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Forecast Analysis of Hydro-climatic Data of Nouhao Sub-basin in East-Central of Burkina Faso

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Abstract: Forecast analysis of hydro-climatics data of Nouhao Sub-Basin shows how useful local rain gauges data collected by population during 4 to 7 years in three (03) villages on the experimental site for the local planning and forecasting. The first results show that i) the breakdown of the series determines the seasonality and occurrence of "casual" rains; ii) the auto-correlation detection test showed that casual rains are not self-correlated and validates the model; iii) the dry/rainy season cycle is from mid-October to April and from mid-April to mid-October for this experimental site, iv) the forecasts for N+1 years in 2016, 2017 and 2018, compared to the collected data, clearly show that the statistical forecast model is robust. The level of correlation is satisfactory with a positive correlation coefficient close to unity. The deficit of cumulative rainfall average around to 14%. The 2019 forecast shows a deficit compared to the previous year (2018). It is a dry year compared to the average index for the period 2012-2018. However, the 2019 forecast for the experimental area corroborates well with the Permanent Interstate Committee for Drought Control in the Sahel (ICDS/CILSS) forecasts indicating a normal to surplus year with pockets of drought in the second part of the season for part of Burkina Faso. Longer monitoring in the basin would contribute to seasonal forecasting efforts in Burkina Faso.

Keywords: Rural Community, Sahel, Climate Change, Resilience, Forecast

1. Introduction

West African countries, particularly those in the Sahel region, are suffering the adverse effects of climate change, marked by extreme events [1] with long-term reduction in rainfall intensity in semi-arid regions [2]; these countries experienced during the period 1968-1995, the significant deficit of the 20th century in terms of duration, intensity and scope [3–6]. Burkina Faso is severely threatened by climate change. Inappropriate land use methods and increasing pressure on natural resources have led to the degradation of agricultural land. This degradation is further exacerbated by the impacts of climate change and extreme weather events, including unfavourable precipitation patterns in terms of location and timing, extended periods of drought and heavy rains. It is imperative to find adapted solutions and make these vulnerable communities more resilient to climate change. Several sources [5, 7–9] report a decrease in rainfall between 1960 and the early 1970s with a rainfall deficit reaching 22% [1]. In the Nouaho basin, in central-eastern Burkina Faso, in particular, disruptions were observed in the stations of Sangha and Tenkodogo in 2000, and in those of Tenkodogo as well as Ouargaye in 2005. Thus, predominantly, rural communities are increasingly feeling the negative effects of climate change. These effects are marked by a high variability of interannual rainfall [7, 10], extreme weather conditions in terms of drought and/or recurrent floods, violent winds, and rising temperatures making these communities more vulnerable. This makes the planning of social, economic or cultural activities more and more challenging. It is becoming increasingly imperative to find adaptation ways to reinforce the resilience of these communities to the effects of climate change. In the literature, several authors have made resilience a *sine-qua-num* condition for climate change adaptation [11, 12]. Among these adaptation measures, climate forecast seems to us to play an essential role, particularly for agriculture and the management of water resources. This seasonal forecast used as an early warning would be very useful for Sahel producers and makes it possible to anticipate crisis situations based on observations and rainfall forecasts in the coming months [13, 14] These forecasts allow communities to adapt their seed choices and plan water resource use according to future rainfall trends. The purpose of this study is to demonstrate how useful are data collected by local population for local planning, water use plans and in building community resilience in the Sahel.

2. Materials and Methods

2.1. Materials

The data used are daily rainfall collected by community readers recruited and trained by the West African Water Resources Security Project with the support of Burkina Faso's National Meteorological Agency). They consist of a series of data collected from 2012 to 2018 in three villages in the Nouaho basin. Data are collected using a peasant rain gauge of the SPIEA type manufactured by SIMPLAST SA in Mali and distributed by Mali Météo in the ECOWAS zone. Figure 1 shows the study area and the location of the rain gauges installed in the communities where the measurements were made. This study covers the community of Basbedo, Loungo located in the department of Tenkodogo and Sablogo –department of Lalgaye in the central-eastern region of Burkina Faso. This region is in the Sudanese climatic zone where rainfall ranges are between 700 and 900 mm. The sub-basin straddles the North Sudanese climatic zone and the Sudanese zone with annual rainfall of 700 to 800 mm and 800 mm and above.

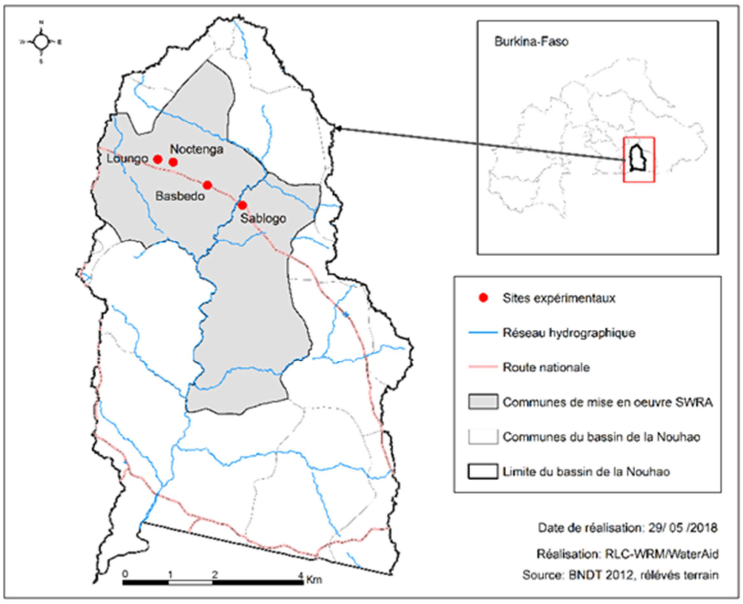

Figure 1. *Location of the Nouaho basin and basin and rain gauges stations.*

All data were collected and stored in a computer database (MS ACCESS 2016), after extraction they were processed by the statistical analysis software R.

2.2. Methods

Data analysis consisted, on the one hand, in breaking down the data series into trend and seasonal components. The assumptions of the Ordinary Least Squares (OLS) were used for forecasting model validation. Two standard statistical tests were used:

-Residue normality test with Shapiro-Wilk test which is based on the W statistic. This tests are powerful for small data (n ≤ 50) [15], and is written as:

$$W = \frac{\left[\sum_{i=1}^{\left[\frac{n}{2}\right]} a_i \left(x_{(n-i+1)} - x_i\right)\right]^2}{\sum_i \left(x_i - \bar{x}\right)^2} \quad (1)$$

x_i corresponds to the series of data sorted, $\left[\frac{n}{2}\right]$ is the entire part of the quotient $\frac{n}{2}$, a_i are constants generated from the average and the covariance matrix of the quantiles of a sample of size n according to the normal distribution.

-Autocorrelation of the residues is verified using the Ljung–Box test [16]. It's a type of statistical test of whether any of a group of autocorrelations of a time series are different from zero. The test allows to formulate a model to represent a chronicle with the aim of predicting future values. The p-value is less than 5%, from which we deduce the absence of autocorrelation of the residues.

3. Results and Discussion

3.1. Results

The results obtained from the tests give W = 0.9918, and W_critic = 0.9258. We have W> Wcritic with a risk of 5%. For the Ljung-Box test, X-squared = 18.9558, df = 10, p-value = 0.04083, with p-value less than 5%. Normality assumption is compatible with our data [15]. We deduce that our model is conform to reality. It allows estimating the precipitation for the experimental area over the period 2019. The forecast is an average estimate of rain on the basis of the evaluation of the previous values of rain over same variable. Figure 2 shows the evolution of the rain forecasts and the rain data collected by the communities during the study period in the observation village. The data for 2016, 2017 and 2018 were used to predict the precipitation for the year 2019. It shows a good consistency between forecast data and data collected by the population with a correlation of 0.94 for 2016, 0.93 for 2017 and 0.91 for 2018. The bias is around 5% for 2016, 24% for 2017 and 14% for 2018. Table 1, summarizes the cumulated rainfall, the correlation coefficients and the bias for each year. All these results have satisfactory shown the potential of this method to forecast rainfall data, in one hand, and on the other one the advantage of having reliable forecast data by populations directly concerned by adaptation measures.

Table 1. *Cumulated rain and forecasting cumul, correlation and bias for 2016, 2017 and 2018.*

Year of forecasting	Yearly observed cumulation (mm)	Year-to-date forecast (mm)	Correlation	Biais
2016	884,26	935,13	0,9412	5%
2017	778	1020	0,9290	24%
2018	906,87	1055	0,9114	14%

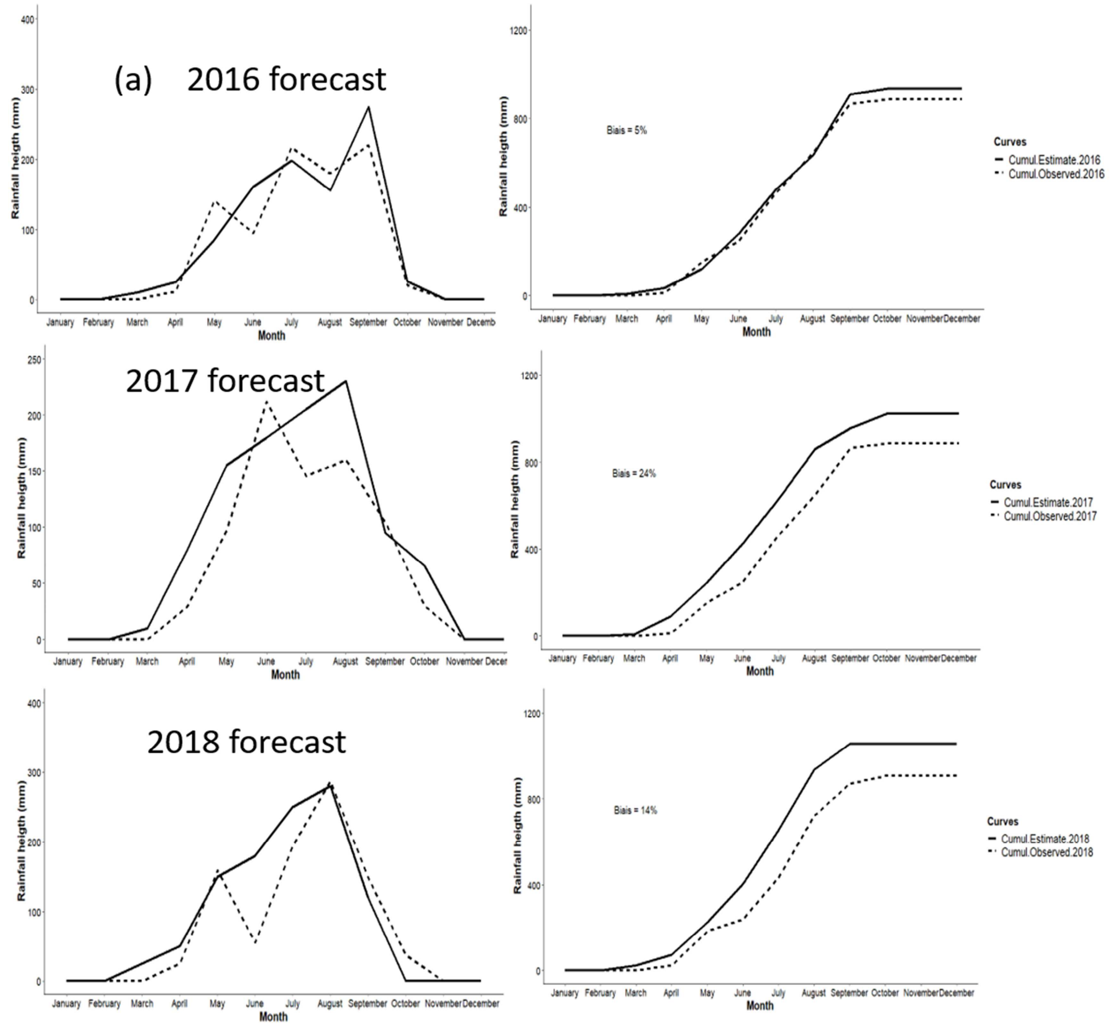

Figure 2. *a) Observed and forecasted rainfall and b) Differential graph of the monthly cumulative rainfall forecast and observed in 2016, 2017, and 2018.*

Figure 4 shows the distribution of the rainfall forecast for 2019. It also reveals that the rainy season from May to October and the dry season from October to April. For the monthly totals, it should be noted that July, August and September will be the rainiest months with a peak of 198.91 mm in August. The annual total will be 746.31 mm compared to 794.66 mm average rainfall over the 2012-2018 period as shows Figure 3 that illustrates the timeline of the rainfall series for the study period. This illustrates that 2019 will be a deficit year compared to the average in the past period. Compared to year 2018, 2019 will reach a deficit of 6.5% according to the rainfall deficit formula (2):

$$Dp = \frac{[M_2 - M_1]}{M_1} \times 100 \quad (2)$$

Dp: Rainfall deficit; M_1: Year-end average of the year-to-date period; M_2: Average of the projected year.

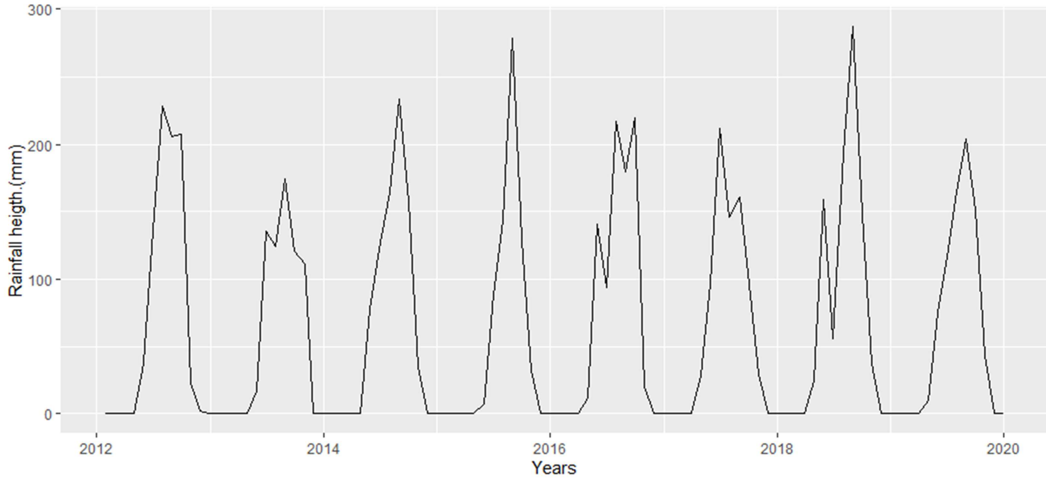

Figure 3. *Timeline of the rainfall series for the 2012-2019 in the experimental area.*

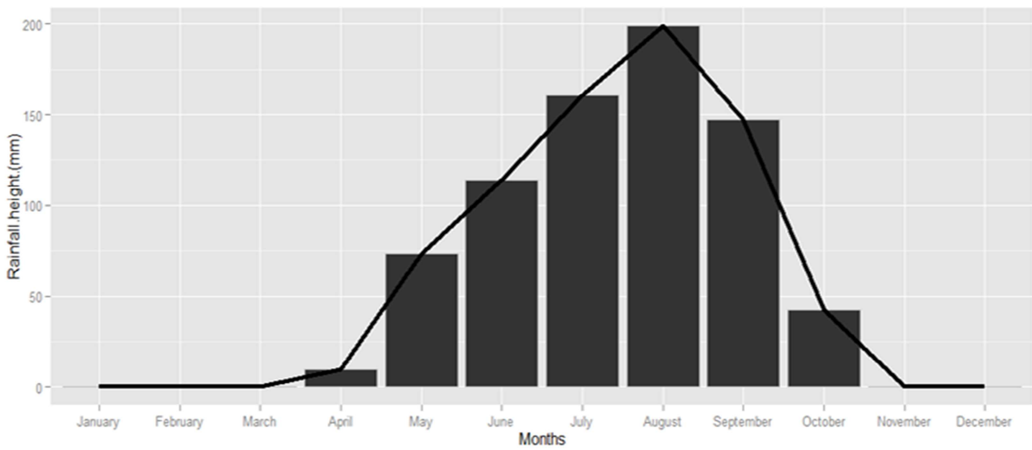

Figure 4. *Diagram of the 2019 forecast in the experimental area.*

3.2. Discussion

Breaking down the series allowed us to determine the seasonality and occurrence of "accidental" rains throughout the series. The dry-rainy season cycle is from November to April and from May to mid-October, in the study area. Autocorrelation detection tests show that accidental rains are not self-correlated and validate the model. The forecasts for 2016, 2017 and 2018 showed a positive correlation close to the unit, which clearly shows the robustness of the model. Also, the calculation of the cumulative rainfall deficit shows a variation between 5% and 24%. The 2019 forecast shows a deficit compared to the previous year 2018 and at the same time is a dry year compared to the average index for the 2012-2018 period. The result compared to the Permanent Interstate Committee for Drought Control in the Sahel (ICDS/CILSS) published in April 2019 indicated that the 2019 will be in deficit compared to 2018 rainfall in the climate zone where is located the project [17]. The year 2019 rainfall is in deficit compared to the Normal period 1981-2010 in Burkina Faso [18, 19].

It is the first time that we use some data collected by local communities for seasonal forecasting in the Nouaho sub-basin. Burkina Faso.-This study reveals the need to act on the climate crisis by involving local communities in the collection of data which, after all, makes it possible to have data in quantity and quality and also to make local predictions of precipitation. In this climatic zone, a forcast based on data collected locally could help local authorities to better understand the local rain behavior. However, since the duration of the series is less than 10 years, the rainfall index compared to the calculated average is insufficient. Nonetheless, it gives a trend that could be clarified at the end of the period. These preliminary results confirm the robustness of the model if we have a good coverage of the basin in rainfall stations through a network of selected sites in the basin.

4. Conclusion

These preliminary results allowed us to verify the robustness of the model used for seasonal forecasts and to confirm it with the forecasts made by AGRYMET which is CILLS' body in charge of managing forecasts. Beyond the model, the study reveals the need to strengthen data collection at the local level, which could make it possible not only to have a better knowledge of climate variability in the sub-basin but also to support the government's efforts to strengthen knowledge of climate events in the region. These results allow us to strengthen community resilience without which the development of society would be compromised by the adverse effects of climate variability and change. The availability of local data throughout the basin would provide a database to be used for further research on knowledge of both climate factors and hydrological and hydrogeological factors. However, support through training and ownership of the tools and methods used by the selected readers could make it possible to better organize collection over territories larger than the Nouaho basin.

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Conflicts of Interest

The authors declare that they have no competing interests.

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