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Climate change and Precipitation evolution in Ifrane Region (Middle Atlas of Morocco).

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INTRODUCTION

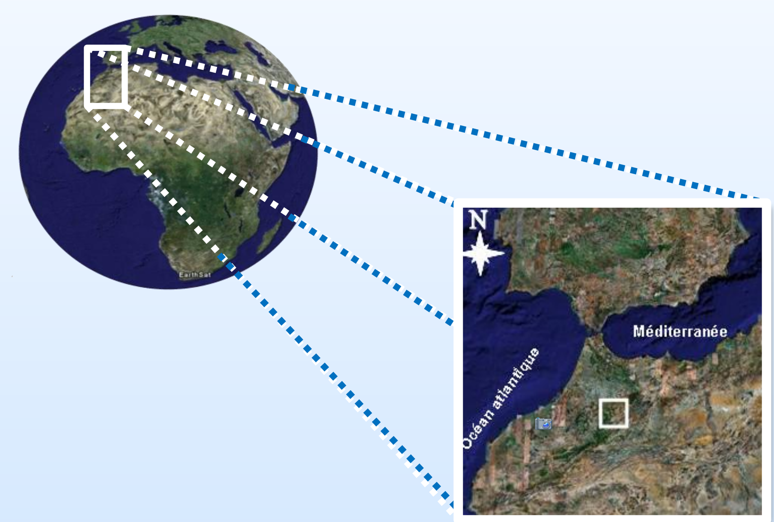
In North Africa, Morocco is located in an arid to semi-arid region with a desert climate in the south, oceanic in the west and Mediterranean in the north. In Morocco, water resources scarcity is a phenomenon that affects all sectors of national economy, threatens environmental, agricultural and rural development and slows national economic growth. Therefore, providing the necessary information on the management of this valuable resource is for crucial importance to policy and decision makers to trigger the appropriate measures that address the environmental, economic and social impacts. In a country like Morocco, where the way of life is primarily governed by the availability of water resources, an efficient monitoring hydrologic system, namely Precipitations, is highly demanded. For this purpose, precipitation modeling and forecasting based on hydro-meteorological data is becoming more and more solicited and maybe widespread.

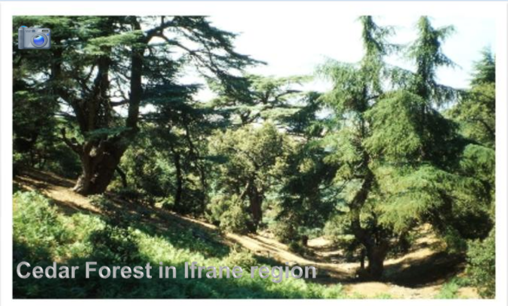
Time series approach has been widely used to forecast short and long term regional and national precipitations. The seasonality feature, present in the rainfall time series in different regions of Morocco, should be treated cautiously.

It is well documented in the time series literature that seasonality can either be deterministic or stochastic (Hylleberg et al., 1995). A stochastic process, in turn, can be either stationary or non-stationary integrated process (having seasonal unit roots). For a deterministic seasonality, the innovations will have no effects of the subsequent process. While for a stochastic process, an integrated process at any frequency has an "infinite memory", the effects of sudden shocks will last forever causing permanent changes in the seasonal pattern. For a stationary stochastic process, sudden shocks decay exponentially, in the sense that the effect is transitory. These different patterns have important implications on modeling a process. Hence, treating stochastic seasonality as deterministic, or vice versa, leads to a misspecification problem of the time series model and therefore has substantial effects on forecasting performance. Consequently, we must expend the analysis with the ***Hylleberg-Engle-Granger-Yoo*** **(HEGY)** and **Canova and Hansen (CH)** tests to determine which type of seasonality is present in our rainfall data.

STUDY AREA

- Ifrane (33° 32′ 00″ N - 5° 06′ 00″ W) is a Moroccan city, situated in the Middle Atlas region (population 13,000 in December 2008). It is 1713 m in altitude and is part of the Meknès-Tafilalet region.
- Ifrane has a Mediterranean climate, with annual average precipitation of 1498 mm and an annual average temperature of 10.8 ° C.
- Characterized by their great natural richness, the managers of the region were asked to create a national park of 53,000 ha.
- This region shelter the largest cedar forest in the country .
- It represents a large water reserve of the country, knowing that it shelter more than fifteen lakes (permanent and semi-permanent) classified as SIBE .





METHODOLOGIES

Data analysis:

- The data is monthly from January 1970 to December 2005 (Fig.1 and 2).
- The analysis was made using Eviews and R softwares to manipulate 432 observations, to define parameters and make graphics, in addition to various tests.
- ***Figure 1*** shows the time series we analyzed corresponding to a monthly average of rain rate for 36 years of data.
- ***Figure 2*** depicts the transformed time series, showing that the differences between maximum and minimum values have been reduced getting more variance stability.
- ***Figure 3*** represent the graphs of the monthly mean precipitations for the four seasons. It can be seen that for each of the series, the patterns of the four seasons seem to evolve similarly over time with prominent fluctuations during autumn, winter and spring.

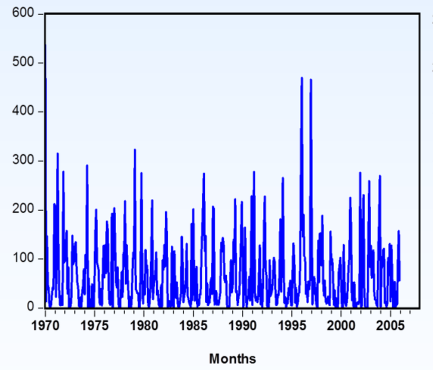


Figure. 1: **Ifrane Data Time Series - Monthly average rainfall in Ifrane**

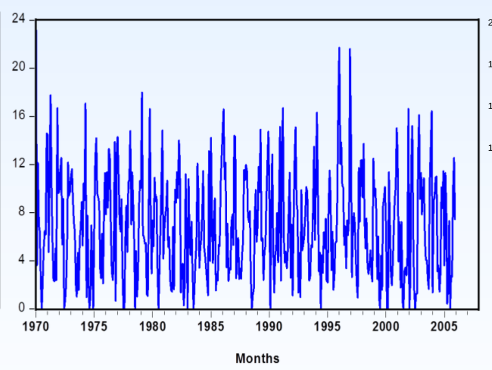


Figure. 2 : **Modified Time Series – Square Root of original data series.**

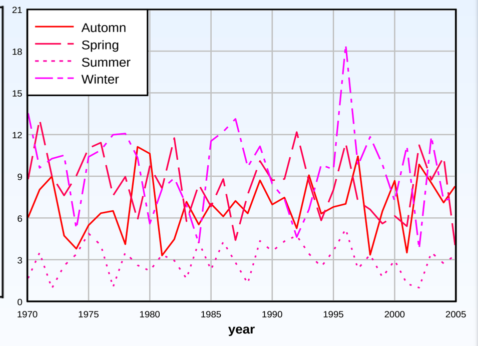


Figure. 3: **Monthly means for the four seasons.**

Time series modeling :

Time series modeling includes three steps of model identification, model estimation and diagnostic checking (goodness of fit test).

Step 1

• The model is identified following Box and Jenkins (1976) methodology which is based on the the behavior of the autocorrelation functions (ACF) and partial autocorrelation functions (PACF).

Step 2

•Estimation of the parameters. The model parameters should satisfy two conditions, namely, ***stationarity*** and ***invertibility*** for the autoregressive and the moving average parameters, respectively.

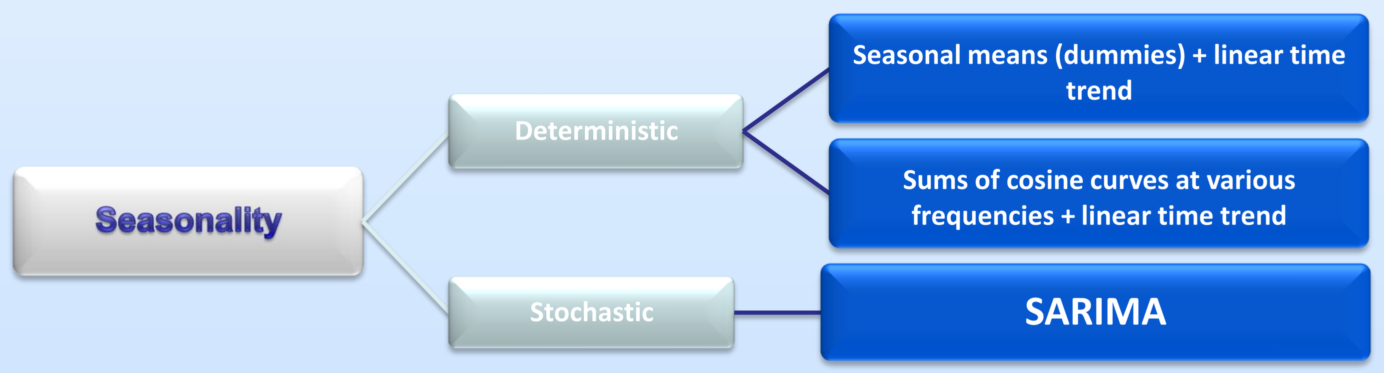
Step 3

•For diagnostic checking, In this step, the residuals of the modelare considered to be time-independent and normally distributed over time. Portmanteau fit test based on Ljung – Box statistic is used.

Modeling Seasonality :

Periodic patterns or seasonality can be modeled in different ways. Under the assumption that the autocorrelations remain constant over the period, a wide class of processes exhibiting seasonality is constructed by including one or two of the following elements:

1. Deterministic seasonality, modeled by constatnt seasonal intercepts
2. Stationary stochastic seasonality, modeled by stationary seasonal Auto-Regressive-polynomial
3. Integrated stochastic seasonality, modeled by integrated seasonal Auto-Regressive-polynomial



In general, when specifiying a model for a given time series, we first need to determine whether any possible linear trend is best described by a deterministic trend or by a unit root, next or simultaneously we must decide which of the multiplicative seasonal ARIMA is the most appropriate for capturing the seasonality. Hence we eliminate trend and/or seasonality from the original series and try to fit a seasonal ARMA model to the detrended/deseasonalized series.

As a consequence, when eliminating trends and seasonality, two methods will be considered:

1. Substruction by deterministic trends and seasonal effects (The trend and seasonality may be estimated by classical decomposition, using moving average filter,or by regressions including seasonal dummy variables)
2. Differencing (Box and Jenkins)

Seasonal unit root tests:

To check the adequacy of the double differencing filter in SARIMA models, which are specified using the Box and Jenkins methodology, and mainly address the issue of deterministic/stochastic seasonality in the time series process under study, two different seasonal unit roots are performed.

HEGY test:

Beaulieu and Miron (1993) and Ghysels et al. (1994) extend the seasonal integration test developed by HEGY to monthly data. If we consider the seasonal dummies and deterministic trends, the HEGY regression takes the following form:

$$\Delta_{12} y_{s,\tau} = \gamma_s + \delta_s \tau + \pi_0 y^{0}_{s,\tau-1} + \pi_6 y^{6}_{s,\tau-1} + \sum_{k=1}^{5} \pi_{k,\alpha} y^{\alpha}_{k,s,\tau-1} + \sum_{k=1}^{5} \pi_{k,\beta} y^{\beta}_{k,s,\tau-1} + \sum_{j=1}^{P} \phi_j \Delta_S y_{s,\tau-1} + \varepsilon_{s,\tau}$$

where $y_{s\tau}$is the observation in season s in year τ . The annual index runs from 1 to *N* where *N*=n/12 is the number of the years in the data. *P* is the order of augmentation and in practice it is determined using the AIC and SC information criterion, for other methods used to determine the lag augmentation polynomial in the HEGY test regression, see del Barrio et al. (2010).

And $\Delta_{12} = 1 - L^{12}$ with *L* the usual backshift operator , and the auxiliary variables are specified as

$$y^{0}_{s,\tau} = \sum_{j=0}^{11} y_{s,\tau-j},\ y^{0}_{s,\tau} = \sum_{j=0}^{11} \cos[(j+1)\pi] y_{s,\tau-j},$$
$$y^{\alpha}_{k,s,\tau} = \sum_{j=0}^{11} \cos[(j+1)w_k] y_{s,\tau-j},\ y^{\beta}_{k,s,\tau} = \sum_{j=0}^{11} \sin[(j+1)w_k] y_{s,\tau-j}$$
$$w_k = \frac{2\pi k}{12}, k = 1,2,\ldots,5, s = 1,..12, \tau = 1,\ldots, N$$

The HEGY test is a joint test for LR (or zero frequency) unit roots and seasonal unit roots. If none of the π_i are equal to zero, then the series is stationary (both at seasonal and non-seasonal frequencies).

Canova and Hansen test :

The test developed by Canova and Hansen (1995) takes as the null hypothesis that the seasonal pattern is deterministic.

From:

$$y_t = \alpha\, y_{t-1} + \sum_{i=1}^{S-1} D_{it} \beta_i + \varepsilon_t$$

The idea is (provided stationarity, i.e. |α|< 1) to test for instability of the β_i parameters as the KPSS test does.

RESULTS

Box and Jenkins approach:

ARIMA $(1,0,0)(1,0,0)_{12}$and ARIMA $(0,0,0)(1,1,0)_{12}$ are the selected models in this approach and the estimated parameters are presented in following table[1]:

	$Pre^{1/2}$	$\Delta 12(Pre^{1/2})$
	Coefficient	Coefficient
C	6.930***	
AR(1)	0.244***	
SAR(12)	0.292***	-0.479***
Adjusted R-squared	0.190	0.235
S.E. of regression	3.979	4.270
Sum squared resid	6398	7204
Log likelihood	-1138	-1136
F-statistic	48.713	
Prob(F-statistic)	0.000	
Akaike info criterion	5.607	5.744
Schwarz criterion	5.637	5.754
Hannan-Quinn criter.	5.619	5.748
Durbin-Watson stat	1.995	1.796

1 To reduce heteroskedasticity the original time series is transformed to its square root form .

Differencing approach based on seasonal unit roots:

Tests for seasonal unit roots:

The HEGY test results in the modified time series of Ifranes precipitations

Seasonal and Zero frequency Unit Root Tests with SD and No trend													
Variable	Years		Aug.										
IFRANE	36	AIC	12	-3.922 ***	-4.907 ***	23.560 ***	24.442 ***	24.665 ***	14.811 ***	25.646 ***	21.368 ***	22.734 ***	
IFRANE	36	SC	0	-8.210 ***	-5.575 ***	39.510 ***	29.683 ***	39.110 ***	58.894 ***	42.196 ***	42.996 ***	48.147 ***	

*** Sig at 1%; **sig at 5%; * sig at 10%. The Critical values are obtained using a Monte Carlo analysis with 100,000 replications for a sample size of 36 years.

the results are similar: the rejection of the Δ1Δ12-filter seems reasonable for the series of Ifranes' precipitation time series. Tests reject the hypotheses of seasonal unit roots as overall F-tests as well as t-tests on zero and *pi* frequency.

The Canova-Hansen test results in the modified time series of Ifranes precipitations

		Test statistic						
Variable	Years	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IFRANE	36	0.061	0.521	0.287	0.313	0.372	0.690	1.963

Note: The 5 percent critical values of [illegible] (j<q), [illegible] and [illegible] are 0.749, 0.470 and 2.750

All computed values are smaller than the corresponding critical values, so it is evident that the series has no seasonal unit roots, which is consistent with the overall results of the HEGY tests.

- As a general result for the modified series (square root) of Ifranes' precipitation, the tests reveal no seasonal unit roots. For that the modified data rejects the presence of unit roots at the long run frequency and at all seasonal frequencies. This indicates that the time series in question can be modeled with seasonal dummies by equation (A) :

Eq. (A)

$$y_t = \sum_{i=1}^{S} \alpha_i D_{it} + \varepsilon_t$$

α is a constant
D is a dummy variable for each season (month)
ε_t is an error term

- There would be a misspecification by the incorrect assumption of the presence of seasonal unit roots. The Δ12-filter would imply an over-differencing, and this misspecification originates from treating deterministic seasonality incorrectly as being stochastic (Franses, 1991).

CONCLUDING REMARKS

- The seasonality present in IFRANE precipitation time series should be treated appropriately.
- The assumption of the presence of seasonal unit root (stochastic seasonality) would result in a misspecification of the model and therefore a poor forecasting model.
- The result confirm the use of a purely deterministic model as the equation (A) is stating
- The forecasting performance of the model with seasonal dummies outperforms the two models specified, solely, with Box Jenkins approach.