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VISIBILITY ANALYSIS FOR SURVEILLANCE PURPOSES IN MODIBBO ADAMA UNIVERSITY, YOLA, ADAMAWA STATE, NIGERIA

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Abstract

Visibility analysis determines the perceptibility of certain areas from a given viewpoint or set of viewpoints for surveillance purposes to thwart the security challenges in Modibbo Adama University (MAU), Yola. The study conducted a visibility analysis to identify optimal locations for CCTV surveillance at MAU, Yola, in order to address security concerns. Using a Digital Elevation Model (DEM) as the primary dataset, the study analyzed the terrain in ESRI ArcMap 10.4.1 to visualize elevation and landscape structure. Twelve high-elevation points were selected as potential CCTV camera locations. A visibility analysis was carried out using these points, treating the DEM as a raster surface and the selected locations as observer points. Observer parameters included surface and observer offsets, viewing radii, and angles. Observer height was varied (2.50m, 6.00m, and 10.00m), revealing that increasing observer height expanded the visible area while reducing blind spots. However, some areas remained obscured due to tall buildings and vegetation. The study concluded that visibility analysis is a valuable tool for planning surveillance infrastructure, highlighting its importance in enhancing campus security.

Keywords: CCTV Camera, Crime Detection, DEM, Surveillance, Viewpoint and Visibility Analysis

1.0 Introduction

Surveillance is commonly understood as the systematic observation or monitoring of behaviour, activities, or information with the intent to influence, manage, or direct specific events. Although it serves various functions, it is often critiqued for its implications on individual privacy. The ubiquity of surveillance cameras in both public and private spaces has rendered their presence commonplace, despite the substantial legal and social implications this may entail [17]. A primary rationale for deploying surveillance technologies, especially Closed-Circuit Television (CCTV), is their capacity to deter and manage crime within specific environments. CCTV systems have played a significant role in contemporary crime prevention efforts across the globe [18]. The use of surveillance through CCTV has become widespread, particularly in developed nations where it is employed to monitor individual behaviour and prevent unlawful activities.

Today, CCTV systems are increasingly adopted in universities, urban centres, industrial facilities, and developing nations, with notable growth recorded in Asia, Europe, North America, and South America [4]. According to [5], the growing reliance on technology in modern policing practices has contributed to a significant increase in the adoption of CCTV by law enforcement agencies in the United States. CCTV surveillance provides not only tangible security benefits but also enhances public confidence and mitigates the perceived fear of crime [10]. According to [6], video surveillance represents a crucial component of campus safety strategies due to its "force-multiplying" capabilities. Security personnel increasingly depend on this technology to monitor activities and respond to incidents of violence, criminality, and other potential threats factors that are significant considerations for prospective students, university staff, and their families.

In recent years, the need for enhanced security in academic institutions has become increasingly important due to the growing threats of crime, vandalism, and unauthorized access. Universities, by nature, are open and densely populated environments, making them vulnerable to various security risks. The deployment of effective surveillance systems, particularly CCTV cameras, is a critical component in mitigating these risks and ensuring the safety of students, staff, and institutional property [1]. Both wired and wireless CCTV systems offer effective solutions for monitoring student activities on university campuses. Their implementation contributes significantly to crime detection and the reduction of insecurity within educational institutions.

While the installation of surveillance cameras may appear straightforward, several technical and environmental factors must be considered for effective deployment [7]. These include camera specifications such as range, field of view, resolution, and operational costs, as well as contextual environmental conditions. A naive approach uniform distribution of cameras may suffice in non-complex environments focused solely on coverage maximization. However, in real-world applications, camera placement requires a multifaceted strategy aligned with the system's specific goals. The overarching objective of camera placement is to optimize viewpoints for capturing informative and relevant footage of areas under surveillance. The deterrent function of CCTV relies on the assumption that potential offenders engage in rational cost-benefit analyses and may abandon criminal intentions when aware of surveillance [17].

One of the most effective approaches to maximizing the efficiency of CCTV systems is through visibility analysis, which identifies areas that are visible or hidden from specific viewpoints. This form of spatial analysis allows planners to determine optimal camera placement, minimize blind spots, and improve overall surveillance coverage [3]. Geographic Information Systems (GIS) and Digital Elevation Models (DEMs) are essential tools in this process, offering detailed insights into the topography and landscape features of a given area [11]. With advancements in remote sensing, especially the increasing availability of high-resolution DEMs and Digital Surface Models (DSMs) from Light Detection and Ranging (LiDAR) technology, visibility assessments have become more precise and widely applicable.

Visibility, in this context, refers to the area that is observable from a particular vantage point. This functionality, available in most GIS software, uses elevation data from DEMs to determine line-of-sight visibility between observation and target cells [9]. The output of visibility analysis assigns values to raster cells based on the number of observer points that can be seen from each cell, allowing for objective identification of effective surveillance locations [15].

Ensuring the safety and security of students, staff, and infrastructure in university campuses has become a major concern in Nigeria due to the increasing incidence of crime, theft, and vandalism [12]. Traditional security measures, such as physical patrols and static checkpoints, often fall short in covering expansive and complex campus environments like that of MAU, Yola. Consequently, many vulnerable areas remain unmonitored, creating opportunities for criminal activity to occur undetected. Despite the growing availability of geospatial technologies, many institutions in Nigeria underutilize tools such as GIS and DEM for surveillance planning [2]. There is a noticeable gap in integrating visibility analysis into surveillance infrastructure design, particularly within Nigerian universities.

Security challenges have significantly hindered the operational efficiency of many Nigerian tertiary institutions, especially those located in the North-Eastern states. At MAU, Yola, the need for improved surveillance systems has become increasingly urgent due to incidents such as the abduction of a professor and three undergraduate students on November 14, 2019, and the recent vandalism of campus electrical installations. According to [14] much of the security research in Nigeria, particularly in the North-Eastern region, emphasizes the importance of community involvement in addressing security concerns. In response to

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these threats, the installation of CCTV surveillance systems is anticipated to contribute meaningfully to crime prevention and campus safety.

Therefore, this study applies visibility analysis techniques within the context of MAU, Yola, Adamawa State, Nigeria. It aims to identify optimal high-elevation points suitable for the strategic installation of CCTV cameras to enhance surveillance and address ongoing security concerns. By integrating GIS and elevation data, this study provides a data-driven framework for improving campus security at MAU Yola and serves as a reference model for similar educational institutions.

2.0 Description of the Study Area

MAU Yola is in Girei Local Government Areas of Adamawa state, Nigeria. The study area is located between longitudes 223603.232mE to 226301.987mE and latitudes 1032698.033mN to 1035410.018mN as shown in Figure 1. It is one of the 27 universities in the country and part of the Federal Government university system and one of the only 4 Federal Technology Universities established with the sole purpose of advancing science-based research. It was founded in 1988. MAU, Yola is a non-profit public higher education institution located in the small city of Yola with a student population of over twenty thousand. The University runs undergraduate in nine faculties which includes: Faculty of Agriculture (FOA); Faculty of Environmental Science (FES); Faculty of Social and Management Sciences (FSMS); Faculty of Physical Sciences (FPS); Faculty of Life Sciences (FLS); Faculty of Engineering (FOE); Faculty of Education (FED), Faculty of Computing (FOC); Faculty of Law (FOL); and one college which is College of Medicine (COM); and also one school which is School of General Studies (SGS); and postgraduate programs under School of Postgraduates Studies (SPGS)

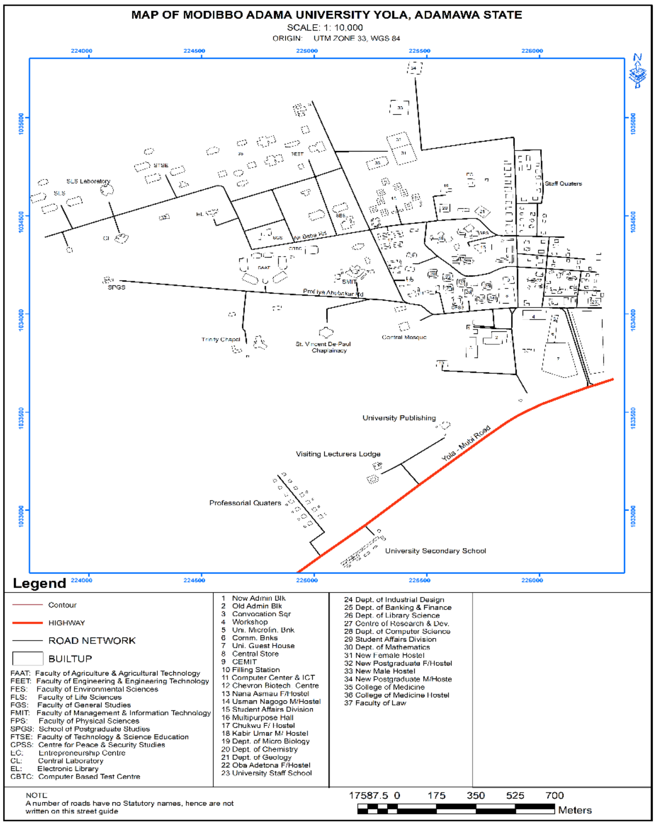

Figure 1: Map of the Study Area

3. 0 Materials and Methods

3.1 Data Acquisition

The study primarily involved the use of Digital Elevation Model (DEM) known as Advanced Land Observing Satellite/Phased Array type L-band Synthetic Aperture Radar (***ALOS/PALSAR***). The ***ALOS/PALSAR*** DEM covering the study area used has a resolution of 12.5m. The DEM downloaded from ASF NASA Land Processes Distributed Active Archive Centre (NASA's LP DAAC) and extracted by mask using the ESRI ArcMap 10.4.1 to the size of the study area. The DEM was reclassified into five classes to show the elevation in different symbology and visibility analysis to obtain optimal position that will command wide area coverage for suitable location in mounting CCTV camera in the University. A high-resolution satellite image of Pleiades with a 0.5m resolution was obtained and used as the basemap for the study area. The ESRI ArcMap 10.4.1 was used for the analysis in the study. Table 1 shows the breakdown of dataset used in this study.

Table 1: Dataset used

S/No.	Data Name	Data type	Source	Year	Resolution
1.	ALOS PALSAR RTC Digital Elevation Model (DEM)	Raster	ASF NASA's LP DAAC	2024	12.5m
2.	Pleiades Image	Raster	Google earth	2024	0.5m

3.2 Geospatial Analysis

To create the digital map of the study area, vector layers representing roads and buildings were digitized as shapefiles using ESRI ArcMap 10.4.1. Ground truthing was conducted to validate all digitized features and to accurately identify places and building names. The Digital Elevation Model (DEM) was clipped to the study area boundary, and then reclassified into five elevation classes as shown in Figure 2. Different colours were assigned to each class using the symbology tool for better visualization. The proposed CCTV camera locations were carefully selected by integrating information from the DEM, the digital map, and ground truthing verification.

Visibility analysis assessed what could be seen from specific observer locations. By examining key terrain features, observation points, and other sites, the analysis identified areas that were visible (capabilities) and those that were hidden (vulnerabilities). Visibility analysis tool in ESRI ArcMap 10.4.1 was utilized to analyze for twelve strategic viewpoints, which corresponded to the proposed CCTV installation sites and to determine the raster surface areas visible from these points. The input raster was the ALOS PALSAR DEM, while the observer points were the proposed CCTV locations.

Parameters for the observer analysis were selected based on established standards and practical considerations for effective visibility modeling. A surface offset of 2.5 meters was used, representing a point slightly above the average human height, which ensures a realistic simulation of ground-level surveillance perspectives. Observer offsets of 6.0 meters and 10.0 meters were chosen to reflect the typical mounting heights for CCTV cameras on poles or building structures or designated platforms, enhancing the line-of-sight and minimizing blind spots. The inner and outer radii were set to their default values of 1 meter and infinity, respectively, as recommended for comprehensive visibility assessments that aim to capture all possible sightlines from a viewpoint. Likewise, the horizontal angles were maintained at the default range of 0° to 360°, allowing for a complete 360-degree field of view, which is essential for surveillance systems intended to monitor surroundings in all directions. The vertical upper and lower angles were also left at their default values of 90° and -90°, providing unobstructed vertical visibility to simulate real-world camera operations in varied terrain.

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4.0 Results and Discussion

In visibility analysis, elevation data is a fundamental component as it forms the topographic basis for determining line-of-sight, optimizing surveillance system design, and identifying strategically significant locations. Without elevation data, visibility models lack the spatial realism necessary for accurate decision-making in surveillance planning. As illustrated in Figure 2, the DEM and observer height inputs clearly show how terrain has influenced the selection of surveillance points. The elevation data was reclassified into five distinct ranges using colour-coded symbology to enhance the visual interpretation of terrain variability within the study area. Higher elevation classes, ranging from 249m to 261m in deep blue colour, correspond to areas with improved visibility and therefore greater surveillance potential. Conversely, lower elevation areas, from 239m to 248m in brown colour, are associated with reduced visibility and a higher likelihood of blind spots. Such visual classification facilitates the quick identification of optimal camera sites and potential surveillance gaps. The application of elevation stratification for enhancing surveillance coverage is well-supported in terrain-sensitive infrastructure planning [11]. It was revealed that elevated terrain points were deliberately selected to maximize visibility. Observer offsets of 6.0m and 10.0m were used to simulate camera installations on poles or building rooftops or some platforms, thereby improving vertical visibility across diverse terrain levels. Incorporating DEM into this process ensures the surveillance design effectively accounts for the area's topographic constraints, reducing blind spots and increasing monitoring efficiency. This approach is consistent with the findings of [9], who underscored the critical role of elevation in enhancing the output accuracy of visibility analysis models.

Figure 3 presents the digitized road network interconnecting the university's faculties and major landmarks. This network was analyzed alongside elevation data to determine strategic CCTV camera placement. Figure 4 illustrates the integration of the road network with proposed camera locations.

Additionally, Table 2 outlines the coordinates and elevations of the proposed CCTV camera locations, reflecting a carefully planned spatial distribution aimed at covering the most vulnerable and high-priority zones within the university. Key areas such as the main entrance, student residences, lecture halls, the Senate building, and staff housing have been prioritized as depicted in Figure 4, indicating a focus on safeguarding both administrative operations and student welfare. This comprehensive spatial coverage supports a proactive and integrated security strategy, ensuring that both high-traffic and high-risk areas are effectively monitored. These findings align with previous research advocating for the strategic deployment of surveillance infrastructure in areas with elevated security needs [18; 1].

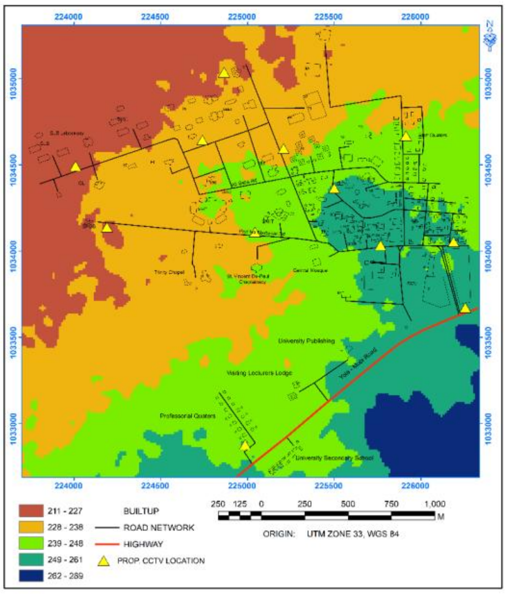

Figure 2: Elevation Map

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Table 2: Coordinates of the Proposed CCTV Locations

S_N	Prop. CCTV Locations	Eastings	Northings	Surface Elevation (m)	Obs. Offset A (m)	Obs. Offset B (m)	Obs. Offset C (m)
1	Main gate	226255.081	1033672.916	256.000	2.5	6	10
2	Behind Industrial Design Dept.	225766.13	1034034.867	255.000	2.5	6	10
3	Abuja Hostel	225499.43	1034365.067	251.477	2.5	6	10
4	Professorial Quart.	224985.079	1032879.164	249.000	2.5	6	10
5	Senate	225042.229	1034111.067	241.344	2.5	6	10
6	Faculty of Engr.	224864.429	1035038.169	230.347	2.5	6	10
7	Medical College	224739.212	1034644.115	233.000	2.5	6	10
8	Faculty of Life Sci.	224007.805	1034494.351	225.000	2.5	6	10
9	Kabir Umar Hostel	225207.263	1034595.508	235.990	2.5	6	10
10	Staff Quatres	225912.969	1034669.271	241.000	2.5	6	10
11	Uni. Staff Pri. Sch.	226187.72	1034055.104	251.000	2.5	6	10
12	SPGS	224188.915	1034139.096	226.364	2.5	6	10

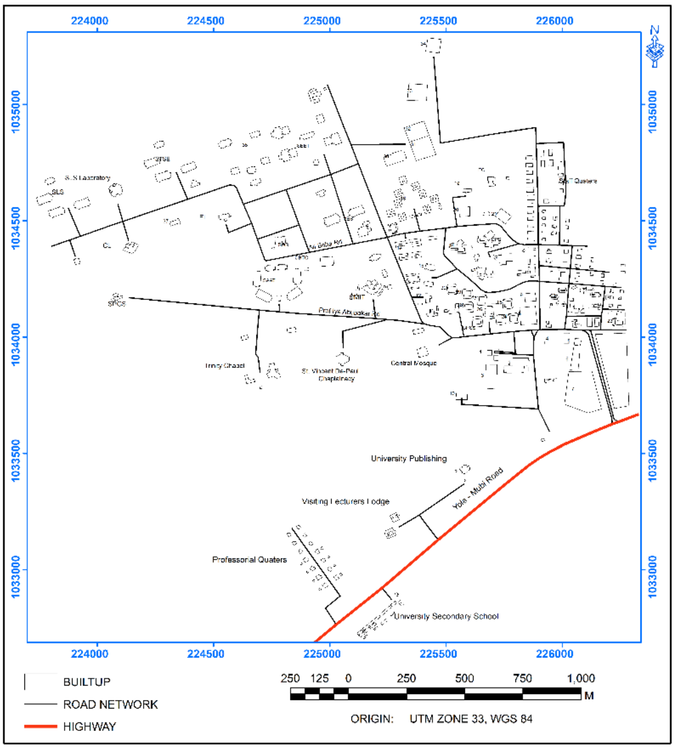

Figure 3: Road Network of Modibbo Adama University, Yola

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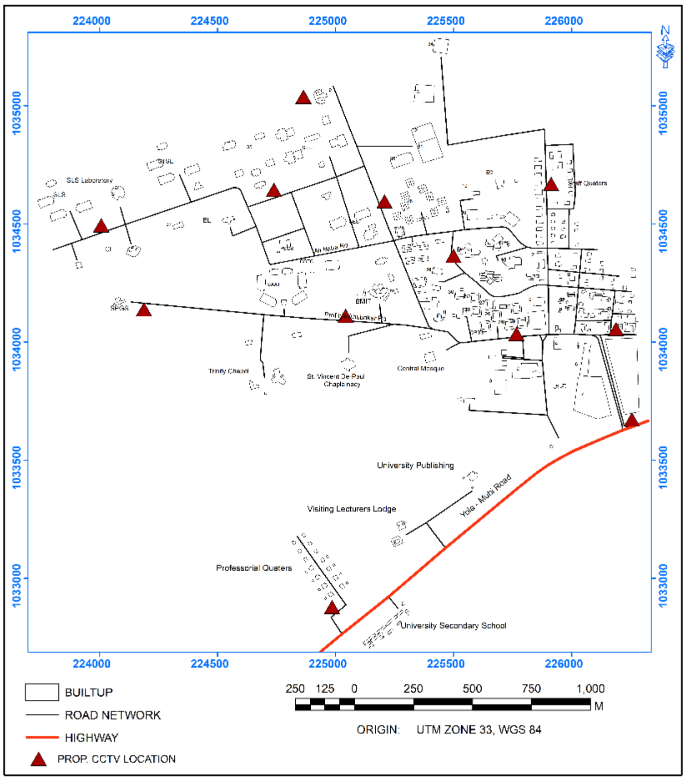

Figure 4: Road Network with proposed CCTV Locations

Figures 5 to 7 shows the visibility analysis which demonstrates the area visible from each proposed CCTV location using the varying heights. Overlapping viewsheds in critical areas such as the hostels and Senate building reflect redundancy for added security, while unshaded (not visible) areas in the outputs indicate blind spots due to terrain or obstacles. This highlights the importance of comprehensive visibility analysis in avoiding unmonitored zones and adjusting camera placement for maximal coverage. Visibility tools such as those in ESRI ArcGIS 10.4.1 when informed by DEM, have been shown to improve surveillance planning in complex environments [3; 15].

[13] noted that integrating CCTV systems allows communities to leverage technology to improve safety and discourage criminal behaviour. The study of [13], further assert that the constant monitoring from CCTV cameras serves as a deterrent, as individuals are aware they are being recorded, which can result in quicker identification and arrest. Also, Placement Optimization of Surveillance Cameras: Visibility Analysis by [8] noted that Visibility analysis provides insights into the spatial relationships between two points in either two-dimensional or three-dimensional space hence Figure 5 is the Visibility analysis at offset height of 2.5m.

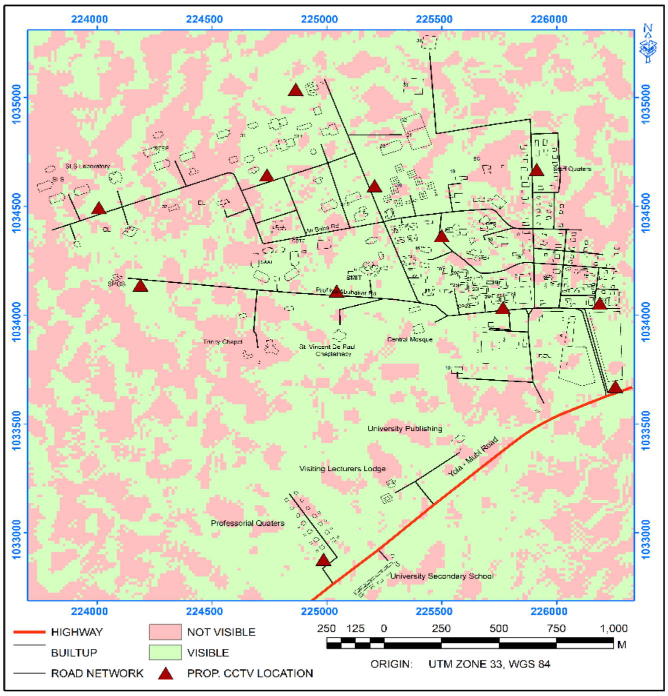

Figure 5: The Visibility Offset Height of 2.5m

Figure 5 indicated that 3.743km^2 is not visible with areas such as the E-Library, Faculty of Law, Trinity Chapel, School of General Studies, Faculty of Education, Faculty of Life Sciences and School of Post Graduate Studies. In contrast, all other areas are visible covering an area of 5.291km 2. As the offset height increased to 6m as shown in Figure 6, the visible area increased to 6.614km2 while the not visible area reduced to 2.420km^2. Parts of the Faculty of Life Sciences, Kabir Umar Hostel and Faculty of Agriculture were not visible.

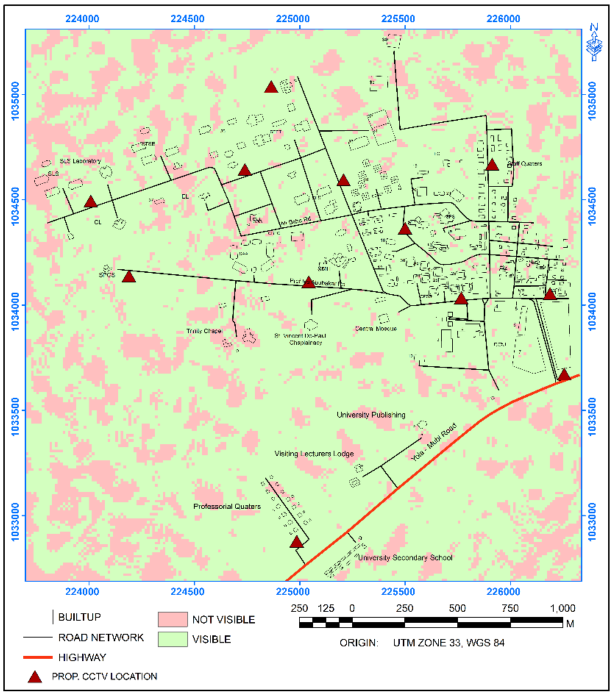

Figure 6: The Visibility Offset Height at 6m

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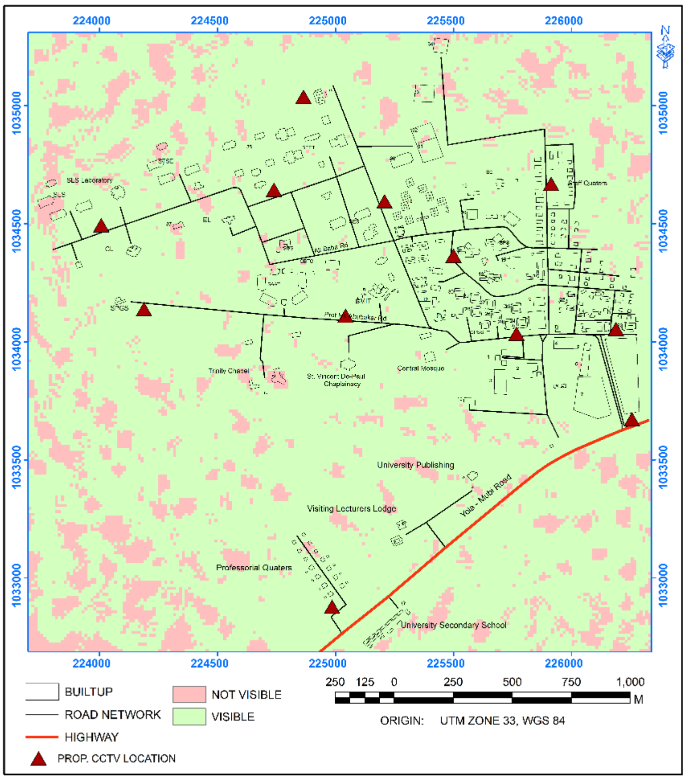

Figure 7: The Visibility Offset Height of 10m

As the visibility offset height was increased to 10m as shown in Figure 7, visible area increased to 7.377km^2 while not visible area deceased to 1.657km^2 which are mostly not built-up areas. The study presented a panoptic isovist which refers to the ability to observe a full 360° view in a location in all directions from the origin point, offering an omnidirectional perspective as noted by [16].

Moreover, enhanced visibility can increase the sense of security among students and staff, which is important not only for physical safety but also for psychological well-being. [10] stated that a secure campus environment fosters a more conducive atmosphere for learning and productivity. However, the benefits of increased visibility must be balanced with privacy considerations and ethical deployment. Over-surveillance without transparency may generate mistrust or lead to a "panopticon" effect, where individuals feel constantly monitored [17].

Additionally, while high visibility improves surveillance efficiency, it does not eliminate all threats. Sophisticated or targeted attacks may still bypass visible surveillance zones. Therefore, increased visibility must be integrated with other proactive security measures, such as access control systems, community policing, and emergency response protocols as noted by [14].

In nutshell, increased visibility plays a critical role in threat reduction on university campuses. When combined with spatial analysis tools like GIS and DEMs, visibility assessments enhance the strategic deployment of surveillance assets, leading to improved safety outcomes while minimizing blind spots and vulnerabilities.

5.0 Conclusion

This study has demonstrated the critical role of visibility analysis in enhancing surveillance infrastructure at MAU, Yola, Adamawa State, Nigeria. By integrating DEMs, GIS, and field-based ground truthing, the study successfully identified optimal high-elevation points for CCTV camera placement across the campus. These proposed locations were selected to maximize line-of-sight coverage, reduce blind spots, and provide surveillance over strategically important and high-traffic areas such as hostels, academic buildings, the Senate building, and the main gate.

The findings of this study underscore the value of spatial analysis in ensuring effective surveillance planning, particularly in complex and expansive university environments. Properly planned CCTV deployment not only strengthens physical security and deters crime but also supports real-time monitoring and enhances emergency response capabilities. Moreover, the integration of geospatial data allows for scalable surveillance solutions and informed decision-making for future infrastructure expansion.

In conclusion, visibility analysis offers a data-driven approach for improving campus safety at MAU and provides a replicable model for similar institutions across Nigeria facing increasing security challenges. Future research can build on this work by incorporating dynamic factors such as vegetation cover, building height and real-time video analytics to further refine surveillance planning and effectiveness.

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