The Effect of Rainfall Patterns on Dairy Farming in Naivasha Sub-County, Kenya

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Abstract:-**Dependence on natural pastures with little or no supplementation makes dairy farming in East African region vulnerable to seasonal weather variations, characterized by low dry–season milk production and high wet-season production, sometimes exceeding the consumption capacity of the market. There was, therefore, a need to develop a method that can help farmers and policymakers estimate future milk production for purposes of planning, in order to avoid losses brought about by the excessive wet season production. This research used time series analysis to examine the rainfall patterns and milk production trends over a period of eight years between 2011 and 2018 in an attempt to establish a relationship between the two variables in Kenya Agricultural and Livestock Research Organization-Dairy Research Institute (KALRO-DRI) Naivasha Sub-County, Kenya. This research used monthly milk production averages and monthly average rainfall data from KALRO DRI Naivasha. Secondary Data was collected from the organization and analyzed using R software where two ARIMA models were used to compare the two variables. Climate change has resulted in the emergence and rise of both-vector borne and viral diseases through increased rainfall. There has been a significant rise in outbreaks of foot and mouth disease and tick-borne diseases in the area thus affecting milk production. The overall objective of this study was to assess the influence of changes in rainfall patterns on dairy farming in KALRO Naivasha with a focus on milk output for the various season.**

I. INTRODUCTION

Dairy farming is one of the key sectors in agriculture which contributes to improved nutrition and employment in rural areas. The influence of climate change in dairy productivity in East Africa is manifested through impacts on fodder production and supply, availability of pasture, livestock disease outbreak and water availability for livestock.

Dairy cattle in KALRO Naivasha are reared in an open grazing system sometimes with little or no grazing rotation. They rely on rainfed pastures that receive no supplementary irrigation throughout the year. Dependence on seasonal weather variations, therefore, becomes a major influencing factor on their productivity, demonstrated by low milk production and loss of livestock body condition during the dry season and high production coupled with good body condition during the wet season. Sometimes the wet season is accompanied by such a high level of milk production that the capacity of the market to consume it is overwhelmed bringing about a milk glut. Pastures consisting of associations of perennial grasses form the most important source of feed for Dairy Cattle in KALRO DRI Naivasha [1]. The purpose of this study was to investigate the relationship between changes of rainfall patterns on dairy farming in KALRO Naivasha and to determine a trend that will help in estimation of milk production in the future based on the previous productivity levels and rainfall patterns.

1.1. Dairy Farming in Kenya

Report from the East Africa Dairy Development (EADD) project, currently working with smallholder dairy families in Kenya, Uganda, and Rwanda showed that milk production is dependent on rain-fed forages production. This production is characterized by a surplus fodder supply during the rainy season and a corresponding rise in milk production. The dry season is characterized by a reduction in forage supply and a general deficit in milk production [2].

Rainfall unreliability is increasingly becoming common. Kenya National Climate Change Response strategy indicate that climate variability and change have resulted into frequent droughts and emergency of vector-borne parasites that affect milk production, this is due to increased seasonal variability within the year and also a decline of the long rainy season[3].

Understanding the past, present and future trends of rainfall in the study area will help in developing and promoting climate-smart agricultural practices in fodder and pasture production, fodder conservation and manure management. Extension practitioner with knowledge on expected future rainfall and milk variability will develop appropriate climate-smart agricultural practices to help research centres cope with climate change. Results from this study will assist programs operating in the study site on the future trend of rainfall and milk production.

II. LITERATURE REVIEW

Similar research has been done before by [4]and [5]and confirmed that increased rainfall brings about improved pastures in both quantity and quality. They further confirmed the findings of[6],[7],[8]and [9] that improved pastures lead to increased milk production. This would be explained by the fact that it takes some time for pasture to grow after it has rained. This study focused on the changes in rainfall patterns and the effect on dairy milk production.

III. RESEARCH METHODOLOGY

3.1. Target Population

The desired population of the study was from a breed of cattle known as National Sahiwal stud which was adopted to encounter the changing climate on dairy farming. Rainfall data from KALRO Naivasha weather station was also used.

Sahiwal is a breed of Zebu cattle, which is preferred for its ability to give high-quality milk with high butterfat content. It is fairly resistant to tick-borne diseases and thrives in arid and semi-arid areas where pure exotic breeds find it difficult to cope. According to research conducted by KARI, the breed is a good milk producer compared to other local breeds and is capable of an average of producing about 8-10kgs per day, with a fat content of 4.5 %, within an average lactation period of 10 months. Sahiwal is an excellent grazer, able to use pastures in arid and semi-arid areas, making it a good alternative choice for farmers who are not interested in zero-grazing or want to have both milk and beef.

3.2.Methods of Data Collection

This study used secondary quantitative data which was obtained from KALRO records. Milk data was obtained from the Dairy cattle research section (DCRS) department at KALRO Naivasha while rainfall data was obtained at KALRO Naivasha weather station.

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3.3. Box-Jenkins Methodology

This method is concerned with the selection of an appropriate model that can produce an accurate forecast based on a description of a historical pattern in the data and how to determine the optimal model orders. Statisticians George Box and Gwilym Jenkins developed a practical approach to build the ARIMA model, which best fit to a given time series and also satisfy the parsimony principle. Their concept has fundamental importance on the area of time series analysis and forecasting.

The Box-Jenkins methodology does not assume any particular pattern in the historical data of the series to be forecasted. Rather, it uses a three-step iterative approach of model identification, parameter estimation,and diagnostic checking to determine the best parsimonious model from a general class of ARIMA model. This three-step process is repeated several times until a satisfactory model is finally selected. Then this model can be used for forecasting future values of the time series

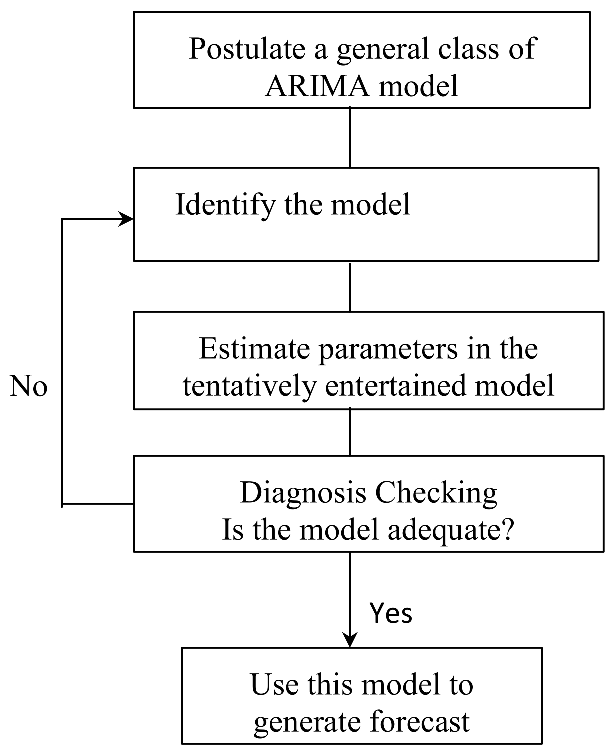

Figure 1: The Box-Jenkins methodology for optimal model selection

3.4.Autoregressive Integrated Moving Average (ARIMA) Model

The best ARIMA model can be described as:

$$X_{2019} = \alpha + \emptyset_1 X_{2018} + \emptyset_2 X_{2017} + \ldots + \emptyset_p X_{2011} + \varepsilon_t + \theta_1 \varepsilon_{2018} + \theta_2 \varepsilon_{2017} + \ldots + \theta_q \varepsilon_{2011}$$

$$\varepsilon_t \sim N(0, \sigma^2)$$

Variables in the model were defined as follows:

$\emptyset_2, \ldots, \emptyset_p$ and $\theta_1 \theta_{2,\ldots,} \theta_q$ Were constants

$$t = 1, 2, \ldots, 8\ (denotes\ time\ steps)$$

$\varepsilon_t = the\ error\ term\ at\ time\ t$

It has 3 parameters, (p) for AR order, (d) for the number of differencing passes made and (q) for MA order.

IV. RESULTS AND DISCUSSION

4.1. Time Series Analysis of Rainfall and Milk

The trend of rainfall and milk-based on observed data had the following time series plot.

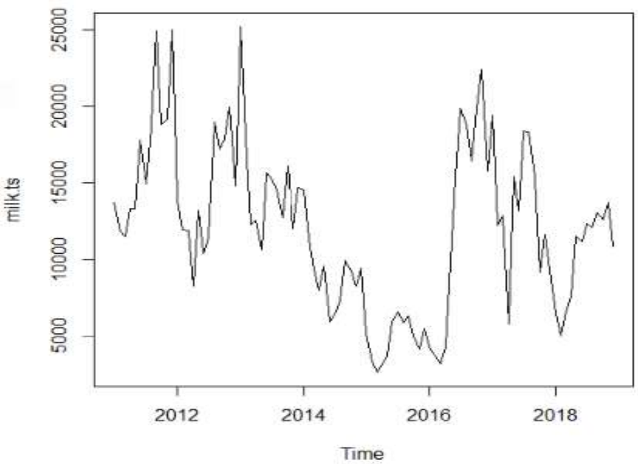

Figure 2: R output of milk production.

The time series plot above shows milk production fluctuations over the years with an inconsistent pattern in milk productions resulting in peaks and troughs over the years with the largest decreases in 2013 to 2016.

The resulting time series does not appear to be stationary in the mean. Therefore, we differenced the time series once, which gave a stationary time series as follows:

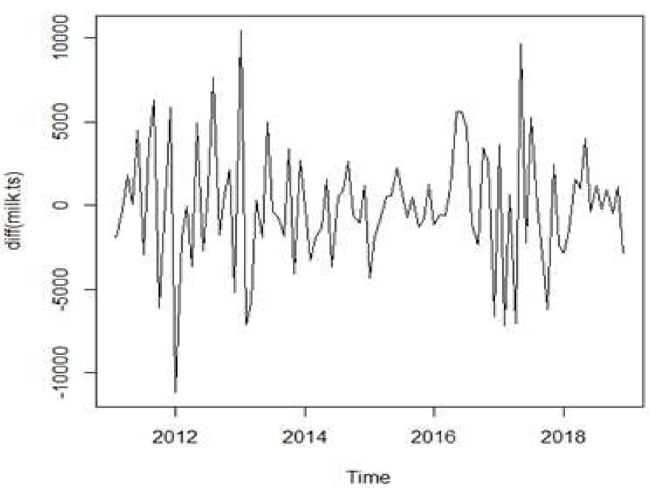

Figure 3: First order difference of milk data.

This is the graph of the rain time plot

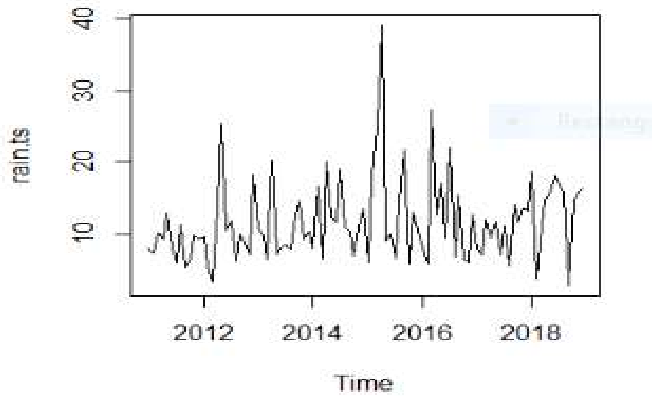

Figure 4: R output of rainfall.

The above time plot seems to have seasonal variation there are peaks and troughs with the highest peak been observed in 2015.

We estimate the trend component of this time series by decomposition. We decomposed the time series data into its components which are a trend, random, and seasonal then plot the trend of time series data, as shown in Figure 5.

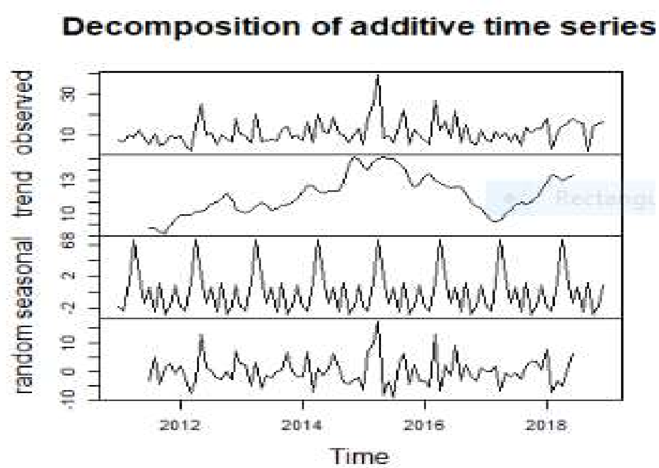

Figure 5: Decomposed rainfall output.

4.2. ACF AND PACF

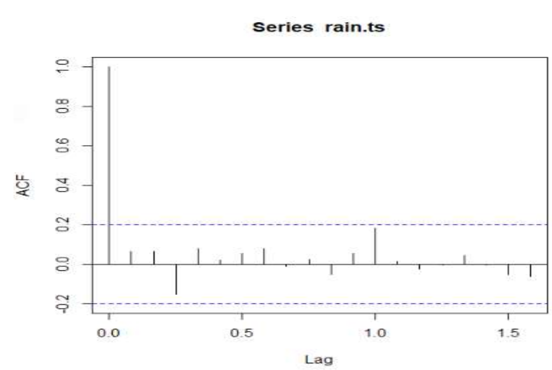

Figure 6: rain ACF

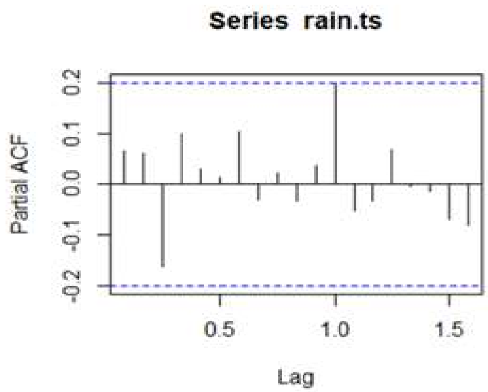

Figure7: rain PACF

Since the correlogram shows that none of the sample autocorrelations and partial autocorrelations for lags 0.0 - 1.5 exceeds the significance bounds.

```
> Box.test(resid(arima_model1),type="Ljung",lag=1)

        Box-Ljung test

data:  resid(arima_model1)
X-squared = 0.0013217, df = 1, p-value = 0.971
```

The p-value for the Ljung-Box test was 0.971, the study concludes that there was very little evidence for non-zero autocorrelations in the forecast errors at lags 0.0 - 1.5.

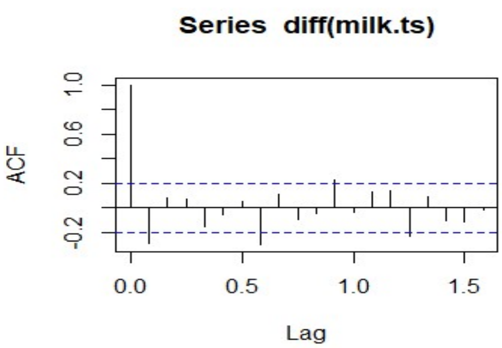

Figure 1: milk ACF.

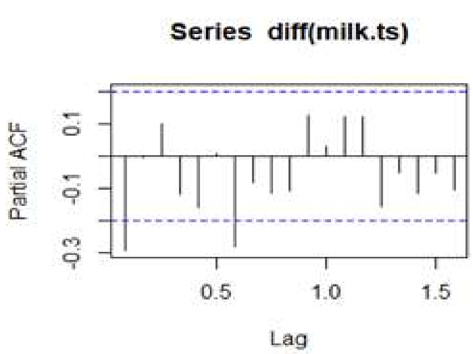

Figure 9: milk PACF.

We see from the correlogram that the autocorrelations for lags 0.1, 0.6, 0.8 and 1.25 exceed the significance bound. The autocorrelations for lags 0.1, 0.6,1.25 are negative while for lag 0.8 is positive.

From the partial auto correlogram, it is evident that the partial autocorrelation at lag 0.1 and 0.6 are negative and exceeds the significance bounds.

4.3. Arima Models, Point Forecasts and Forecast Errors

The results showed that ARIMA (1,0,0) was the best ARIMA model for rainfall.

```
> Y<-auto.arima(rain.ts)
> Y
Series: rain.ts
ARIMA(0,0,0)(1,0,0)[12] with non-zero mean

Coefficients:
        sar1     mean
      0.1889  11.6176
s.e.  0.1015   0.6883

sigma^2 estimated as 32.32:  log likelihood=-302.25
AIC=610.51   AICc=610.77   BIC=618.2
```

Using the best model obtained, a model forecast using "forecast. ARIMA ()" was carried out to predict future values of rainfall. The 2019 predicted values for point forecast, 80%, and 95% interval were as follows:

```
> g<-forecast(Y,h=12)
> g
         Point Forecast    Lo 80    Hi 80      Lo 95    Hi 95
Jan 2019      12.917935 5.632665 20.20320  1.7760763 24.05979
Feb 2019      10.102844 2.817575 17.38811 -1.0390144 21.24470
Mar 2019      11.519836 4.234566 18.80511  0.3779775 22.66170
Apr 2019      12.199992 4.914723 19.48526  1.0581337 23.34185
May 2019      12.388925 5.103655 19.67419  1.2470659 23.53078
Jun 2019      12.842362 5.557092 20.12763  1.7005034 23.98422
Jul 2019      12.558964 5.273694 19.84423  1.4171050 23.70082
Aug 2019      12.407818 5.122548 19.69309  1.2659592 23.54968
Sep 2019       9.951699 2.666429 17.23697 -1.1901602 21.09356
Oct 2019      12.199992 4.914723 19.48526  1.0581337 23.34185
Nov 2019      12.370032 5.084762 19.65530  1.2281727 23.51189
Dec 2019      12.483391 5.198121 19.76866  1.3415321 23.62525
```

The forecasts seemed to be consistent with little fluctuations overtime.

Next, the study checked on forecasting errors as follows:

```
> Box.test(resid(arima_model1),type="Ljung",lag=1)

        Box-Ljung test

data:  resid(arima_model1)
X-squared = 0.0013217, df = 1, p-value = 0.971
```

The Ljung -Box test statistic was 0.0013217, and the p-value was 0.971, meaning there was little evidence of non-zero autocorrelations in the in-sample forecast errors at lags 1. Hence, there were no correlations in the forecast errors for successive predictions in rainfall patterns.

An appropriate ARIMA model for the time series of milk production was considered to be an ARIMA (1,1,0) model which was fitted as below:

```
> Y<-auto.arima(milk.ts)
> Y
Series: milk.ts
ARIMA(1,1,0)

Coefficients:
          ar1
      -0.2938
s.e.   0.0979

sigma^2 estimated as 12243909:  log likelihood=-909.57
AIC=1823.13   AICc=1823.26   BIC=1828.24
```

The 2019 milk production predicted values for point forecast, 80% and 95% interval were obtained Using the best model,

```
> y<-forecast(Y,h=12)
> y
         Point Forecast      Lo 80    Hi 80      Lo 95    Hi 95
Jan 2019       11676.43  7192.1141 16160.74  4818.2611 18534.60
Feb 2019       11430.69  5940.8792 16920.50  3034.7478 19826.64
Mar 2019       11502.89  4963.1359 18042.64  1501.2003 21504.58
Apr 2019       11481.68  4092.2709 18871.08   180.5555 22782.80
May 2019       11487.91  3322.7831 19653.03  -999.5734 23975.39
Jun 2019       11486.08  2616.6283 20355.53 -2078.5748 25050.73
Jul 2019       11486.62  1963.7496 21009.48 -3077.3514 26050.58
Aug 2019       11486.46  1352.5073 21620.41 -4012.0822 26985.00
Sep 2019       11486.50   776.1984 22196.81 -4893.4951 27866.50
Oct 2019       11486.49   229.3222 22743.66 -5729.8629 28702.84
Nov 2019       11486.49  -292.1802 23265.17 -6527.4340 29500.42
Dec 2019       11486.49  -791.5551 23764.54 -7291.1614 30264.15
```

The forecasts were consistent with little variations indicating that predictions were suitable for the prediction of the future values.

To investigate whether there was significant evidence for non-zero correlations, the study used the Ljung-Box test.

```
> Box.test(resid(arima_model1),type="Ljung",lag=1)

        Box-Ljung test

data:  resid(arima_model1)
X-squared = 0.0013087, df = 1, p-value = 0.9711
```

The Ljung-Box test statistic is 0.0013087, and the p-value is 0.9711, meaning there was little evidence of non-zero autocorrelations in the in-sample forecast errors at lags 1.Hence, this shows that there are no correlations in the forecast errors for successive predictions in milk productions.

4.4. Forecasting

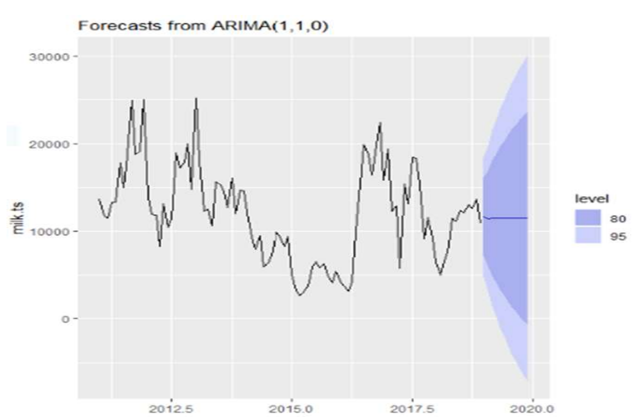

Figure 10: Forecast of milk.

The forecasts for 2019 were plotted with a blue line, the 80% prediction interval as a

Light blue shaded area, and the 95% prediction interval as a sky blue shaded area.

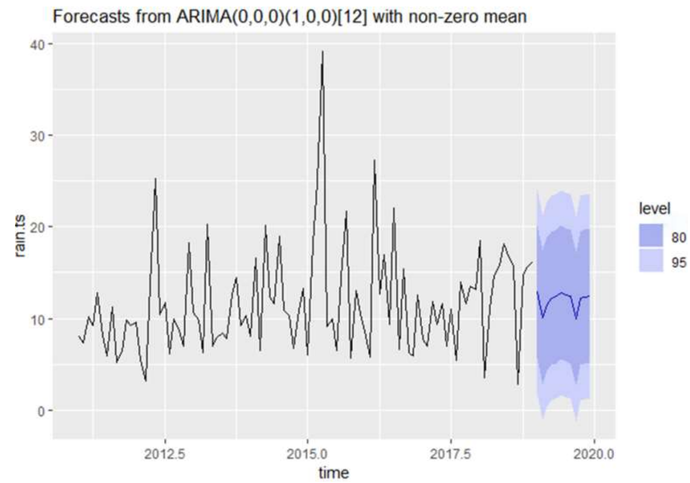

Figure 11: Forecast for rainfall.

Here the forecasts for 2019 are plotted as a blue line, the 80% prediction interval as a

Light blue shaded area, and the 95% prediction interval as a sky blue shaded area.

4.5. Relationship Between Rainfall and Milk Production

The study found that rainfall does not have an immediate effect on milk production but has a significant effect on production after some time. This would be explained by the fact that it takes some time for the pasture grow after it has rained.

From the results both rainfall and milk, it was evident that there was a relationship between the two variables in the study.

The results confirmed evidence of the existence of a relationship between rainfall and milk. The amount of milk produced tends to be influenced by the prevailing rainfall patterns. Low rainfall was associated with relatively high milk production while high rainfall was associated with a decline in milk production.This decline in milk production could be attributed to seasonal diseases, floods, and the cold weather during the high rainy seasons. Unlike in the years with low or moderate rainfall where there is relatively high milk production due to the good body condition of dairy cattle and relatively dry pasture that is rich in nutrients. This was illustrated by the trend between the years 2017-2018 when the rainfall trend was increasinggradually while milk production was high.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The major results of the study indicated that seasons experiencing low or moderate rainfall had slightly high milk production and seasons with low milk production had high rainfall amounts.There existed a relationship between the changing rainfall patterns and dairy cattle productivity in the study site. Further, projected changes based on ARIMA model output and observed variables indicated fluctuations in the two variables. These changes are expected to have adverse impacts on livestock productivity.

5.2 Recommendations

As a response to the effects of climate variability and change, research institutions should invest in fodder development and conservation in order to sustain their dairy herd productivity.The government should empower dairy farmers and research institutions to adapt and mitigate the effects of excessive rainfall, drought, and the emergence of new vectors and livestock diseases occasioned by extreme weather variability.

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