American Journal of Science, Engineering and Technology
2025, Vol. 10, No. 3, pp. 130-140
https://doi.org/10.11648/j.ajset.20251003.15

Research Article

Examining the Integration of Geographic Information Systems for Land Rights Confirmation in the Republic of Benin: A Comparative Analysis Using RTK NTRIP Data

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Abstract

Geodetic sciences play a pivotal role in catalyzing socio-economic development and exerting a profound influence on our daily lives. These sciences proffer a multitude of methodologies for obtaining geographic coordinates of land parcels, thereby posing a precision challenge that is integral to effective land management and dispute mitigation. In a broader context, particularly within the unique landscape of Benin, where land is increasingly becoming a valuable commodity, the imperative to optimize land databases is pronounced. Attaining precision in coordinates stands out as a critical factor for effective land management, offering a proactive approach to mitigate potential land disputes. To streamline the process and reduce expenses associated with obtaining land titles for parcels, there is a need to explore strategies that efficiently minimize costs incurred by the array of stakeholders involved in the procedural framework. The focal point of this research is the exploration of the utilization of coordinates derived from openly accessible Geographic Information Systems in the formulation of boundary plans during the verification of land rights. Subsequent to this exploration, the acquired results are systematically compared with coordinates derived through direct field surveys employing the RTK NTRIP methodology. The outcomes infer that, notwithstanding the cadastre.bj website providing coordinates with a precision of four decimal places and being intricately linked to permanent stations, field surveys, despite their elevated cost, persist as the reliable modality for procuring coordinates with centimeter-level accuracy.

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Received: 24 August 2024; **Accepted:** 18 September 2024; **Published:** 19 September 2025

Keywords

Geodetic Sciences, Geographic Coordinates, Land Parcels and Land Management,
Open Access Geographic Information Systems, Land Rights Confirmation, RTK NTRIP Method, Precision Coordinates

1. Introduction

The land registration process entails the execution of a contradictory survey and the formulation of a boundary survey report. Precision is of paramount importance, necessitating centimeter-level accuracy in the coordinates outlined on the contradictory survey plan. The adoption of topography and geodetic methods is deemed apt for acquiring precise coordinates, thereby ensuring that errors are confined within the specified range of ±20 cm [1].

The advent of precision mapping in the Republic of Benin has culminated in the establishment of an online platform, cadastre.bj. Serving as a pivotal repository for land information, particularly in urbanized regions, the platform provides users with the capability to capture coordinates of parcel vertices visible in satellite images, each coordinate delineated to four decimal places.

Within an economic context characterized by a relatively high cost of living and where property transactions hinge on the confirmation of land rights, obtaining land rights for a 500 m ²plot commands a minimum investment of 300,000 FCFA ($600). It is worth highlighting that the formulation of a topographic survey plan in this process incurs a cost of at least 180,000 FCFA ($400). This raises the inquiry: Can geographic information systems' coordinates be effectively integrated into contradictory surveys to mitigate the expenses associated with topographic surveys? [1]

2. Materials and Methods

2.1. Selection of Study Locations

The selection of study sites was systematically conducted, taking into account several pivotal parameters:

1. Land Area: The comprehensive size of each site;
2. Nature of the Land: The characterization of whether the land is enclosed by a fence, undeveloped, featuring a lightweight structure, or hosting a substantial building;
3. Plot Position Relative to a Permanent Station: In anticipation of acquiring direct coordinates using the RTK NTRIP method, we modulated the distance between the designated permanent station and the study sites accordingly.

Figure 1. *Spatial Distribution of Sites in Relation to the Permanent Station in Cotonou.*

Within the confines of Cotonou municipality, an urbanized locale, three sites were pinpointed. Simultaneously, in Abomey-Calavi municipality, an area devoid of urbanization, three sites were identified, each exhibiting diverse surface areas. The conspicuous visibility of all six sites on Google Earth and the cadastre.bj platform, coupled with their convenient accessibility, further underscores the efficacy of our site selection methodology.

Figure 1 depicts the spatial distribution of diverse sites in Cotonou and Abomey-Calavi in proximity to the permanent BJCO station situated in Cotonou. A thorough examination of the map offers valuable insights into the mean distance separating the measurement sites from the BJCO station. On average, sites in Cotonou are approximately 2 km from the permanent station, while those in Abomey-Calavi are, on average, situated around 21 km away.

2.2. Data Collection

2.2.1. Recording Vertex Coordinates Using Google Earth

Leveraging the Google Earth application, this study systematically identified parcels conducive to diverse survey methodologies. As articulated earlier, our selection methodology adhered to predefined criteria. It is imperative to underscore that, extending beyond the initial criteria, preference was given to plots manifesting distinct boundaries and structures discernible on the cadastre.bj platform. The designated sites, labeled A, B, C, D, E, F, G, H, J, K, and L, encompass a range of characteristics. Specifically, A, B, C, F, G, and H constitute undeveloped parcels, each enclosed by a masonry fence of varying dimensions. On the other hand, D, J, and K denote multi-story edifices, while E and L embody structures featuring lightweight roofing. The precise coordinates of the vertices pertaining to these selected entities were meticulously documented.

2.2.2. Capturing Summit Coordinates on Cadastre.bj

The aerial imagery disseminated by the cadastre.bj platform undergoes georeferencing within the framework of Benin's permanent station system (UTM31-N, WGS 84, ITRF 2005). This methodology confers the advantage of acquiring coordinates for cursor-indicated points directly within the requisite reference framework, obviating the necessity for subsequent data conversion or transformation procedures [2-4].

Given the pre-identification of land parcels, the subsequent process involved the meticulous documentation of summit coordinates. To augment precision, a maximum zoom level was applied, facilitating a more refined pinpointing of each summit. The resultant coordinates were systematically recorded in a tabular format.

2.2.3. Coordinates Obtained by Direct Measurement in RTK NTRIP Mode

The NTRIP mode stands as a networked framework designed for the transmission of GNSS correction data in RTCM format via the Internet protocol. Originating in Germany during the early 2000s, it has gained widespread application across diverse sectors, including topography, cartography, precision agriculture, engineering, and construction. NTRIP demonstrates versatility by facilitating the transmission of both differential correction data and various other types of GNSS data. Its primary application lie s in achieving real-time precision positioning, thereby fostering heightened operational efficiency and productivity [5, 6].

The network of permanent GNSS stations in Benin encompasses seven strategic locations situated in Cotonou, Abomey, Parakou, Natitingou, Savalou, Nikki, and Kandi. In pursuit of modernizing Benin's geodetic infrastructure, the network underwent a substantial upgrade in 2022, affording it the capability to operate seamlessly in RTK NTRIP mode. Access to this advanced service is available free of charge upon request from the National Geographic Institute of Benin. The adoption of this mode or the georeferencing within the permanent station system facilitates operations within a coherent coordinate system, markedly contributing to the mitigation of boundary conflicts and property disputes [1].

The surveying of vertices across diverse plots was meticulously executed using a GNSS receiver in RTK NTRIP mode. This deliberate selection ensures the alignment of coordinates obtained on the cadastre.bj site with the same reference system utilized in direct survey measurements [1].

3. Comparative Analysis of Acquired Coordinates

3.1. Comparison of Coordinates Extracted from Google Map and Measured by GNSS Receiver

The table presented below includes the coordinates derived from the Google Earth application alongside the corresponding coordinates acquired through survey using RTK NTRIP mode.

Table 1. *Deviation in X and Y Coordinates Between Surveyed Data in RTK NTRIP Mode and Google Earth Application.*

Sites	Point No.	Number of Satellites Received by Rover	GNSS Survey in RTK NTRIP Mode (m)		Coordinates Extracted from Google Earth (m)		Discrepancies (m)	
			X	Y	X	Y	d X	d Y
Cotonou								
A	A1	10/22	440704.387	704490.632	440678.899	704474.049	3.541	3.005
	A2	12/30	440704.045	704470.656	440678.867	704443.341	4.005	1.254
	A3	11/28	440687.253	704470.774	440678.867	704443.341	3.997	2.215
	A4	10/28	440687.452	704490.855	440678.899	704474.049	3.550	3.021
B	B1	10/26	440765.783	704430.193	440740.246	704381.861	4.350	2.217
	B2	14/31	440765.680	704410.111	440740.246	704381.861	1.078	0.214
	B3	15/33	440743.196	704410.405	440740.277	704412.569	2.919	-0.214
	B4	13/33	440739.561	704413.907	440740.277	704412.569	-0.716	1.338
	B5	13/32	440739.755	704426.833	440740.277	704412.569	-0.522	2.478
	B6	10/31	440743.311	704430.383	440740.277	704412.569	3.034	3.214
C	C1	13/31	440723.697	704407.719	440740.246	704381.861	0.795	4.007
	C2	9/21	440709.954	704407.852	440740.246	704381.861	3.043	1.214
	C3	13/34	440710.395	704430.729	440740.277	704412.569	2.145	2.214
D	D1	12/29	440724.597	704490.445	440709.620	704474.017	3.215	3.875
	D2	10/25	440724.112	704470.997	440709.588	704443.309	4.024	1.047
	D3	12/30	440704.045	704470.656	440678.867	704443.341	4.215	4.587
	D4	10/22	440704.387	704490.632	440678.899	704474.049	3.215	0.581
E	E1	15/34	440510.333	704594.192	440494.667	704566.364	3.215	2.146
	E2	31/34	440510.290	704583.892	440494.667	704566.364	1.211	1.214
	E3	16/34	440471.232	704583.716	440463.946	704566.396	3.215	3.214
	E4	15/33	440471.414	704594.628	440463.946	704566.396	1.257	0.560
Abomey-Calavi								
F	F1	14/37	419372.811	713322.855	419370.486	713313.693	2.325	6.257
	F2	12/36	419347.831	713320.071	419339.768	713313.737	8.063	2.961
	F3	14/37	419346.188	713344.027	419339.812	713344.446	6.376	-0.419
	F4	14/38	419371.120	713346.862	419370.530	713344.402	0.590	2.460
G	G1	10/25	419365.747	713419.421	419339.900	713405.864	5.245	2.214
	G2	14/36	419366.867	713395.553	419339.856	713375.155	3.750	5.214
	G3	12/35	419343.114	713392.002	419339.856	713375.155	3.258	4.214
	G4	10/30	419340.944	713415.378	419339.900	713405.864	1.044	6.257
H	H1	10/25	418393.520	713502.388	418387.787	713499.362	5.733	5.782
	H2	8/29	418395.920	713491.800	418387.787	713499.362	8.133	-7.562
	H3	11/31	418382.937	713500.415	418357.070	713499.407	4.024	1.008
J	J1	12/30	418361.103	713431.185	418356.936	713407.279	4.167	-3.881

Sites	Point No.	Number of Satellites Received by Rover	GNSS Survey in RTK NTRIP Mode (m)		Coordinates Extracted from Google Earth (m)		Discrepancies (m)	
			X	Y	X	Y	d X	d Y
K	J2	12/30	418358.308	713424.160	418356.981	713437.989	1.327	4.856
	J3	11/27	418350.842	713426.449	418356.936	713407.279	4.055	2.014
	J4	11/30	418354.175	713434.426	418326.263	713438.033	7.254	-3.607
	K1	9/35	419335.394	713296.012	419309.006	713283.072	6.245	5.254
	K2	11/35	419336.509	713263.904	419308.962	713252.362	5.254	1.201
	K3	14/35	419332.248	713263.535	419308.962	713252.362	3.215	0.248
	K4	12/35	419330.437	713296.148	419309.006	713283.072	7.215	3.214
L	L1	10/35	419334.311	713320.606	419309.050	713313.781	5.214	2.715
	L2	7/29	419334.461	713318.491	419309.050	713313.781	6.214	4.710
	L 3	12/32	419334.739	713311.654	419309.050	713313.781	4.214	-2.127
	L 4	10/31	419326.612	713310.633	419309.050	713313.781	3.214	-3.148
	L5	14/36	419325.260	713317.080	419309.050	713313.781	7.125	3.299
	L6	14/36	419324.873	713320.358	419370.486	713313.693	-1.857	2.145

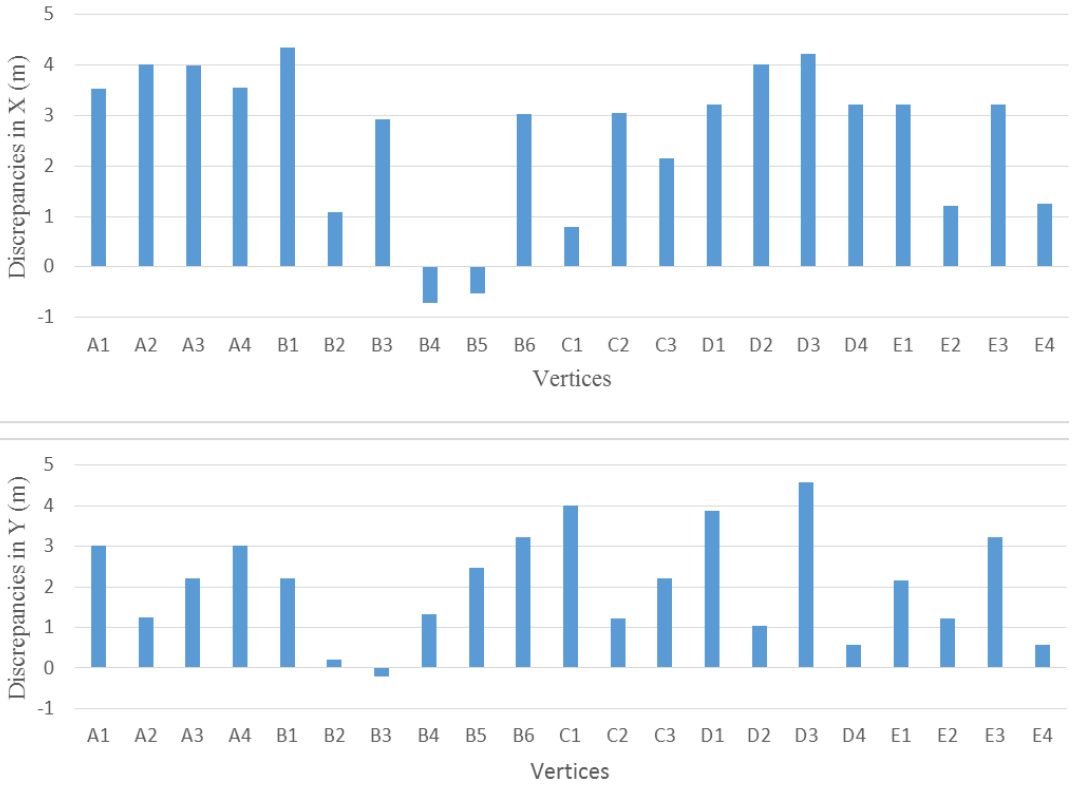

Figure 2. *Relative discrepancies in coordinates obtained through direct survey in RTK NTRIP mode compared to those derived from Google Earth along the X and Y axes in the Cotonou region.*

The examination of the two graphs presented in Figure 2 indicates that, individually along the X and Y axes, discrepancies within the range of 0 to 5 meters in absolute value are observed. The mean deviation along the X axis is measured at 2.73 meters, while along the Y axis, it is recorded at 2.09 meters.

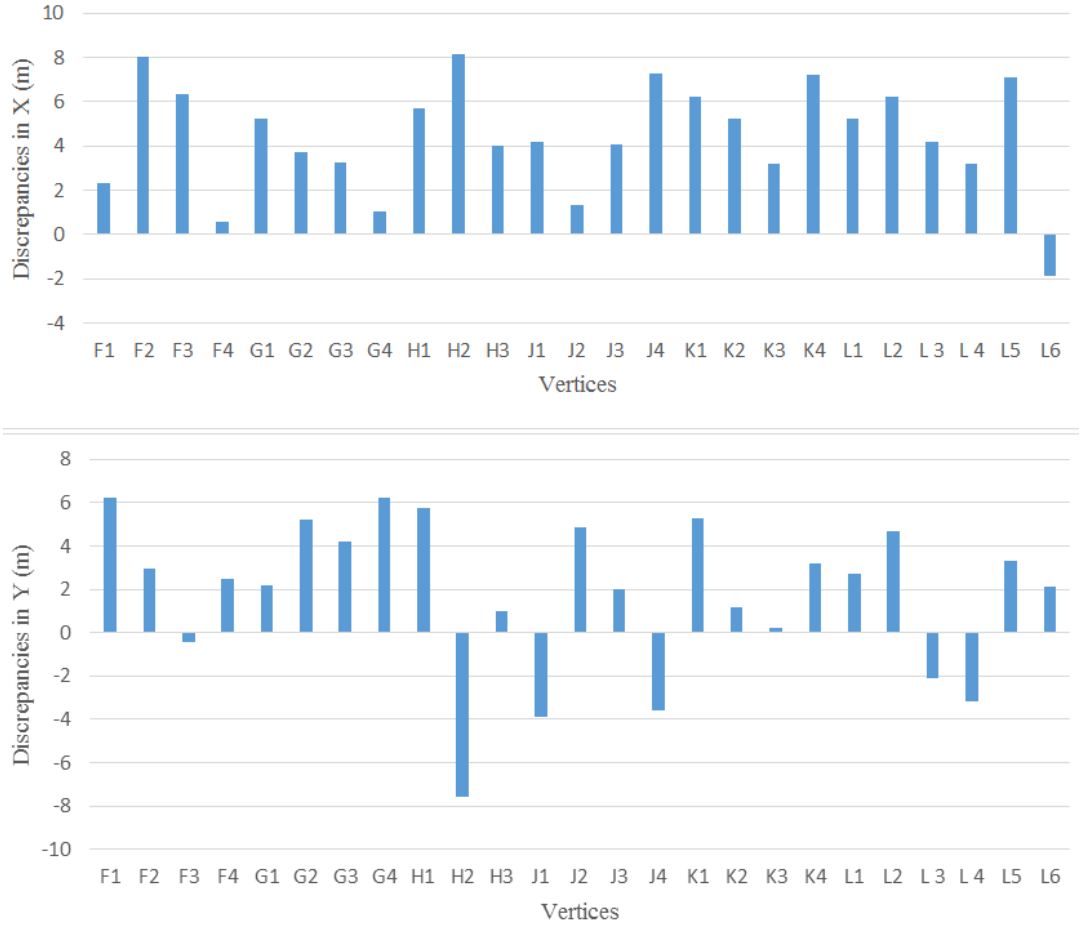

Figure 3. *Relative discrepancies in coordinates acquired through direct survey in RTK NTRIP mode and those derived from Google Earth along the X and Y axes in Abomey-Calavi.*

The graphs in Figure 3 delineate the disparities between coordinates directly surveyed on-site using RTK NTRIP mode and those extrapolated from Google Earth for the Abomey-Calavi locations. The initial graph represents discrepancies along the X-axis, exhibiting values spanning from 0 to 8 meters in absolute magnitude. Simultaneously, the second graph displays discrepancies along the Y-axis, with values fluctuating between 0 and 8 meters in absolute magnitude. The mean discrepancy along the X-axis is recorded as 4.60 meters, while along the Y-axis, it stands at 3.47 meters.

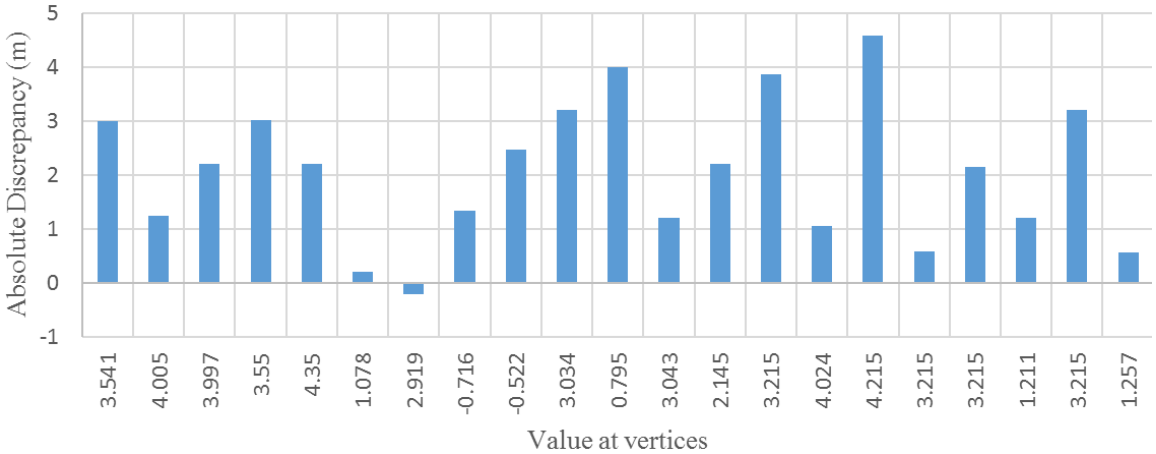

Figure 4. *Absolute Discrepancy in Coordinates Acquired via GNSS Receiver in RTK NTRIP Mode and Extracted from the Google Earth Application in Cotonou.*

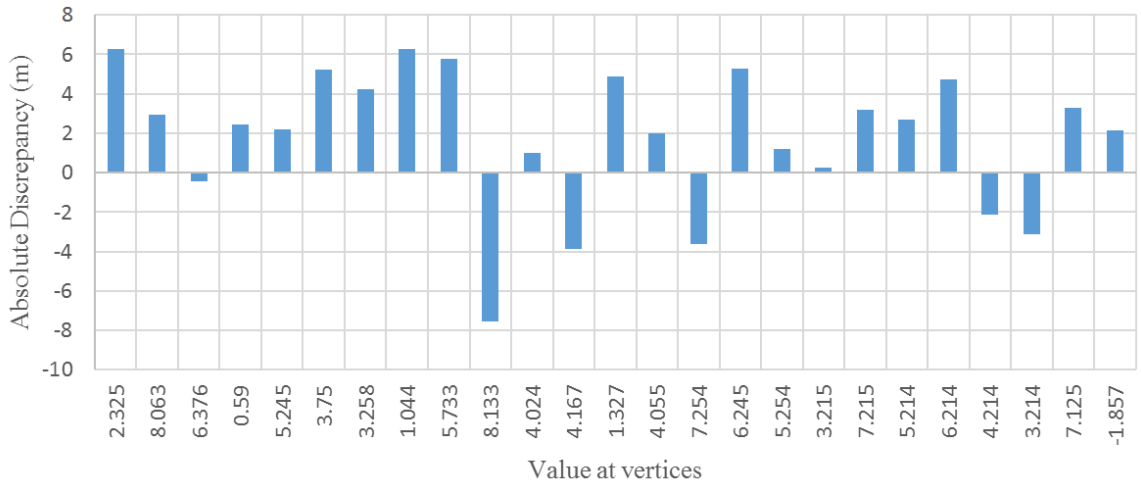

Figure 5. *Absolute Discrepancy in Coordinates Acquired via GNSS Receiver in RTK NTRIP Mode and Extracted from the Google Earth Application in Abomey-Calavi.*

The graphs presented in Figures 4 and 5 delineate the absolute positioning disparities among the vertices of parcels at the Cotonou sites (Figure 4) and the Abomey-Calavi sites (Figure 5). In this context, the observed values span the intervals [1-7] meters for locations within the municipality of Cotonou and [2-8] meters for those in Abomey-Calavi. The average absolute discrepancies in the determination of vertex coordinates amount to 3.62 meters and 6.12 meters for parcels located in Cotonou and Abomey-Calavi, respectively.

Observation

The observed disparity between these two coordinate types does not conform to any discernible mathematical pattern. Moreover, the discrepancy in both the X and Y dimensions fluctuates within the range of 0 to 7 meters. This phenomenon can be elucidated by the inherent distinction in the coordinate systems employed by these two types.

3.2. Comparison of Coordinates from Cadastre.bj and Measured by GNSS Receiver

The table provided below illustrates the coordinates sourced from the cadastre.bj website alongside the coordinates acquired through on-site, direct field survey utilizing RTK NTRIP technology.

Table 2. *Discrepancies in the X and Y coordinates obtained through RTK NTRIP survey method compared to those extracted from the cadastre.bj website.*

Sites	No. of Points	Satellites Captured by Rover	Coordinates Extracted from Cadastre.bj (m)		GNSS Survey in RTK NTRIP Mode (m)		Discrepancies	
			X	Y	X	Y	dX	dY
Cotonou								
A	A1	10/22	440704.458	704492.080	440704.387	704490.632	0.071	1.448
	A2	12/30	440704.458	704471.799	440704.045	704470.656	0.413	1.143
	A3	11/28	440687.458	704472.097	440687.253	704470.774	0.205	1.323
	A4	10/28	440687.756	704492.676	440687.452	704490.855	0.304	1.821
B	B1	10/26	440765.530	704430.725	440765.783	704430.193	-0.253	0.532
	B2	14/31	440765.232	704411.041	440765.680	704410.111	-0.448	0.93
	B3	15/33	440742.565	704411.041	440743.196	704410.404	-0.631	0.637
	B4	13/33	440739.284	704413.725	440739.560	704413.907	-0.276	-0.182

Sites	No. of Points	Satellites Captured by Rover	Coordinates Extracted from Cadastre.bj (m)		GNSS Survey in RTK NTRIP Mode (m)		Discrepancies	
			X	Y	X	Y	dX	dY
	B5	13/32	440738.986	704428.041	440739.755	704426.833	-0.769	1.208
	B6	10/31	440743.456	704431.023	440743.311	704430.383	0.145	0.64
	C1	13/31	440723.728	704409.079	440723.697	704407.719	0.031	1.36
C	C2	9/21	440710.904	704408.780	440709.954	704407.852	0.95	0.928
	C3	13/34	440710.903	704431.447	440710.395	704430.729	0.508	0.718
	D	12/29	440725.157	704491.944	440724.597	704490.445	0.56	1.499
	D 2	10/25	440724.859	704471.365	440724.112	704470.997	0.747	0.368
D	D3	12/30	440704.458	704471.798	440704.045	704470.656	0.413	1.142
	D4	10/22	440704.458	704492.080	440704.387	704490.632	0.071	1.448
	E 1	15/34	440511.068	704595.193	440510.333	704594.192	0.735	1.001
	E2	31/34	440510.173	704584.158	440510.290	704583.892	-0.117	0.266
E	E3	16/34	440471.401	704584.792	440471.232	704583.716	0.169	1.076
	E 4	15/33	440471.699	704595.231	440471.414	704594.628	0.285	0.603
Abomey-Calavi								
	F1	14/37	419369.750	713323.317	419372.811	713322.855	-3.061	0.462
	F2	12/36	419345.890	713322.124	419347.831	713320.071	-1.941	2.053
F	F 3	14/37	419344.697	713345.984	419346.188	713344.027	-1.491	1.957
	F4	14/38	419368.557	713346.879	419371.120	713346.862	-2.563	0.017
	G1	10/25	419365.574	713419.055	419365.747	713419.421	-0.173	-0.366
	G2	14/36	419366.171	713395.493	419366.867	713395.553	-0.696	-0.06
G	G 3	12/35	419342.609	713393.704	419343.114	713392.001	-0.505	1.703
	G4	10/30	419341.715	713418.160	419340.944	713415.378	0.771	2.782
	H1	10/25	418395.271	713503.675	418393.520	713502.388	1.751	1.287
H	H2	8/29	418398.253	713491.447	418395.920	713491.800	2.333	-0.353
	H3	11/31	418383.937	713500.991	418382.937	713500.415	1	0.576
	J 1	12/30	418363.067	713430.597	418361.103	713431.185	1.964	-0.588
	J 2	12/30	418358.593	713424.333	418358.308	713424.160	0.285	0.173
J	J 3	11/27	418351.733	713426.421	418350.842	713426.449	0.891	-0.028
	J 4	11/30	418355.014	713434.474	418354.175	713434.426	0.839	0.048
	K 1	9/35	419335.917	713296.624	419335.394	713296.012	0.523	0.612
	K2	11/35	419337.408	713261.133	419336.509	713263.904	0.899	-2.771
K	K3	14/35	419332.636	713260.834	419332.248	713263.535	0.388	-2.701
	K4	12/35	419331.145	713296.922	419330.437	713296.148	0.708	0.774
	L1	10/35	419335.733	713321.352	419334.311	713320.606	1.422	0.746
L	L 2	7/29	419335.435	713318.966	419334.4614	713318.491	0.9736	0.475
	L3	12/32	419336.032	713311.509	419334.7386	713311.6542	1.2934	-0.1452

Sites	No. of Points	Satellites Captured by Rover	Coordinates Extracted from Cadastre.bj (m)		GNSS Survey in RTK NTRIP Mode (m)		Discrepancies	
			X	Y	X	Y	dX	dY
	L4	10/31	419326.970	713310.344	419326.612	713310.633	0.358	-0.289
	L 5	14/36	419326.075	713317.800	419325.260	713317.079	0.815	0.721
	L6	14/36	419325.180	713321.080	419324.873	713320.357	0.307	0.723
	L1	10/35	419335.733	713321.352	419334.311	713320.606	1.422	0.746

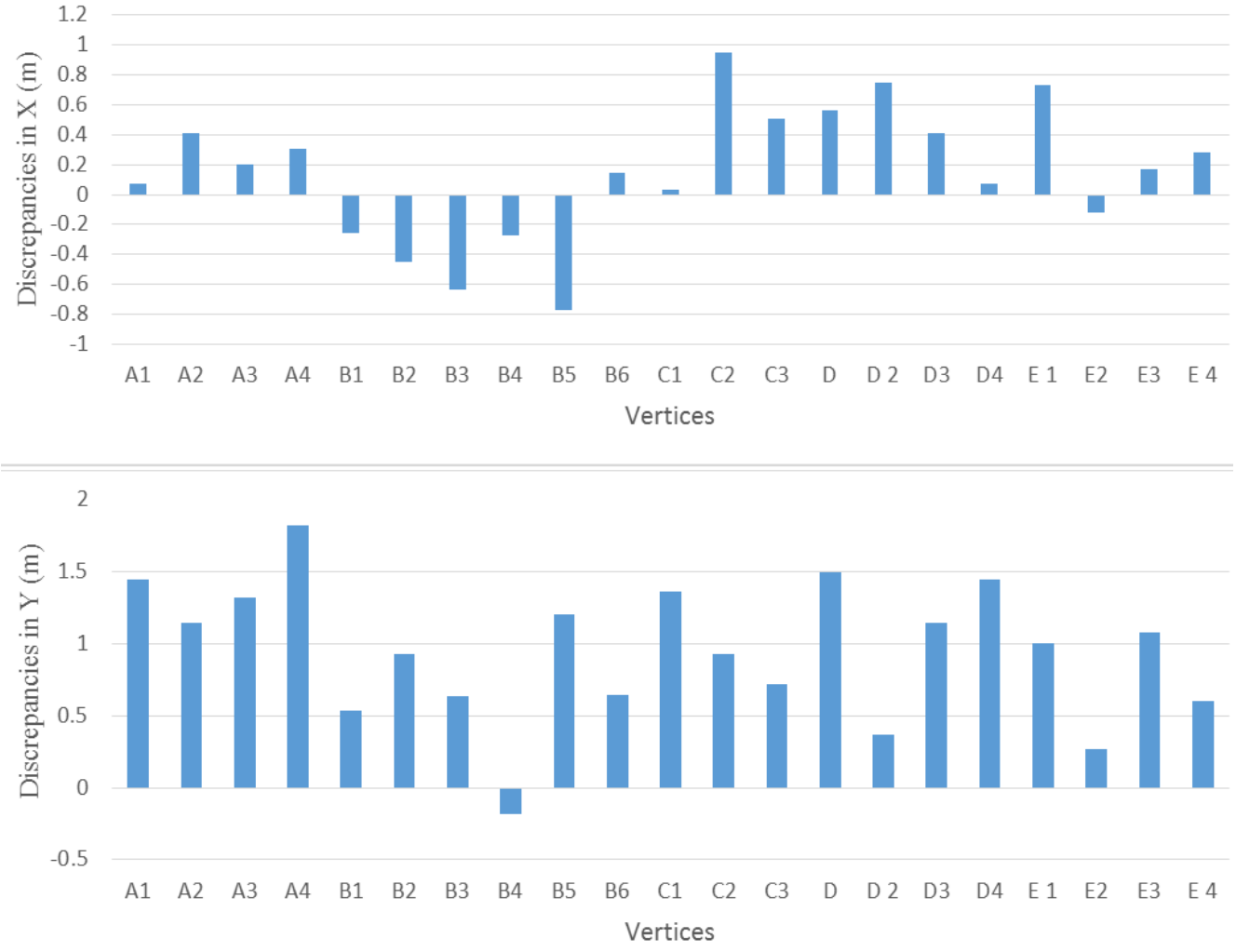

Figure 6. *Relative discrepancies along the X and Y axes between coordinates acquired through direct survey using RTK NTRIP mode and those derived from the cadastre.bj website in the Cotonou region.*

Figure 6 presents the observed discrepancies between the coordinates of vertices obtained through RTK NTRIP mode survey and those extracted from the cadastre.bj website along the X and Y axes. These variations fall within the range of 0 to 1 meter for the X component and 0 to 2 meters for the Y component. The mean discrepancy along the X axis is 0.39 meters, while along the Y axis, it is 0.97 meters.

The charts in Figure 7 reveal the differences in coordinates directly surveyed on-site using RTK NTRIP mode and those obtained from the cadastre.bj website for the Abomey-Calavi sites. The initial graph illustrates discrepancies along the X-axis, with absolute values ranging from 0 to 3 meters. The second graph displays discrepancies along the Y-axis, also with absolute values varying from 0 to 3 meters. The mean discrepancy along the X-axis is 1.13 meters, and along the Y-axis, it is 0.89 meters.

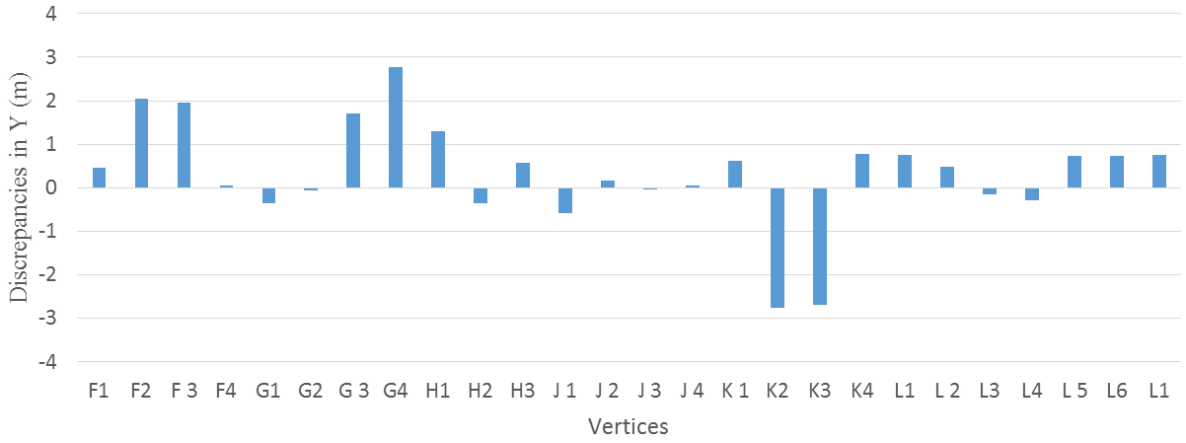

Figure 7. *Relative discrepancies between coordinates obtained by direct survey in RTK NTRIP mode and those derived from the cadastre.bj website along the X and Y axes in Abomey-Calavi.*

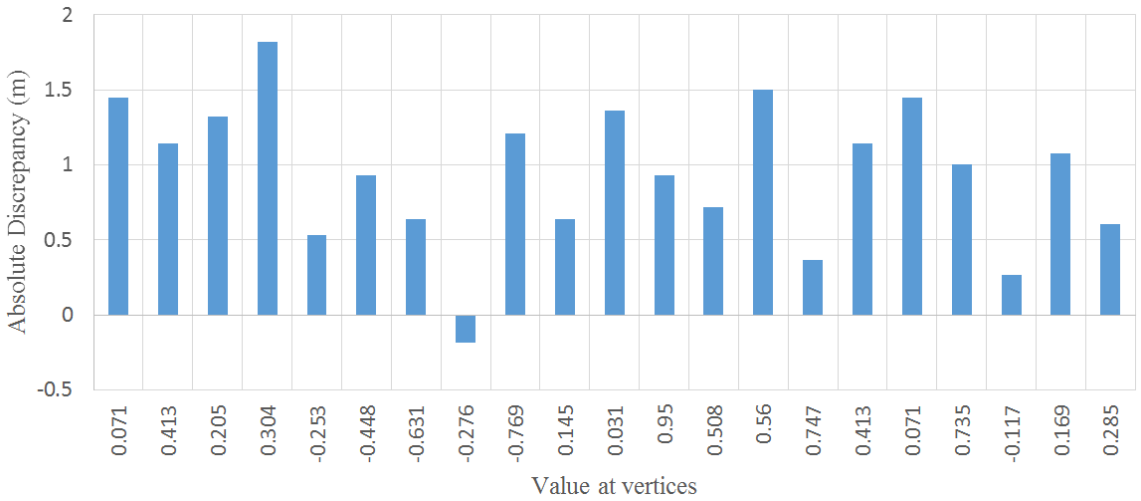

Figure 8. *Absolute Discrepancy between Coordinates Obtained by GNSS Receiver in RTK NTRIP Mode and Extracted from the cadastre.bj Website in Cotonou.*

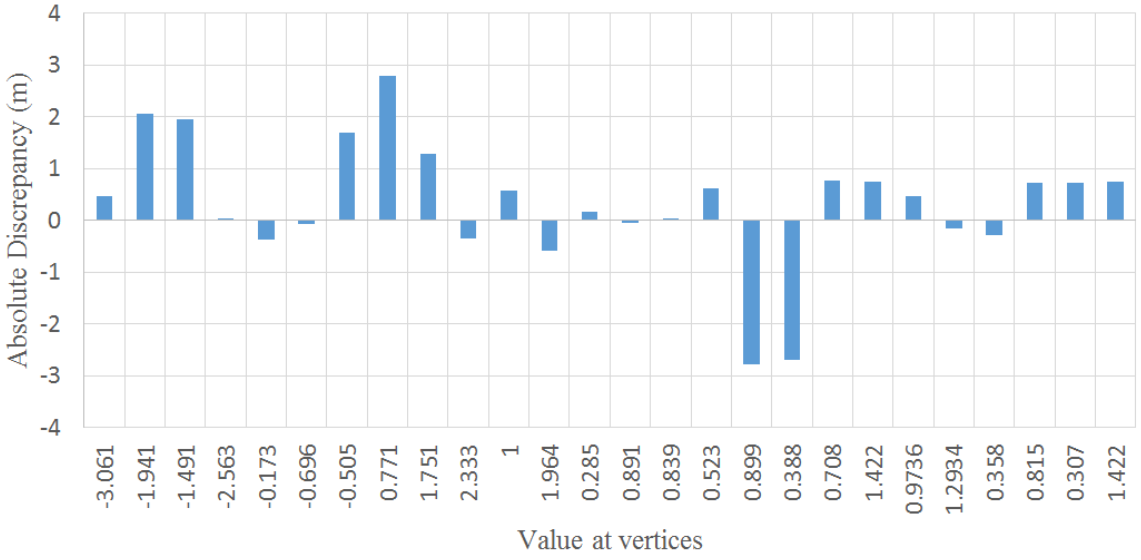

Figure 9. *Absolute Discrepancy between Coordinates Obtained by GNSS Receiver in RTK NTRIP Mode and Extracted from the cadastre.bj Website in Abomey-Calavi.*

The graphs in Figures 8 and 9 depict the absolute positioning discrepancies of parcel vertices at the Cotonou sites (Figure 8) and the Abomey-Calavi sites (Figure 9). In this scenario, the values lie within the interval [0-2] meters for sites located in the municipality of Cotonou and within the interval [0-3] meters for those in Abomey-Calavi. The average absolute discrepancies in determining the coordinates of the vertices are 1.08 meters and 1.61 meters for parcels situated in Cotonou and Abomey-Calavi, respectively.

Observation

The absolute discrepancies observed between the coordinates acquired through the GNSS receiver in RTK NTRIP mode and those derived from the cadastre.bj website range within the interval of 0 to 3 meters. It is crucial to highlight the distinction between these values and those obtained in the preceding scenario. This variation can be elucidated by the fact that the data originating from the cadastre.bj website is georeferenced within the framework of permanent stations (UTM31-N, WGS 84, ITRF 2005).

The disparities noted in Abomey-Calavi occasionally surpass those documented at the Cotonou sites. This discrepancy is attributed to the length of the baseline, which fluctuates between the permanent station situated in Cotonou and the specific features surveyed in both Cotonou and Abomey-Calavi [5, 7, 8].

4. Conclusion

The comprehensive analysis of the findings reveals that the datasets acquired from the Google Earth application and the cadastre.bj website are insufficient for the accurate georeferencing of parcels within the established cadastre database in the Republic of Benin. The identified disparities exceed the defined tolerance interval (±20 cm) [1, 6, 8].

Even in instances where certain values of relative discrepancies along the X or Y axes from the cadastre website are below 10 cm (in absolute terms), it is crucial to acknowledge the inherent unreliability of this method. The absolute discrepancies in the coordinates of planar vertices fail to meet the stipulated tolerance criteria.

Nevertheless, a potential avenue for improvement exists if the cadastre.bj website database incorporates higher-resolution imagery. This enhancement could facilitate a more meticulous enlargement of visible elements, preserving clarity and offering the prospect of precise vertex delineation and data extraction.

Abbreviations

RTK	Real Time Kinematic
NTRIP	Network and Transport of RTCM via Internet Protocol
GNSS	Global Navigation Satellite System
WGS 84	World Geodetic System 1984
ITRF	International Terrestrial Reference System
UTM	Universal Transverse Mercator

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] National Land and Property Agency. NLPA. Confirmation of land rights Available from: https://www.andf.bj/index.php/procedures-et-demarches/confirmation-des-droits-fonciers (accessed 7 March 2024)

[2] Dhonju, Hari Krishna, Kerry Brian Walsh, and Thakur Bhattarai. "Web Mapping for Farm Management Information Systems: A Review and Australian Orchard Case Study" Agronomy, Geoinformatics Application in Agriculture vol. 13, no. 10. 2563 pp. 1-23. 2023. https://doi.org/10.3390/agronomy13102563

[3] Dardanelli, G.; Maltese, A. "On the Accuracy of Cadastral Marks: Statistical Analyses to Assess the Congruence among GNSS-Based Positioning and Official Maps. Remote Sens. "GNSS CORS Application vol 14, no. 16. 4086 pp. 1-21. 2022. https://doi.org/10.3390/rs14164086

[4] Cahalane, Conor. "Combining 2D Mapping and Low Density Elevation Data in a GIS for GNSS Shadow Prediction" ISPRS International Journal of Geo-Information vol 4, no. 4: pp. 2769-2791. 2015. https://doi.org/10.3390/ijgi4042769

[5] Beltrán-Iza, E. A.; Noroña-Meza, C. O.; Robayo-Nieto, A. A.; Padilla, O.; Toulkeridis, T. "Creation of a Mobile Application for Navigation for a Potential Use of People with Visual Impairment Exercising the NTRIP Protocol." Health, Well-Being and Sustainability, vol. 14, no. 24. pp. 1-20. 17027. 2022. https://doi.org/10.3390/su142417027

[6] Kyriou, A.; Nikolakopoulos, K.; Koukouvelas, I.; Lampropoulou, P. "Repeated UAV Campaigns, GNSS Measurements, GIS, and Petrographic Analyses for Landslide Mapping and Monitoring." Minerals, Application of UAV and GIS for Geosciences. vol. 11, no. 3. 300. pp 1-26. 2021. https://doi.org/10.3390/min11030300

[7] Olcina, J. H.; Julián, A. B. A.; Furones, Á. E. M. "Treatment and Analysis of the GNSS Signal from Smartphones and Its Applicability to Urban Mobility." Environ. Sci. Proc. IV Conference on Geomatics Engineering. vol. 28. no. 1. 1. pp 1-5. 2023. https://doi.org/10.3390/environsciproc2023028001

[8] Janos, D.; Kuras, P. "Evaluation of Low-Cost GNSS Receiver under Demanding Conditions in RTK Network Mode." Sensors - Sensors in Structural Health Monitoring and Smart Structural Control. vol. 21 no. 16. 5552. pp 1-19. 2021. https://doi.org/10.3390/s21165552