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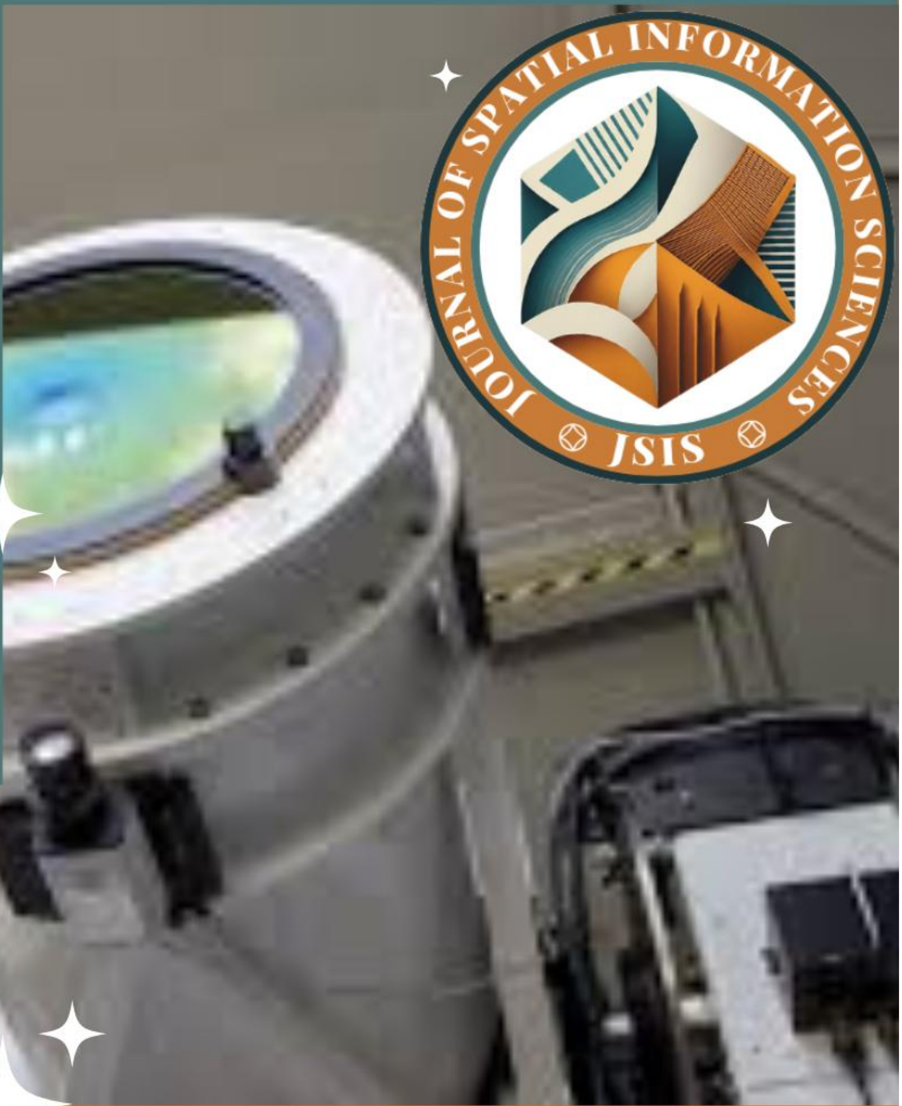

# EVALUATION OF GNSS OBSERVATION TIMING USING DILUTION OF PRECISION AND SATELLITE VISIBILITY ANALYSIS IN NORTH-EAST, NIGERIA

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# EVALUATION OF GNSS OBSERVATION TIMING USING DILUTION OF PRECISION AND SATELLITE VISIBILITY ANALYSIS IN NORTH-EAST, NIGERIA

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## ABSTRACT

*This study evaluates GNSS observation timing in Northeast Nigeria using Dilution of Precision (DOP) and satellite visibility analyses to determine optimal periods for data collection and evaluate temporal variations in positioning conditions. Twelve weeks of GNSS data were analysed using descriptive statistics, paired-samples t-tests, ANOVA, and orthogonal contrast analysis. The results showed that nighttime observations provided significantly better satellite geometry, with lower mean DOP values (2.447) than daytime observations (2.624), and higher satellite visibility (8.429 satellites compared to 8.292 satellites during the day). Statistical tests confirmed these differences to be significant. However, ANOVA results revealed no significant differences were found among morning, afternoon, and evening observation periods ($F(2,33) = 0.063, p = 0.939$), indicating relatively stable GNSS performance throughout the daytime. These findings suggest that although nighttime observations offer slightly more favourable positioning conditions, reliable and acceptable GNSS accuracy can be achieved at any time of the day. This flexibility is particularly beneficial in Northeast Nigeria, where security concerns often restrict fieldwork schedules. The study concludes that GNSS surveys can be effectively conducted across different observation periods without substantial loss of positioning quality, thereby improving operational efficiency, safety, and survey planning for geospatial, infrastructure, and security-related applications.*

**Keywords:** Global Navigation Satellite System (GNSS), Dilution of Precision (DOP), Satellite Visibility, Northeast Nigeria, GNSS Mission Planning.

## 1.0 INTRODUCTION

Global Navigation Satellite Systems (GNSS), including GPS, GLONASS, Galileo, and BeiDou, have become fundamental technologies for positioning, navigation, and timing applications worldwide. The availability of multiple satellite constellations has enhanced positioning accuracy, reliability, and continuity, making GNSS indispensable in surveying, mapping, engineering, transportation, precision agriculture, and disaster management [1]. Recent studies have shown that the integration of multiple GNSS constellations significantly improves satellite availability and geometric strength, thereby enhancing positioning performance on a global scale [2]; [3]. However, the accuracy of GNSS positioning depends not only on receiver quality and processing techniques but also on satellite geometry, which is commonly expressed using Dilution of Precision (DOP). Lower DOP values indicate stronger satellite geometry and improved positioning accuracy, while higher values are associated with greater positional uncertainty [3].

To improve positioning performance, GNSS mission planning has become an essential aspect of modern surveying practice. Advances in satellite technology and planning software enable surveyors to predict satellite visibility and DOP values before field observations, allowing the selection of optimal observation periods that reduce field time, operational costs, and positioning errors [4]. Tools such as SKYPLOT_DEM have demonstrated the importance of satellite visibility prediction and DOP simulation for optimizing GNSS survey schedules and improving operational efficiency [5]. Although modern multi-constellation GNSS systems provide access to a large number of satellites, satellite geometry continues to vary throughout the day because of satellite orbital motion. Consequently, observation timing remains a critical factor in achieving optimal positioning accuracy [6]. Studies on BeiDou-3 and other multi-GNSS systems have further shown that satellite visibility and DOP values exhibit temporal variations that can influence positioning performance despite the increased number of available satellites [2].

Furthermore, GNSS positioning is also affected by several error sources collectively known as User Equivalent Range Errors (UERE), including satellite clock errors, orbital inaccuracies, atmospheric delays, receiver noise, and multipath effects. The influence of these errors on positioning accuracy is amplified or reduced by satellite geometry, as represented by DOP. Therefore, favourable satellite distribution and low DOP values are essential for minimizing positional uncertainty and achieving high-precision GNSS observations [3]; [7].

The Northeast region of Nigeria, comprising Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe States, increasingly relies on accurate geospatial information for infrastructure development, land administration, environmental monitoring, disaster management, and security operations.

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Despite the growing use of GNSS technology in these applications, limited empirical information exists regarding the optimal observation periods for GNSS surveys in the region. Previous studies have demonstrated that satellite geometry changes throughout the day and significantly influences positioning accuracy. For example, studies conducted in Nigeria reported that evening and nighttime observations often produce better positioning results than observations carried out during less favourable periods of the day [8]; [9]; [10]. Similar global assessments have shown that variations in satellite availability and geometry remain important considerations for GNSS mission planning despite improvements in constellation coverage [3].

Although techniques such as Differential GPS (DGPS), Assisted GPS (AGPS), and post-processing improve GNSS measurement precision, they primarily address range measurement errors and do not eliminate the effects of poor satellite geometry [3]; [7];[11]. Poor observation timing can therefore result in reduced positioning accuracy, increased survey costs, and the need for repeat observations. Consequently, evaluating temporal variations in satellite visibility and DOP is essential for effective GNSS mission planning and efficient survey operations [5].

This study therefore evaluates GNSS observation timing in Northeast Nigeria using satellite visibility and DOP analysis. Specifically, it seeks to identify optimal observation periods, assess temporal variations in satellite geometry, and determine how satellite visibility influences positioning accuracy. The findings are expected to provide valuable guidance for GNSS mission planning and contribute to improved efficiency and accuracy in surveying and geospatial applications across the region.

## 2.0 STUDY AREA

Northeast Nigeria comprises Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe States and spans approximately 280,000 km² across the Sahel Savannah, Sudan Savannah, and Northern Guinea Savannah ecological zones. The region exhibits diverse terrain ranging from the low-lying plains of the Chad Basin in Borno and Yobe States to the mountainous landscapes of the Adamawa Highlands and Mandara Mountains, where elevations exceed 2,000 m above sea level [12]; [13]. These topographic variations influence satellite visibility, signal obstruction, and multipath effects, which are important factors affecting GNSS positioning accuracy [7].

The region experiences a tropical continental climate characterized by distinct wet and dry seasons. Annual rainfall ranges from less than 500 mm in the northern Sahelian areas to over 1,500 mm in the southern highlands, while temperatures generally vary between 25°C and 35°C, often exceeding 40°C during the dry season [14]; [15]. Such climatic conditions affect GNSS signal

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www.journals.unizik.edu.ng/jsis

propagation through atmospheric delays associated with variations in temperature, humidity, and atmospheric pressure [3].

Vegetation cover varies from sparse Sahel vegetation in the north to denser Guinea Savannah woodland in the southern parts of Adamawa and Taraba States. While the predominantly open savannah landscape provides favourable conditions for satellite reception, dense vegetation and mountainous terrain may obstruct satellite signals and increase multipath errors [7]. Additionally, seasonal atmospheric phenomena such as Harmattan dust and increased moisture during the rainy season can influence tropospheric and ionospheric conditions, thereby affecting GNSS positioning performance [11]; [1].

Overall, the largely open terrain and low urban density of Northeast Nigeria generally favour GNSS observations. However, spatial and temporal variations in topography, vegetation cover, and atmospheric conditions necessitate careful GNSS mission planning based on satellite visibility and Dilution of Precision (DOP) analysis to ensure optimal positioning accuracy and survey efficiency.

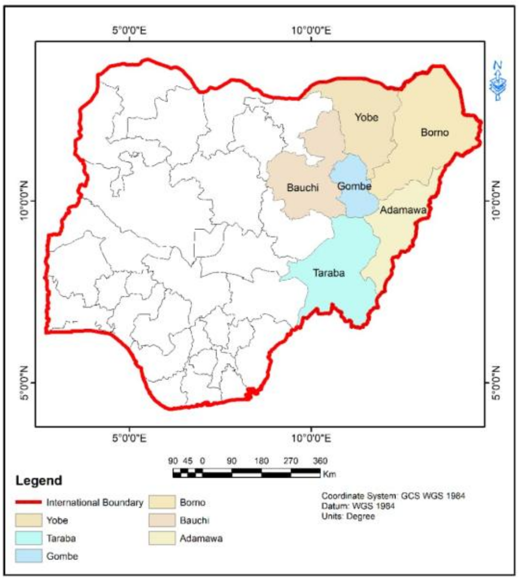


Figure 1: Map showing the six states of Northeast Geopolitical zone of Nigeria.

## 3.0 MATERIALS AND METHODS

### 3.1 Hardware and Software

i. Sokkia GRX I GNSS Receiver
ii. Trimble GNSS Planning Software
iii. Monthly Broadcast GNSS Almanac

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www.journals.unizik.edu.ng/jsis

iv. Hp Laptop Computer
v. Microsoft Excel
vi. SPSS

### 3.2 Data Acquisition

GNSS field observation for the acquisition of broadcast Almanac was carried out for a period of 12 weeks. The current Almanac which contains information about the Space Vehicle Code (SVC) numbers and names of the satellites that was visible at a given location for a specified period of time was acquired. For the purpose of this study a systematic random sampling technique was adopted for the weekly field observation. The random sampling technique was adopted to ensure that selection bias is minimized and the resulting data is a statistical representative of the entire group. Observations were conducted every day at an epoch intervals of 15 minutes over a continuous 24-hour period. Sokkia GRX I GNSS receiver was installed at an obstruction-free control point with minimal multipath interference to acquire both positional and navigational data for a period of 24hours on each sampled day of a week. The elevation mask angle used in the observation is restricted at 10 degrees and the antenna height is 2 meters. The observation took place in the morning, afternoon and at evenings in January, February, March and April of 2024. The Almanac data was extracted in PDC format.

#### 3.2.1 Computation of DoPs and Satellites Visibility

The computation of DOPs and satellites availability was done by downloading the acquired current Satellite almanacs from the GNSS receiver in a form of PDC file and was processed using sokkia planning software. The software generated DOP values and corresponding satellite visibility statistics for each observation epoch.

#### 3.2.2 Collation of Weekly Mean DoP Values

A large volume of DOP and satellite visibility data was acquired and stored. For every sampled day of the week, the data was acquired at 15 minutes epoch time for 24hours. The data was obtained base on the period of this research. The period covers January, February, March and April of 2024. The mean data for every week were computed and used in Statistical models. Analysis of variance (ANOVA) is the statistical model used in this research. It determines whether there are significant differences between the means of the different DOP values.

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## 4.0 RESULTS AND DISCUSSION

### 4.1 Presentation of Results

Results were presented according to the research questions and Hypothesis which were formulated as follows:

Table 1: Paired t-Test to investigate if there is a Significance Difference between DOP Value observed during Day and Night

| Variable | Day Mean | Night Mean | Mean Difference | t-value | df | p-value | Decision |
|---|---|---|---|---|---|---|---|
| DOP | 2.624 | 2.447 | 0.1775 | 6.410 | 11 | 0.00005 | Significant |
| No. of Satellites | 8.292 | 8.429 | -0.1375 | -3.172 | 11 | 0.0089 | Significant |

From Table 1 above, a paired-samples t-test which was conducted to compare daytime and nighttime GNSS observation conditions. The analysis revealed a statistically significant difference in DOP values between daytime (M = 2.624) and nighttime (M = 2.447) observations, $t(11) = 6.41, p < 0.001$. Similarly, a significant difference was observed in the number of visible satellites, with nighttime observations (M = 8.429) recording more satellites than daytime observations (M = 8.292), $t(11) = -3.17, p = 0.009$. These results suggest that nighttime observation periods provide better satellite geometry and increased satellite visibility, which are likely to enhance GNSS positioning accuracy in the study area.

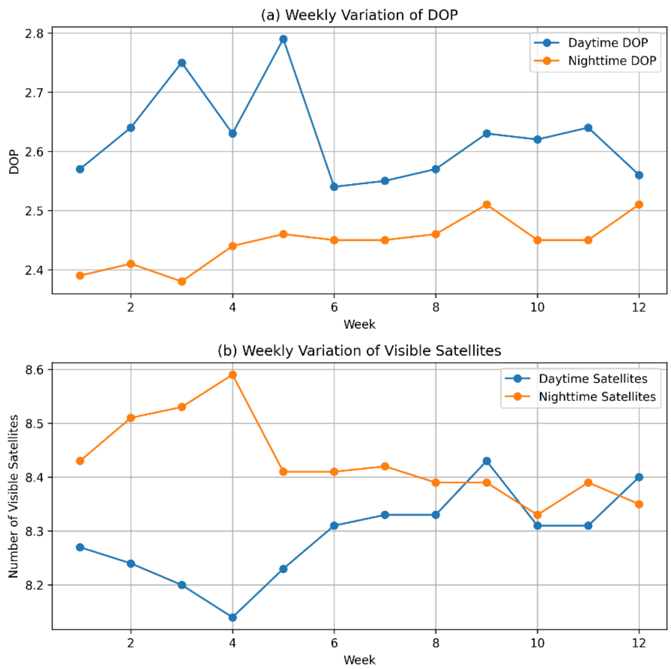

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Figure 2: Temporal variation of GNSS observation parameters over the 12-week study period: **(a)** comparison of daytime and nighttime Dilution of Precision (DOP) values, and **(b)** comparison of daytime and nighttime satellite visibility.

Figure 2(a) shows the temporal variation of DOP values during daytime and nighttime observations. Throughout the study period, nighttime observations consistently recorded lower DOP values than daytime observations, indicating better satellite geometry. Figure 2(b) presents the variation in the number of visible satellites, where nighttime observations generally recorded slightly higher satellite availability than daytime observations. These findings support the results of the paired-samples t-test, which revealed significant differences between daytime and nighttime observation conditions, suggesting that nighttime periods provide more favourable conditions for GNSS positioning in the study area.

**Hypothesis Testing**

Is there a significant difference in the mean DOP values between morning, afternoon, and evening, during day hours?

This can be done by ANOVA (Analysis of Variance).

Hypothesis B1 Ho: $\mu 1 = \mu 2 = \mu 3$,

H1: Two or more mean DOP values are not equal.

At Level of significant $\alpha = 0.05$.

Table 2: ANOVA Test of Variance Between Morning, Afternoon, and Night

| Weeks | MORNING | AFTERNOON | EVENING | |
|---|---|---|---|---|
| **1** | 2.55 | 2.62 | 2.64 | |
| **2** | 2.54 | 2.61 | 2.68 | |
| **3** | 2.58 | 2.61 | 2.5 | |
| **4** | 2.71 | 2.62 | 2.61 | |
| **5** | 3 | 2.89 | 2.5 | |
| **6** | 2.49 | 2.64 | 2.36 | |
| **7** | 2.34 | 2.64 | 2.3 | |
| **8** | 2.62 | 2.18 | 2.8 | |
| **9** | 2.39 | 2.78 | 2.64 | |
| **10** | 2.71 | 2.51 | 2.39 | |
| **11** | 2.67 | 2.66 | 2.75 | |
| **12** | 2.8 | 2.62 | 2.95 | |
| **TOTAL** | 31.40 | 31.38 | 31.12 | T= 93.90 |
| **MEAN** | 2.617 | 2.615 | 2.593 | $T^2/N$ |
| **$T^2$/ni** | 82.163 | 82.0587 | 80.7045 | 244.9225 |

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Table 3: ANOVA Parameters for Hypothesis testing

| Source | Sum of Square | Degree of Freedom | Mean Squares | Ratio |
|---|---|---|---|---|
| **Between** | BSS = $\sum\left(\frac{T^2}{n_i}\right)$-$\frac{T^2}{N}$ = 0.00407 | $V_i = 2$ | S = $\frac{BSS}{k-1}$ = 0.00202 | F = $\frac{S_1}{S_2}$ = 0.06236 |
| **Within** | WSS = $\sum\sum X_{ij}^2 - \sum\left(\frac{T^2}{n_i}\right)$ = 1.06883 | $V_2$ = N – K = 33 | S = $\frac{WSS}{N-K}$ = 0.03239 | $F_{1-\alpha}(V_1, V_2)$ =3.28 |
| **Total** | TSS = $\sum\sum X_{ij}^2 - \sum\left(\frac{T^2}{n_i}\right)$ =1.07290 | N-1 = 35 | | |

From Table 3 above, A one-way ANOVA showed that DOP values did not differ significantly across morning ($M = 2.617$), afternoon ($M = 2.615$), and evening ($M = 2.593$) observations, $F(2,33) = 0.06236, p = 0.939$. Therefore, no evidence was found to suggest that observation period significantly influenced DOP values.

**ANOVA Orthogonal contrast**

H: C1 = 0, H : C2 = 0

Where; C1 = μ1 - μ2= 0, C2 = μ2-μ3 = 0 At Level of significant α = 0.05

Table 4: ANOVA Table for Orthogonal Contrast

| Source | Sum of Squares | Degree of Freedom | Mean Squares | Computed F-Ratio | Tabulated F-Ratio |
|---|---|---|---|---|---|
| $SS_{H:C1=0}$ | $\frac{(\bar{X}_1-\bar{X}_2)}{\frac{1}{n_1}-\frac{1}{n_2}}$ = 0.00135 | 1 | $S_3^2 = \frac{BSS}{k-1}$ = 0.00135 | $F_1 = \frac{\text{SSH:C1}}{S_3^2}$ = 0.042 | $F_{0.95}(V_1, V_2)$ = 4.14 |
| $SS_{H:C2=0}$ | $\frac{(\bar{X}_2-\bar{X}_3)}{\frac{1}{n_2}-\frac{1}{n_3}}$ = 0.00290 | 1 | $S_3^2 = \frac{WSS}{N-k}$ = 0.00290 | $F_1 = \frac{\text{SSH:C2}}{S_3^2}$ = 0.090 | $F_{0.95}(V_1, V_2)$ = 4.14 |
| Error | 1.06883 | 33 | 0.03239 | | |
| Total | 1.07290 | 35 | | | |

The result of ANOVA Orthogonal contrast in Table 4 above revealed that there is no significant difference between morning observations and the combined afternoon and evening observations, $F(1,33) = 0.042, p = 0.839$, nor between afternoon and evening observations, $F(1,33) = 0.090, p = 0.766$. Thus, DOP values were statistically similar across all observation periods.

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**4.2 Discussion of Results**

The results of this study indicate that GNSS satellite geometry in Northeast Nigeria remains relatively stable throughout the daytime observation periods considered. The one-way ANOVA revealed no statistically significant differences in DOP values among morning, afternoon, and evening observations ($F(2,33) = 0.06236, p = 0.939$), while orthogonal contrast analysis similarly showed that neither the comparison between morning and combined afternoon-evening observations nor the comparison between afternoon and evening observations was significant. The mean DOP values for morning (2.617), afternoon (2.615), and evening (2.593) observations were remarkably similar, suggesting that temporal variations in satellite geometry were minimal during the study period.

The observed DOP values, which generally ranged between 2 and 3, indicate favourable satellite geometry suitable for high-precision GNSS applications [3]. The absence of significant temporal variations suggests that satellite distribution remained sufficiently uniform throughout the day, thereby providing comparable positioning conditions across all observation periods. This finding contrasts with earlier studies that reported improved GNSS performance during specific periods of the day, particularly during evening and nighttime hours [9]; [10]; [8]. However, it is consistent with recent developments in multi-constellation GNSS, where the combined availability of GPS, GLONASS, Galileo, and BeiDou satellites has substantially improved satellite visibility and geometric strength. Previous studies have shown that multi-GNSS integration increases satellite availability and reduces temporal fluctuations in positioning quality, resulting in more stable DOP values throughout the day [1]; [2]; [3]. Similarly, [16] reported that multi-GNSS integration significantly enhances satellite availability and reduces temporal fluctuations in positioning quality.

Although the daytime observation periods exhibited comparable DOP conditions, the broader analysis showed that nighttime observations generally produced lower DOP values and higher satellite visibility than daytime observations. This indicates that satellite geometry is slightly more favourable during nighttime hours, thereby providing enhanced positioning conditions. Similar observations have been reported in GNSS mission-planning studies, which demonstrated that satellite visibility and DOP predictions can vary with observation time and influence positioning performance [5]. Nevertheless, the magnitude of these variations in the present study was not sufficient to compromise positioning quality during daytime observations.

From an operational perspective, the findings suggest that GNSS surveys in Northeast Nigeria can be conducted successfully throughout the day without substantial degradation in satellite geometry. This flexibility is particularly important in the region, where environmental conditions,

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logistics, and security challenges may restrict field operations. Consequently, surveyors may prioritize factors such as observation duration, receiver quality, multipath mitigation, and atmospheric corrections while retaining flexibility in observation scheduling. However, for applications requiring centimetre- or millimetre-level accuracy, mission planning based on satellite visibility and DOP forecasts remains advisable to ensure optimal positioning performance.

Overall, the results demonstrate that the current multi-constellation GNSS environment provides stable and favourable satellite geometry across different observation periods in Northeast Nigeria. While nighttime observations offer slightly better positioning conditions, morning, afternoon, and evening periods all provide acceptable DOP levels for routine surveying and geospatial applications.

## 4.0 CONCLUSION AND RECOMMENDATION

### 4.1 Conclusion

This study evaluates GNSS observation timing in Northeast Nigeria using DOP and satellite visibility analyses. The results showed that nighttime observations provide more favourable positioning conditions, with lower DOP values and higher satellite visibility than daytime observations, indicating improved satellite geometry and potential positioning accuracy. However, no significant differences were found among morning, afternoon, and evening observation periods, suggesting that GNSS conditions remain relatively stable throughout the day.

These findings offer operational flexibility for surveyors and other geospatial practitioners, particularly in Northeast Nigeria where security challenges and logistical constraints often affect fieldwork scheduling. Consequently, GNSS surveys can be conducted at different times of the day without significant loss of positioning quality, although nighttime observations remain preferable for high-precision applications. The study highlights the importance of GNSS mission planning using DOP and satellite visibility analysis to optimize survey efficiency, accuracy, and safety in the region.

### 4.2 Recommendation

The study recommends that Surveyors in Northeast Nigeria should prioritize nighttime observations for high-precision applications due to their lower DOP values and higher satellite visibility. However, the relatively stable satellite geometry observed throughout the day provides flexibility in scheduling field operations according to security and logistical requirements. Routine GNSS mission planning and the adoption of multi-constellation GNSS receivers are recommended to enhance positioning accuracy, operational efficiency, and survey reliability in the region.

## REFERENCES

[1] Teunissen, P. J. G., and Montenbruck, O. (Eds.). (2017). *Springer handbook of global navigation satellite systems*. Springer. https://doi.org/10.1007/978-3-319-42928-1

[2] Wang, M., Wang, J., Dong, D., Meng, L., et al. (2019). Performance of BDS-3: Satellite visibility and dilution of precision. *GPS Solutions, 23*(2), 56. https://doi.org/10.1007/s10291-019-0847-x

[3] Kaplan, E. D., and Hegarty, C. J. (2006). *Understanding GPS: Principles and Applications* (2nd ed.). Artech House.

[3] Zhang, Q., Chen, Z., Rong, F., and Cui, Y. (2019). Preliminary availability assessment of Multi-GNSS: A global scale analysis. *IEEE Access, 7*, 147215–147226. https://doi.org/10.1109/ACCESS.2019.2946221

[4] Federici, B., Giacomelli, D., Sguerso, D., Vitti, A., and Zatelli, P. (2011). A web processing service for GNSS realistic planning. *Applied Geomatics, 5*(1), 1–13. https://doi.org/10.1007/s12518-011-0058-9

[5] Gandolfi, S., and La Via, L. (2011). SKYPLOT_DEM: A tool for GNSS planning and simulations. *Applied Geomatics, 3*(1), 35–48. https://doi.org/10.1007/s12518-011-0045-1

[6] Dan, B., Zhang, X., and Li, X. (2019). Multi-constellation GNSS performance assessment and satellite visibility analysis. *Journal of Navigation, 72*(4), 857–872.

[7] Leick, A., Rapoport, L., and Tatarnikov, D. (2015). *GPS Satellite Surveying* (4th ed.). John Wiley & Sons.

[8] Abubakar, T., Babayo, A., and Umar, S. (2017) Time Optimization for GPS Observation Using GNSS Planning *International Journal of Innovative Research in Technology, Basic and Applied Sciences (IJIRTBAS)* vol.4 No.1 pp18-28

[9] Funtua, I. I., & Kamalu, O. J. (2010). Investigation of GPS observation timing and positioning accuracy in Nigeria. *Nigerian Journal of Surveying and Geoinformatics, 3*(1), 45–53.

[10] Opaluwa, Y. D., Ono, M. N., and Eteje, S. O. (2015). Evaluation of temporal variation of dilution of precision and satellite visibility for GNSS positioning in Nigeria. *Journal of Geomatics, 9*(2), 89–96.

[11] Seeber, G. (2003). *Satellite Geodesy: Foundations, Methods and Applications* (2nd ed.). Walter de Gruyter.

[12] Adebayo, A. A., and Tukur, A. L. (1999). *Adamawa State in Maps*. Paraclete Publishers.

[13] Mortimore, M. J. (1989). *Adapting to Drought: Farmers, Famines and Desertification in West Africa*. Cambridge University Press.

[14] Ayoade, J. O. (2004). *Introduction to Climatology for the Tropics* (2nd ed.). Spectrum Books.

[15] Nigerian Meteorological Agency (NIMET). (2023). *Seasonal Climate Prediction Report*. Abuja, Nigeria.

ISSN: 2354-3361
**DOI:** https://doi.org/10.5281/zenodo.21038805

www.journals.unizik.edu.ng/jsis

[16] Li, M., Qu, L., Zhao, Q., Guo, J., Su, X., and Li, X. (2019). Satellite availability and point positioning accuracy evaluation on a global scale for integration of GPS, GLONASS, BeiDou and Galileo. *Advances in Space Research, 63*(9), 2696–2710. https://doi.org/10.1016/j.asr.2017.07.029