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Predictive study of the end of the Covid-19 pandemic in Morocco by regression, and ARIMA modeling (p, d, q)

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ABSTRACT

Objective and methods: The objective of our study is to provide forecasts on the key data of the epidemiological situation in Morocco in order to predict the number of beds in hospitals.The data sources used in this study are official and they were daily collected updated with information from the Moroccan Ministry of Health at 6:00 p.m. before the month of Ramadan and 4:00 p.m. for this month.

The autoregressive integrated moving average ARIMA was applied to real-time for the two month Predictions on the Moroccan population. ARIMA models were able to estimate the number of positive cases confirmed based on two criteria. The first criterion is to determine the reliability of the statistics and the second one is to measure the accuracy of forecasting ability of the model equation. The sparse model with the lowest order of the (AR) or (MA) and (RMSE) values of the forecasts for each dataset was considered the best.

Result and Conclusion: The ARIMA (1,0,0), ARIMA (9,0,0) and ARIMA (10,0,1) models were deemed to be the best suited to provide the best possible model to predict the number of positive cases for two months of prediction of the coronavirus disease 2019 (Covid-19).

However, the ARIMA model (10,0,1) predicts the best model with an expected end of home confinement at the end of June 2020 with an epidemiological peak of 5000 accumulated cases caused by the coronavirus disease 2019 (Covid-19) on 13/05/2029.The models were able to predict the number of confirmed cases of the coronavirus disease 2019 (Covid-19) within a range of two months in Morocco. Thus, it can be a useful tool for health officials to improve management of the fight against the pandemic and to warn in advance of the spread of the pandemic.

Keywords: Pandemic, Morocco, COVID-19, Accumulated at Covid-19, ARIMA, AR, MA.

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1.INTRODUCTION

Covid-19 refers to "Coronavirus Disease 2019", the disease caused by a virus of the Coronaviridae family, SARS-CoV-2. This infectious disease is a zoonosis. The coronavirus disease 2019 (Càvid-19) emergency, which changed our habits and our lifestyles this year 2020, it occurred as an epidemic in the city of Wuhan, China, but it later became a pandemic affecting the populations of the whole planet [1].

The coronavirus disease 2019 (Covid-19) pushed scientific researchers to make forecasts on its duration for various aggregation territories, by age... to continue the epidemic without waiting for the end also for reasons of organization and adaptation of the system and healthcare facilities, as well as for the effects of imbalance in the socio-economic system [2,3].

The coronavirus disease 2019 (Covid-19) pandemic has already affected more than 2.4 million people and claimed the lives of more than 160,000 people. It takes a very heavy toll on families, societies, health systems and economies around the world and, as long as this virus threatens a country, whole world will be at risk [4]. Mo-rocco introduced mandatory quarantine as early as March 20, 18 days after the first confirmed the coronavirus disease 2019 (Covid-19) case appeared. It has then car-ried out 100,000 screening tests in early April (initially) then extended, from Mon-day, April 13, to six Centers University HealthCare (CHUs) the possibility of carry-ing out tests. However, quarantine and isolation confirm that these two factors played an important role in Morocco [5,6].In this pandemic we adopted the ARIMA mathematical model according to the XLSTAT software to study the dynamics of the spread of the coronavirus disease 2019 (Covid-19) while taking into account the ef-fect of quarantine of healthy individuals and isolation of those infected.

Next, we will examine the iterative statistical approach which consists in refining ARIMA forecast models or space-state models, chosen according to the tests for re-siduals [7].

The objective of our study is to provide forecasts on the key data of the epidemio-logical situation in Morocco, namely:

- The number of deaths and the mortality rate;
- The number of beds to be provided in hospitals.
- The number of positive and cumulative cases at the coronavirus disease 2019 (Covid-19);
- Lethality rate;
- The number of healing and the number saved (negative test);
- The forecast date of the epidemiological peak.

2. MATERIAL AND METHODS

The data sources used are official. They were daily collected and kept up to date with numbers from the Ministry of Health of Morocco at 6 hours and at 4 hours the month of Ramadan.

The following (**Table 1 and Table 1 bis**) shows the data for the months of March and April during the pandemic period in Morocco.

Table 1: Data collected by the Ministry of Health during the Covid 19 pandemic in March

Date	**Number of confirmed cases /**	**Number of Accumulated**	**Number of deaths /**	**Number Healing**	**number saved /**	**Case fatality**	**Mortality rate / M**

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	Day	Cases / Days	Day	/ Day	Day	rate %	
01/03/2020	0	0	0	0	25	0	0
02/03/2020	1	1	0	0	28	0	0
03/03/2020	0	1	0	0	32	0	0
04/03/2020	0	1	0	0	34	0	0
05/03/2020	1	2	0	0	36	0	0
06/03/2020	0	2	0	0	50	0	0
07/03/2020	0	2	0	0	55	0	0
08/03/2020	0	2	0	0	58	0	0
09/03/2020	1	2	0	0	60	0	0
10/03/2020	0	3	0	0	66	0	0
11/03/2020	3	6	1	0	78	16,667	0,029
12/03/2020	0	6	1	0	91	16,667	0,029
13/03/2020	2	8	1	1	106	12,500	0,029
14/03/2020	10	18	1	1	112	5,556	0,029
15/03/2020	10	28	1	1	122	3,571	0,029
16/03/2020	9	37	1	1	152	2,703	0,029
17/03/2020	7	44	2	1	183	4,545	0,057
18/03/2020	10	54	2	1	263	3,704	0,057
19/03/2020	9	61	2	1	276	3,279	0,057
20/03/2020	16	77	3	2	374	3,896	0,086
21/03/2020	17	96	3	3	441	3,125	0,086
22/03/2020	19	115	4	3	512	3,478	0,114
23/03/2020	28	143	4	5	643	2,797	0,114
24/03/2020	27	170	5	6	685	2,941	0,143
25/03/2020	55	225	6	7	740	2,667	0,171
26/03/2020	50	275	10	8	931	3,636	0,286
27/03/2020	58	333	21	11	1207	6,306	0,600
28/03/2020	65	359	24	11	1461	6,685	0,686
29/03/2020	65	463	26	13	1756	5,616	0,743
30/03/2020	71	534	33	15	2195	6,180	0,943
31/03/2020	68	600	36	24	2298	6,000	1,029

With

Number of cases confirmed by Covid 19 / day, Number of cases accumulated by the Covid 19 / day, Number of deaths by Covid 19 / day,Number of Covid Heals 19 / day, number saved by the Covid 19 / day.

:• **Lethality rate %** = Number of deaths ÷ Cumulative number of infected people * 100.

• **Mortality rate / Million** = Number of deaths ÷ Number of population (35, 000,000).

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Table 1bis : Data collected by the Ministry of Health during the Covid 19 pandemic in April

Date	Number of confirmed cases / Day	Number of Accumulated Cases / Days	Number of deaths / Day	Number Healing / Day	number saved / Day	Case fatality rate %	Mortality rate / M
01/04/2020	40	642	37	26	2653	5,763	1,057
02/04/2020	49	691	44	30	2815	6,368	1,257
03/04/2020	70	761	47	56	3062	6,176	1,343
04/04/2020	122	883	58	65	3304	6,569	1,657
05/04/2020	107	990	69	71	3589	6,970	1,971
06/04/2020	130	1120	80	81	3984	7,143	2,286
07/04/2020	64	1184	90	93	4253	7,601	2,571
08/04/2020	91	1275	93	97	4372	7,294	2,657
09/04/2020	99	1374	97	109	5009	7,060	2,771
10/04/2020	74	1448	107	122	5791	7,390	3,057
11/04/2020	97	1545	111	146	6403	7,184	3,171
12/04/2020	116	1661	118	177	6943	7,104	3,371
13/04/2020	102	1763	126	203	7365	7,147	3,600
14/04/2020	125	1888	126	217	8034	6,674	3,600
15/04/2020	136	2024	127	229	8626	6,275	3,629
16/04/2020	259	2283	130	249	9713	5,694	3,714
17/04/2020	281	2564	135	281	10388	5,265	3,857
18/04/2020	121	2685	137	314	11004	5,102	3,914
19/04/2020	170	2855	141	327	12668	4,939	4,029
20/04/2020	191	3046	143	350	13340	4,695	4,086
21/04/2020	163	3209	145	393	14891	4,519	4,143
22/04/2020	237	3446	149	417	16439	4,324	4,257
23/04/2020	122	3568	155	456	18379	4,344	4,429
24/04/2020	190	3758	158	486	20175	4,204	4,514
25/04/2020	139	3897	159	537	21546	4,080	4,543
26/04/2020	168	4065	161	593	23334	3,961	4,600
27/04/2020	55	4120	162	695	25134	3,932	4,629
28/04/2020	132	4252	165	778	26998	3,881	4,714
29/04/2020	169	4321	168	928	28600	3,888	4,800
30/04/2020	38	4359	168	969	29963	3,854	4,8

With Number of cases confirmed by Covid 19 / day, Number of cases accumulated by the Covid 19 / day, Number of deaths by Covid 19 / day,Number of Covid Heals 19 / day, number saved by the Covid 19 / day.

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:• **Lethality rate %** = Number of deaths ÷ Cumulative number of infected people * 100.
• **Mortality rate / Million** = Number of deaths ÷ Number of population (35, 000,000).

2.1 Computational methods

The XLSTAT-Time Series Analysis module has been developed to provide XLSTAT 2018 users with a powerful solution for time series analysis and forecasting.

XLSTAT-Time Series Analysis functions provide you with outstanding tools to find out the degree of dependence between the values of a time series, to discover trends - seasonal or not, to apply specific pretreatments such as the Autoregressive Moving Average variants and finally to build predictive models [8].

The models of the ARIMA family allow to represent in a synthetic way phenomena that vary with time, and to predict future values with a confidence interval around the predictions.

The mathematical writing of the ARIMA models differs from one author to the other. The differences concern most of the time the sign of the coefficients. XLSTAT is using the most commonly found writing, used by most software.

An ARIMA model is labeled as an ARIMA model (p, d,q), wherein:

- p is the number of autoregressive terms;
- d is the, number of differences; and
- q is the number of moving averages.

The autoregressive process. Autoregressive models assume that Yt is a linear func-tion of the preceding values and is given by equation (1)

$$Yt = c + \Phi 1 Y(t-1) + \varepsilon t \qquad (1)$$

Literally, each observation consists of a random component (random shock, ε) and a linear combination of the previous observations. Φ1 in this equation is the self-regression coefficient.

3. RESULTS

3.1Descriptive analysis

(**Figure 1**) represents the descriptive analysis of the data collected by the Ministry of Health during the months of March and April.

The growth in cumulative Covid-19 cases reached a maximum of 4321.

The growth of cured cases of Covid-19 has reached a maximum of 969. It seems that the number of cured cases and the number of confirmed cases are correlated with each other.

The time series “mortality rate / fatality rate” seems to converge towards the series “the death / reported rate”. The latter is stable around 4.257%.

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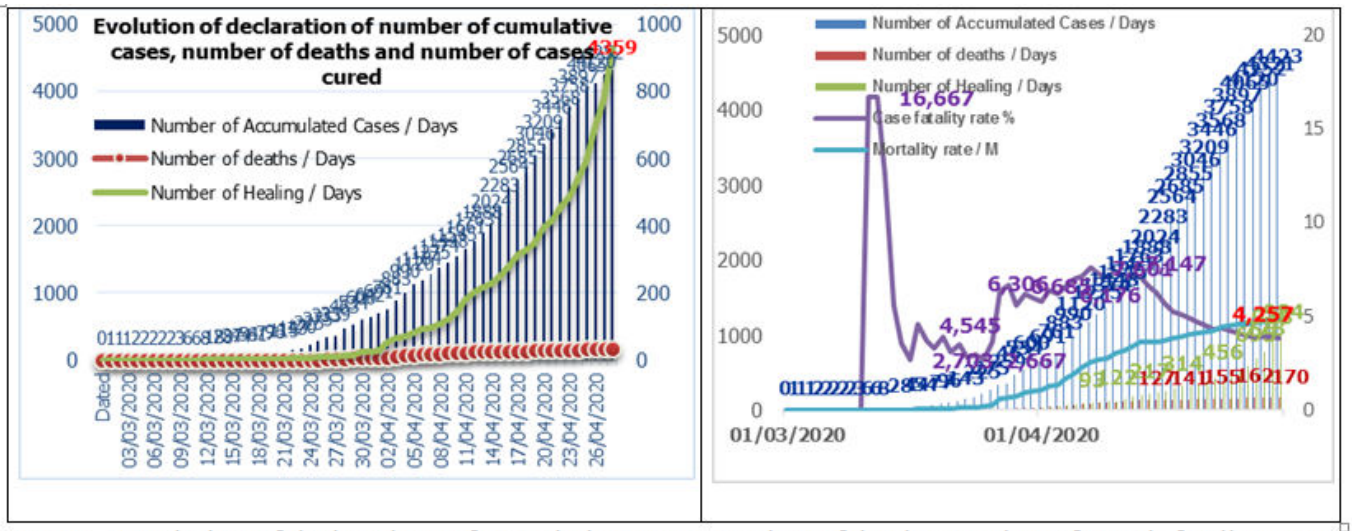

Figure 1 : Evolution of declarations of cumulative cases, number of deaths, number of cured, fatality rate and

3.2 ARIMA model

(**Table 2**) provides simple statistics for the selected series. It allows assessing the quality of the model after optimization. These different indices allow you to compare the different models with each other.

XLSTAT allows including explanatory variables in the ARIMA model. In our case, we used OLS, which is a classic linear regression model that is fitted to the data, and then the residuals are modeled through the (S) ARIMA model.

Table 2: ARIMA model parameters for the number of cumulative cases in Cov-19

Adjustment coefficients	**RMCE**	**Model equation**	**Validation**	**Iteration**	**Forecast**
AR(1) ;(1,0,0) (**Figure 1**)	151,588	**Yt** = 1616,201 +0,951 $\mathbf{Y_{(t-1)}}$	10	1000	60 days
AR(9); (9,0,0) (**Figure 2**)	144,384	**Yt**= 1483,266 - 0,041 $\mathbf{Y_{(t-1)}}$	20	1000	60 days
AR(10)and AM(1); (10,0,1) (**Figure 3**)	35,098	**Yt**=1850,791-0,044 $\mathbf{Y_{(t-1)}}$+0,484$_{\mathbf{(t-60)}}$	10	501	60 days
RMSE: The root mean square of the errors (RMSE)					

4. DISCUSSION

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ARIMA model (1,0,0): (Figure 2) shows the ARIMA model (1,0,0) named (p, q, d) with q, d equal to zeros however the given model is called Auto Regressive Model AR (1) coefficient of order 1 of the polynomial Yt, according to the following model:

$$Y_t = c + \varphi_1 Y_{(t-1)} + \varphi_2 Y_{(t-S)} + \varepsilon t$$

The preliminary estimate is according to Yule-Walker,
Optimization: Likelihood (Convergence = 0.00001 / Iterations = 500, with a 60-day Prediction.

The constant **C** = 1616,201 ; **AR** (1) = 0.951, (φ_1 = 0.951 <1 and positive.
the slope coefficient ϕ_1 is positive and less than 1 in magnitude (Y is stationary), the model describes mean-reverting behavior in which next period's value should be predicted to be ϕ_1 times as far away from the mean as this period's value [9].

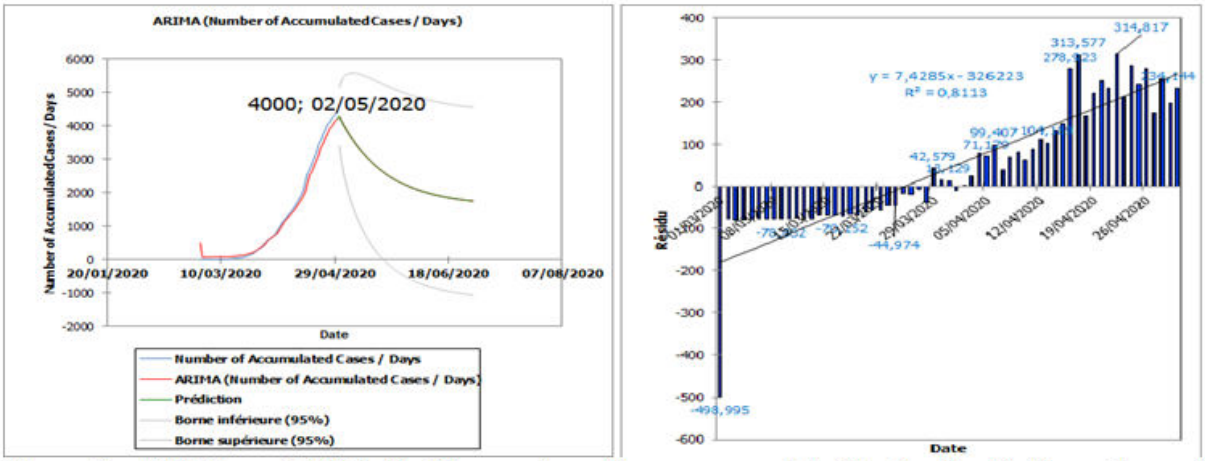

Figure 2: ARIMA model (9.0,0) of the number of cases accumulated by the Covid-19 per day and the residues of the cumulative cases

ARIMA model (9.0,0): (Figure 3) presents the ARIMA model (9,0,0) with q, d equal to zeros, the given model is called Auto Regressive model AR (1) coefficient of order 9 of the polynomial Yt, according to the following model:

$$\mathbf{Yt} = 1483.266 - 0.041\ \mathbf{Y}_{(t-1)}$$

The preliminary estimate by the Yule-Walker equations,
Optimization: Likelihood (Convergence = 0.00001 / Iterations = 500 with a 60-day Prediction. The constant C = 1483.266 different from zero, **AR** (1) = - 0.044. (φ**1** = - 0.044 <1 and negative.
ϕ_1 is negative, it predicts mean-reverting behavior with alternation of signs, ϕ_1, it also predicts that Y will be below the mean next period if it is above the mean this period [9].

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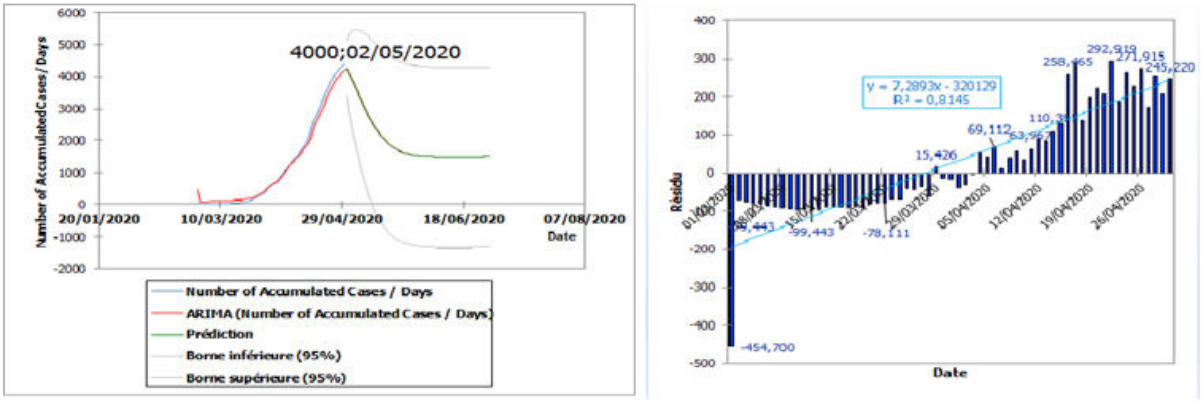

Figure 3: ARIMA model (9.0,0) of the number of cases accumulated by the Covid-19 per day and the residues of the cumulative cases

ARIMA model (10,0,1): (Figure 4) presents the ARIMA model (10,0,1) with d equal to zeros and d = 1, the given model is called Auto Regressive model AR (10) coefficient of order 10 of the polynomial Yt, according to the model following:

$$\mathbf{Yt}=1850{,}791-0{,}044\mathbf{Y}_{(t-1)}+0{,}484_{(t-60)}$$

The parameters MA(1) and AR(10) are significantly different from 0, their 95% confidence interval not including the value 0. The confidence intervals are calculated on the basis of the Hessian matrix after optimization with (MA (1) Adjustment coefficients).

The preliminary estimate is according to Yule-Walker,
Optimization: Likelihood (Convergence = 0.00001 / Iterations = 500, with a Prediction of 60.
The constant **C** = 35.098, **AR** (10) = 0.044, **MA** (1) = 0.484 φ_1 = 0.044 <1 positive

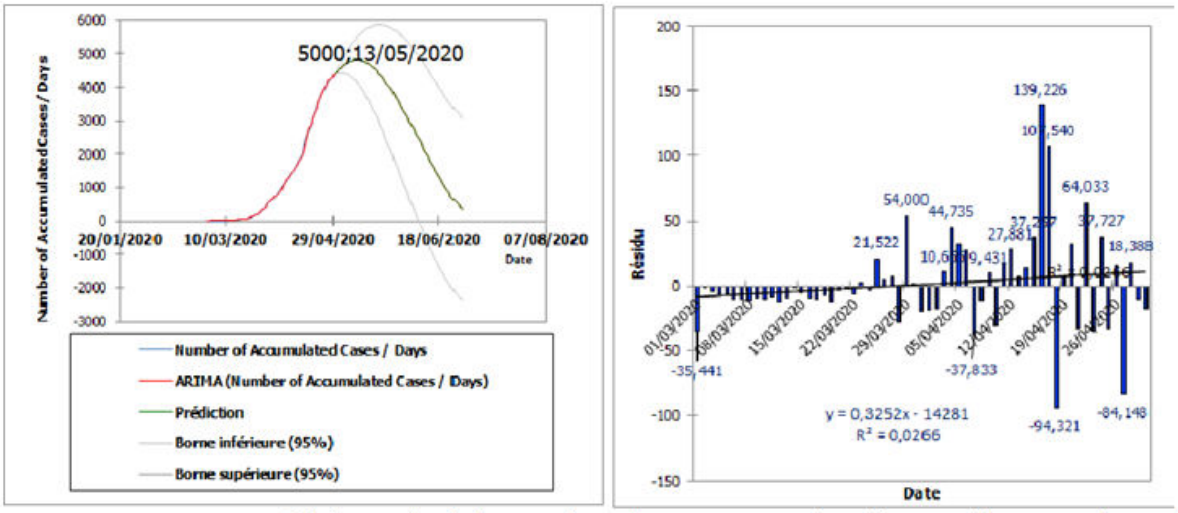

Figure 4: ARIMA model (10,0,1) of the number of cases accumulated by Covid-19 per day and the residues of the cumulative cases

The prediction curve shown in green in (**Figures 2**) and (**Figure 3**) indicates an epidemiological peak of around 4000 cumulative cases Covid-19 d according to the date 02/05/2020.

(Figure 2) of (**Figure 3**) gives us an infinite plateau from 06/29/2020, however (**Figure 2)** and (**Figure 3)** do not give us a good prediction.

We note that for the ARIMA model (10,0,1) of (**Figure 4**)we have a good forecast. This is illustrated by the curve indicated in green (**Figure 4**) which tends towards the horizontal axis coinciding with the end of June 2020 with a forecast epidemiological peak of 5000 cases accumulated by Covid-19 the 13/05/2029.

However, for the upper bound (95%) illustrated in gray we predict an epidemiological peak.

Of 6000 cumulative cases Covid-19 according to the forecast date of 5/24/2020 with an end of confinement of a date of 7/15/2020.

For the lower bound (95%) also shown in gray, we predict an epidemiological peak of 4548 cumulative cases Covid-19 d according to the forecast date of 05/01/2020 with an end of confinement of a date of 06/10/2020.

Comparison of the end of confinement : Our results coincide well with those reported by [10]. SUTD Data-Driven Innovation Lab |ddi.sutd.edu.sg[10].

We referred to Luo, Jianxi (2020), When will Covid-19 end. The Prediction is based on the data in (**Table 3**) below:

Table 3: Data-based Prediction Table (as of April 26, 2020) [10]

Countries	**Turning Date**	**End 97% (sorted by)**	**End 99%**	**End 100%**
Morocco	24-Apr-20	1-Jun-20	**13-Jun-20**	30-Jul-20
Italy	29-Mar-20	8-May-20	21-May-20	25-Aug-20
France	3-Apr-20	6-May-20	18-May-20	5-Aug-20
Egypt	18-Apr-20	20-May-20	30-May-20	8-Jul-20
Iran	1-Apr-20	20-May-20	9-Jun-20	22-Oct-20

5. CONCLUSION

Morocco was one of the first countries to prepare to deal with this pandemic.

He noted that the national epidemiological watch and surveillance system follows all the news and information related to this virus.

The trials of the ARIMA (1,0,0), ARIMA (9,0,0) and ARIMA (10,0,1) models were considered to be the best suited to provide a possible model for predicting the number of positive cases by the Covid-19 for two months of prediction.

However, the ARIMA model (10,0,1) we predicts the best model with an end of confinement expected at the end of June 2020 with an epidemiological peak of 5000 cases cumulated by Covid-19 on 05/13/2029.

The results also indicate that Covid-19 cases will continue to occur in the near future if the appropriate response measures are not taken in time.

The potential implication of this study is that by developing forecasting models we predict in advance the number of cases confirmed by the Covid-19 virus to undertake preventive and control measures in order to effectively plan for containment, spraying insecticides and public awareness.

The study also provided a model for planning and allocating the appropriate resources to maintain a steady decline and fight the Covid-19 virus.

However, the ARIMA model used in this article can also be applied to other diseases.

Competing interests

Reminder

The authors declare no competing interests. In this part, we perform a simulation battery based on historical data. We would like to remind you that all the results of this study are strictly and solely dedicated to educational, research purposes, and may contain errors.

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