first rule, we have as inputs the dates of the rain's beginning for the year 1981 and 1982 give the output for the year 1983. In the second rule, the year 1982 and 1983 give the rain's beginning for the year 1984 and so on until 2017.

For a model of order 3 (rain's ending), we have 3 antecedent years for an output; that is, we enter the dates of the rain's ending of the three previous years such as the year 1981, 1982 and 1983 to have the rain's ending for the year 1984 and the year 1982, 1983 and 1984 give the year 1985 and so on until 2017.

Rain's beginning (Order 2) :	***Rain's ending (order 3) :***
Precedents ---> consequents	Precedents ---> consequents
A12, A19 ---> A19	a24, a8, a8 ---> a22
A19, A19 ---> A9	a8, a8, a22 ---> a12
A19, A9 ---> A1	a8, a22, a12 ---> a6
……	……
……	……
A39, A15 ---> A21	a9, a4, a15 ---> a1

Table 3: Example of fuzzy rules for rain's beginning and ending dates

3.5. Cartography of model

The two figures (Figures 4 and 5) illustrate the mappings of the resulting model. For the beginning of rain (figure 4), it is a model with 2 inputs, one output and 34 fuzzy rules. As for the end of rain, we have a model with 3 inputs, one output and 34 fuzzy rules.

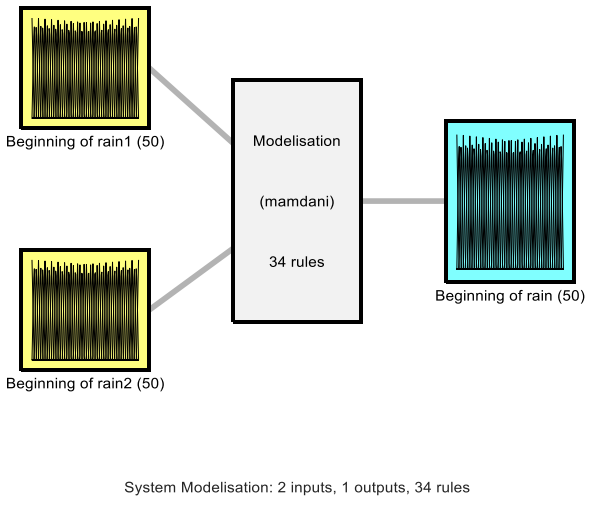

Figure 4: Cartography of rain's beginning model

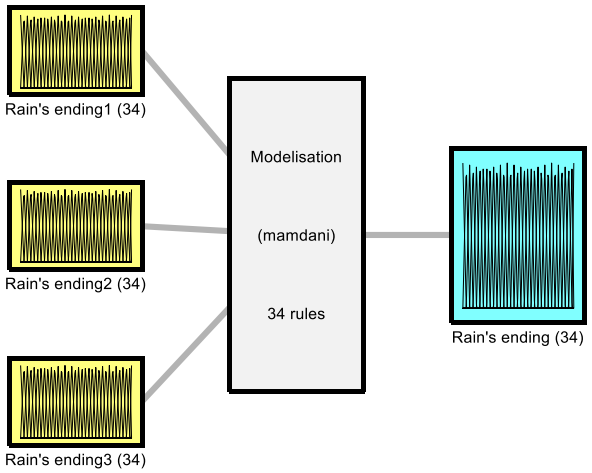

Figure 5: Cartography of rain's ending model

3.6. Defuzzification

The table 4 shows the defuzzified values of the model output of the rain's beginning and ending dates.

Year	Rain's beginning	Rain's ending	Year	Rain's beginning	Rain's ending
1983	320	108	2001	341	131
1984	312	88	2002	344	100
1985	326	76	2003	343	72
1986	332	110	2004	350	110
1987	361	90	2005	344	80
1988	349	92	2006	322	76
1989	337	112	2007	351	68
1990	325	116	2008	314	96
1991	346	104	2009	320	78
1992	356	96	2010	348	106
1993	356	84	2011	336	112
1994	335	106	2012	344	104
1995	329	88	2013	327	82
1996	335	76	2014	350	72
1997	321	66,6	2015	326	94
1998	338	86	2016	332	100
1999	344	94	**2017 (Forecast)**	**320**	**110,5**
2000	335	84			

Table 4 : Defuzzification of rain's beginning and ending dates

3.7. Graphic representation of model

The Figures 6 and 7 show respectively the models of the rain's beginning and the ending during the study period. It can see that the curves of the observation data (in black) are combined with the obtained models (in blue). This combination suggests that we have good models. The predict date of the rain's beginning and ending for the year 2018 is :

- November 15th, 2017 (beginning)
- April 19th, 2018 (ending)

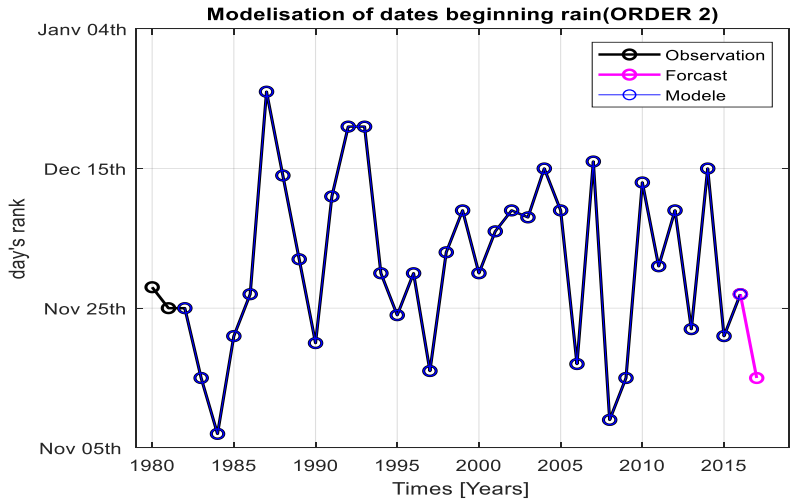

Figure 6 : Modeling of dates beginning rain

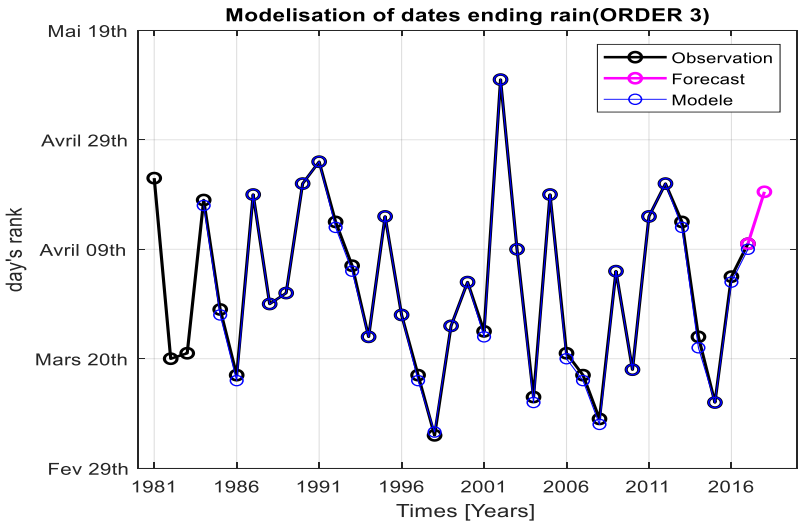

Figure 7: Modeling of dates ending rain

3.8. Model validation

The calculation of the percentage of mean error (MAPE) and the percentage of accuracy allow us to validate the performance of our models. Indeed, the MAPE values calculated and the accuracy percentages are showed on Table 5. Those results present that our models selected for the dates of rain's beginning and ending are excellent.

Error	Start of rain	End of rain
MAPE	0%	1,32%
Pourcentage of accuracy	100%	97,43%

Table 5 : MAPE values and percentage accuracy of model

IV. CONCLUSION

The fuzzy logic method allowed us to model the dates of the rain's beginning and the ending in the coastal areas of the South-East of Madagascar in the integrality of time from 1980 and 2017. The model retained for the rain's beginning is at order 2 with 34 fuzzy rules. Those models are excellent because the curve of the observation data and that of the models obtained are combined. Also the error calculated between those two curves is less than 10%. Thus, the rainy season for the year 2018 will be started on December 15, 2017 and will be ended on April 19, 2018.

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