VALIDATION OF AUTOMATIC WEATHER OBSERVATION SYSTEM DATA IN UGANDA

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ABSTRACT

Uganda is a country in which, the lives of most of the local communities depend of agriculture apart from nomadic pastoralism. Over the recent years the occurrence of climatic extremes (droughts and floods) has increased in many parts of the country that has caused public outcry for adequate meteorological information for planning and management purposes.

The goal of this study is to contribute to provision of reliable meteorological information to the end users (farmers, researchers etc). Specifically the study investigated the relationship between rainfall data obtained from Automatic weather observation system (AWOS) and traditional (conventional) surface observation system.

It was hypothesised that a significant relationship exists between data sets from the two observation methods. Namulonge Meteorological station was chosen for this study due to availability of data for both observation systems, on-going agricultural research by NARO-Uganda and being an area of bimodal type of rainfall.

The normalised pentad rainfall totals for March-April-May (MAM) and September-October-November (SON) 2005 seasons were analysed. Time series graphs, scatter-grams, Spearman's rank correlation and Analysis of variance (ANOVA) F-test were used to investigate the relationship. Moderately strong positive correlations were obtained for MAM ($r = 0.59$) and SON ($r = 0.50$). The correlation for MAM was also statistically significant ($p < 0.05$) while for SON ($p > 0.05$) it was not statistically significant at 95% confidence level.

More research is still needed since this comparison can also be useful in data quality control and management.

Key words
Climatic extremes, agriculture, public outcry, quality data, planning and management.

1. INTRODUCTION

1.1 General Introduction

The lives and livelihoods of most communities in Uganda depends on Agricultural production which is determined by climate as one of the key factors. Over recent years the occurrence of hydro-climatic events such as Droughts and Floods increased in many parts of country causing severe socio-economic impacts that include food insecurity, famine, deaths, epidemic diseases, pests and economic losses among others. The impacts spread over large areas and differ in severity, magnitude and duration as stated by Smakhtin (2001). The problem has caused public outcry for adequate meteorological information for planning and management purposes.

In line with the above public demands, accurate and timely high quality data must be collected and disseminated to the end users such as farmers. In collecting, managing and analysing data, the methods of observation define their character (Stephen, 2005). For this research, traditional (conventional) gauging and automatic weather observation systems (AWOS)(CIMO, 2002 in Stephen, 2005) were considered. Conventional surface observation provides benchmark data for climatic and agricultural monitoring. However the information may not be sufficient for some users due to the time lapse between subsequent observations. This problem can be addressed by AWOS that collects data continuously from seconds to 24 hours depending on the need and data storage capability. The logger can be programmed to provide daily summaries in addition to regular acquisition.

It is therefore worth mentioning that if sufficient quantity and quality data is available the risk of extreme climatic events and their damage can be reliably assessed.

1.2 Objectives

The goal of this study is to contribute to the provision of reliable meteorological information to the end users (farmers, researchers etc). Specifically the study investigated the relationship between rainfall data obtained from traditional (conventional) and automatic weather observation systems.

1.3 Hypothesis

It was hypothesised that, there is significant relationship between conventional and automatic weather observation system rainfall data.

2. DATA AND METHODS

2.1 Study area

The daily rainfall data (mm) for Namulonge Agro-meteorological station (32° 27' E and 00° 19' N) for 2005 was obtained from Department of Meteorology (Uganda). This station was chosen due to availability of data for both conventional and automatic weather observation systems, on going agricultural research by National agricultural research organisation (NARO)-Uganda and the station being representative of bimodal type of rainfall.

2.2 Methods

The data was subjected to quality control and consistency checks, then grouped into pentads spanning March-April-May (MAM) and September-October-November (SON) seasons respectively. The pentad rainfall departures from the mean were normalised by the standard deviation as follows ($(e - \bar{e})/\sigma$). Time series graphs of the actual pentad rainfall (mm) and rainfall indices (normalised pentad rainfall totals) were plotted to assess the trends in the AWOS and conventional observation systems data. Scatter-grams and Spearman's rank correlation analysis were used to determine the nature of the relationship between the two data sets. Analysis of variance (ANOVA) F-test was then performed to investigate the significance of the relationship at 95% confidence level.

3. Results and Discussion

3.1 Time series

The time series graphs show similar trends in the pentad rainfalls from the AWOS and Traditional weather observation system over the seasons of MAM (Fig: 1 and 2) and SON (Fig: 3 and 4). However in some cases the differences between rainfall measured by AWOS and traditional gauging were high. For instance, in MAM the traditional observation rainfall records for the 4^{th}, 6^{th}, 9^{th} and 13^{th} pentads (March 16^{th}-20^{th}, 26^{th} – 30^{th}, and April 10^{th} - 14^{th}, 25^{th} -29^{th} respectively), were much higher (>20 mm) than for Automatic weather observation system (Fig: 1) while for the 8^{th}, 10^{th}, and 17^{th} pentads (April 5^{th} to 9^{th}, 15^{th} to 19^{th} and May 20^{th} to 24^{th}), AWOS also registered much higher (>10 mm) rainfall than the Conventional observation. Similar anomalies were also realised in the SON season rainfall data (Fig: 3, September 6^{th} to 10^{th} and October 31^{st} to November 4^{th}).

The pentad rainfall indices for 2005 MAM and SON seasons (Fig: 2 and 4) were mostly normal to wet (-0.5 to 0.5 and greater than 0.5 standard deviations of anomaly from the mean respectively), punctuated with dryness (less than – 0.5 standard deviations of anomaly from the mean). MAM the long rain season appeared more wet than SON (short rain season). These rain seasons are associated to: the northward and southward movement of the ITCZ respectively, and influence of Congo air mass that enhances the ITCZ especially during MAM season.

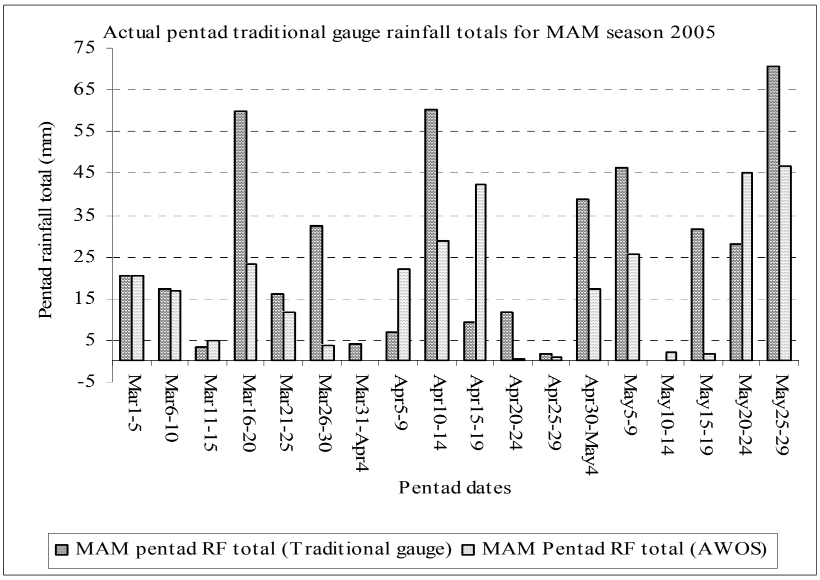

Figure 1: MAM season actual pentad rainfall for AWOS and traditional gauging

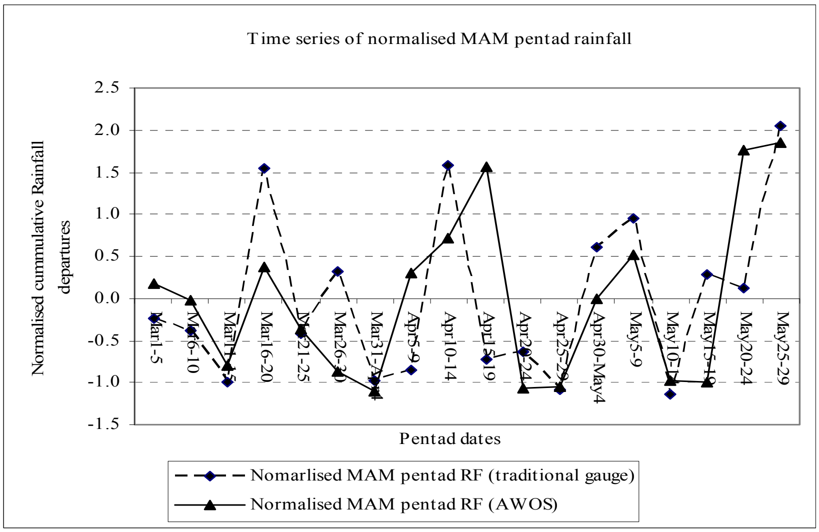

Figure 2: Time series of pentad rainfall indices for MAM season

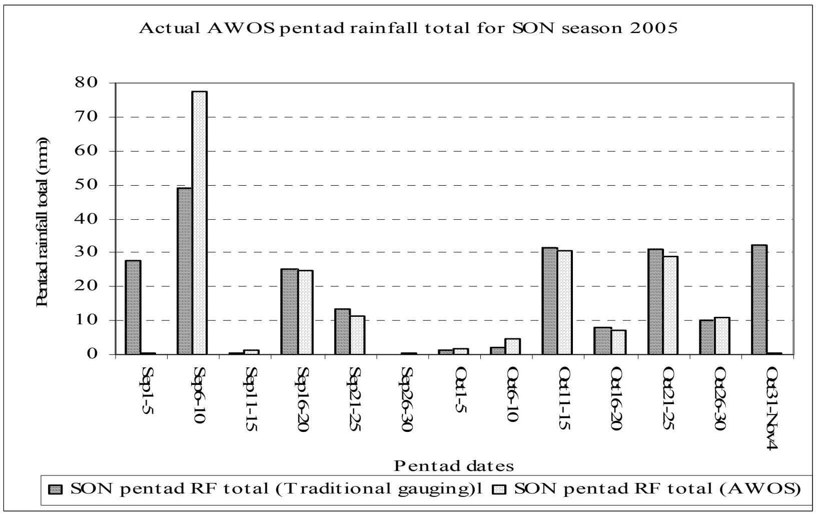

Figure 3: SON season actual pentad rainfall for AWOS and traditional gauging

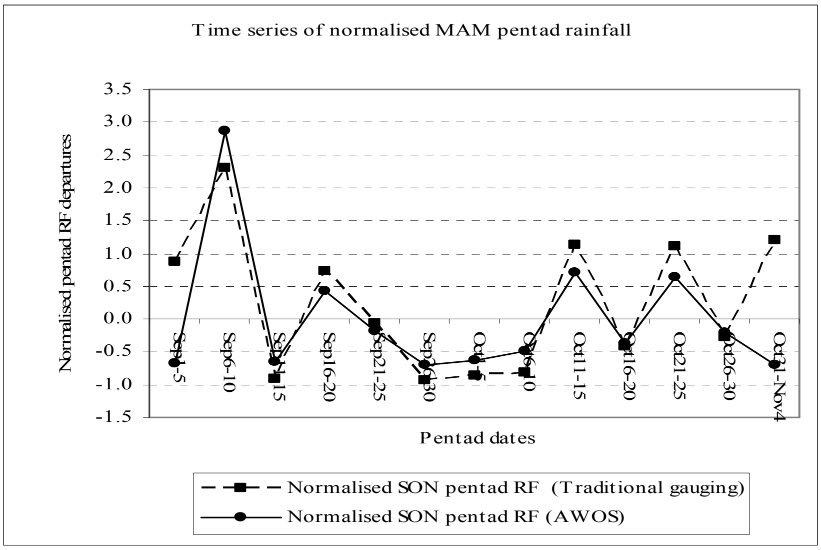

Figure 4: Time series of pentad rainfall indices for SON season

3.2 Correlation analysis and significance test

The results in Fig: 5, 6 and Table: 1 (next page) reveal moderately strong positive correlation between the rainfall from the Automatic weather observation system (AWOS) and traditional gauging for both MAM and SON season (with correlation coefficients r = 0.59 and r = 0.50 respectively). The coefficients of determination r^2 reveal 34% and 25% degree of the relationship between the two data sets for March-April-May (MAM) and September-October-November (SON) season. It's also surprising to note that the relationship between the two pentad rainfall series for SON is not statistically significant (F= 1.72, p = 0.06, which is greater than $p_{critical}$ of 0.05) while for MAM season the correlation is statistically significant (F= 1.22, p = 0.009, which is less than $p_{critical}$ of 0.05 or 0.01) at both 95% and 99% confidence levels. This implies that the observation results for MAM season are more reliable than for SON and that the moderately strong correlation for SON season could have been by chance. Some other environmental or human factors such as errors during digitising of data from conventional rain gauge could also have influenced these results or otherwise.

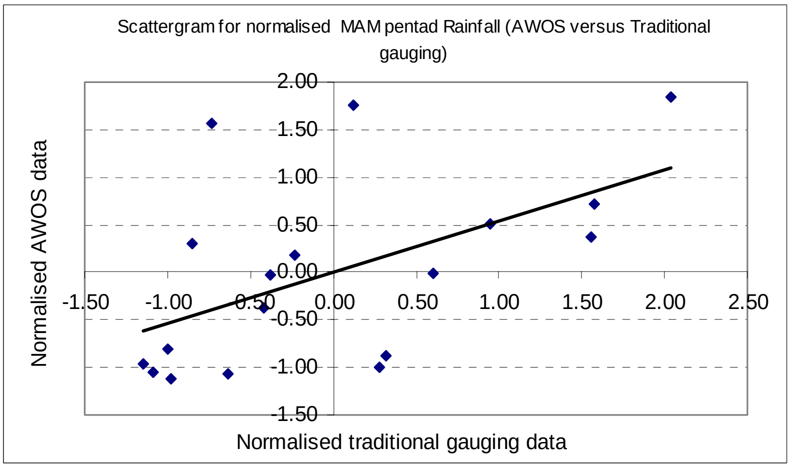

Figure 5: Scatter-gram for MAM season AWOS versus Traditional observation System pentad rainfall indices

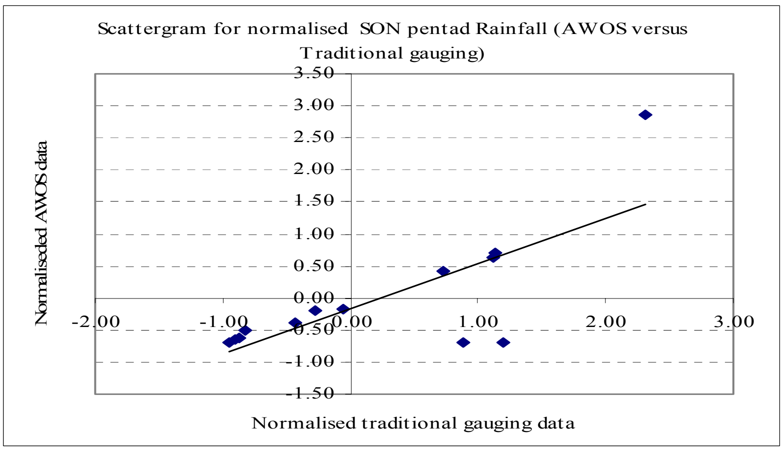

Figure 6: Scatter-gram for SON season AWOS versus Traditional observation System pentad rainfall indices

Table 1: Coefficients of determination r^2, Correlation coefficients and ANOVA F-statistics at 95% confidence level ($p_{critical} = 0.05$)

SEASON	r^2	r	F-statistic	p
MAM	0.34	**0.59**	**1.22**	**0.009****
SON	0.25	0.50	1.72	0.06

The bolded values are significant at both $p_{critical} = 0.05$ and 0.01

3.3 Discussions

Looking at the graphical results, the rainfall trends were similar, though AWOS recorded less rainfall than the conventional observation system in most instances (Fig. 1, 2, 3 and 4). It can be argued that the generally lower rainfall recordings by the automatic rain gauges is due to the greater installation heights (than for traditional, manual standard rain gauges) that results into systematic errors subject to wind field distortions along the gauge orifice. This causes the wind speed to increase over the orifice, forcing off the lighter rain droplets (blocking effect) hence loss before measurement (Goodison, 2001, in Sevruk et al 2002). Since the Automatic gauge uses the tipping bucket mechanism, and the rainfall in the tropics is mostly of showery type, there is also the possibility of overflow of the water collected due to the delay of the tipping hence a lower recording than actual. However, the departures in MAM were further apart than for SON season.

It should not also be ruled out that other possible sources of disparity in the data set could have been observers biases due to lack of motivation, or AWOS equipment failure under any combination of the following environmental elements; temperature, sunshine, wind, humidity etc (Stephen, 2005). Nonetheless inadequate funding leading to irregular inspection of the instruments and lack of regular instrument calibrations, non replacement of malfunctioning instruments could also affect data quality and quantity.

The correlation analysis results ($r = 0.59$, $F= 1.22$, $p = 0.009$ for MAM and $r = 0.50$, $F = 1.72$, $p = 0.06$ for SON) reveal that moderately strong and statistically significant positive correlation existed between the rainfalls from AWOS and conventional observation method for MAM season which is in agreement with the hypothesis. Unexpectedly, the results for SON imply that there is no significant relationship between AWOS and conventional observation rainfall data.

Since much has not been done to investigate long-time series for reliability and accuracy of AWOS measurements in Uganda it can not be conclusive to say which observation system performs best at this stage of research. More is yet to be done, since such comparisons are important for data quality control and Standardisation of data (Chivla et al, 2002 in Sevruk et al 2005; WMO, 2001).

4. Conclusions and recommendations

4.1 Conclusions

- The trends of rainfall for both automatic and traditional rainfall observation systems for the seasons of MAM and SON 2005 were similar.
- The relationships between the pentad rainfalls from the two observation methods for the seasons of MAM and SON were moderately strong and statistically significant for MAM season only.

4.2 Recommendations

- The observers should be motivated and well trained to avoid biases in data collection so as to improved data quality.
- The Governments should avail adequate funds to ensure regular inspection and replacements of malfunctioning observation systems for timely and high quality data.
- Regular calibration of measuring instruments for accurate and reliable data is required.
- This research should be given spatio-temporal dimension when up-scaling to national or regional levels.

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