Forecasting of Niger Grain Production and Harvested Area

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Abstract: Niger agriculture is predominantly rain-fed and remains the main source of income for large population. Despite its importance in Niger economy, agriculture sector is still traditional and largely affected by severe weather conditions. High population growth which experienced Niger continues to increase pressure on limited land resulting in extension of crop production on marginal land unfavorable for agriculture. The fact that Niger agriculture is rain-fed is behind the country vulnerability to food insecurity. The main purpose of this study is to forecast Niger grain production and harvested Areas and for the two main staple crops (Millet and Sorghum) using ARIMA model. The time series data of production and harvested area covering the period 1970-2010 were used in the study. The findings showed that the total harvested Area and total grain production would be 21317.4 thousand of ha and 12677.9 thousand tons in 2030, respectively. The model also showed that Millet and Sorghum production would be 4503 thousand tons and 1574.8 tons, respectively at the same period. The results of study are expected to help Niger authorities to build strong strategy in reducing population’s vulnerability to food insecurity and make policies with regard to relative price structure, production and consumption.

Keywords: Area harvested, ARIMA, forecasting, grain, millet, Niger, production, sorghum

INTRODUCTION

Agriculture is the backbone of Niger’s economy because it contributes large share to the GDP (40%). Agricultural sector plays a particularly important role in development performance, affecting both economic growth and equity, simply due to its sheer size in the GDP compared to other sectors of economy. Niger depends most on agriculture, for both output and employment (more than 70% is engaged in the sector) and this fact reflects Niger's low level of development.

Despite large labor is employed in Agricultural sector, Niger is regularly exposed to food insecurity and must resort to imports and international aid, as shown in the most recent crisis in 2005. In fact, Niger’s domestic food production has for decades been outpaced by population growth, which at an annual rate of 3.3% is now one of the fastest in the world. This situation is attributable to a number of factors: climate constraints, sandy soil with limited potential, strong demographic pressures leading to imbalanced resource use, limited access to inputs and equipment that would favor intensification and serious inadequacies in basic services and infrastructure.

Nigerien agricultural production is also characterized by subsistence farming where rural household needs determine the scale of production. Small pieces of land are cultivated by individual owners or sub-owners using traditional method of farming systems. Rural farming families have landholdings averaging five acres of dry land. Some families also have access to small plots (less than one hectare) of irrigated land. The deteriorating quality of the soil has caused farmers to expand the area of land cultivated, often encroaching on land used by pastoralists for grazing and creating the potential for conflict (FAO, 2007).

Grain production for domestic consumption appears to follow the pattern of food demand rate; increased production was achieved mainly through extension of cultivated land. According to FAO (2005) each year 70,000 to 80,000 ha of new land are occupied by agriculture at the expense of forests and livestock because of population growth and land cultivation. Variation in area and yield occurs mainly in response to distribution, timeliness and irregularity in rainfalls and other climatic factors and also availability of crop specific inputs. Cereal production represents almost 80% of the total national grain production. Millet and sorghum are the main cereal crops producing in the country and represent about 75.64 and 23.12% of the total cereal output, respectively (WFP, 2005).

Indeed Niger domestic food production plays an important role in the country food security as more than 80% of rural area depends on agriculture and animal rearing for their livelihood. The main challenge for
Niger authorities is how to become self-sufficient in food with marginal agricultural land and huge rural labor force. The matter is really challenging, but finding ways to increase agricultural production is crucial for the well being of Niger population. Bad harvest periods are always followed by chronic food shortage and because of high level of poverty of its population, Niger cannot rely on import for food. Approximately two thirds of the population lives below the poverty line and a full one third below the extreme poverty line according to World Bank (2005).

Crop production forecasts are widely recognized as an important input into food balance sheets and for anticipating shortfalls. The main purpose of crop forecasting is to provide advance information on food crop production and food supply in a country. One of the most important and highly popularized time series models is the Box-Jenkins approach, commonly known as ARIMA (Autoregressive Integrated Moving Average). Researchers have used this approach for many different scientific and technical applications. Iqbal et al. (2005) forecasted the wheat area and production in Pakistan up to 2022 and found that the cropped area and output would increase in future, if soil conservation and reclamation measures are adopted. Ahmad et al. (2005) also developed ARIMA models to forecast growth trends of production and export of Kinnow from Pakistan up to 2023 and concluded that there will be increase in trend in the coming years. Goldsmith and Masuda (2009) used time-series data to forecast world soybean production and harvested area up to 2030 by developing ARIMA models and found that world soybean production is predicted to increase about 2.2% annually. Badmus et al. (2011) forecasted Nigeria Maize production and harvested Area and concluded that production and harvested Area will expect to increase in next years.

The main purpose of this study is to forecast Niger total grain production and total crop harvested area and also for the two main crops (Millet and sorghum) cultivating in the country. Forecasting future land that may be used under cultivation will help Niger Government to make policies on available land use and further food production capacity. Projection of total food production is important for implementing proper measures to face an eventual food deficit in the country.

**MATERIALS AND METHODS**

Respective time series data for this study were collected from National Institute of Statistics of Niger. Production and harvested area data covering the period 1970 to 2010 were used in the forecasting.

Box and Jenkins (1976) linear time series model was applied. Auto Regressive Integrated Moving Average (ARIMA) is the most general type of model for forecasting a time series. The methodology of ARIMA estimation and model selection is a classical topic covered in most textbooks on time series analysis (Brockwell and Davis, 2003; Hamilton, 1994; Tsay, 2005; Wei, 2005). According to Meyler et al. (1998), the main advantage of ARIMA forecasting is that it requires data on the time series in question only. First, this feature is advantageous if one is forecasting a large number of time series. Second, this avoids a problem that occurs sometimes with multivariate models.

The model was introduced to restore the behavior of a process subjected to random shocks over time between two successive observations of series measuring the activity of the process. A random event is called disturbance affects the temporal behavior of this process and thus changes the observation values of the time series.

In general, an ARIMA model is characterized by the notation ARIMA (p, d, q), where p, d and q denote orders of auto-regression, integration (differencing) and moving average respectively.

- **A p**$^{{\text{th}}}$**-order autoregressive model**: AR (p), which has the general form:
  \[ Y_t = \Phi_0 + \Phi_1 Y_{t-1} + \cdots + \Phi_p Y_{t-p} + \varepsilon_t \]

  where,
  \[ Y_t = \text{Response (dependent) variable at time } t \]
  \[ Y_{t-1}, Y_{t-2}, \ldots, Y_{t-p} = \text{Response variable at time lags } t-1, t-2, \ldots, t-p, \text{respectively} \]
  \[ \Phi_0, \Phi_1, \Phi_2, \ldots, \Phi_p = \text{Coefficients to be estimated} \]
  \[ \varepsilon_t = \text{Error term at time } t \]

- **A q**$^{{\text{th}}}$**-order moving average model**: MA (q), which has the general form:
  \[ Y_t = \mu + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \cdots - \theta_q \varepsilon_{t-q} \]

  where,
  \[ Y_t = \text{Response (dependent) variable at time } t \]
  \[ \mu = \text{Constant mean of the process} \]
  \[ \theta_1, \theta_2, \ldots, \theta_q = \text{Coefficients to be estimated} \]
  \[ \varepsilon_t = \text{Error term at time } t \]
  \[ \varepsilon_{t-1}, \varepsilon_{t-2}, \ldots, \varepsilon_{t-q} = \text{Errors in previous time periods that are incorporated in the response } Y_t \]

- **Autoregressive moving average model**: ARMA (p, q), which has the general form:
  \[ Y_t = \Phi_0 + \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \cdots + \Phi_p Y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots - \theta_q \varepsilon_{t-q} \]

If the original series is stationary, d = 0 and the ARIMA models reduce to the ARMA models. The difference linear operator (\(\Delta\)), defined by:
\[ \Delta Y_t = Y_t - Y_{t-1} - Y_t - BY_t = (1 - B)Y_t \]

The stationary series \( W_t \) obtained as the \( d \)th difference \((\Delta^d)\) of \( Y_t \),

\[ W_t = \Delta^d Y_t = (1 - B)^d Y_t \]

ARIMA \((p, d, q)\) has the general form:

\[ \Phi_p(B) (1 - B)^d Y_t = \mu + \theta_q(B) \varepsilon_t \]

or

\[ \Phi_p(B) W_t = \mu + \theta_q(B) \varepsilon_t \]

\( B \) is the lag or backward linear operator \((B)\) defined by \( BY_t = Y_{t-1} \).

We first developed ARIMA models for the total harvested area and total grain output and then for the two main staple crops (Millet and Sorghum) cultivated in Niger.

The model specification was automatically made by the SPSS package. The minimum Mean Absolute Percentage Errors (MAPEs) of forecasting values were used in selecting an adequate model.

**RESULTS AND DISCUSSION**

For the specification and estimation of model edited, time series data were analyzed by using the “SPSS” package. The process consisted of three steps as follows: model identification (the specification of \( p, d, q \)), model estimation (estimation of parameters of the model) and model diagnostic. The results thus obtained were put to various diagnostic checks like residual analysis, Normality tests and Goodness of fit. The model specification involved the plots of the Auto Correlation Function (ACF), Partial Auto Correlation Function (PACF) and the plot of different series. Auto correlation function indicated the order of the autoregressive components ‘q’ of the model, while the partial correlation function gave an indication for the parameter \( p \). First step was to check the stationary of the data using in the study. The plot of time series of area and production showed increasing trend. The auto correlation functions of both series showed non-stationary. To make the series stationary, we differenced the data.

Based on these analyses, forecasts for the coming 20 years (i.e., up to 2030) were worked out at 95% confidence interval values.

**Forecasting for total harvested area and total grain production:** The ARIMA \((2, 1, 2)\) and ARIMA \((1, 1, 0)\) are found to be appropriate for Total harvested area and total grain production respectively and the parameters are presented on the Table 1 and 2.

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**Diagnostic checking for the model:** Augmented Dickey-Fuller unit root test on time series data of Total Production was applied (Table 3).

As the absolute value of ADF test-statistic is greater than the critical values at 10% level of significance, therefore, time series is stationary of the ARIMA \((2, 2, 1)\). Hence, ARIMA \((2, 2, 1)\) is fit for the forecasting Total Production.

**Diagnostic checking for the model:** Augmented Dickey-Fuller unit root test on time series data of Total Area was applied (Table 4).

As the absolute value of ADF test-statistic is greater than the critical values at 10% level of significance, therefore, time series is stationary of the ARIMA \((1, 1, 0)\) Hence, ARIMA \((1, 1, 0)\) is fit for the forecasting Total Area.

The forecast for total area in 2030 will be \(21317.4\) thousand of ha with upper and limit of \(27179.9\) and \(15455.7\) thousand ha, respectively. For total production, the forecast value will be \(12677.9\) thousand tons. The forecasted results of Total Production and Total harvested Area are presented in the Table 5.
From 2011 to 2030; the total harvested area would increase about 40% that is 6 millions ha of new farm land will be occupied while the total grain production may be doubled in the same period. The total output will continue to be affected by many factors such as timeliness of rainfall, yield of individual crops, droughts, floods etc. Future increase in grain production will only be possible if there is huge investment in high yielding varieties, cultural practices, land management, technology and input transfer to farmers combine with extension services. These results give us Niger domestic food production capacity in future which is very important in making policies concerning strategy to reduce food shocks. Policy makers can plan how much of food will to be imported and harvested areas to reduce food shocks. Policy makers can plan how much of food will to be imported and harvested areas that will be used in future.

**Forecasting for millet area and production:** Pearl millet (*Pennisetum glaucum* [L]) is an important crop in many developing countries in West Africa and accounts about 80% of total cereal production in Niger. It is the main staple for Niger population. Besides providing food for human, millet stems are used for a wide range of purposes, including: the construction of hut walls, fences and thatches and the production of brooms, mats, baskets, sunshades, etc. In addition to tolerating hot and dry climates, pearl millet is able to produce reasonable yields on marginal soils, where other crops would fail.

The fitted ARIMA models and their parameters for millet harvested area and production are presented in the Table 7 and 8.

We obtained the model in the form:

\[ \hat{Y}_t = 120.0451 (Y_{t-1} - Y_{t-2}) \]

**Diagnostic checking for the model:** Augmented Dickey-Fuller unit root test on time series data of Millet Area was applied (Table 8).

As the absolute value of ADF test-statistic is greater than the critical values at 10% level of significance, therefore, time series is stationary of the ARIMA (1, 1, 0) Hence, ARIMA (1, 1, 0) is fit for the forecasting Millet Area. The forecasted results are presented in the Table 7. We obtained the model in the form:

\[ \hat{Y}_t = 62.392 - 0.331 (Y_{t-1} - Y_{t-2}) - 0.642e_{t-1} \]

**Diagnostic checking for the model:** Augmented Dickey-Fuller unit root test on time series data of Millet Production was applied (Table 9).

As the absolute value of ADF test-statistic is greater than the critical values at 10% level of significance, therefore, time series is stationary of the ARIMA (1, 1, 1) Hence, ARIMA (1, 1, 1) is fit for the forecasting Millet Production. The forecasted results are represented in the Table 10.
The forecast for Millet area in 2030 will be 9446.9 thousand ha with an expected production of 4503.2 thousand tons. Approximately, 2,354 thousands ha of new land may be occupied for only Millet production from 2011-2030.

Millet production is important in Niger food security because its production alone accounts for more than 70% of the total grain output. Millet is recognized to be adaptive for the semi-arid because of its exceptional ability to tolerate drought. Even with minimal rainfall millet will typically still produce reasonable yields. In many areas where millet is the staple food, nothing else will grow.

**Forecasting for sorghum area and production:**
Sorghum cultivation comes second to millet as staple food crop in Niger and accounts about 20% of grain production. Like millet, sorghum can also withstand harsh weather conditions and it is only growing mainly for household consumption.

The fitted ARIMA models and parameters developed for sorghum area and production are presented on Table 11 and 12.

We obtained the model in the form:

\[ \hat{Y}_t = 62.708 - 0.529 (Y_{t-1} - Y_{t-2}) \]

**Diagnostic checking for the model:** Augmented Dickey-Fuller unit root test on time series data of Sorghum Area was applied (Table 13).

As the absolute value of ADF test-statistic is greater than the critical values at 10% level of significance, therefore, time series is stationary of the ARIMA (1, 1, 0) Hence, ARIMA (1, 1, 0) is fit for the forecasting Sorghum Area. We obtained the model in the form:

\[ \hat{Y}_t = 21.43 - 1.515 (Y_{t-1} - Y_{t-2}) - 0.823 (Y_{t-2} - Y_{t-3}) + 0.845\varepsilon_{t-1} \]

**Diagnostic checking for the model:** Augmented Dickey-Fuller unit root test on time series data of Sorghum Production was applied (Table 14).

As the absolute value of ADF test-statistic is greater than the critical values at 10% level of significance, therefore, time series is stationary of the ARIMA (2, 1, 1) Hence, ARIMA (2, 1, 1) is fit for the forecasting Sorghum Production. The forecasted results are represented in the Table 15.

The forecast for sorghum area and output will be 4329.1 and 1574.8 thousand ha in 2030. We will expect an increase in trend of both area and output in next two decades.

Any strong food security strategy that will make Niger to be self-sufficient in food depends on improvement of the production systems of the two main staple crops (Millet and Sorghum). Most of cultivated land area are occupied by the cultivation of these two crops. Thus, selection of high yielding varieties, modernization of agriculture, appropriate cultural practices, adequate supply of inputs are prerequisite to increase Niger grain production.

These supply projections of grain production will play a vital role in the adjustments of supply and demand in the future.
CONCLUSION

Niger agricultural production is based essentially on rain-fed agriculture where farmers produce mainly cereal crops through subsistence farming. Millet and sorghum are the main staple crops and account more than 80% of the total production. Increment in production was achieved through extension of new farming areas. Forecasting using ARIMA model for the coming 20 years revealed that harvested area would be 21317.4 thousand ha and Total crop output may be doubled. The harvested area for millet and sorghum would be 9446.9 and 4329.1 thousand ha, respectively in 2030 while millet production would 4503.2 thousand tons and sorghum output would be 1574.8 thousand tons in the same year. These forecasting results will assist Niger government in developing strategy in reducing population’s vulnerability to food insecurity. The projected values of production give an estimation of the capacity of food that the country can be produced in future and to compare with actual population food demand.

High population growth which requires high food demand is behind extension of new lands as agriculture remains primary source of employment in Niger. Desertification and urbanization will be major constraints in the expansion process of farmland. As family members are increasing, limited arable land is being fragmented and overused; crop yield will be reduced due low fertility of soils. Many problems such regular food deficit, conflicts among families and between farmers and pastoralists may be arisen. Therefore, Proper management is needed in the area of land tenure, soil conservation and cropping systems. Selection high yielding varieties, adequate input supply at the right time, education of farmers are necessary to increase yield and production in future. In addition, Niger government should invest more in irrigation to develop horticultural crops to avoid full dependence on rain-fed agriculture. Thus, there is a need to strengthening capacity to address institutional and strategic challenges for Niger agriculture to ensure its full potential for poverty reduction, food security and economic growth.

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REFERENCES