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EXPLORING THE USE OF GNSS DATA IN THE IDENTIFICATION OF ACTIVITY AREAS FOR CENSUS ENUMERATION EXERCISE

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ABSTRACT

The Global Navigational satellite System (GNSS) is a satellite based positioning tool that uses signals from artificial satellites in the space to determine time, velocity and positions. The GNSS receiver has countless uses and these may include navigation, surveying and Mapping in general. The aim of this study is to determine, using the GNSS, areas with dense population and more so, areas of much activities for census planning exercise. The Hi-Target V30 GNSS receiver and its accessories were used for the study. The Hi-Target V30 Standalone Receiver's Data were collected for 12 months interval observation. Observations were carried out for 1 hour each on ten (10) different stations and the GNSS raw data were downloaded and converted into RINEX data. A Post-Processing platform was used to process the result in ITRF 14 and WGS 84 datum. The differencing of results showed shifts in the directions to much denser populations areas. These shifts, after interpretations could assist enumerators in further decision making. It is obvious that, the GNSS potentials are limitless as the aim of the research was achieved.

Keywords: GNSS Receiver, coordinate, RINEX data, datum, ITRF 14

INTRODUCTION

Through census, the number of people in a country as well as the structure of the various societies that make up the people can be determined (Zawadi and Simwa, 2021). Census and its significance can be trace back to the earliest century days of Caesar Augustus, the Roman who dominated the entire world as at then (Brindle, 1984). Baffour, King and Valente (2012), expressed that, the primary goal of every census from its inception has been to provide population information of any country where it is undert0aken.

Census outcomes could be used in forecasting of economic needs of a country and which may lead towards providing of jobs to the unemployed and improving the standard of living of the citizens (Okolo, 1999).Census information on the population density could help any government know the social amenity needs of a people and same. More so, foreign donors need this knowledge to provide assistance to governments of nations (Zawadi and Simwa, 2021).

Eromosele *et al.,* (2020) revealed that the global urban population as at 1900 to 2005 has increased by 50% and, these populations could be found more in the urban areas and as the human population increases, activities that could be earth threatening has also increased. Chen (2007) observed that, these threatening activities may include quarrying, mining, borehole drilling, excessive land usage and so on. Anytime the human race migrates into a new location, an imbalance in the system such as increase in earth activities especially, the acquisition of the natural resources underneath the earth likely occurs (ibid).

Technological advancement especially, in the field of Surveying has made it possible to use Global Navigational Satellite System (GNSS) to monitor, analyze and infer earth's movements that could be a result of increased human activities (Grapethin, *et al.,* 2018). Grapethin *et al.,* (2018), Yasuko, *et al.,*(2014) and Steven, (2019) agreed that extraterrestrial impulses like explosions, storm waves buffeting the shores, tidal impacts alongside limestone or rock mining and blasting are also liable for causing earth dynamisms. Of course, other techniques have been used to detect and study movements in the form of velocity detections but, the GNSS has proven to be more reliable, that it detects movements on the ground at high accuracies.

Moreover, from all the reviewed related literatures visited for this work, none investigated the use of GNSS data for census enumeration exercise. Hence, this particular research aims at exploring the use of GNSS data in the identification of activity areas for census enumeration exercise. It is in the objective of this research to monitor earth dynamism in the study area in order to have knowledge of movements or displacements for absolute characterization for census needs; more so, this research wants to reduce the rigours of determining dense areas with large financial budgets by simply deploying the use of GNSS technique.

GNSS and direction determination paradigm

GNSS, is an acronym for Global Navigational Satellite System that has satellites in the space which sends signals to the receivers on any point on the earth's surface. These signals are used to determine positions, time and velocity of points or places of interest on the earth's surface (Salvatore and Petovello, 2015). The velocity, which is movement with directions, is a function of activities on the earth's surface.

Roland *et al.,* (2018) developed algorithms for the instant detection of hazardous slope movements using GNSS data and after use, the estimated results of the GNSS field observations actually showed significant hazardous movements which was likened to slope movements in alpine in the Swiss Alps. The results after further analysis showed that alpines are disposed to breakages, and movements of rocks especially rock glacier which could cause harm to human lives and manmade features.

How *et al.,* (2002) investigated the car racing applications with GNSS data and this investigation measured various key parameters of a test vehicle which include inertial velocity, their precise locations as well as side slips. The results generated by GNSS were a great accomplishment of the objectives of authors.

GNSS receivers can determine the direction of motions to especially the busiest areas (Guma, 2022). Norman and Wisdom (2004) reported that, GNSS data has been used on various platforms including its usage in road vehicles, off-road vehicles, bikes, trains, humans, ships, aircrafts, etc. for assessment of speed limits, energy consumptions, fuel efficiencies, driver performance, mobility of persons, sporter performance in sports activity and traffic management.

Using GNSS to monitor activities on the earth could help to manage the activities in the urban areas and possibly control the threats that urbanization has birthed. These threats have raised concerns from earth tremor to human induced erosions and earthquakes (Guma, 2022).

When the population of a country increases over a period and the area still remains constant, know that its density has increased proportionally. A way of studying the density of population in a place has been by means of Lorenz curve whereby the curve creation involves the plotting of cumulative percentages of population against the cumulative percentages of the area of the place (Clark, 1951). This method could be cumbersome, time consuming and waste of resources.

Research direction

This study tends to use GNS data to determine the directions of many activities in all the places of interest identified in this work. This direction is obtained through the velocity computation which is one of the three major results the GNSS displays to the user community. In the past, population census data have been used to determine most populated areas or the areas with higher activities for planning and decision making. This process of obtaining these data could be cumbersome and rigorous. However, the deployment of velocities using GNSS satellite data has come to make this process easy.

METHODOLOGY

Study Area

Ten (10) points were scattered all over three local Governments Areas (LGAs) in Kogi State and they are Lokoja, Adavi and Ajaokuta respectively. Lokoja is the administrative capital of Kogi State and it has a population of 195, 261 people as at 2006 census (NPC, 2006). Adavi and Ajaokuta are borders to Lokoja LGA in the central direction of the State. The study area covers latitudes 7^0 33’ 30”N to 7^0 55’ 11”N and longitudes 6^0 38’ 4”E to 6^0 25’ 59”E. Kogi state is in North central of Nigeria. It was created in 1991 from parts of Kwara and Benue states. It is bordered by Nassarawa State, Benue, Enugu, Anambra, Delta, Ondo, Ekiti, Kwara and Niger. Abuja Federal Capital Territory also borders Kogi to the north (Lotha, 2022).

Obajana in Lokoja LGA was chosen as a study area because of the mining activities going on at the Dangote Cement factory such that, up to 40, 000 tons of limestone are being mined on daily basis. In Ajaokuta, we still have some partial steel operations there as well as the operations of the Geregu power plants in that area. While in Adavi LGA, in Zango community for example, lots of borehole drilled wells are there. To study their impacts on the earth also spurned this study.

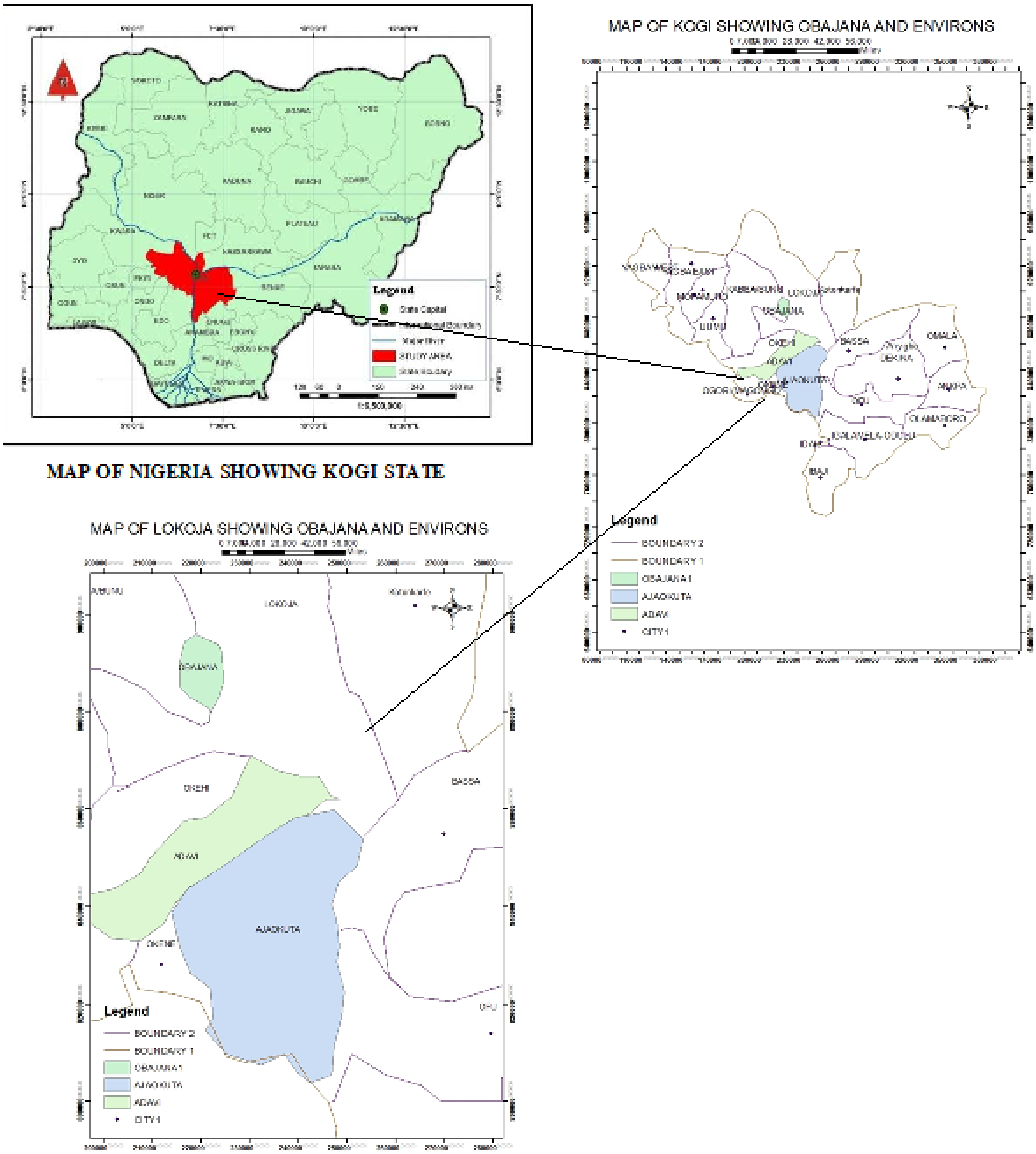

Figure 1: Map of Nigeria showing the 3 LGAs used for the research
Source: Guma, (2022).

Data Acquisition

In order to acquire data for this study, some hardwares were used. They include; the Hi-Target V30 GNSS receivers and its accessories, laptop computer etc. The softwares used include; Microsoft word, excel, and Hi-Target Geomatics office. The data needed is a primary one which comes in Easting and Northing. In Surveying, they are parameters used to define a point on the earth's surface. Recall, it was said that GNSS receiver obtains signal in the form of position, time and velocity (Salvatore and Petovello, 2015). The position that is being referred to here is the Easting and Northing.

The data acquisitions were carried out on Static mode with Hi-Target v30 receiver. The GNSS receiver was made to occupy each of the observation stations for one (1) hour on 12 months interval. The moment for the first phase of observation was February, 2020. Before the observation commenced, an integrity check was performed on the GNSS Hi-Target receiver and the instrument was in order then, a temporary adjustment was usually carried out before every observations as well. The temporary adjustment include; the setting up of the GNSS receiver on the observation stations, centring of the spirit bubble was done with the aid of optical plummet to focus the receiver on the middle of the ground point. Then, the foot screws that are attached with the tribrach of the receiver were simultaneously turned either in or out to guide the spirit bubble to the centre of its run. Subsequently, the height of instrument was noted down by measuring from the tip of the iron rod on the ground mark to the Trunnion axis of the receiver head. The data collector or logger was put on and the connection between the receiver and data logger was established through their inbuilt Bluetooth system.

On the data collector, move to "PROJECT" then, click "STATIC". The station ID were registered as well as the time interval for signal acquisition which was set at 5 seconds. The receiver's antenna mask was left at 15^0 after which the "OK" was pressed to begin acquisition of data. The receiver beeps at every 5 seconds as indication that it is receiving satellite data. At 60 minutes, the data collector was stopped. After this stoppage, all the received data are stored automatically in the memory of the receiver. This process of data acquisition was repeated at all the selected stations of interest.

The second phase of observation commenced in February, 2021. The same procedure as the first was performed on the selected 12 stations. At Obajana, the data for one (1) observation point with the Prefix, PHD 017 was acquired. The point PHD 017 is located few meters away from the main mining site of Dangote cement factory in Obajana, where bombings and quarrying are been carried out.

In Adavi Local Government Area, there were PHD 023 and PHD 024. In Felele area of Lokoja, there were PHD 001 (around Naval Base, Banda), PHD 006. In Lokoja town, there are PHD 008, PHD 007, PHD 023 and PHD 024 and in Ajaokuta Local Government Area, there is PHD 011. After the acquisition of satellite data in both phases of observations, the downloading cable was then, used to transfer the data into a laptop. The Primary data came in the form of ".GNS".

Data Analysis

After the post-processing computation was done using CSRS-PPP platform, the results were displayed with their individual error ellipse in table 1 which were computed for also.

Guma (2022) and trimble (2019) expressed that, the standard (1 sigma) error ellipse can be used to analyse the accuracy of observation data. However, the error ellipse for each position is calculated by the post-processing platform and the results are presented in table 1. The general results showed that the results were in centimeter level accuracy which is typical of GNSS-PPP observation made for one (1) hour duration.

Table 1: Error ellipse for the observations.

STN ID	95% ERROR ELLIPSES ()	FIRST PHASE	FOURTH PHASE
	Semimajor Axis (m)	0.092	0.016
PHD 001	**Semiminor Axis (m)**	0.039	0.012
	Semi-major Azimuth (°)	-89.4	86.60
	Semimajor Axis (m)	0.146	0.131
PHD 006	**Semiminor Axis (m)**	0.065	0.037
	Semi-major Azimuth (°)	57.70	-83.98
	Semimajor Axis (m)	0.15	0.227
PHD007	**Semiminor Axis (m)**	0.044	0.063
	Semi-major Azimuth (°)	78.51	-75.75
	Semimajor Axis (m)	0.0113	0.262
PHD 008	**Semiminor Axis (m)**	0.038	0.051
	Semi-major Azimuth (°)	-80.92	82.64
	Semimajor Axis (m)	0.095	0.109
PHD011	**Semiminor Axis (m)**	0.04	0.028
	Semi-major Azimuth (°)	-84.07	83.45
	Semimajor Axis (m)	0.024	0.021
PHD016	**Semiminor Axis (m)**	0.015	0.016
	Semi-major Azimuth (°)	46.18	-61.27
	Semimajor Axis (m)	0.0014	0.223
PHD017	**Semiminor Axis (m)**	0.0010	0.049
	Semi-major Azimuth (°)	-64.46	86.88
	Semimajor Axis (m)	0.023	0.163
PHD018	**Semiminor Axis (m)**	0.019	0.049
	Semi-major Azimuth (°)	83.48	-81.06
	Semimajor Axis (m)	0.023	0.019
PHD021	**Semiminor Axis (m)**	0.013	0.010
	Semi-major Azimuth (°)	-89.80	67.80
	Semimajor Axis (m)	0.161	0.0283
PHD023	**Semiminor Axis (m)**	0.035	0.035
	Semi-major Azimuth (°)	84.99	-86.70
	Semimajor Axis (m)	0.13	0.402
PHD024	**Semiminor Axis (m)**	0.04	0.06
	Semi-major Azimuth (°)	-79.9	-80.36

Source: Guma (2022)

Data Processing

The results for the two separate phases of observations are presented in table 2 and they were obtained as stated earlier in 12 months interval.

Table 2: PPP result for February, 2020 and 2021 GNSS-PPP Observations

S/N	STN ID	FEBRUARY 2020		FEBRUARY, 2021	
		EASTING (m)	NORTHING (m)	EASTING(m)	NORTHING(m)
1	PHD 001	252506.448	872471.814	252506.491	872471.823
2	PHD 006	252670.394	868382.856	252670.505	868382.891
3	PHD 007	249303.245	862100.665	249303.325	862100.626
4	PHD 008	251812.304	864381.901	251812.334	864381.899
5	PHD 011	241153.682	843998.099	241153.662	843998.130
6	PHD 016	217416.604	881042.205	217416.606	881042.204
7	PHD 017	218015.872	883422.256	218015.899	883422.248
8	PHD 018	217698.872	882087.851	217698.895	882087.844
9	PHD 021	246109.945	864605.587	246109.949	864605.568
10	PHD 024	239193.685	864424.162	239193.763	864424.186

Source: Guma, (2022)

In the processing of the GNSS data obtained, this study adopted the formula called positional differencing as postulated by Tu (2013) and used by Guma, (2022) for velocity determination. Velocity being a vector quantity, must have direction however, the scalar of it is called the speed or displacement and can be obtained first via;

$$\text{PPPVE} = \frac{dr}{dt} = \frac{r_2 - r_1}{t_2 - t_1} \quad (1)$$

PPPVE means Precise Point Positioning Velocity Estimation, $r_2 - r_1$ is the change in position between two epoch observations, $t_2 - t_1$ is the time interval the SPP acquires the data. In this research, 5 seconds interval was used.

To go further, the direction of this speed or movement must be determined in order to know the directions of movements. Mind you, locations of much activities or population density are usually the directions of our displacements (How *et al.*, 2002). In determining the direction of velocity or movement, the surveying conventional bearing formula was used, thus;

$$\theta = Tan^{-1}\left[\frac{\Delta E}{\Delta N}\right] \quad (2)$$

ΔE = difference in easting of same point observed twice

ΔN = difference in Noerthing coordinate of same point observed twice

After the speed has been measured with equation 3.1, then the direction would be obtained using equation 3.2. This computation was carried out for every point in the various study area.

Let us solve for observation point, PHD 001 and see; for the speed calculation in the Easting direction, we have; $\Delta E_{21-20} = 252506.491 - 252506.448 = \mathbf{0.043}$

Δt is the time interval at which the receiver was set to capture signal. In this case,Δt is 5 seconds.

Recall,

$$\frac{E_{21} - E_{20}}{\Delta t} \quad (3)$$

$$= \frac{0.043}{5} = \mathbf{0.0086 m/s}.$$

For speed in the N direction; $N_{21-20} = 872471.823 - 872472.814 = \mathbf{0.009}$

$$\frac{N_{21} - N_{20}}{\Delta t} \quad (4)$$

$$= \frac{0.009}{5} = \mathbf{0.0018 m/s}$$

For speed of the station, we have;

$$\frac{\sqrt{\Delta E^2 + \Delta N^2}}{\Delta t} \quad (5)$$

$$\frac{\sqrt{0.043^2 + 0.009^2}}{5} = \mathbf{0.0087 m/s}$$

The same procedure was used to compute the E-direction movements, N-direction movements and station movement for all the points. Therefore, the results of movement (velocity) estimation using February, 2020 and February, 2021 GNSS data are presented in table 3. For understanding of the headings, V_E means speed in the Easting direction, V_N means speed in the Northing direction and V_{EN} means velocity (direction from the station in degree decimal).

Table 3: Results of observations and the displacement and Directions of movement with their values respectively

STN	EASTING (m)	NORTHING (m)	V_E(m)	V_N(m)	V_{EN} (m)	V_{EN} (Degree decimal)
PHD 001	252506.448	872471.814	0.0086	0.0018	0.0087	78.1785
PHD 006	252670.394	868382.856	0.022	0.007	0.023	72.4991
PHD 007	249303.245	862100.665	0.016	0.0078	0.0178	115.9892
PHD 008	251812.304	864381.901	0.006	-0.0004	0.006	273.8141
PHD 011	241153.682	843998.099	-0.004	0.0062	0.0074	327.171
PHD 016	217416.604	881042.205	0.0004	-0.0002	0.000089	116.5651
PHD 017	218015.872	883422.256	0.0054	-0.0016	0.001126	106.5044
PHD 018	217698.872	882087.851	0.0046	-0.0014	0.00480	106.9275
PHD 021	246109.945	864605.587	0.0008	-0.0038	0.0007766	168.1113
PHD 024	239193.685	864424.162	0.0156	0.0048	0.016321	72.8973

Source: Guma, (2022).

RESULTS AND DISCUSSIONS

Discussions on the findings of the direction of movements (velocities)

The major findings on the various directions of movements indeed corresponded with what Norman and Wisdom (2004) inferred and wrote about in their work. In their research, directions of movements (velocities) were estimated and in turn used to derive recreational density, deer and elk movements.

At the point PHD 001, the GNSS data showed lots of activities and movements in the North East (NE) direction and this point falls under the bearing value of 78.1785 degree decimal. Of course, since the point of observation PHD 001 is actually located in Banda town close to the Naval Base, a closer investigation showed that the movement which was towards the NE direction was in the direction of the most populated or what is called the core of the Banda town itself. Which clearly indicated that, the activities of that part of the town is having effect on the earth as observed from the point of observation. Every other part of the town may be having activities but, it is more in the direction of the velocity of the GNSS data.

At PHD 006, the direction was towards the NE direction from the observation point. After investigating this direction of movement, it was revealed that the direction of the point's movement as provided by the GNSS data is the ever busy Abuja-Lokoja express way. Vehicular movements have effects on the observation point.

At PHD 007, the movement of velocity was in the SE direction from the observation point. After due investigation, it was discovered that in the SE direction of PHD 007, there were roundabout, shopping malls, motor parks and garages. The activities in this area are having effects on the earth as displayed by the GNSS data.

From the observation point PHD 008, the direction of movement is towards the North West (NW) direction with the bearing of 273.8141 degree decimal. After careful investigation, it was discovered that the popular old market, the Palace of the Maigari of Lokoja (a first class chief of Lokoja Township) and the heart of that area is in that direction. This showed that the activities of the people in this area have been causing some earth movements.

Ajaokuta LGA where the observation point, PHD 011is, the GNSS data acquired showed movement in the North West (NW) direction. In this NW direction from the observation point, there is the popular Ajaokuta Steel Company, Geregu Power Plant and the Ajaokuta Villages. The activities in this area can characterize the area as having much dense population.

Observation points PHD 016, PHD 017 and PHD 018 were all located close to the Dangote Cement Mining site in Obajana. The three points' directions are towards the South East (SE) of the observation point. A careful analysis showed that the three directions are towards the main mining site where quarrying, mining and blasting of limestone occur almost on daily basis.

At PHD 021, the bearing is 168.113 degree decimal and it was moving in the direction of SE from the observation point. It was noticed that in that direction, there is the Army Barrack and Otokiti Housing Estate, which suggest that, there are more human activities in that direction.

At PHD 023, the velocity was in the SE direction which has a popular Timbershed where lots of activities occur on a daily basis.

At PHD 024, the direction of velocity movement was in the NE direction of the observation point. It was discovered that, in that direction, there were dug six boreholes and the Obajana-Lokoja express way passed through that direction too.

Therefore, with the various findings, it can be inferred that velocity flow in the directions of more activities. This finding tends to agree with Norman and Wisdom (2004) who used GPS data to detect direction of movements of deer, elk and recreational density.

CONCLUSION

The GNSS has proven one of its potentials of determining the directions of many activities in a locality. With the various results obtained after simulations, it could be said that the demography of a place can be characterized with it. The aim of this study, exploring the use of GNSS in the identification of activity areas for census enumeration exercise was achieved. The Hi-Target Standalone Receiver's 12 months interval data were downloaded, converted into RINEX data and Post-Processed. The differencing of the two different data showed shifts in the directions of much denser populations. This shifts, after interpretations could assist enumerators in further decision making.

This study may have some limitations hence, it is recommended that further research such as exploring the use of sophisticated and more accurate techniques like the inSAR and LIDAR which are capable of producing higher accuracies in terms of deformation monitoring and earth dynamic analysis. The use of GNSS-PPP is yet to have wide acceptability so, there is need for a comparison with Differential GNSS positioning technique to conduct further research. Finally, it is recommended that the National Population Commission (NPC) create a geodynamic unit to help in collating dense population data of activities in places for these data may reveal disaster prone localities for census documentations. As this may help also, not only in census alone but in disaster management too.

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