ESTABLISHMENT OF A BASIC GEODETIC NETWORK FOR TOPOGRAPHIC SURVEYS AT 1/25000 SCALE IN THE MUNICIPALITY OF ALLADA

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ABSTRACT

The geodetic network is an important element in the reliability of geographic information. The insufficiency of the geodetic points on a territory reduces the positioning precision of the elements collected at certain places during the work of topographic surveys carried out on this territory. Surveyors, cartographers and other geographic information actors are often confronted with these kinds of situations in Benin. This is why the National Geographical Institute (IGN) is often asked to put in place two points serving as a basis for carrying out certain punctual topographic works. Thus, in order to contribute to the grid of the Beninese territory by the geodetic points that the municipality of Allada was identified within the framework of the realization of the project. The methodology put in place to achieve the set objectives includes three (03) parts that are: the documentary research, the collection of the data and their treatment. These various steps resulted in the establishment of fifty one (51) new geodetic points added to the existing ten (10) to cover the entire area of the municipality. The average distance between two points being 2.5km. Among the various GPS / GNSS methods used to carry out the observation campaigns of these points, it is the method of the central pivot or static mode with short baselines that has been chosen in order to have centimeter precision. The realization of the assembly chart of the aerial photography photos (PVA) on a scale of 1/25000 on the map of the Allada geodetic points made it possible to assess the position of the geodetic points. The marking of these terminals (signaling of the terminals) on the photos is obtained thanks to the construction of horizontal slabs or terraces of dimension (1.50mx 1.50m and 0.10m thickness above the ground) realized on the spot in such a way that the marker represents the center of the dallette. Durability, precision and homogeneity are the three characteristics of this geodetic network.

KEYWORDS: Allada, geodetic points, scale 1/25000, signaling.

1. INTRODUCTION

Land information is of great interest to all those concerned with knowledge of land use and / or development. This information is obtained through topographic maps or maps from topographic surveys.The geodetic network represents the support of topographic surveys. It constitutes the unique reference, guarantor of the geometric coherence, at the national level, of the reliability of the geographical information and all the works of regional planning (Legendre, 2013).Each country concerned with the sustainable development of its territory tries to set up a policy to improve its geodesic network in order to have a precise geodetic network in a unique system accessible to any actor in order to guarantee land security. In order to contribute to the quality of data collection through topographic surveys in Benin, the theme "Implementation of a basic geodetic network for 1/25000 scale topographic surveys in Allada" was initiated.

The work was organized around three main parts and is as follows:

- The first part deals with the theoretical framework and the geographical framework of the study;
- The second part presents the methodological approach adopted for setting up this geodetic network;
- The third part presents the results and discussions.

2. BACKGROUND AND JUSTIFICATION

In Benin, as in most African countries, increasing competition for access to land and other natural resources is leading to increased conflict and speculation over the main factor of production, land. As a result, Benin now ranks among the countries of the West African subregion, which are marked by a steady growth in land disputes of all kinds (Diakété, 2003). If the reasons for these conflicts are of several kinds, the technical device used by topographers and cartographers greatly contributes to this situation. This is the case of the existence of several coordinate systems whose use of the coordinates of a system instead of another resulting in overlaps on different planes. Indeed, the attachment to several geodetic systems has sometimes led to the duplicity of titles on the same parcel of land; similarly, the absence of a reliable tracking system can lead to many errors ranging from the positioning of a simple monument to the delimitation of national boundaries. All this leads to land insecurity, which has consequences for socio-economic development, peace and stability (Degbegnon, 2017).

These problems of land insecurity will find a solution in the establishment of a unique geodetic reference system throughout the national territory for the realization of topography, mapping, sanitation and urban planning (Degbegnon, 2012). It is with this in mind that since 2009, the land access component of the Millennium Challenge Account (MCA) compact had funded the construction of seven (7) permanent GPS / GNSS stations that covered 95% of national territory (Degbegnon and Houinou, 2014). These stations are integrated into the global GNSS-CORS (Global Navigation Satellite System - Continuously Operating Reference Station) network (Da Morou, 2016). They made it possible to establish the Rural Land Plans (PFR) in several localities of Benin. This new equipment makes it possible to attach topographic work with GPS / GNSS receivers to the WGS84 global geodetic system, despite the fact that the geodetic points provide little coverage of the national territory (Degbegnon and Houinou, 2014).However, surveying surveyors and cartographers encounter difficulties with respect to the insufficiency of meshes of the geodesic points of Benin. And this for several reasons to know:

- Real-time information from permanent stations is only accessible with the use of GPS/GNSS receivers as a field survey instrument. While this modern instrument is not within the reach of all budgets. Very few surveying firms have them;
- Information from permanent stations depends on satellites and information and communication technologies. They may be inaccessible because of these facilities that are destroyed in undesirable conditions: period of clashes, war ... Similarly, permanent stations may cease to function for several reasons: destruction of facilities, power failure, disconnection of the telephone network or the Internet (Degbegnon, 2012);
- The coverage at 40% of the national territory in geodetic points (Degbegnon, Houinou, 2014), does not allow the attachment of all topographic works with the use of conventional instruments such as optico-mechanical devices, total stations ..., taking into account the distance between two consecutive points of 40km for the first order and 8km for the second order (order 0068 / MUHRFLEC / DC / SGM / IGN / DGURF / SA) of 28th December 2009;
- Some topographical work requires the materialization of ground points for the processing of collected information: This is the case of photogrammetric surveys.

Today, surveys of large areas are carried out almost exclusively by photogrammetry. These types of surveys are performed either on a scale and with resolution or scale only; this depends on the type of equipment used for collecting field data. The choice of the aerial shooting scale (PVA) is conditioned by the details that one wants to be able to identify, because the identification of the objects to be restored must be done on the photo itself. (CNIG, 1993). To promote the realization of major economic development projects of the Republic of Benin, it is desirable to survey the territory of Benin at the scale of 1: 25,000. This is why it is necessary to densify the network to at least 3rd order (Degbegnon, 1993) in order to create a basis for horizontal and vertical surveys. Always to go in the same direction, (Annals of geography, 1901) recommend on a surface of 100km², one needs at least six (06) points for a survey to scale 1/50000 and twelve (12) to fifteen (15) points for surveys at 1/25000 scale. For this, it takes a geodetic network of 3 to 4 order to reach this density and locatable on the PVA.

Faced with the various reasons listed above, many technicians who operate with conventional equipment, find arguments to work in a so-called local system or that of their choice without worrying about the necessary connection. This can lead to conflicts between alleged owners. To reduce the risks of land insecurity that plague municipalities, it is desirable to progressively install the complete geodetic network in seventy-seven (77) communes. This is the reason why the municipality of Allada which is about fifty kilometers from Cotonou has

been identified. With its strategic position in relation to the road infrastructure that is the interstate national road (RNIE) No. 2 and the national road (RN) No. 3, Allada is currently the chief town of the department of the Atlantic. This research whose theme is entitled: **"Establishment of a basic geodetic network for topographic surveys on a scale of 1/25000"** which involves putting In place of geodetic points throughout the territory of Allada, arises from a real need felt and this through questions asked in regular ways namely:

- What is the role of land surveyors in the prevention and settlement of land disputes?
- What is the current state of the geodetic network of the commune of Allada?
- How to densify the network and make reliable topographical work on the entire area of the municipality?

These are some questions that motivate and justify the choice of theme.

The general objective of this research is the creation of a geodetic network that will meet the requirements of topographic surveys at 1/25000.

It is specifically about:

- To Realize the densification of the geodetic network of the municipality of Allada;

- to Propose a mode of observation of the points created by the GNSS method;
- to Carry out the survey topographical scale 1/25000 of the municipality of Allada.

3. PRESENTATION OF THE STUDY AREA

Geographically, the municipality of Allada, capital of the department of the Atlantic, is about 56 km from Cotonou, the economic capital of Benin. It covers an area of 384 km². It is limited to the North by the municipality of Toffo, to the South by the municipality of Tori-Bossito, to the East by the municipality of Zè, to the West by the commune of Kpomassè and the Couffo department. It is subdivided into 12 districts, which in turn are subdivided into 84 village districts.

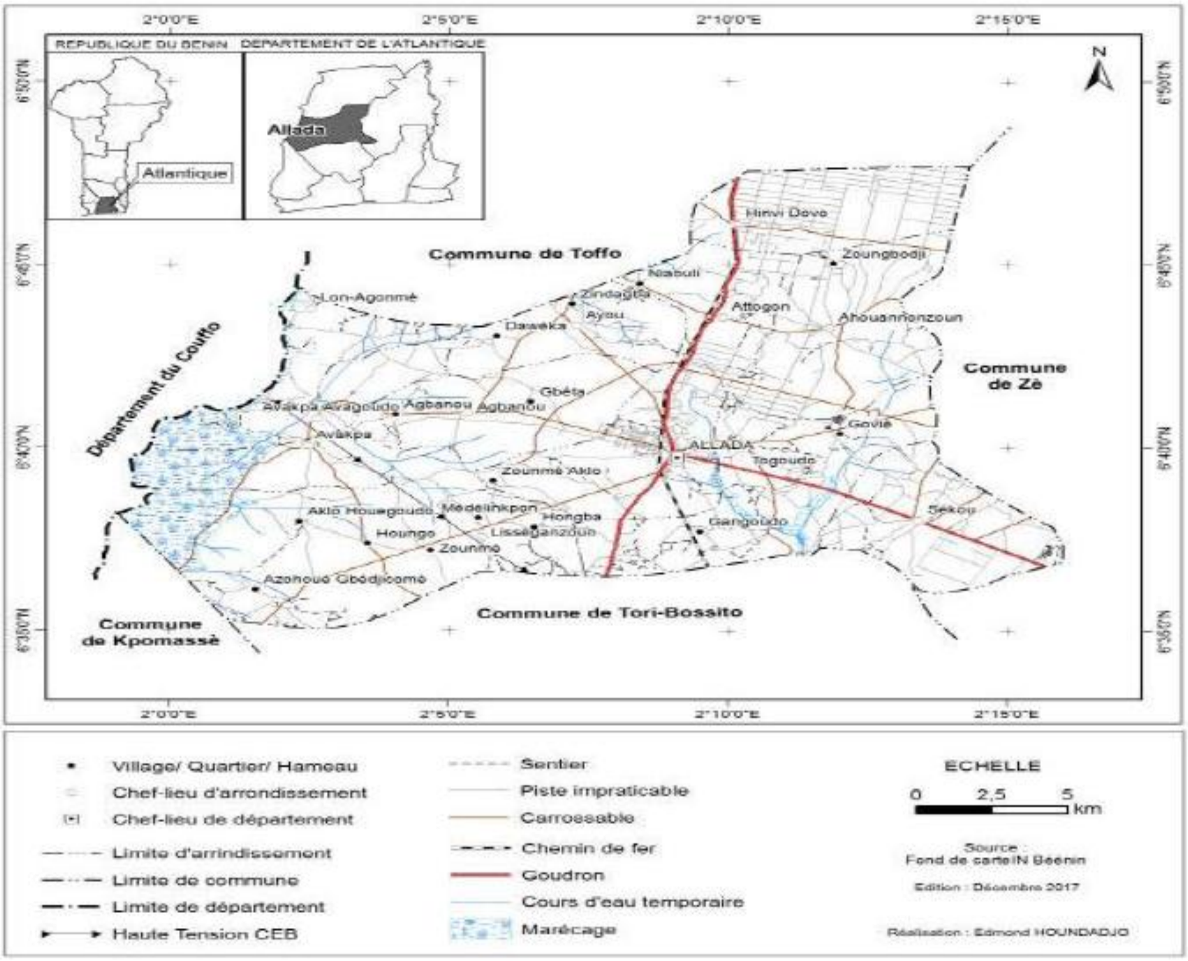


Figure 1 :Administrative map of the municipality of Allada

4. METHODOLOGICAL APPROACH

The methodological approach used to complete the project includes the following elements:

✓ **Inventory management**

This work is limited to checking the location and the state of the Geodesic Network of Benin on the one hand and the General Leveling Network of Benin on the other hand in the municipality of Allada as indicated by the data sheets designed for this purpose. effect.

✓ **Determination of the number of points necessary for the mesh in the municipality of Allada**

In order to know the number of points that will be sufficient to cover the municipality of Allada in order to carry out topographic surveys at the scale 1/25000, the following calculations have been made:

- Number of points offered to cover 100 km² = 15 points.
- Number of points to cover the municipality: N this number

  $N = \frac{15 \text{ x surface d'Allada}}{100} = \frac{15 \text{ x } 384}{100}$= 58 points
- Calculation of the theoretical distance between two geodesic terminals: either from this distance

  $\boldsymbol{d} = \sqrt{\frac{\boldsymbol{surfacedelacommune}}{\boldsymbol{nombredepointscalculés}}}; \boldsymbol{d} = \sqrt{\frac{\mathbf{384}}{\mathbf{58}}}$ **= 2.5731 km**

- ✓ **Technique for creating new geodetic points**

On the digital map of the municipality of Allada and from an existing terminal, precisely point number 240 of 2th order, the new points were created. The intersections of 2500 m radius circles are the new points created. Points that are very close to existing points are deleted or moved. This allowed to have a harmony of distance between the old and the new points which will constitute all the geodetic points of the municipality of Allada.

- ✓ **Criteria for choosing favorable sites for the construction of the new terminals**.

One of the important features of geodetic monuments is their durability. To have this, the Google Earth software is used to identify community social infrastructure namely schools, health centers ... that will receive these terminals because the roads and equipment plans are in paper version and cover only a few villages of 2 districts on the 11 of the commune.

- ✓ **Characteristics of the created terminals**

The created markers will have the pyramidal shape with a base of 40cm x40cm and a height of 30cm above ground. The final choice of the site is determined by considering the characteristics that are: accessibility, satellite visibility, seating and stability.

- ✓ **Evaluation of the accuracy of the new points by the least squares method.**

To do this work, we took part of the study area. Thus, over an area of 100km² we have: 13 points created (ALD05; ALD09; ALD10; ALD11; ALD13; ALD14; ALD15; ALD20; ALD21; ALD22; ALD23; ALD26 and ALD27) and 4 existing points (235; 236; 237 and 239). These are connected to each other by 33 base lines named 1 to 33. Matrix calculations are done in Excel.

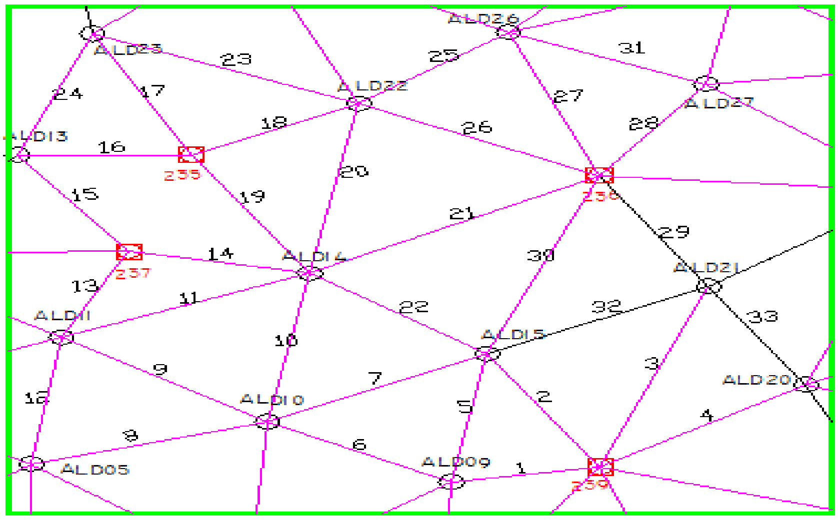


Figure 2: project evaluation area

- ✓ **Choosing a GNSS method**

To make it possible to observe new points from existing geodetic points, the so-called central pivot GNSS method or short-baseline GNSS method was used. Thus, the coherence between the two orders of the network will be more easily ensured. For the implementation of this method an empirical formula is used with bi-frequency GNSS receivers, geodetic networks whose baselines do not exceed 30 km.

Station time = 15min + 1 min per kilometer of baseline + 1 min per 100 m of elevation gain

Some factors are to be considered in the use of this method: it is about the influence of the observation time and that of the number of pivot on the results obtained.

- ✓ **Stability control of existing 2nd order points that constitute the pivots**

For this, we must see if they have not moved in time. The method used is the multi-station and the reference points will be the permanent stations of Cotonou, Abomey and Savalou.

- ✓ **Altitude of the points of the geodesic network created**.

The geodesic points will be known in altitude thanks to the geometric or direct leveling taking as markers, the macarons of the RNGB which are on the territory of ALLADA.

- ✓ **Signaling of geodesic points**

The signaling of the points of the network will be carried out as follows:

- It will be manufactured and cast on site, a horizontal slab of 150 x 150 cm² base and 10cm thick above the ground so that the terminal will be the center of the slab.
- Pass white paint over the entire surface of the slab. This color will locate the terminals on the photos.

- ✓ **Realization of aero-photographic survey at the scale 1/25000 of the municipality of Allada.**

For this project the plane was chosen considering the surface to be covered. After the various calculations in the planning of the flight plan for aerial photography, the following summary table was made.

Table I: Summary of flight plan calculation results

General parameters	**values**
Focal Length	100.5 mm
Scale of survey	1/25000
Total number of images to cover 483km²	392
Resolution	15 cm
Hover-height	2625 m
Longitudinal overlap	60%
Side overlay	30%
Size of the image in the direction perpendicular to the flight	1696.5 m
Size of the image in the direction of the flight	2596.5 m
Inter-band distance	1187.55 m
Inter cliché distance	1038.6 m
Number of flight lines	20

5. RESULTS AND DISCUSSION

5.1 Results

- ✓ **Inventory of 2nd order geodetic markers:**

Plate 1: Results of the nine (09) geodetic markers in place in the municipality of Allada out of the 10 announced at the start.

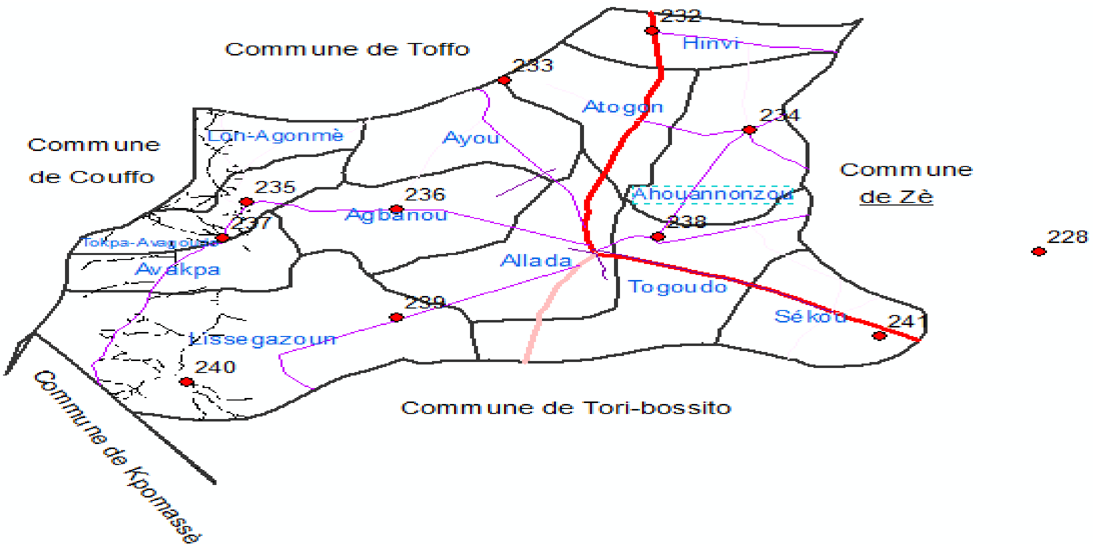


Figure 3: Position of existing 2nd order geodetic points in the municipality

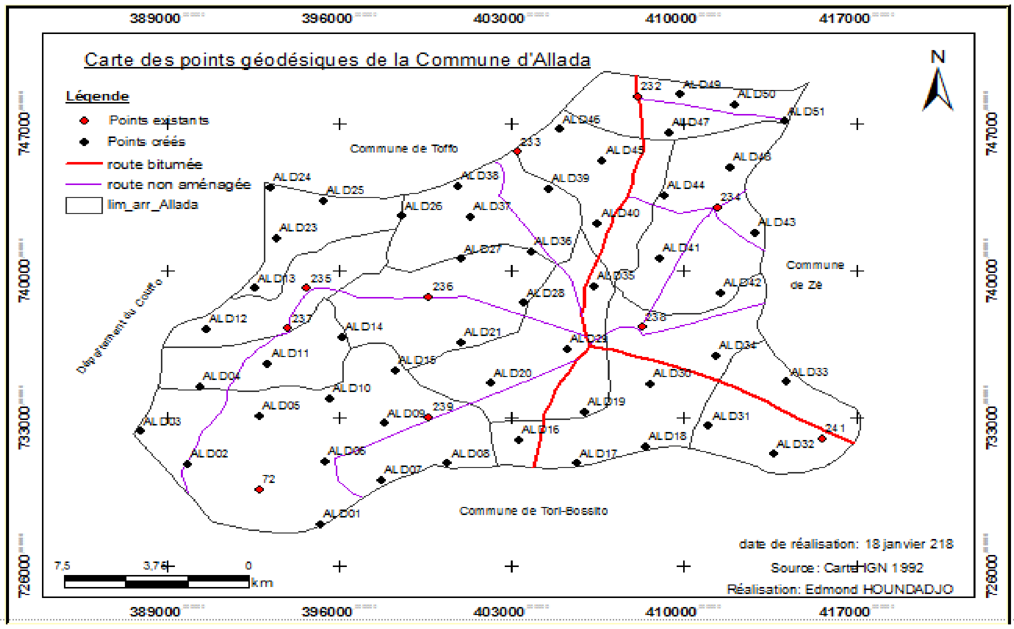


Figure 4 : Map of the geodesic points after the creation of the new points

A total of 51 new and 10 old points.

- ✓ **Choice of favorable sites for the construction of the new kiosks with Google Earth**

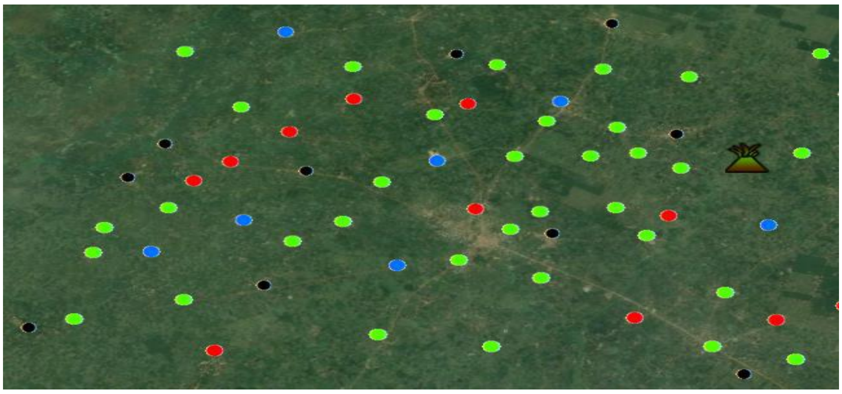


Photo 2:Overview of the spatialization of Allada points after study on Google Earth. In black color the points of the 2nd order existing and the other colors the new points created.

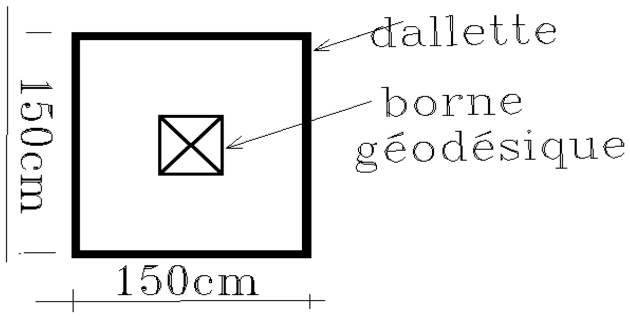
Photo 3: Locating the new ALD09 point that will be in the Adjadji-Cossoe EPP

Photo 4: Locating the new ALD06 point that will be in CEG Lissègazoun ALD09

Table II: Accuracy of each point in the project evaluation area

Points	rms	Points	rms
XALD09	0.00873746	YALD11	0.00783288
YALD09	0.0066099	XALD14	0.00739567
XALD15	0.00791847	YALD14	0.00903652
YALD15	0.011592	XALD13	0.01136365
XALD21	0.00848927	YALD13	0.0084698
YALD21	0.01123026	XALD23	0.01032132
XALD20	0.00879424	YALD23	0.00862269
YALD20	0.0067883	XALD22	0.00610732
XALD10	0.00871413	YALD22	0.0071951
YALD10	0.00894779	XALD26	0.01140457
XALD05	0.00762969	YALD26	0.00782145
YALD05	0.00947966	XALD27	0.0138004
XALD11	0.01107974	YALD27	0.01273284

- ✓ **Result of the signaling of the geodesic terminals**



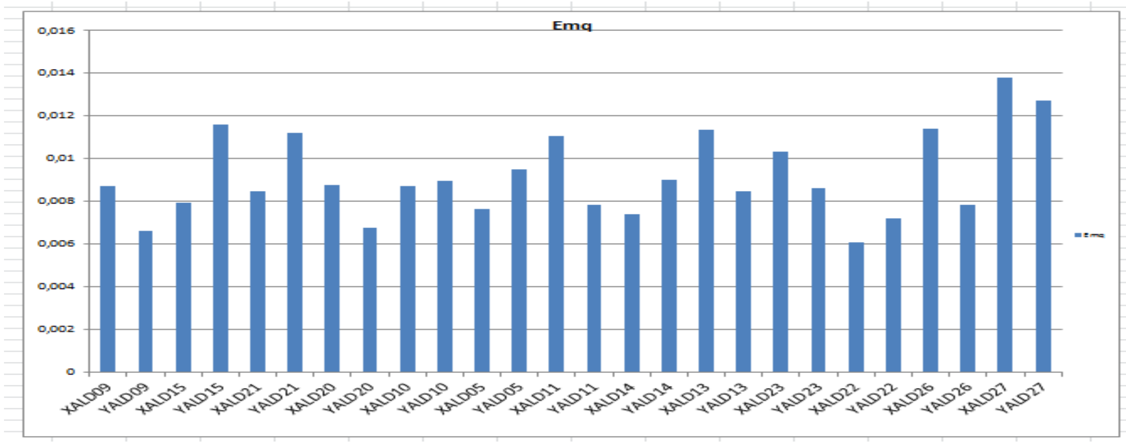


Figure 5: Histogram of the precision of each point created from the calculated data

Table III: Calculation of network accuracy indicators

	Precision (meter)		
parameters	**Min**	**Max**	**consumption**
dx	0061	0,0138	0.00995
Dy	0.0066	0.0127	0.00965
$\sqrt{dx^2 + dy^2}$	0.0090	0.0188	0.0139

From the histogram and the table above, it is noted that the accuracies of the calculated points vary between 0.006m and 0.014m which is less than c = 0.015m fixed at the beginning. From which it can be concluded from this sampling that the network produced will have centimeter accuracy on average.

- ✓ **Results from test observations made on 4 points, from 2 pivots (COLLIGNON, 2014)**

Differences observed after studying the influence of observation time

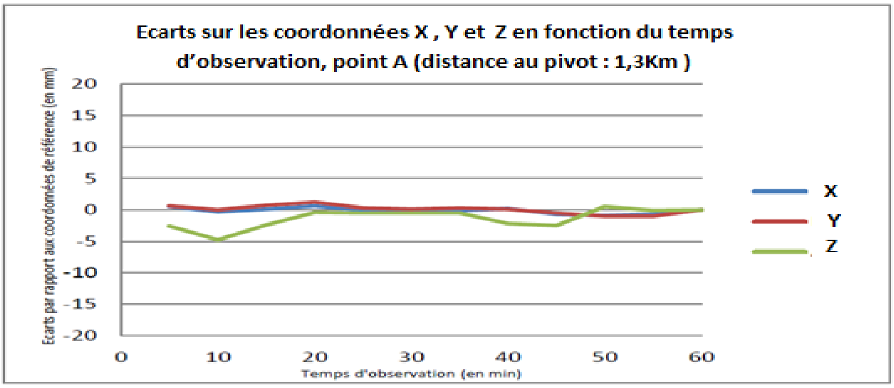


Figure 6: Deviations between coordinates from observation sessions between 5 and 55 min and reference coordinates (60 min observation session) Results for point A (distance to pivot: 1.3 km)

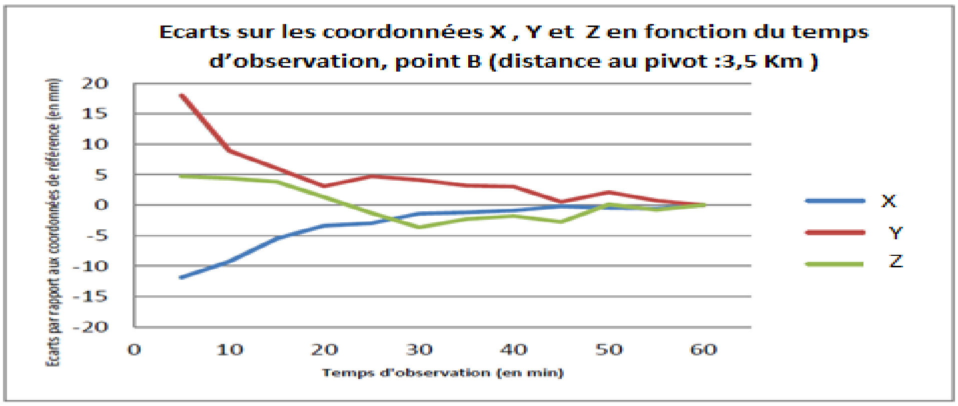


Figure 7:Differences observed between coordinates from observation sessions between 5 and 55 min and reference coordinates (60 min observation session) Results for point B (distance to pivot: 3.5 km)

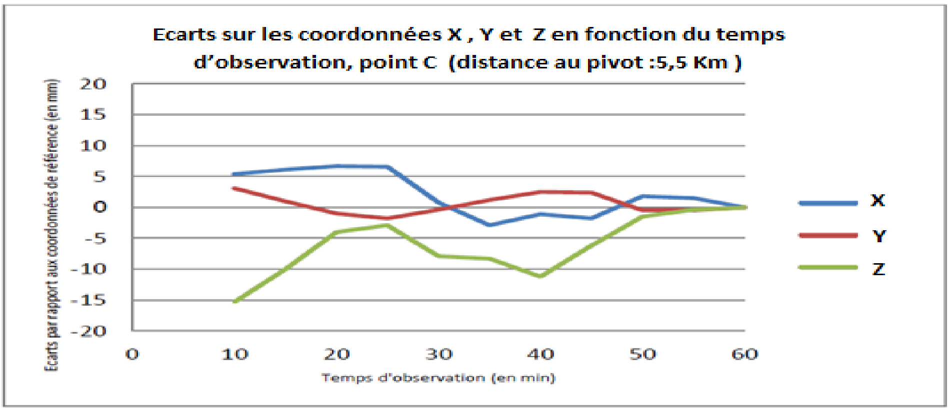


Figure 8: Differences observed between the coordinates resulting from observation sessions between 10 and 55 min and the reference coordinates (60 min observation session) - Results for point C (distance to the pivot: 5.5 km)

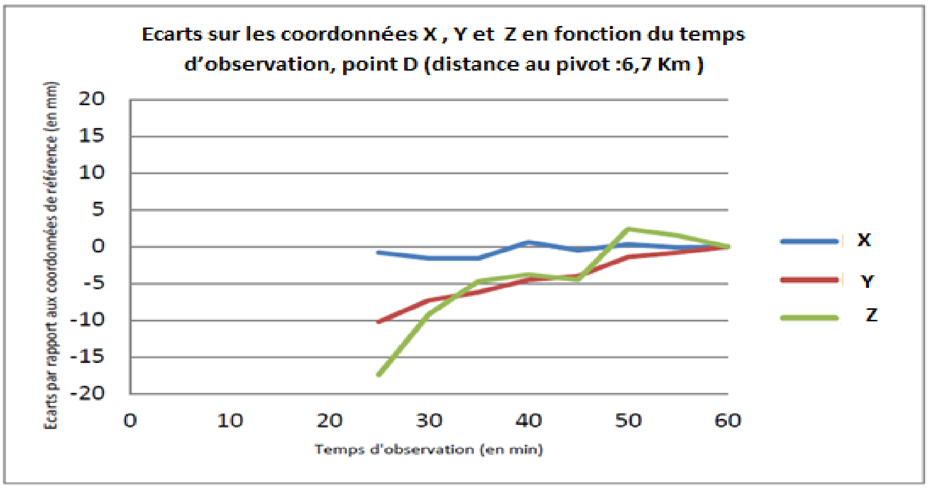


Figure 9: Differences observed between the coordinates resulting from observation sessions between 25 and 55 min and the reference coordinates (60 min observation session) - Results for point D (distance to the pivot: 6.7 km).

From the four figures above, it can be seen that the differences observed depend on the distance between the observed point and the point from which it was observed. We can say here that if the distance is short, we reach the expected result in a few minutes; and that the more the point observed away from the pivot, it takes more time of observation to reach the result.

- **Differences observed after studying the influence of the number of pivots on the results obtained.**

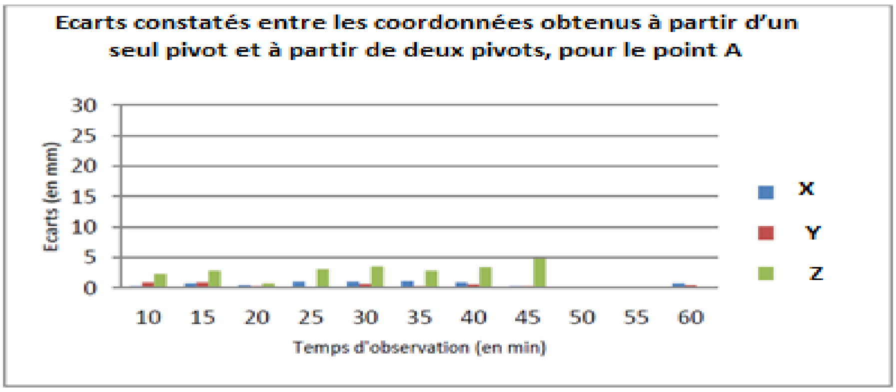


Figure 10: Differences observed between the coordinates obtained from a single pivot and from two pivots for the point A, as a function of the observation time

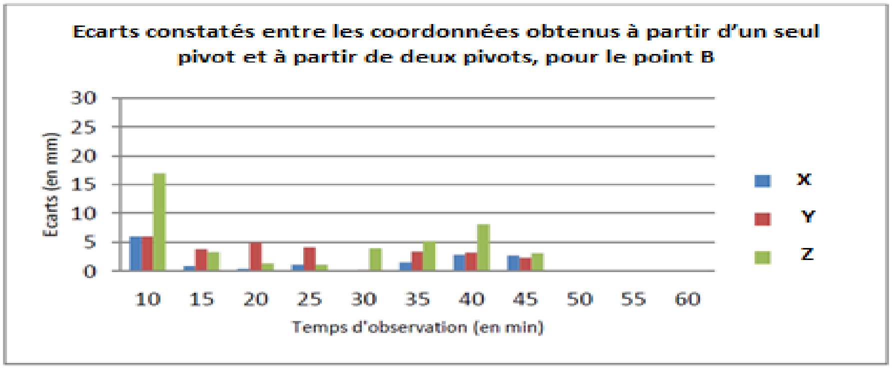


Figure 11: Differences observed between the coordinates obtained from a single pivot and from two pivots for the point B, as a function of the observation time.

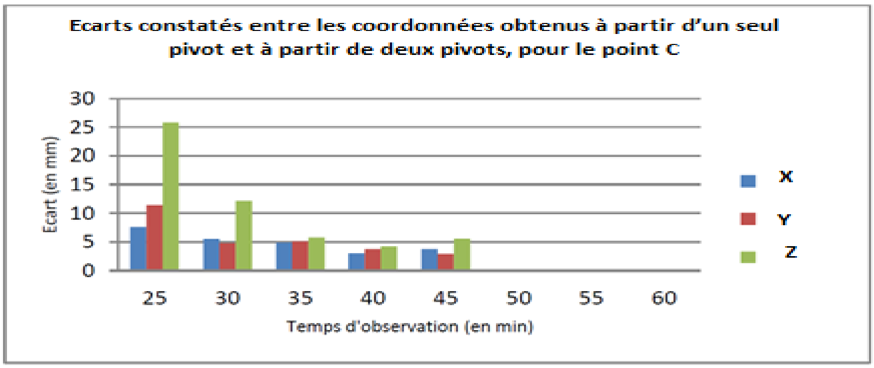


Figure 12: Differences observed between the coordinates obtained from a single pivot and from two pivots for the point C, as a function of the observation time.

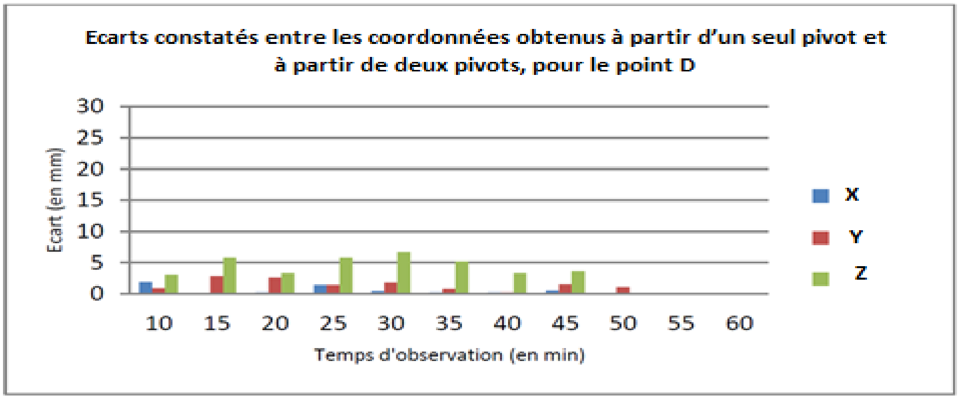


Figure 10: Differences observed between the coordinates obtained from a single pivot and from two pivots for the point A, as a function of the observation time

From the four figures above, we note that the use of two pivots does not give so much significant differences on the coordinates obtained. But the presence of the latter is not negligible; because the consistency between the existing points and those created is important. Therefore, the presence of a second pivot is strongly desired. Thus the position of the created point will be a function of the position of the existing points which frame it. This reduces the risk of inconsistency. In addition, the redundancy of the observations is always appreciable.

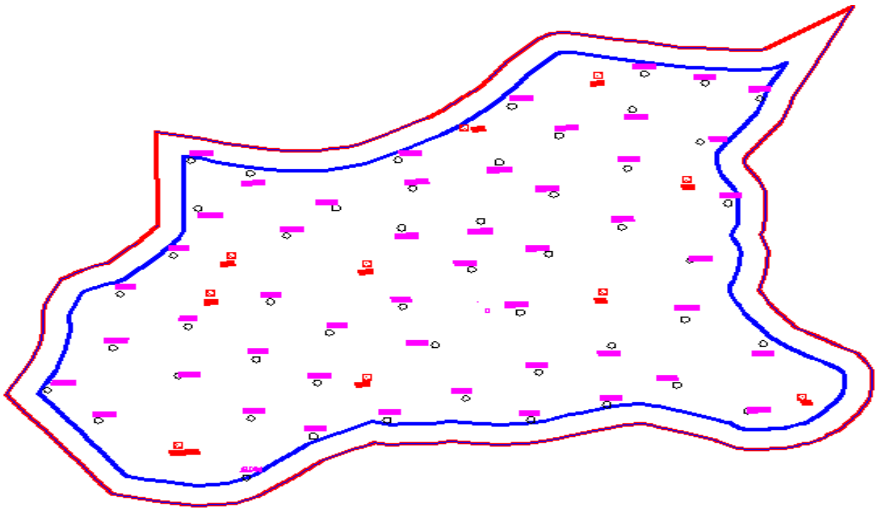


Figure 14: figure showing the extent of the photographic coverage: In blue color the boundary of the municipality; in red color the buffer of 1 km.

- ✓ **Result of the coverage of the municipality by the realization of the assembly board**

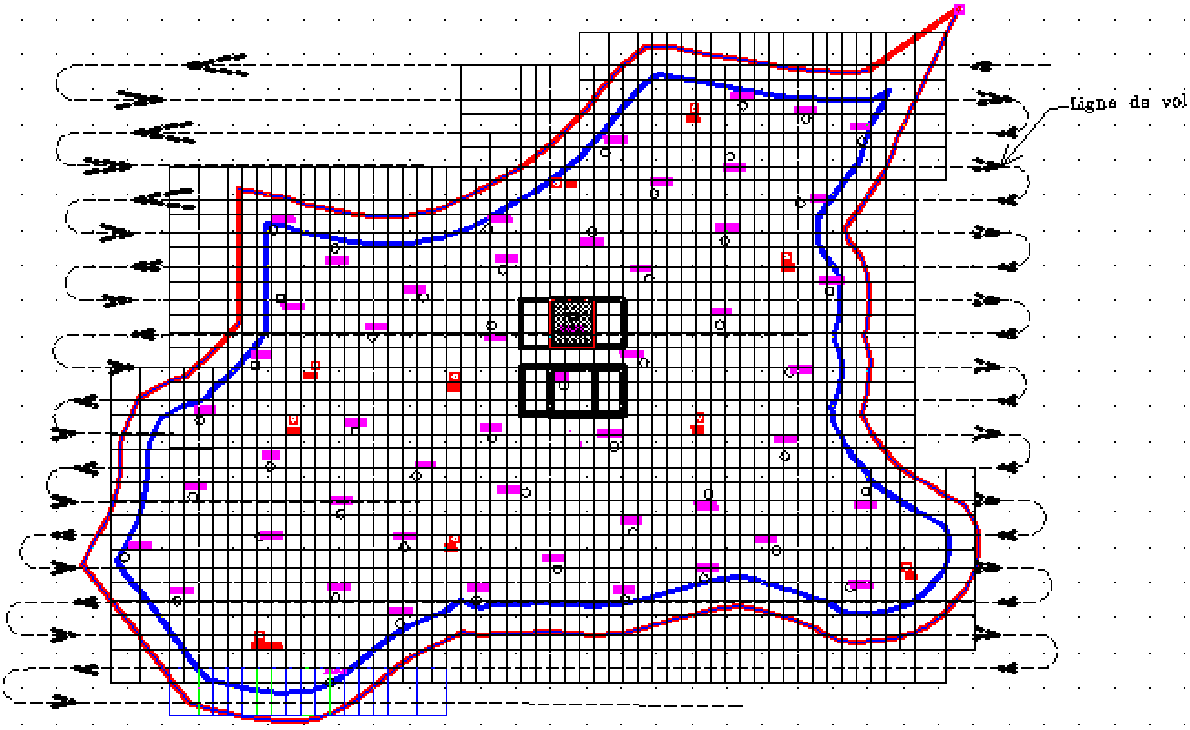


Figure 15: Assembly chart and flight lines of aerial photography with spatialization of geodetic points.

5.2 Discussions

In order to carry out the geodetic network implementation project meeting the requirements of a topographical survey at 1/25000, a rigorous analysis of the results obtained from the various works carried out was carried out in order to better assess the quality of the project.

As a first step, 51 new geodetic points were added to the existing 10. In total, 61 geodetic points for the commune, which gives a density of 16 points per 100 km². This number is above the original target of 15 geodetic points per 100 km². Next, the studies conducted on the results of the test evaluation of the selected

observation mode called " **static at base line costs** Or still called " **central pivot** "It has been said that for measurement campaigns that must combine speed and precision, the observation time per point must be set at 30 minutes for a maximum radius of 10 km. This time is therefore greater than the time given by the empirical formula listed in the methodological approach (See choice of a GNSS method); This allows a margin of safety in case of adverse conditions. Each point must be observed from a minimum of two separate 2nd order points in order for the direct coherence between old and new points of the network to be ensured. All these precautions guarantee centimeter accuracy relative to time. To identify the points on aerial photography (photos), a slab (1.50 mx 1.50 mx 0.10 m) is built and poured on site horizontally on the ground to receive the terminal in the center of the structure. This will serve on the one hand to signaling and on the other hand to the protection of the terminal against possible destruction. The surface of the terrace will be painted in white just before the shooting crew. Lastly, the planning for the survey at a scale of 1: 25,000 made it possible to notice that the maximum flight height of the shots is 2512.50 ± 110 meters and that three hundred and ninety-two (392) photos format (103.86 mm x 67.86 mm) will be provided for total coverage of the municipality. After the realization of the assembly chart on the whole territory of the commune, it is noticed a good distribution of the geodesic points. Thus, the orthophoto and / or aerial map processing would be done easily with a maximum of geodetic and precision points; hence the reliability sought in the operations of topographic surveys at 1/25000 in general and particularly in the municipality of Allada.

6. CONCLUSION

The realization of the geodetic network in the commune of Allada meets the needs of topographic surveys at 1/25000 in terms of density of geodetic points and accuracy throughout the territory. This will result in a more accurate cartographic document, ie a basic plan for assessing the existing state of the Allada territory and for a subsequent study of the various projects that will allow the development to begin economic of said municipality. The complete geodetic network (1st, 2nd, 3rd and 4th order) if it covers the entire territory of the country will meet current needs, but also contribute to the security of tenure in a sustainable way for stability, cohesion and peace. to foster economic development and the growing needs of the country.

Thus the present study will serve as a basic sample for further analysis. In addition, the study should be extended to a departmental scale and serve as a reference for a more precise diagnosis and provide more effective solutions that can be applied throughout the territory.

REFERENCES

[1] Legendre E., 2013. Opportunity and feasibility study of the extension of the Topographic Canvas of the city of Rennes on the territory of the Urban Community of Rennes-Metropole, thesis defense of the diploma of engineer geometer, 130p.
[2] Diakété, 2003. Quoted by Tossou D. & Kiki A., 2011: Contribution of GPS / Permanent Station technology to land security in Benin, p.76.
[3] DEGBEGNON, 2017. Geographical framework of Cotonou and adopted reference systems, 16p.
[4] Degbegnon L., 2012. Issue and perspective of the Network of Permanent Stations of Benin, 12p.
[5] Degbegnon L. and Houinou G., 2014. Design of a legal cadastre at lower cost for the least developed countries (case of Benin), 7p.
[6] Da Morou O., 2016. Establishment of a geoid model on the city of Cotonou in southern Benin, final report of geometry engineer, 82p.
[7] (CNIG, 1993). Technical specifications of orthophotoplan, 13p.
[8] Degbegnon L., 1993. Project to create a basic geodetic network for topographic work at a scale of 1: 25,000 in Benin, French version, 130p.
[9] Annals of Geography, 1901. Accessed 12/03/2018 on the site: https://www.persee.fr/doc/geo_0003-4010_1901_num_10_51_4944