Utilizing UAV Techniques to Investigate the Dynamics of Encroachment on The Right-Of-Way for The N8 Highway in Peri-Urban Ghana

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SUMMARY

Encroachment on highway reserves is a major problem in Ghana as it hinders the efforts to develop and expand highways in Ghana. This paper draws on Asef Bayat's theory of "quiet encroachment" and uses UAV (drone) imagery to detect and analyze the development of informal settlements along the N8 highway reserves in Ghana.

Aerial images of the corridor were acquired and processed using Agisoft Metashape software and finally, an orthophoto was produced. The buildings and road features were extracted using a computer vision algorithm add-on in QGIS; Orfeo Toolbox. A GIS buffering operation was performed on the Right of Way (ROW) using 35m and 45m distances according to the standards of the Ghana Highway Authority and the physical planning committee. It was identified that thousand and eighty-six (1,086) buildings were identified in the buffered region. Using google earth historic data, these structures within the buffer were tracked (object detection) to determine the trend of encroachment within the reservation. A structured questionnaire was designed and administered to the affected people in the encroachment zone.

The results obtained from the datasets were analyzed by overlay operation and computing the areas of encroachment of adjacent structures with emphasis on evaluating the potential of the high-resolution drone images in the determination of encroachment into the ROW and as well determining the positional accuracy obtainable based on the spatial resolution of the input drone image used for this study.

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1.0 Introduction

In Ghana, people depend on road connectivity as the main channel to their various destinations. The N8 national highway is a key resource that connects many districts and regions in the country. The growth of the road network is vital to the development of trade and commerce, inter-regional connectivity, and transportation of goods and services.

Physical planning standards and compliance are essential as it builds the urge to control spatial development (Omollo, 2020). Physical planning standards on the roads and highway entails reservations with their respective setback from property line, thus any encroachments by the public constitute a violation for which restoration is necessary (Jibrin, 2013). These reservations are made with the view to providing for future expansion, and allowing a right of way to effectively give room for carriageway, side drains, and roadside parking without distracting the traffic (Ojo-Fajuru and Adebayo, 2014). However, various contraventions in Ghanaian cities have taken different forms such as the construction of permanent structures in open spaces or setbacks, front shops, and much unsightly development on road and utility setbacks. Most of the residential buildings and commercial activities in Ghana cities are located within the right of way of the highway, through the use of temporary structures such as kiosks and other structures fronting the road (Aluko, 2011; Jonah, 2014). This reduces road spaces and thus increases traffic delay during peak hours and the frequency of vehicle accidents in such areas where there is encroachment.

With the advent of Geographic Information Systems (GIS) and remote sensing technologies, capturing the spatial details by remote sensing either by satellite imageries or aerial photographs has offered tremendous ease in the identification, mapping, and monitoring of encroachments on highway corridors. It is more important to have high spatial resolution when detecting spatial

features in an urban environment. Gopalan (2009) in his research discussed that fine spatial resolution satellite data permits small objects to be seen and mapped, special choice of spectral bands improves the discriminating ability between different land features.

For the purpose of this study, a segment of the N8 highway from Ahenema kokoben to Anwia Nkwanta was selected for evaluation. This study thus adopted aerial images (drone) data to examine the existing pattern and extent of highway right-of-way encroachment in the study area using buffering operations in a GIS environment; and assess the level of compliance of buildings to road setbacks.

2.0 Study Area

The study area is located along the N8 National Highway, from Ahenema Kokoben through to Anwia Nkwanta. It is approximately 20 kilometers in length. Geographically, the road is between latitude 6° 37' 31" N and longitude 1° 38' 51" W of the Greenwich meridian. It passes through a lot of communities and further to other regions in Ghana. The immediate impact area is the 300ft along the road corridor in which the encroachment occurred.

The study area route falls mainly in the Atwima Kwanwoma district. It has about 234,846 population with 114,123 males and 120,723 females according to the 2021 population and housing census, it is said to be a peri-urban community (Ghana Statistical Service 2021).

The selection of this area was based on their increasing socioeconomic activities, increasing land acquisition, and housing projects coupled with proximity and the willingness of the people to assist with this work.

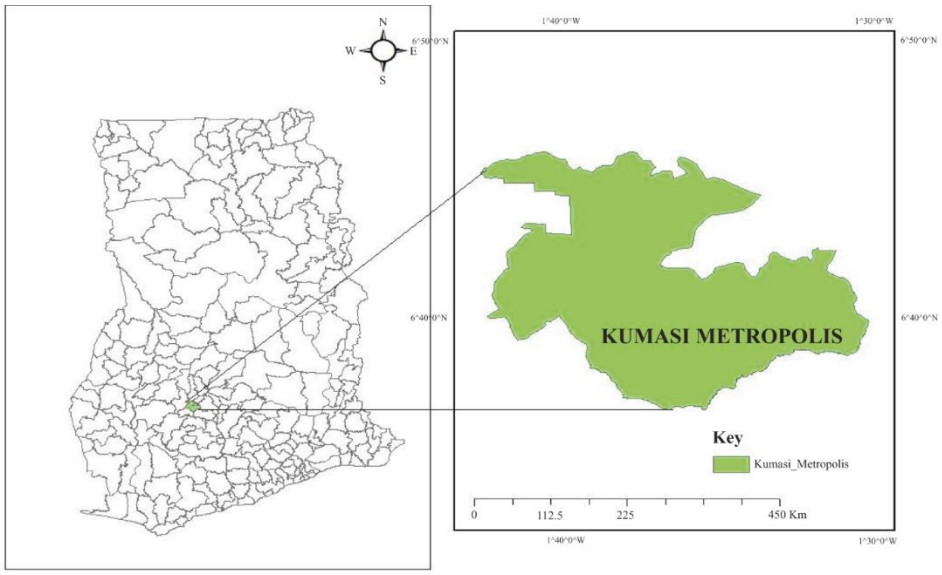


Figure 1. Digital Map of Study area

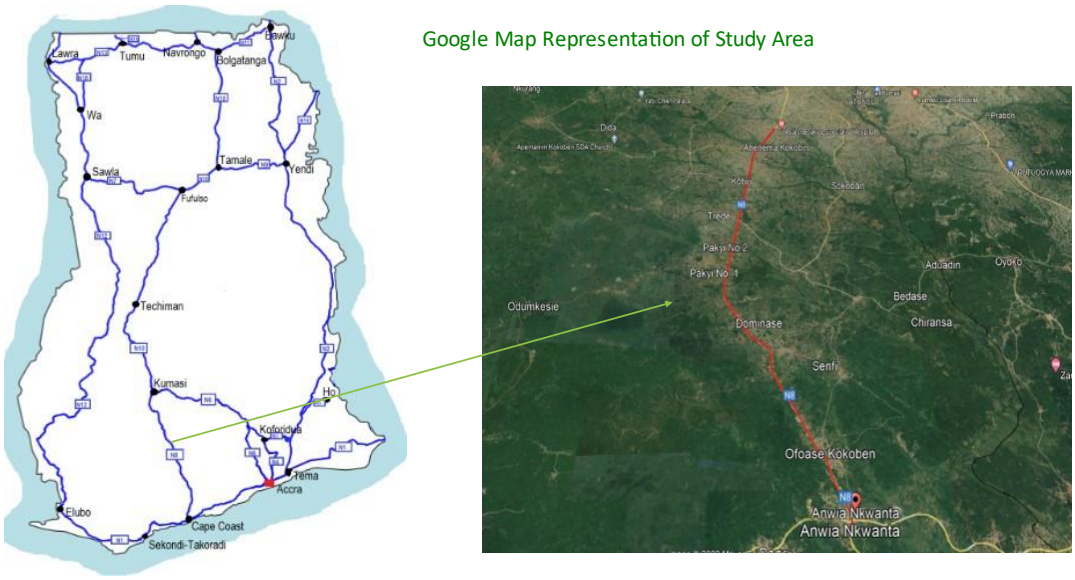


Figure 2. Google Earth view of Study area

3.0 Materials and Methodology

3.1 Materials

A DJI Phantom 4 pro v2 drone was used to capture aerial images of the study area. The drone was launched to capture images in the visible region (RGB) of the electromagnet spectrum. The base map and the flight specifications were set in the drone deploy application. Specifications as shown in Table 1 were accepted and the drone was deployed to capture aerial images.

Table 1: Flight specifications

	Altitude (150m)
Focal length	8.8mm
Flying height	150m
Forward Overlap	75%
Side lap	65%
Shutter speed	1/8000

3.2 Method

The flowchart of the methods used in the UAV survey is outlined in Figure 3. First, a reconnaissance survey was carried out to help determine the terrain of the study area and also to help decide the optimum height to fly.

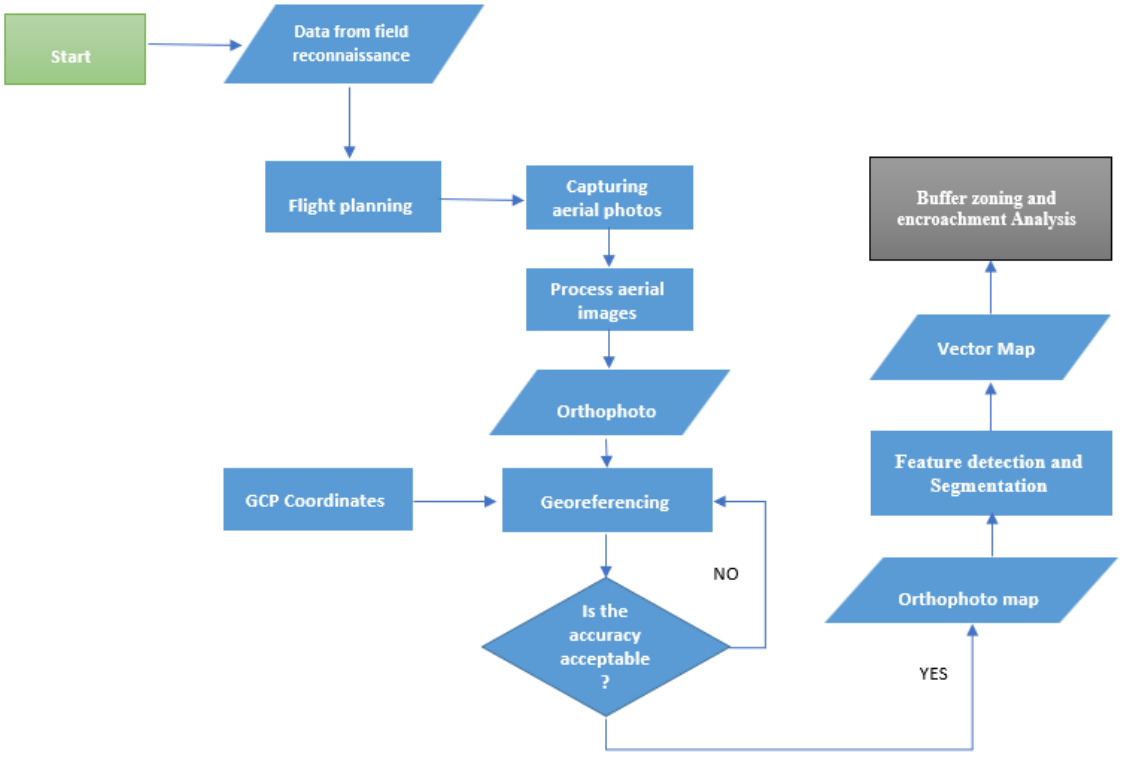


Figure 3. Flowchart of Methodology

3.2.1 Flight Planning

To acquire the requisite information needed to plan a successful flight, a reconnaissance survey of the area under study was conducted. The Drone Deploy Software was then used to plan the flight. Care was taken to determine a suitable location without shade which could cause an obstruction to the Ground Control Points (GCPs). The image scale, the area of interest (AOI), the required ground sample distance (GSD), and the flying height were set for the UAV to operate in an autonomous mode instead of the manual mode. The UAV was flown at a flying height of 150 m and the flight plans had forward and side overlaps of 75% and 65% respectively to achieve a 4.5cm GSD.

3.2.2 Image Processing

Agisoft Metashape was used to generate the final orthophoto as shown in Figure 4.

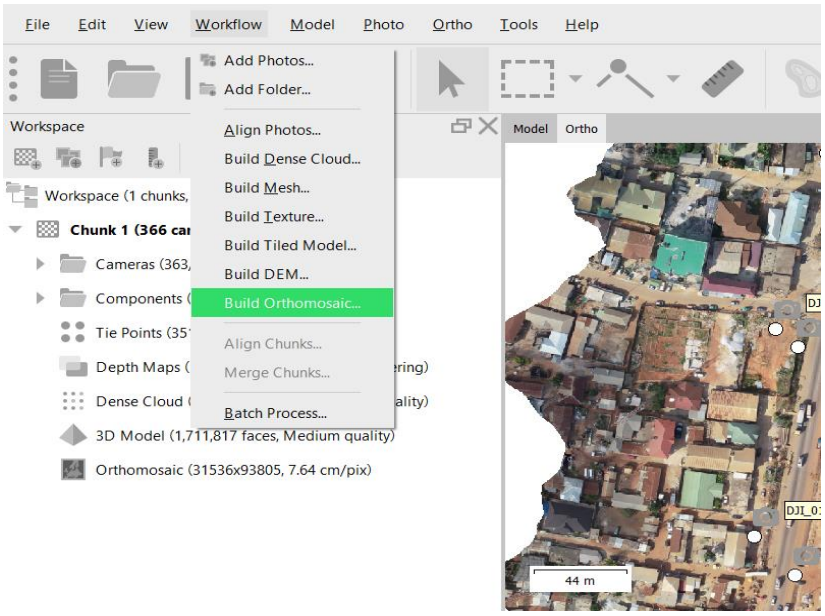


Figure 4. Workflow for Image processing

Figure 5. Orthophotomosaic of study area

3.2.3 Feature Detection and Extraction

The computer vision algorithm as an addon package known as the Orpheo Toolbox (OTB) in QGIS was used in extracting the buildings. However, the road and some other structures within these reservations were manually digitized in the QGIS software. Together with the automated extraction datasets were used in further processing, analyzing and discussing the results.

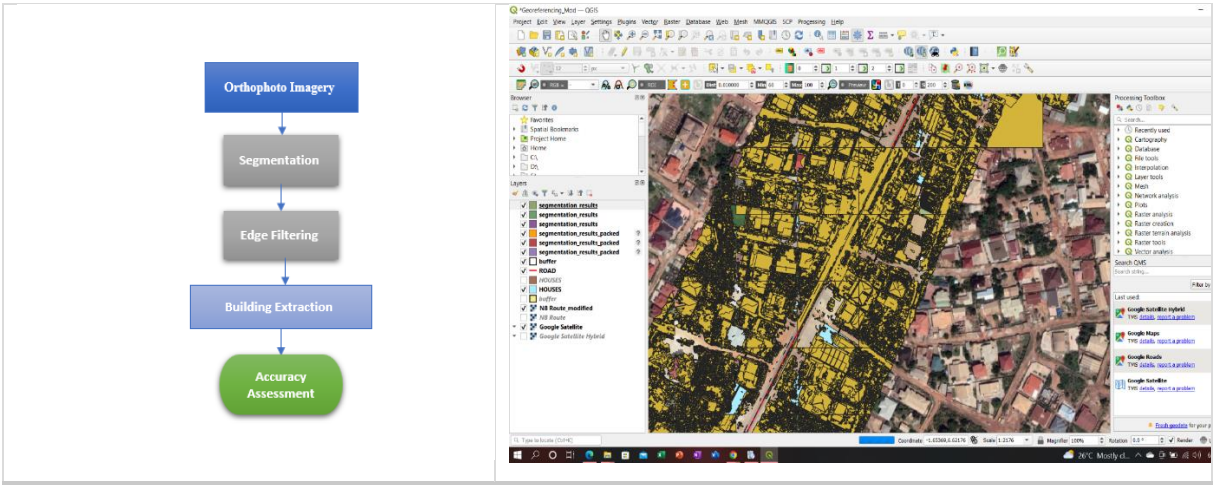


Figure 4. Orthophotomosaic of study area

3.3 Questionnaires

Questionnaires and interviews from various target groups were used in this research. The questionnaires were designed according to the key objective which is identifying the drivers, pressures and state of encroachment of the highway corridors. The study considered mixed method of sampling thus, purposive and stratified sampling method. The purposive sampling method was used as the inhabitants along the road had the essential information for the study and therefore were the main target sample frame to select key informants in order to allow experts with experience and insight information on the subject matter to come to bear. To ensure spatial distribution of responses from residents, the stratified sampling technique was adapted for the administration of questionnaire to residents in order to reach out to many respondents as possible within the short time. The sampled individuals constituted those affected by the

compulsory acquisition. Upon consultation with interviewees and some leaders of the communities, these people were located and interviewed. In total, 255 questionnaires were administered.

3.4 DPSIR Framework

The Driver-Pressure-State-Impact-Response (DPSIR) framework is an effective and simple framework for illustrating ecosystem-based management (Kanwal et al., 2022). The framework is a robust instrument that may be used in social, economic, and institutional domains due to its adaptability and broad applicability. According to the (OECD 2003), an indicator is a parameter, or a value derived from parameters, which provides information about or describes the state of a phenomenon. This study used indicators from reviewing literature and from the data collected on field. General information from informal discussions and interviews were used as indicators for the DPSIR framework.

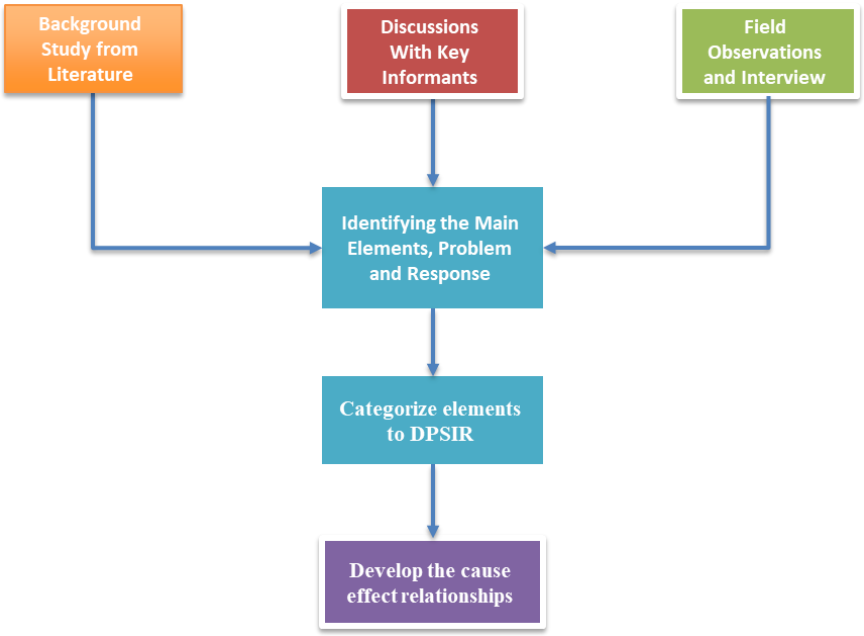


Figure 5 The DPSIR indicators and methodological framework

4.0 Results and Discussion

4.1 The state of encroachment on the N8 Highway reserves

The N8 highway corridor has a mixed kind of development though a large portion of it has been developed for residential and commercial land use. From the orthophoto, the areas which had been encroached were mapped out and showed as settlements or built-up areas.

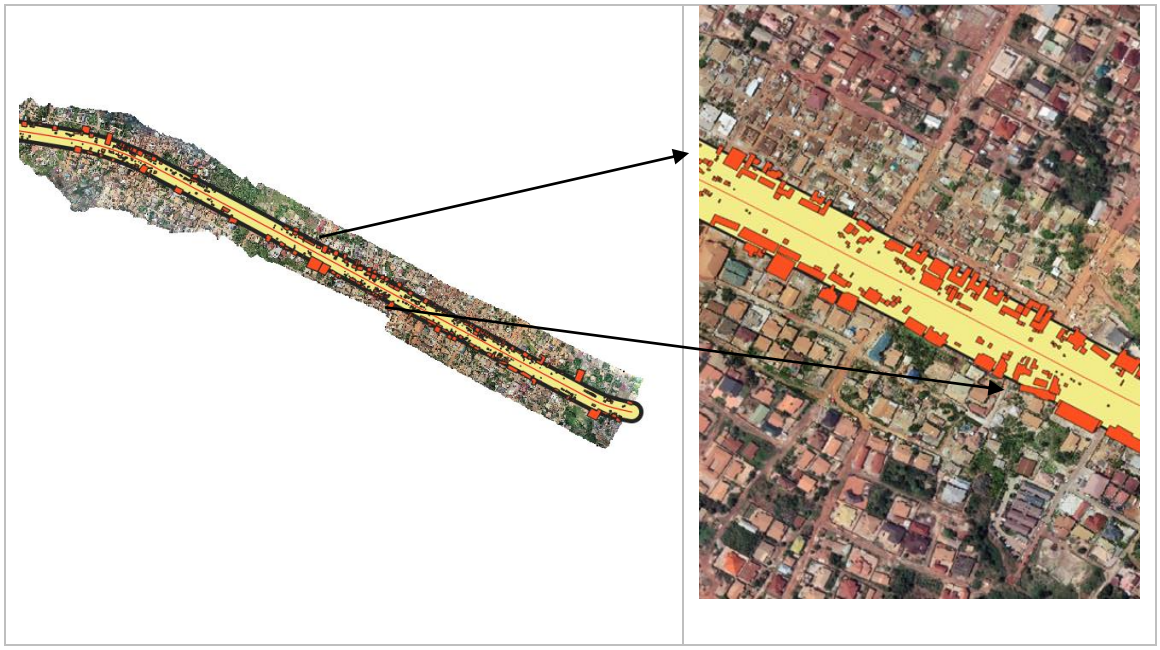


Figure 6. Encroachment situation in the Study Area

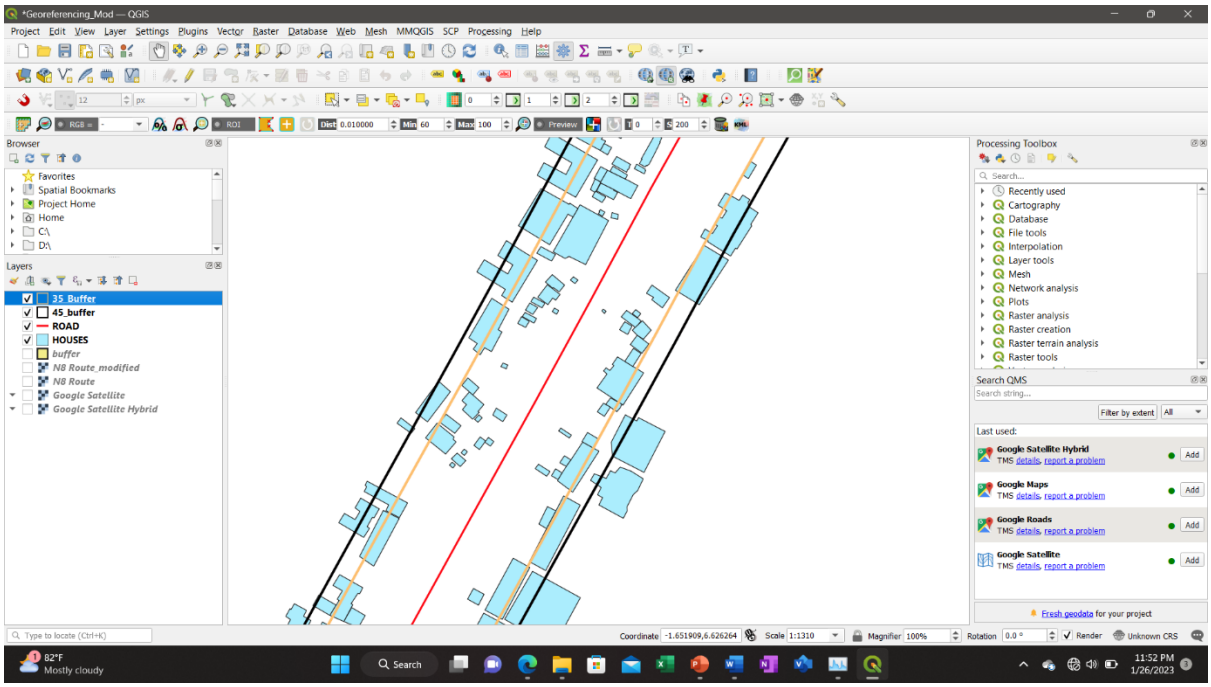


Figure 7. Structures within the 45m and 35m Encroachment buffer zones

4.2 Pattern and Trend of Encroachment Using Object detection with google earth

Encroachment of the highway corridors commenced over two decades ago but became more pronounced in 2012. To determine the spatio-temporal changes in the land use of encroachment within the road reserve, the historic data of google earth images were used in tracing these structures from 2010 to 2022 (i.e., 2011, 2016, and 2022). This technique helped in identifying the various structures which just got developed as a result of peri-urbanization and the increasing socio-economic activities in the Atwima Kwanwoma district.

The vector dataset extracted and digitized from the georeferenced orthophoto imagery was converted to a Keyhole Markup Language (KML) and then overlaid with the google earth base map satellite data. From Table 4.1 and Fig 4.1, the magnitude of buildings in the encroached area increased by about 33.8% from 2011 to 2022.

Table 2: The magnitude of buildings in the encroached area from 2011 to 2022

Year(s)	2011	2016	2022
Permanent Structures	238	512	637
Temporary Structures	103	196	449
Total	341	608	1086

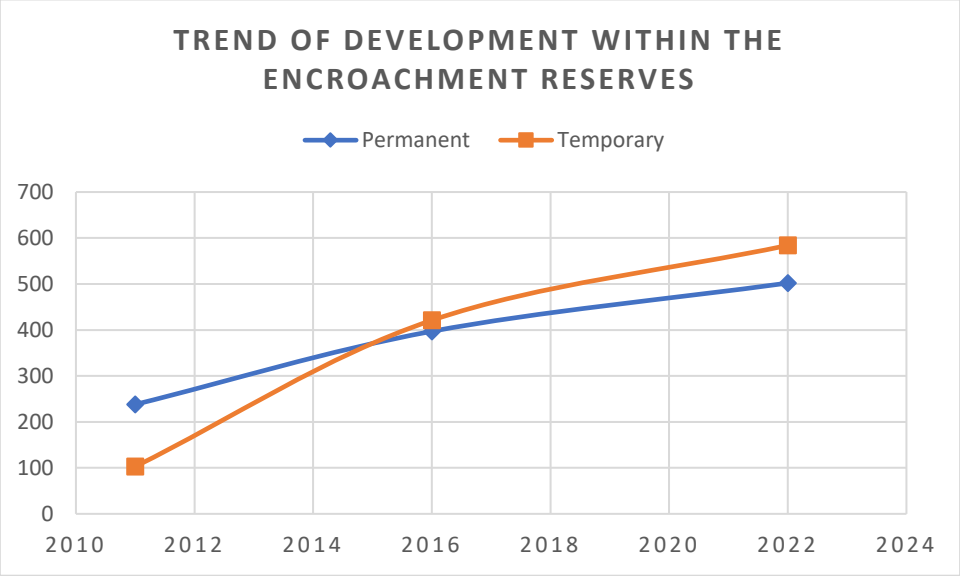
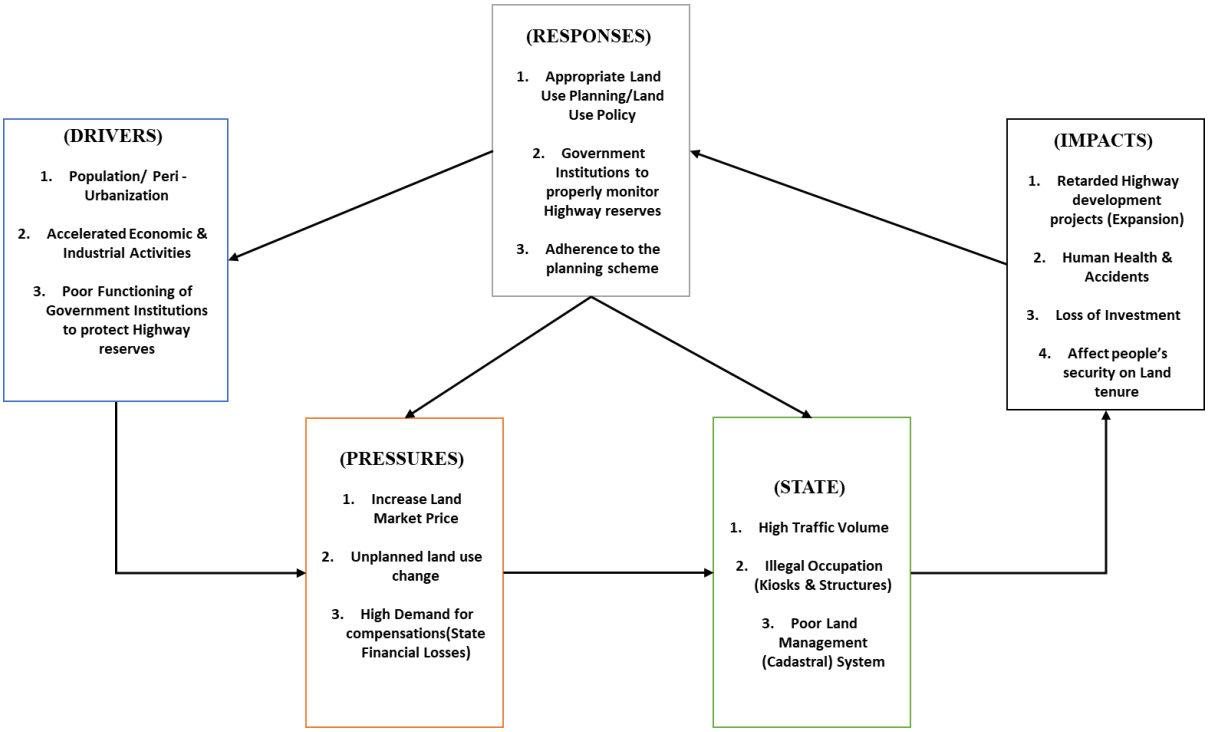


Figure 8. Trend of development within the encroachment zone

4.2 Factors contributing to illegal occupation and development on the N8 highway reserves

The occupation and development of the road corridor arose due to different factors. The residents could have knowingly or unknowingly settled on this road corridor. Many of the respondents interviewed felt that their developments did not fall within the encroachment zone. When asked whether they were aware that their developments fell within the catchment, 107 (51%) answered in the negative and 14.3% did not know whether their developments formed part of it and so did not know they had encroached. However, 73 people, or 34.7% knew that

they were occupying a portion of the zone. The DPSIR framework was a tool to assess and analyze cause-effect relationship diagram as seen below;



5.0 Conclusion and Recommendation

Based on this study, which aims at evaluating the evaluating potentials of aerial images (UAV) in carrying out ROW surveys, it is evident that the high-resolution aerial images have shown good potentials in determination of encroachment within the right of way ROW. Furthermore, this has shown an easier, quicker, and cheaper approach in determination of encroachment on right of ways.

This study revealed the distinctiveness of aerial mapping and GIS in evaluating the case of encroachment on road setback along the N8 highway. The study concluded that there was high level of contraventions on the road setback in the study area. Haphazard developments were linearly patterned along the road corridor dominated by buildings constructed spontaneously. The road setbacks were dominated by informal development such as kiosks, containers, and wooden shops, which were located within the right of way (ROW) thereby leading to congestion within the city. Despite the high level of awareness on development control

regulation, developers still contravened road setback without regards to approved development plan.

To address and amend this challenge, the study recommended that the Ghana government should provide adequate support for the Local Planning Authority in term of technical and manpower; and demolish the contravened structures. The Kumasi Metropolitan Authority (KMA) should adopt geospatial technique in timely monitoring of development control activities, and this will serve as a routine check and prompt discovery of all contravention within the city.

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