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# Cross Correlation Analysis on the Relationship Between Maximum Temperature and Relative Humidity in Bida, Niger State

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**Abstract:** Cross Correlation (CC) analysis provide a correlation between two time series. The observations of one series are correlated with the observations of another series at various lags and leads. CC analysis also help in identifying variables which are leading indicators of other variables or how much one variable is predicted to change in relation of the other variable. In this paper we attempt study the relationship between monthly maximum temperature and relative humidity in Bida, Niger state from 1981 to 2012 collected from the NCRI, Baddegi. The results revealed that there is a negative relationship between Temperature and relative humidity in Bida. Also negative relationship is revealed at lag 0, positive lags of 1, 2, 9, 10, 11, 12 and 13 while for negative lags of 1, 2, 3, 10, 11, 12, and 13. We recommended that our work will be helpful to farmers, statisticians and to Agricultural Economist and Econometrician to understand the interrelationship between these variables and to take appropriate action or caution.

**Keywords:** Cross Correlation (CC), Relationship, Maximum Temperature, Relative Humidity

## 1. Introduction

The application of univariate residual cross correlation analysis is a notion put forth by Granger, that is, a time ordered variable X may be said to lead or cause a second time ordered variable Y if Y may be predicted with the use of the history of X than without, with all other information (including the history of Y) being used in either case [1]. This methodology allows empirical assessment of lead-lag relationship between economic time series, but today cross correlation has been very useful in almost every fields of life.

Meteorological parameters such as relative humidity and temperature plays an important role in the radiative energy budget of the Earth and in the transfer of energy between the surface and the atmosphere [2].

The relative humidity is maximum (100%) when the air has become saturated. If the air becomes saturated, condensation of water vapour occurs leading to the formation of tiny water droplets [3]. [3] They added that for example, records of rainfall, temperature, humidity, winds, clouds, pressure or sunshine will typically consist of a complex mixture of variations. Therefore, relative humidity is the line of rainfall trend in Nigeria. On the other hand, temperature is good to agricultural productivity but extremely high temperature can cause climate change and can exert negative effect on agricultural productivity [4]. Temperature plays an important role in influencing the growth of fungi [5]. They recommended that fruits and vegetables should be stored at low temperature and low relative humidity regimes to avoid infections due to *H. fulvum.*

This paper therefore focused on the interrelationship between maximum temperature and relative humidity in Bida, Niger with the application of Cross Correlation Analysis. This work was motivated by the study of [6] that reported that there is an inverse relationship between temperature and relative humidity. This study was also motivated by studies such as [7]-[9] reported forecast for temperature and relative humidity using univariate and multivariate time series techniques. The work of [10] was also a motivation to this study.

Several works has been carried out using cross correlation and its extension both in theoretical and in empirical analysis. For instance, [11] investigated the fluctuation and cross correlation analyses of protein motions observed in Nanosecond Molecular Dynamics simulation; [12] carried out an experimental comparison of Sum of Squares Difference (SSD), Normalized Cross Correlation (NCC) and Zero Mean Normalized Cross correlation (ZNCC) in the presence of change in light level, additive Gaussian noise and salt-and pepper noise. They concluded that in general, SSD provides a more stable result than NCC or ZNCC; [13] proposed a definition of the normalized cross correlation between two vectors and showed a link with the coherence function; [14] used the cross correlation analysis to study Ten-nanosecond Molecular Dynamics Simulation of the motions of the $HLADH.PhCH_2O^{-}.NAD^{+}$ in order to understand the relative motions between the domains; [15] carried out the cross correlation of seismic noise at the Northern California Seismic Network; [16] work concluded that cross correlation technique offers much higher accuracy for velocity determination and also for the spatial resolution resulting in an accurate flow profile estimation for oceanographic investigation and in the flow rate of water waste; [17] proposed novel estimators of differential reflectivity $Z_{DR}$ and correlation coefficient $\rho_{hv}$ between horizontally and vertically polarized echoes. These estimators used the autocorrelation and cross correlation of the returned signals to avoid bias by omnipresent but varying white noise; [18] extended the mathematical analysis to establish the theoretical relationship between a time-delayed Hebbian learning network and the mathematical cross correlation function; [19] noted that the most popular procedure for deriving relative velocities between a stoller spectrum and a template is the cross correlation method; [20] they related cross correlation function to computer vision; [21] presented novel matching method called Gradient cross correlation, which they from the well known normalized cross correlation coefficient formulation; [22] considered three distance measures such as Euclidean Distance, Dynamic Time Warp (DTW) and cross correlation for continuous time series. They noted that cross correlation measure finds the maximal correlation between one time series and a phase lagged version of the second time series; [23] developed X-ray cross correlation analysis (XCCA) concept together with brilliant coherent X-ray sources. They were able to access and classified the otherwise hidden local order within disorder; [24] investigated the interrelationship between logarithmic volume change and the logarithmic price change using cross correlation analysis; [25] studied the functional interactions between neurons in vivo by cross correlation functions (CCFs); [26] showed that P-waves can be extracted from closely spaced receivers (less than 11km) from the cross correlation of seismic noise; [27] noted that the cross correlation method is one of the most commonly used methods for leak detection of buried pipes; [28] proposed and applied a new algorithm of principal component analysis which is suitable for large sized, highly random time series data, such as a set of stock prices in a stock market and compared the eigenvalue spectrum of cross correlation matrix to the spectrum derived by the Random Matrix Theory (RMT); [29] considered a fresh look at the Cross Correlation between West Texas Intermediate (WTI) crude oil market and the US stock market from the perspective of econophysics; [30] noted that cross correlation is a popular signal processing technique used in numerous localization and tracking system for obtaining reliable range information; [31] analyze cross correlation between daily price change and daily volume change of Bovespa index. They apply Detrended Cross Correlation Analysis (DCCA) method to quantify power law cross correlations between simultaneous non stationary temporal series; [32] extended their work to the use of longitudinal spatial cross correlation functions to transform temporal correlation functions from one-point measurements into two-point in a Fully Turbulent Flow (FTF).

# 2. Model Specification

### *2.1. Cross Correlation Analysis (CCA)*

Cross Correlation Analysis (CCA) is the correlation between a selected set of time series data and the corresponding set displaced in time and/or space [33]. That is CCA provide a correlation between two series. In the CCA, the observations of one series are correlated with the observations of another series at various lags and leads. CCA help to identify variables which are leading indicators of other variables or how much one variable is predicted to change in relation to the other variable. The Cross-Correlation test of two time series data sets involves many calculations of the coefficient (r) by time-shifting the one data set relative to the other data set. Each shift is called a 'lag' and the lag time is simply the sampling period of the two time series data sets.

Furthermore, a typical cross correlation graph shows enough lags in both negative and positive directions to show the cyclical relationship of the two sets of data. The strength of the relationship between two time series data will be perfect at ±1 and will diminish to a minimum when approaching 0.

Another feature of the Cross Correlation Function (CCF) is that a high degree of symmetry or stability along the X axis indicates a stable relationship between the two time series data. But when the relationship between the time series varies, thereby creating decreasing correlation beyond zero lag, this would indicate less stability in the relationship. For application of the CCA see [34].

### *2.2. Cross Correlation Function (CCF)*

This is a useful measure of strength and direction between two random variables. If two stochastic process Xt and Yt are both univariate stationary processes, the covariance function is defined as $\gamma_{XY}(K) = E(X_t - \mu_X)(Y_{t+K} - \mu_Y)$ where K=0,

±1, ±2,... is a function of (s-t) only. The Cross Correlation Function (CCF) is then defined as $\rho_{XY} = \frac{\gamma_{XY}(K)}{\sigma_X . \sigma_Y}$ for K = 0, ±1, ±2, . . . where $\sigma_X$ and $\sigma_Y$ the standard deviation of Xt and Yt respectively. However, the CCF $\rho_{XY}$ is not symmetric that is $\rho_{XY}(K) \neq \rho_{XY}(-K)$ [35]. Detailed on the mathematical expression of the CCF are also presented in [36]. [35] further shown the relationship between the CCF and the Transfer Function for two time series data. [37] explained that the CCF can either be implemented in either in Slow Cross Function (SCF) or Fast Cross Correlation (FCC). [37] also added that the Cross Correlation (also called Cross Covariance) can be done in any number of dimension in relation to Discrete Fourier Transform (DFT) and the Inverse Discrete Fourier Transform (IDFT).

## 3. Materials and Methods

The data used is secondary data on monthly maximum Temperature and Relative Humidity collected from the meteorological unit of the National Cereal Research Institute, Baddegi, Bida. The data spanned from January 1981 to December 2012.

## 4. Analysis and Discussion of Results

MINITAB 15.0 software was used for the analysis and the results are presented below. The correlation analysis between maximum temperature and relative humidity revealed a strong negative correlation between maximum temperature and relative humidity ($r = -0.678$ with P-Value = $0.000<0.05$), this result agrees with [6]-[7] and [9]. This result revealed an inverse relationship between maximum temperature and relative humidity in Nigeria. That is, when there is increase in temperature, it will lead to decrease in relative humidity, while when there is decrease in temperature, it will lead to increase in relative humidity. As recommended by [5], farmers and sellers of agricultural products such as fruits and vegetables should be stored at low temperature and low relative humidity to avoid infections by fungi.

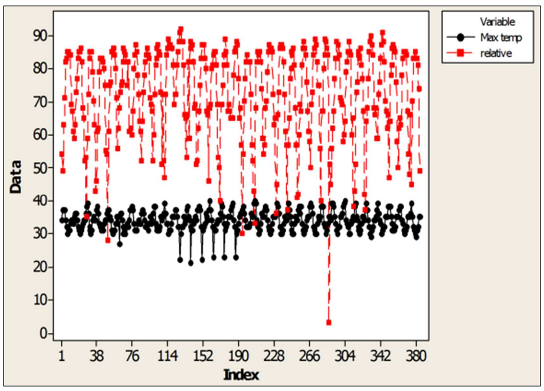


***Fig. 1.*** *Time Series Plot of Monthly Maximum Temperature and relative humidity in Bida, Niger State from 1981 to 2012.*

In Figure 1 above presented the time series plot for the maximum temperature and relative humidity in Bida. The plot revealed some evidence of seasonality in the time series data. This therefore means that the method of cross correlation analysis can be applied to maximum temperature and relative humidity relationship in Nigeria.

***Table 1.*** *Cross Correlation Function: Max temp, relative.*

| CCF - correlates Max temp (t) and relative (t+k) | |
|---|---|
| **Lag** | **CCF** |
| -13 | -0.661196 |
| -12 | -0.623247 |
| -11 | -0.440347 |
| -10 | -0.17882 |
| -9 | 0.112671 |
| -8 | 0.403011 |
| -7 | 0.622359 |
| -6 | 0.657228 |
| -5 | 0.515451 |
| -4 | 0.156648 |
| -3 | -0.230922 |
| -2 | -0.500459 |
| -1 | -0.703629 |
| 0 | -0.678042 |
| 1 | -0.464668 |
| 2 | -0.171631 |
| 3 | 0.129236 |
| 4 | 0.433989 |
| 5 | 0.641543 |
| 6 | 0.671872 |
| 7 | 0.523083 |
| 8 | 0.159566 |
| 9 | -0.226781 |
| 10 | -0.509805 |
| 11 | -0.659707 |
| 12 | -0.624354 |
| 13 | -0.420207 |

The Table 1 presented the CCF for maximum temperature and relative humidity with their respective lags. The choice of the maximum lag of 13 is in line with our previous work, see [7] and [9] for detail. The results revealed that there is a negative relationship between Temperature and relative humidity in Bida. Also negative relationship is revealed at lag 0, positive lags of 1, 2, 9, 10, 11, 12 and 13 while for negative lags of 1, 2, 3, 10, 11, 12 and 13. The other lags revealed a positive relationship between maximum temperature and relative humidity in Nigeria. Furthermore, some of the CCF for some lag are similar to the simple correlation coefficient of the series while others revealed weak negative correlation between the series. The implication of these findings shows that in dealing with lag related models the choice of the appropriate lag is very important.

The CCF plot presented below in Figure 2 revealed some evidence of a stable relationship between maximum temperature and relative humidity in Bida (that we can see in peaks and troughs of the graph) which agree with the results presented in [7] and [9]. This result further indicates that temperature and relative humidity are interrelated in Bida Niger State. This shows that temperature and relative humidity can help improve forecast of each time series.

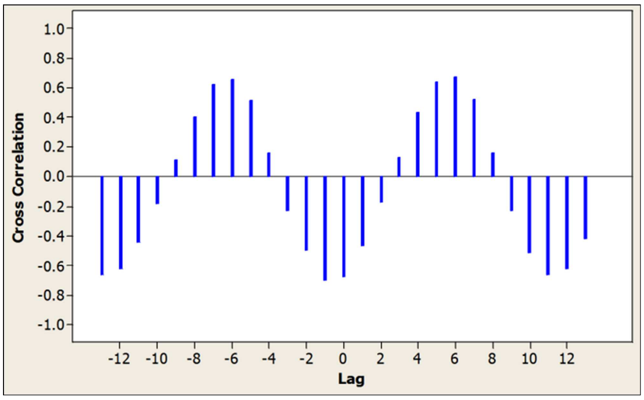


***Fig. 2.*** *CC for Temperature and relative Humidity in Bida, Niger State.*

## 5. Conclusion and Recommendations

This present work revealed that there is a strong negative relationship between Temperature and relative humidity in Bida. Also the negative relationship is revealed at lag 0, positive lags of 1, 2, 9, 10, 11, 12 and 13 while for negative lags of 1, 2, 3, 10, 11, 12, and 13. The CCF further revealed a stable relationship between maximum temperature and relative humidity in Bida.

We therefore recommend the following

1. That farmers and agricultural extension workers should be aware that there is strong negative relationship between temperature and relative humidity in Bida.
2. Statisticians, Agricultural Economists and Econometricians that the choice of appropriate lag for lag related model is very important to modeling and forecasting.
3. The stable relationship between maximum temperature and relative humidity in Bida, means that temperature can help improve the forecast of the relative humidity and vice visa.
4. To store fruits and vegetables low temperature and low relative humidity is suitable.

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