Forecasting Water Demand For Agricultural, Industrial And Domestic Use In Libya

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This paper examines water demand for all needs to determine the future water demand for agricultural, industrial and domestic use; it uses annual data on consumption of water demand by the year 2020. The method of demand forecasting of water is based on Box –Jenkins method. By 2020, as a whole, water demands will increase to the double in Libya. So, Available water in 2020 will be less than half of water demands' which means an increase of the shortage over time. The future water demand for agriculture purposes is expected to increase. Also, it becomes the biggest consumer of water, It represents about 83%of the estimated water consumption of 2020.

Field of Research: Economics of Water Resource Management in Libya

1. Introduction

One of the serious problems that many countries are facing today is water shortage, even though there is over 70% of surface water covered the earth.
Water shortage like other economic resources, it is no different from one country and part of a country into another. In the last few years, domestic water shortage has increased worldwide, increase water demand as result of, increase of the population, increase in the individual agricultural domestic and industrial demand and rising of living standard. Libya, like other countries worldwide, is no different in respect of the causes leading to the increase of water shortage and I believe that population growth and water consumption are among the areas that should be addressed by any scientific study. Large increases in water demand with very little recharge have strained Libya's groundwater resources resulting in serious declines in water levels and quality, especially along the Mediterranean coast where most of the agricultural, domestic and industrial activities are concentrated. The future estimations of water consumption for all possible purposes indicate to total water consumption increasing from 6293.89 million cubic meters in 2006 to 12473.20 million cubic meters in 2020 with an average of compound annual rate of 4.97%. In 2020 it is expected, that the increase would be 98% of the water consumption in 2006. So, the aims and objective of this study are to forecast the water demand for agricultural, domestic and industrial use in Libya using Box –Jenkins method.

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2. Methodolgy

The methodology of the study is defined as an analytical method practised to realize the study goal. The estimates of water consumption for different purposes are calculated by using the comparative equations stated. The Box-Jenkins is used to forecast the water demand for all purposes .In addition, this study uses econometric tests for Unit Roots, Co integration to estimate this model:

$$\ln W_A = \alpha_A + \beta_1 \ln P_A + \theta_1 \ln pop + \gamma_1 \ln Y + \psi_1 \ln temp + u_A$$

$$\ln W_I = \alpha_I + \beta_2 \ln P_I + \theta_2 \ln pop + \gamma_2 \ln Y + \psi_2 \ln temp + u_I$$

$$\ln W_D = \alpha_D + \beta_3 \ln P_D + \theta_3 \ln pop + \gamma_3 \ln Y + \psi_3 \ln temp + u_D$$

$$\ln W = \alpha + \beta_1 \ln P_A + \beta_2 \ln P_I + \beta_3 \ln P_D + \theta \ln pop + \gamma \ln Y$$
$$+ \psi \ln temp + u$$

Where:
W = total water demand and W_A, W_I, W_D = water demand for the purposes of, agriculture, industry and domestic use, respectively.
P_A, P_I P_D , are the prices of agriculture, industry and domestic water
pop is the number of people, Y is the income a and $temp$ is the temperatre
α = Intercept coefficients
$\beta_1, \beta_2, \beta_3, \theta, \gamma, \psi$ = Slope coefficients
u = residual term
$\ln$ = Natural logarithm

2.1 ARIMA Forecasting Models

This section examines stationary and non stationary time series by formally testing for the presence of unit roots. Various Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) models are estimated over the period 1975-2005 for total water demand and demand for water for agriculture, domestic and industry use. The ARIMA models provide a useful framework to understand how the water time series is generated. Unlike univariate smoothing models which are more commonly used, the ARIMA approach requires a water time series to be tested for nonstationarity prior to undertaking estimation and forecasting. If a series is nonstationary (that is, the series has a mean and variance that are not constant over time), the series has to be differenced to transform it to a stationary series, before generating forecasts. A stationary water demand series typically provides better and more reliable forecasts.

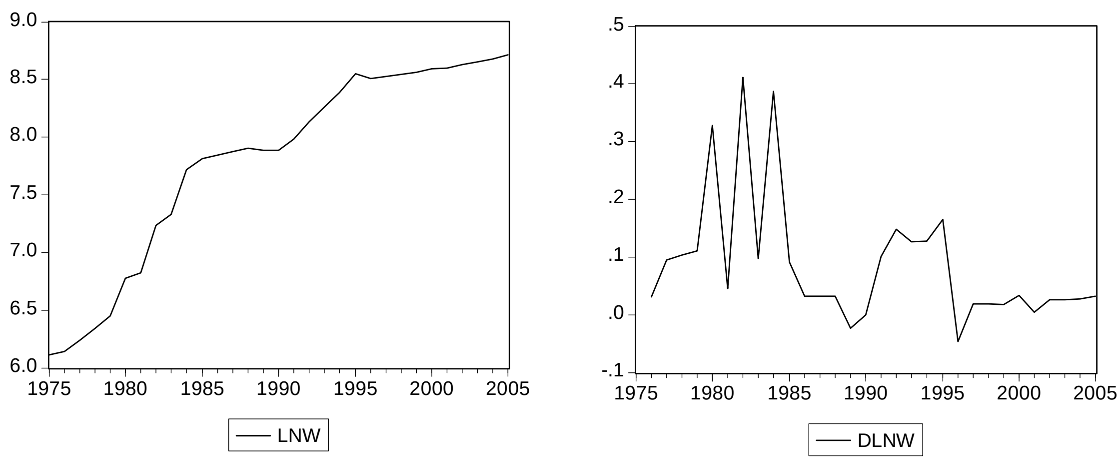
The work of Box and Jenkins (1970) shifted professional attention in time series modelling away from stationary processes to a class of nonstationary processes and the related ideas of the order of integration necessary to obtain stationary series. Furthermore, the Box-Jenkins method is popular because of its generality since it can handle any stationary or nonstationary time series. In the identification phase, a general class of models applicable to a particular situation is examined with the aid of the sample correlograms, and autocorrelation and partial autocorrelation functions.

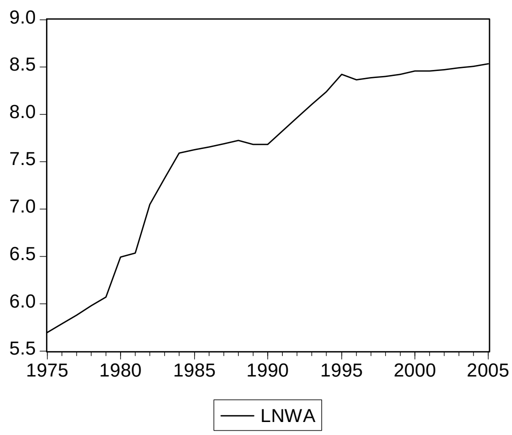
2.2 Testing for Stationarity

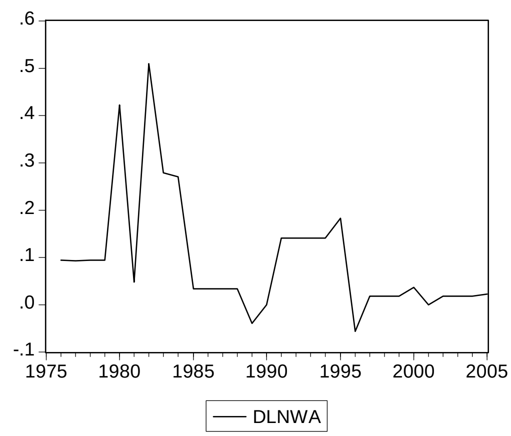
2.2.1 Graphs of Variables

The first method which can be used to check stationarity of the variables is to graph the series. The graphs of these variables in logarithm form are shown in figure (1).

Figure (1) Graphs of the variables (in level and in first and second differences)




9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
1975 1980 1985 1990 1995 2000 2005
LNWA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.5
.4
.3
.2
.1
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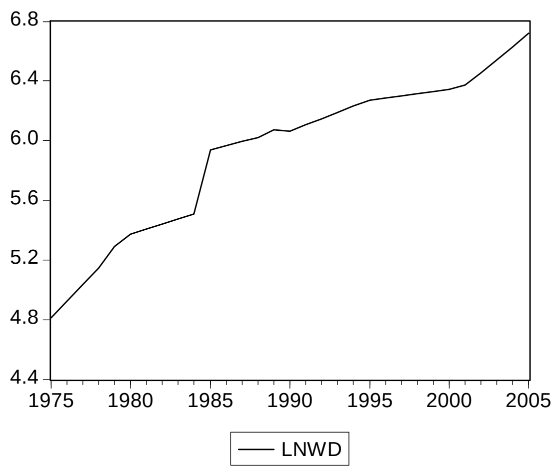
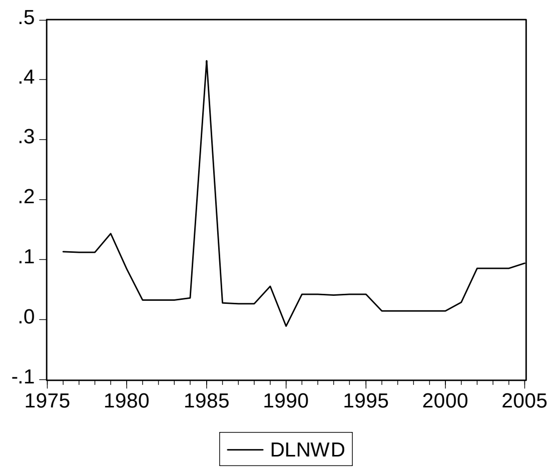
-.1
1975 1980 1985 1990 1995 2000 2005
DLNWA


6.8
6.4
6.0
5.6
5.2
4.8
4.4
1975 1980 1985 1990 1995 2000 2005
LNWD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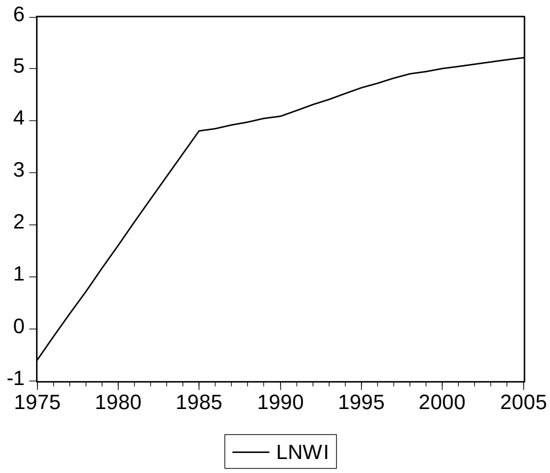
1975 1980 1985 1990 1995 2000 2005
DLNWD



The original time series in logarithm form is checked for stationarity using the augmented Dickey- Fuller (ADF) test for unit roots.

2.2.2 The ADF-Test for Difference Versus Trend Stationarity

The restricted model assumes the time trend is zero and the series for all variables are difference stationary. As shown in tables (1), (2), (3) and (4), then the series are transformed by taking appropriate differences to render the series stationary. A detailed explanation of the test procedure is given in Gujarati (2003).

Table (1): $\ln W$

Wald Test:				
Equation: Untitled				
Null Hypothesis:	C(2)=0			
	C(3)=0			
F-statistic	3.428872		Probability	0.048313
Chi-square	6.857743		Probability	0.032424

$$\Delta Y_t = \alpha_0 + \lambda t + \theta Y_{t-1} + \delta_2 \Delta Y_{t-1}$$

D ($\ln W$) C Trend $\ln W$ (-1) D ($\ln W$ (-1))

$H_0 : \theta = \lambda = 0$

$F =$ 3.43 < $F_c =$ 7.24

We can not reject H_0 ,because the F-statistic is less than the 5% critical value ,then we can say that we are 95% confident that the series $\ln W$ follows a difference stationary process.

Table (2): $\ln W_A$

Wald Test:				
Equation: Untitled				
Null Hypothesis:	C(2)=0			
	C(3)=0			
F-statistic	4.717876		Probability	0.018265
Chi-square	9.435753		Probability	0.008934

$$\Delta Y_t = \alpha_0 + \lambda t + \theta Y_{t-1} + \delta_2 \Delta Y_{t-1}$$

D ($\ln W_A$) C Trend $\ln W_A$ (-1) D ($\ln W_A$ (-1))

$H_0 : \theta = \lambda = 0$

$F =$ 4.72 < $F_c = 7.24$

We can not reject H_0 ,because the F-statistic is less than the 5% critical value ,then we can say that we are 95% confident that the series $\ln W_A$ follows a difference stationary process.

Table (3): $\ln W_D$

Wald Test:				
Equation: Untitled				
Null Hypothesis:	C(2)=0			
	C(3)=0			
F-statistic	1.430434		Probability	0.258117
Chi-square	2.860869		Probability	0.239205

$$\Delta Y_t = \alpha_0 + \lambda t + \theta Y_{t-1} + \delta_2 \Delta Y_{t-1}$$

D ($\ln W_D$) C Trend $\ln W_D$ (-1) D ($\ln W_D$ (-1))

$H_0 : \theta = \lambda = 0$

$F =$ 1.43 < $F_c = 7.24$

We can not reject H_0 ,because the F-statistic is less than the 5% critical value ,then we can say that we are 95% confident that the series $\ln W_D$ follows a difference stationary process.

Table (4): $\ln W_I$

Wald Test:				
Equation: Untitled				
Null Hypothesis:	C(2)=0			
	C(3)=0			
F-statistic	5.0331		Probability	0.000000
Chi-square	1.0132		Probability	0.000000

$$\Delta Y_t = \alpha_0 + \lambda t + \theta Y_{t-1} + \delta_2 \Delta Y_{t-1}$$

D ($\ln W_I$) C Trend $\ln W_I$ (-1) D ($\ln W_I$ (-1))

$H_0 : \theta = \lambda = 0$

$F = 5.03 < \quad F_c = 7.24$

We can not reject H_0 ,because the F-statistic is less than the 5% critical value ,then we can say that we are 95% confident that the series $\ln W_I$ follows a difference stationary process.

2.2.3 Unit Root Test

Another method which can be used to check stationarity of the variables is the ADF tests which are performed sequentially show that not included any lag of the differenced variable for total water demand and demand for water for agriculture is significant, and the ADF test statistics is calculated with and without time trend for water demand for, industrial, and domestic use respectively for lag length of one. Each of the calculated statistics exceeds the critical value the value of this test statistics with 5 per cent critical value, as tabulated in Mackinnon (1991), is included in table (5), so the null hypothesis of a unit root is not rejected, which implies that each of the four water demand series is non stationary in its level. Taking first differences renders each series stationary except demand for water for industry, with the ADF statistics in all cases for total water demand and demand on water for agricultural and domestic, respectively) while demand for water for industrial use, taking second difference renders it stationary being more negative than the critical value. Table (5) indicate the stationarity of all the variables.

Table (5): Unit Root Test

	Level		**First difference**	**Second difference**	
	With trend	With out trend	With out trend	With out trend	
Variable	ADF	ADF	ADF	ADF	Conclusion
$\ln W$	-0.71	-2.58	-4.51	–	I(1)
$\ln W_A$	-0.78	-2.84	-3..77	–	I(1)
$\ln W_D$	-2.19	-1.74	-3.52	–	I(1)
$\ln W_I$	-2.59	-2.91	-1.39	-3.72	I(2)

5% critical values.

Without time trend ADF-2.97

With time trend DF ADF-3.57

3. Estimates of the ARMA Model

3.1 Using the Best Fitting Model during the Period 1975-2005

The best fitting ARMA models are estimated separately for water demand series from 1975 to 2000 and the tests indicate that the ARMA (3,1),(3,1),(1,1)and(1,1) performs well. The coefficients and all significant, and they satisfy the stationarity and invertibility conditions. It has the highest adjusted R^2 and the lowest AIC and SIC values six candidate models. The correlogram and unit root tests of the series before and, if necessary, after differencing are examined for stationarity. After empirical examination, the most appropriate models for total water demand and demand for water for agricultural , domestic and industrial use are determined as ARMA (3,1), ARMA (3,1), ARMA (1,1) and ARMA (1,1) respectively. Using the best fitting model for total water demand, demand for water for agricultural, domestic and industrial use are calculated in tables (6),(7),(8) and (9). (With absolute t-ratios in parentheses):

$$\Delta \ln W_t = \alpha_0 + \alpha_1 \Delta \ln W_{t-1} + \alpha_2 \Delta \ln W_{t-2} + \alpha_3 \Delta \ln W_{t-3} + e_t - \beta_1 e_{t-1} \quad \text{ARMA(3,1)}$$

$$\Delta \ln W_{At} = \alpha_0 + \alpha_1 \Delta \ln W_{A_{t-1}} + \alpha_2 \Delta \ln W_{A_{t-2}} + \alpha_3 \Delta \ln W_{A_{t-3}} + e_t - \beta_1 e_{t-1} \quad \text{ARMA(3,1)}$$

$$\Delta \ln W_{Dt} = \alpha_0 + \alpha_1 \Delta \ln W_{D_{t-1}} + e_t - \beta_1 e_{t-1} \quad \text{ARMA(1,1)}$$

$$\Delta\Delta \ln W_{It} = \alpha_0 + \alpha_1 \Delta\Delta \ln W_{i_{t-1}} + e_t - \beta_1 e_{t-1} \quad \text{ARMA (1,1)}$$

Table (6): d $\ln W$ **(1975-2005)**

	$\bar{R}^2$	AIC	SC	SIG	STAT	INV
ARMA(3,1)	0.63	-2.32	-2.08	All sign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(3,2)	0.45	-1.87	-1.58	2 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(5,1)	0.60	-2.18	-1.84	4 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(4,1)	0.51	-1.95	-1.66	2 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(2,1)	0.25	-1.66	-1.47	2 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(1,2)	0.30	-1.58	-1.59	All sign	$\sum \alpha < 1$	$\sum \beta < 1$

Table (7) d $\ln W_A$ (1975-2005)

	$\bar{R}^2$	AIC	SC	SIG	STAT	INV
ARMA(3,1)	0.42	-1.52	-1.30	All sign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(3,0)	0.20	-1.25	-1.05	3 insign	$\sum \alpha < 1$	………
ARMA(4,1)	0.64	-1.95	-1.66	3 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(1,0)	0.05	-1.22	-1.13	one insign	$\sum \alpha < 1$	……….
ARMA(1,1)	0.09	-1.23	-1.09	2 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(2,1)	0.19	-1.28	-1.09	3 insign	$\sum \alpha < 1$	$\sum \beta < 1$

Table (8) d$\ln W_D$ (1975-2005)

	$\overline{R}^2$	AIC	SC	SIG	STAT	INV
ARMA(1,1)	0.50	-2.23	-2.08	All sign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(1,2)	0.07	-2.17	-1.98	One insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(2,2)	0.16	-2.22	-1.98	2 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(3,2)	0.12	-2.11	-1.82	3 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(5,1)	-0.08	-1.80	-1.49	4 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(4,0)	-0.18	-1.84	-1.60	4 insign	$\sum \alpha < 1$	………

Table (9) dd$\ln W_I$ (1975-2005)

	$\overline{R}^2$	AIC	SC	SIG	STAT	INV
ARMA(1,1)	0.48	-2.83	-2.69	One insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(1,0)	-0.02	-2.19	-2.09	One insign	$\sum \alpha < 1$	…….
ARMA(2,1)	-0.02	-2.09	-1.90	2 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(3,1)	-0.04	-1.99	-1.75	3 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(4,1)	-0.06	-1.90	-1.61	4 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARMA(1,2)	0.45	-2.75	-2.56	3 insign	$\sum \alpha < 1$	$\sum \beta < 1$

Where: $\overline{R}^2$ is Adjusted R-squared, AIC is Akaike info criterion, SC is Schwarz criterion, SIG is Significant, STAT is Stationary i.e. $\sum \alpha < 1$, INV is Invertibility i.e. $\sum \beta < 1$ and insign is insignificant

Since the specific ARIMA models that adequately describe total water demand and demand for water for agriculture, industry and domestic are given above, the fitted models used for forecasting water demand for four categories are given as follows:

Total water demand (1975-2005)

$$\Delta \ln W_t = 0.11 + 1.12 \Delta \ln W_{t-1} + 0.55 \Delta \ln W_{t-2} - 083 \Delta \ln W_{t-3} + e_t + 1.59 e_{t-1}$$

t- values (2.86) (6.29) (2.26) (4.78) (4.22)

$\overline{R}^2$=0.63 SC=-2.08 AIC=-2.32

Demand for water for agriculture (1975-2005)

$$\Delta \ln W_{At} = 0.05 + 0.89 \Delta \ln W_{A_{t-1}} + 0.39 \Delta \ln W_{A_{t-2}} - 0.45 \Delta \ln W_{A_{t-3}} + e_t + 0.99 e_{t-1}$$

t- values (3.399) (4.71) (2.44) (2.59) (9.70)

$\overline{R}^2$=0.42 SC=1.30 AIC=1.52

Demand for water for domestic use (1975-2005)

$$\Delta \ln W_{Dt} = 0.05 + 0.77 \Delta \ln W_{D_{t-1}} + e_t + 0.96 e_{t-1}$$

t- values (5.65) (7.76) (26.54)

$\overline{R}^2$=0.50 SC=-2.08 AIC=-2.23

Demand for water for industry (1975-2005)

$$\Delta\Delta \ln W_{It} = -0.002 + 0.55 \Delta\Delta \ln W_{i_{t-1}} + e_t + 1.45 e_{t-1}$$

t- values (0.29) (3.27) (6.62)

$\overline{R}^2$=0.48 SC=-2.69 AIC=-2.83

Tests for white noise residuals

Having decided to use the ARMA (3,1),(3,1),(1,1) and (1,1) model for total water demand , demand for water for agricultural, domestic and industrial use, it is necessary to use five different tests, to determine if the residuals are white noise theses tests are (residual line graph, check the size of the differences between the fitted and actual values, check the residual correlogram for ARIMA (3,1) if white noise ,test for autocorrelation in the residuals is the Serial Correlation Lagrange Multiplier (LM), normality of the residuals and test if the series is stationary by using unit root) on it. The key tests to determine whether the estimated from the ARMA (3, 1), (3, 1), (1, 1) and (1, 1) model are white noise.

3.2 Magnitude of Forecasting Errors (2001-2005)

With the forecast observations being demand for water for five years (2001-2005), table (10) presents the Root Mean Squared Error (RMSE) forecast accuracy measure of the ARMA models for total water demand, demand for water for agriculture domestic and industry ,the mean absolute percentage error(MAPE) of the ARMA model lower in both(static and dynamic). However, the static ARMA model forecasts were better than the dynamic ARMA model forecasts, these result suggest that the ARMA (3, 1), (3, 1), (1, 1) and (1, 1) model performs better in forecasting total water demand, demand for water for agricultural, domestic and industrial use.

Table (10): Root Mean Squared Error (RMSE) for Five years Ex post Forecasts of the Logarithm of Demand for Water, 2001-2005

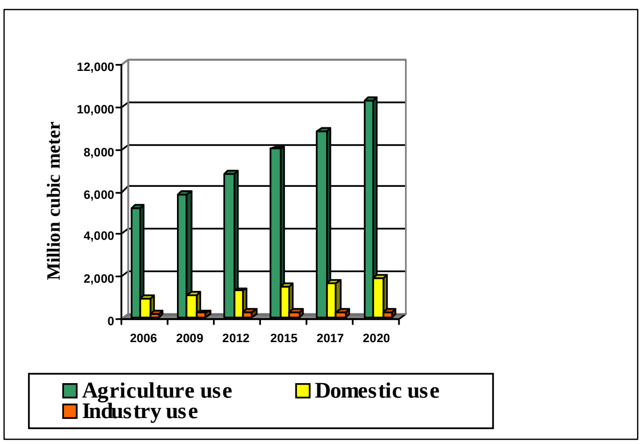
	RMSE		
	ARMA	Static	Dynamic
$\ln W$	(3,1)	0.01	0.04
	(3,2)	0.03	0.06
$\ln W_A$	(3,1)	0.02	0.07
	(1,1)	0.05	0.07
$\ln W_D$	(1,1)	0.04	0.06
	(1,2)	0.18	0.05
$\ln W_I$	(1,1)	0.02	0.01
	(1,0)	0.2	0.02

Table (10) shows the RMSE for the fitted ARMA (3, 1), (3, 1), (1, 1) and (1, 1) models against (3,2),(1,1),(1,2) and (1,0) models according to the forecasting. It suggests that the models which we tested to forecasting are more accurate than others during the period 2001-200. The fitted values, which are interpreted as the forecasts for the next five years, are sufficiently close to the actual values for total water demand, demand for water for agricultural, domestic and industrial use using the ARMA models.

4. The Results of Forecasting of Water Demand from 2006 to 2020

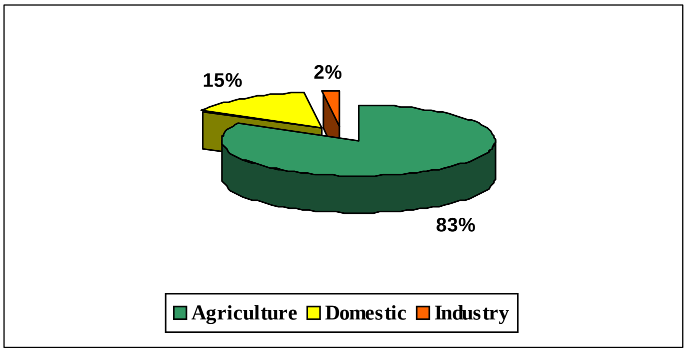
Low RMSE for forecasting purposes is a desirable measure of forecasting fit. The RMSE for forecasting computed over the forecast range provides a measure of the ability of the model to forecast. For estimation of future water consumption the equations for total water demand and demand for agricultural, domestic and industrial use have been applied. By viewing table (11) which shows the estimations of future water consumption during the period 2006 – 2020, the following could be noticed: The future estimations of water consumption for all possible purposes indicate to total water consumption increasing from 6293.89 million cubic meters in 2006 to 12473.20 million cubic meters in 2020 with an average of compound annual rate of 4.97%. In 2020 it is expected, that the increase would be 98% of the water consumption in 2006.

Figure (2): Water Demands in Libya, 2006-2020



Data source: table (11)

Figure (3) Water Consumption in 2020



Data source: table (11)

Agriculture will continue to be the major water consumer; it becomes the biggest consumer of water as shown in table (11) and figure (3). It represents about 83%of the estimated water consumption of 2020 of the current water demand and despite the use of pressurized irrigation techniques in practically all farming areas, application rates are still among the highest in the world. Actually, this great increase in water consumption for agricultural use will affect the water reserve. Therefore, the way to guide water consumption in the agriculture sector has to be necessarily considered. This is mainly due to the unsuitable climatic and soil conditions. Different scenarios can be presented for the estimation of future water demand by the agricultural sector. A reasonable one is that shown in Table (11).

Table (11) Water Demands by Different Users in Libya, 2006-2020 Forecasts

Year	Water Demand (Million Cubic Meter)			
	Agricultural Use	Domestic Use	Industrial Use	Total Demand
2006	**5204.43**	**895.75**	**193.71**	**6293.89**
2007	5384.29	958.96	202.30	6545.55
2008	5601.55	1022.69	210.70	6834.94
2009	5854.41	1084.98	218.69	7158.08
2010	**6171.39**	**1147.69**	**227.24**	**7546.32**
2011	6194.89	1204.19	233.08	7632.16
2012	6803.48	1275.93	241.08	8320.49
2013	7172.95	1342.17	247.79	8762.91
2014	7564.41	1410.49	254.07	9228.97
2015	**7975.77**	**1494.92**	**259.85**	**9730.54**
2016	8405.78	1555.31	265.12	10226.21
2017	8853.87	1631.83	269.82	10755.52
2018	9320.22	1711.56	273.93	11305.71
2019	9805.61	1794.76	277.41	11877.78
2020	**10311.30**	**1881.66**	**280.24**	**12473.20**

The future water consumption for domestic purposes will increase from 895.75 million cubic meters in 2006 to 1881.66 million cubic meters in 2020 with an average of compound annual rate of 5.4% in 2020. That could be explained by the expected increase of population and their needs of water. It is worth mentioning here, that the consumed water quantity in the northern regions will depend, in addition to the groundwater, on waters obtained from desalination plants.

The water consumption of industrial uses will increase. The water quantity to be consumed for industrial purposes in 2020 is expected to be about 2% of the total water consumption. Using water for industrial purposes will rely mainly on desalinated water. In spite of the positive relation between industrial expansion and water demand, and the expected increase of water consumption during the period 2006 – 2020, the consumed quantity of industrial purposes is considered small, if compared with water quantities consumed for other purposes. Industry consumes the least water of all sectors, with a current share of about 2%. A large number of industries depend on private sources for water supply, including desalination of seawater, as in the case of chemical, petrochemical, steel, textile and other industries. Industry uses 2% of the Libyan water resource. Today the volume of water used by industries rises, but an increase in demand, with a rate of 2% is forecast, which increases water demand for industry to 280.24 million cubic meters in 2020.

5. Conclusions

This study has provided the Box-Jenkins approach to modelling ARMA processes. The use of such procedures, particularly tests for unit roots, improves the validity of using the ARIMA models for forecasting and allows the forecaster to make informed judgments at each step as the results are presented by the statistical packages. The dickey-fuller test was used test the stationarity of each individual variable. The test ADF statistic of all variables clearly not rejects the null hypothesis; this is meaning we are 95% confident that the series for all follows a difference stationarity process. Overall, this study shows that by comparing the root mean squared errors, lower post-sample forecast errors were obtained when time series methods, such as the Box-Jenkins ARIMA models, was used.

The most important results of this study:

- Large increase of water consumption in future in Libya. It is estimated for all possible purposes increasing from 6293.89 million cubic meters in 2006 to 12473.20 million cubic meters in 2020 with an average of compound annual rate of 4.97%. In 2020 it is expected, that the increase would be 98% of the water consumption in 2006.
- Agriculture will continue to be the major water consumer; it becomes the biggest consumer of water. It represents about 83%of the estimated water consumption of 2020.
- The future water consumption for domestic and industrial uses will increase, that could be explained by the expected increase of population and their needs of water. It is worth mentioning here, that the consumed water quantity in the northern regions will depend, in addition to the groundwater, on waters obtained from desalination plants.

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