Detecting Disparities in A Proposed Planning Scheme using Unmanned Aerial Vehicle (UAV): A Case Study

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Abstract

A planning scheme is one of the most used legal documents to manage and outlines how land is demarcated. Land is very significant to socio-economic development since most human activities occur on land. The planning scheme usually indicates sections of land for different purposes such as residential, industrial, recreational, and civic purposes. In most communities, however, development precedes planning which is the main cause of improper land use and planning. The leasing of lands is handled mostly by chiefs and local authorities leading to the indiscriminate sale of land without considering proposed planning schemes. This paper examines improper planning and land use at Akyempim, a community in Tarkwa-Nsuaem Municipality in the Western Region of Ghana. High-resolution images and the proposed planning scheme of Akyempim were used to assess the disparity between the proposed planning scheme vis-a-vis actual development. The orthophoto of the study area and the proposed planning scheme were superimposed to detect areas that do not conform to the planning scheme. It was evident that road networks and lanes had been diverted from their original course. This paper found that all buffer zones as per the planning scheme had been encroached upon and the site proposed for a school has been turned into a residential facility. A proposed Day Nursery School site has also been used by a developer for fish farming. The Akyem road linking the Tarkwa-Takoradi highway compared to the planning scheme has been diverted from its course and also heavily encroached upon. This paper concludes that most developments are not in conformity with the planning scheme. The physical planning department and the Lands Commission should work closely with chiefs and local authorities to curtail the indiscriminate sale of land and to comply with planning schemes since indiscriminate land use can have disastrous outcomes.

Keywords: Akyempim, Planning Scheme, Unmanned Aerial Vehicle, orthophoto

1 Introduction

As urban settlements grow in size and population increase, local governments must maintain a smooth development process to manage the physical space and the environment. This according to Anon., (2020), encompasses the creation and implementation of numerous development plan schemes. A planning scheme is a legal document that specifies the boundaries of a given territory (Steffan, 2018; Anon., 2016). It outlines the goals, policies, and procedures for the use, development, and preservation of land in the area to which it applies (Steffan, 2018). These planning schemes depict areas designated for commercial, industrial, educational, residential and civic activities. Due to the economic and social importance of spatial planning, the President of Ghana on September 14, 2016, assented to a law passed by the Parliament concerning regulations on land use and spatial planning (Anon., 2016). The land use and spatial planning Act 2016 was passed to revise and consolidate the laws on land and settlements and to regulate national, regional, district, and local spatial planning (Anon., 2016). According to the Ghana Land Use and Spatial Planning Act (2016), local plans may be prepared to establish legally binding regulations for: the land coverage for construction on a plot in the zone; the type of structure on the land; the form and height of buildings; tree preservation; the preservation of buildings with cultural heritage and historical structures; and any landscaping or tree planting requirements.

Land is a precious natural resource that has been endowed with value and provides a direct and indirect source of income for a vast number of people (De Wit and Verheye, 2003). Because practically all human activities take place in this space, the land is critical to socio-economic progress. The significance of land can be understood by considering its key characteristics, which include its finite nature (Duke and Wu, 2014). While planning schemes are required to ensure the well-being of city dwellers, they are not always followed. When planning schemes are followed to the latter, they help to establish functional settlements. Every township in Ghana is

meant to be established according to a pre-planned framework, however, most towns and cities in Ghana, including Akyempim in the Tarkwa-Nsuaem Municipality, do not meet those criteria. The land use plan is one way that Ghana's physical planning department guarantees that good practices are constantly followed, taking into account problems such as aesthetics, economy, harmony, health, and safety, all of which have been highlighted in the developmental process. The issue of improper land use arises primarily because the right to lease and sell land for development purposes is handled by individual community chiefs and traditional authorities. Leaseholders of land establish unauthorised projects in the neighborhood that contradict the proposed planning scheme, resulting in long-term litigations. District Assemblies (DAs) are mandated by Ghana's decentralisation strategy to design and implement development plans to ensure the overall development of their areas of control. Implementation challenges of the DAs include chieftaincy and land disputes, low levels of commitment by stakeholders and ineffective teamwork, according to a study, which is based on survey data from six District Assemblies in Ghana (Mensah, 2005). To address these challenges, effort must be made to enhance human capacity, organise and effectively deploy financial resources, promote awareness, resolve land disputes and create effective monitoring and assessment mechanisms (Mensah, 2005).

1.1 Spatial Planning in Ghana

The strategies employed by the public sector to impact the distribution of people and activities in spaces of various scales is referred to as spatial planning (Healey, 2007). Spatial planning, according to Healey (2007), is a set of governance methods for designing and implementing strategies, plans, programs, and projects, as well as regulating the location, timing, and form of development. This comprises regional and national spatial plans, as well as all levels of land use planning. One of the internationally accepted strategies used by governments to influence the distribution of activities and their implications for the social, economic and environmental components of development is spatial planning (Acheampong and Alhassan, 2015). It describes several parts of planning practices that provide proactive possibilities for the management of change, including policymaking, policy integration, community participation, and development management, and also indicates a shift beyond a traditional understanding of land-use planning (Tewdwr-Jones, 2004). It intends to integrate strategic development within separate regions that could be sponsored or owned by government or governance entities (Albrechts, 2006).

1.2 Local Planning Scheme

Local plans are detailed plans that conform to the broad land use classification prescribed in the structure plan. It shows the specific details of proposed projects within the area such as streets, markets, schools, recreational centres and other details of the planning area. They form the basis for the issuance of development and building permits for prospective developments. Most municipalities organise city spatial activities by making land use plans to guide long-term development. These plans help to make sure homes and amenities are organised to support residents, and that there are efficient ways to travel to work, shop and have fun. In Ghana, local plans are prepared for each community in a district by zoning regulations to guide spatial development (Anon., 2016). Local plans are based on planning scheme documents.

2 Materials and Methods

2.1 Study Area

The Tarkwa-Nsuaem Municipality is one of the municipalities in the Western region of Ghana (Fig. 1). The municipality lies between latitude 4°5′ N and 5°4′ N and longitude 1°50′ W and 2°10′ W. It has a total land surface area of about 1 045.65 square kilometers (Kumi-Boateng and Stemn, 2020). Based on the 2021 population census, the total population within the area is 218 664 with 129 046 people in the urban centres and 89 618 in the rural areas (Anon., 2021). The study area produces an estimate of 35% of Ghana’s gold output (Ewusi *et al.*, 2017). The daily temperature ranges from 20 ℃ to 40 ℃, with a mean monthly temperature of 24 °C to 30 °C (Ewusi *et al.*, 2017). The municipality has evergreen mountain ranges, which presents an appealing aesthetic scenery for people living in the area. The geological formations in the Municipality are mostly the Birimian and Tarkwaian rock formations (Dzigbodi-Adjimah, 1993). Tarkwa is located on the contact between the Tarkwaian rocks due west and the older Birimian Supergroup of Ghana to the east (Eisenlohr and Hirdes, 1992; Dzigbodi-Adjimah, 1993) Unfortunately, these ridges are the main gold-containing areas and are targeted for open cast mining, so they have undergone tremendous mining-related development in recent decades.

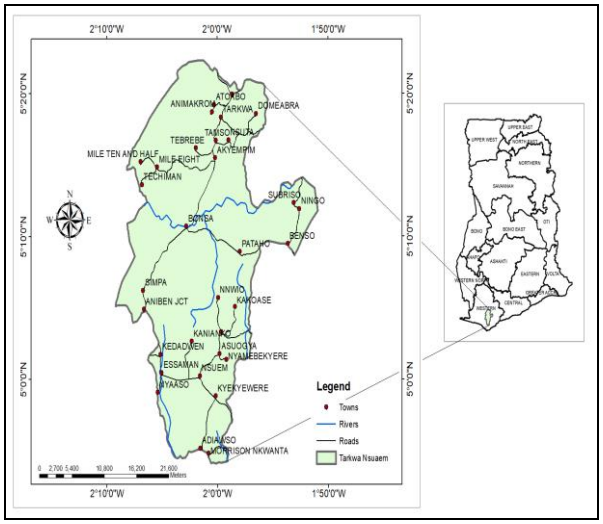

Fig. 1 Map of the Study Area

2.2 Materials

The materials used for this study are discussed in the following subsections.

2.2.1 Data Used

The data used for this study has been grouped into Primary and Secondary data sources.

Primary data

Aerial photographs were acquired from DJI Phantom 4 Pro drone and Static GPS was used in acquiring ground coordinates from the study area for georeferencing the aerial photos (Table 1). Phantom 4 Pro drone was flown at an altitude of 120 m to capture the features of the study area. Static GNSS Receiver was used to pick control points at twelve minutes occupational time for each point. These points were used to georeference the imagery and the local scheme of the study area. The coordinates from the static GNSS receiver served as coordinates on the ground while the plan scheme coordinates (Table 2) served as the map coordinates for georeferencing.

Table 1 Coordinates of the Ground Control Points

Name	Eastings	Northings	Elevation
GCP1	610412.7	581503.7	151
GCP2	610632.9	581679.7	151
GCP3	610708.6	581306.5	151
GCP4	610431.9	581307.5	151

Table 2 Local Planning Scheme Coordinates

ID	Eastings (m)	Northings (m)
1	610217.9635	581433.5917
2	610241.0984	581397.4461
3	610277.9834	581340.9232
4	610327.9384	581252.2116
5	610363.2921	581159.8133
6	610372.6863	581120.1245
7	610379.4412	581077.7793
8	610384.9357	581015.5706
9	610396.9014	580999.7213
10	610475.4280	580995.6897
11	610444.1949	580997.2932
12	610509.9644	580993.9165
13	610555.7334	581010.8210
14	610548.3942	581058.1204
15	610539.5124	581115.3622

Secondary data

Secondary data such as the existing local scheme or the layout of the study area with a scale of 1:2500 was obtained from the physical planning department of the Tarkwa – Nsuaem Municipal Assembly.

2.2.2 Software used

Agisoft Metashape, a stand-alone software application that performs photogrammetric analysis of digital photographs and generates spatial data like orthophotos were used to process and geo-reference flight images. Drone Deploy Software was used to plan the UAV flight. ArcGIS 10.5 was also used to digitise the planning Scheme of Akyempim and to perform superimposition of the Planning scheme and the orthophoto thus detecting the margin of shift.

2.3 Methods Used

The methods used in this study is shown in the following chart:

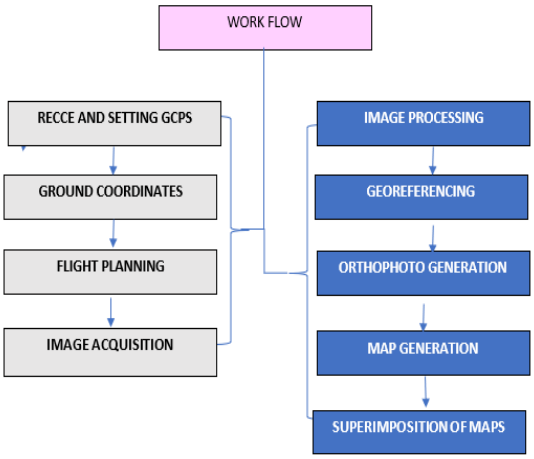

Fig. 2 A flow chart of the methods used

2.3.1 Reconnaissance and setting out of Ground Controls

A preliminary survey was carried out to have first-hand information and get familiar with the community and ascertain key landmarks. This survey was performed to serve as a check between map features and ground features. Features like the Tarkwa-Takoradi Highway were looked out for in the map, the Akyempim School, Community Centre, Akyem road, and a Day Nursery. For the purpose of georeferencing, four GCPs were planted along the boundary of the study area. Coordinates were picked at the centre of all the GCPs using a static GPS. These GCPs are very relevant in image processing; matching the drone location data to the location data measured on the ground. Figure 3 is a sample of GCP planted within the boundary to pick coordinates of specific points.

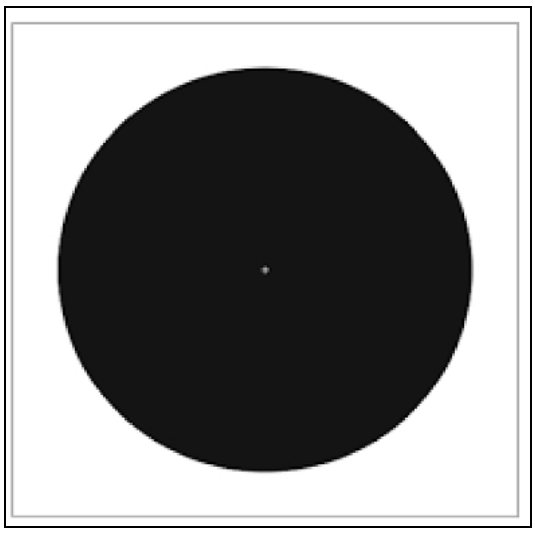

Fig. 3 Ground Control Point

2.3.2 Flight Planning

Flight planning is the first step in a photogrammetric project. The main goal of planning is finding out the best-fit flight lines and camera exposure stations. To cover the project area with a minimum number of models, overlaps and camera exposure stations must be planned carefully. The paths that an aircraft takes to ensure complete coverage of the area to be photographed are also known as Flight Plan (Birute, 2004). To cover the project area with a minimum number of models, flight lines and camera exposure stations were planned carefully. A forward lap of 70% and a side lap of 60% were used in this operation. An altitude of 120 m and a resolution of 3.6 cm/pix and an area of 0.14 square kilometers were covered. The total amount of time taken to complete the flight was 7:47 minutes. Flight planning deals with technical specifications such as required photo scale, flying altitude, and camera specifications. The DJI Phantom Pro 4 drone which was used has two types of flight modes named autonomous flight mode often referred to as waypoint flight mode and the manual flight mode. The autonomous flight mode was used since it gives more stable navigation compared to the manual flight mode. The presence of onboard GNSS/INS navigation devices is usually exploited for autonomous flight (take-off, navigation and landing. The area of interest (AOI) is defined on a graphical interface on an electronic device such as a tablet that has the flight mission software installed on it. On this interface, a take-off point and a landing point are clearly defined. Based on the start point, the mission was set up relative to its coordinates. Also, a flight planning system, which includes parameters like altitude, aircraft position, overlap, camera angle and time is clearly defined on the interface. For this study, the Dronedeploy software was used. During the flight, the autonomous platform was observed with a Ground Control Station (GCS) or the Remote Controller (RC) which shows real-time flight data such as position, speed, altitude and distances and GNSS observations, to ensure that the flight is done within the survey area of interest. The following flight planning procedure was used on the field:

i. A new mission was created on the tablet application for the area to be surveyed;

ii. Mission altitude which includes; the height above ground at the point of take-off was set to 120 m;
iii. The approximate position of take-off and landing was clearly defined;
iv. The project area was clearly defined by drawing a polygon over the Area of interest; image front and side overlaps were set at 80 % and 60% respectively for easy matching of tie points; and
v. The camera angle was also set at an angle of -90 degrees.

Fig. 4 Flight Planning

2.3.3 Image Acquisition

This was done using the Phantom 4 Pro drone. Mapping large areas have never been easy using the conventional surveying method. Therefore, a Phantom 4 Pro drone was deployed to map some sections of the Akyempim township at an elevation of 120 m, a side lap of 60% with a resolution of 3.6 cm/pixel. To further improve the accuracy of the map, ground control points (GCPs) were collected for Geo-referencing and checkpoints processing.

2.3.4 Image Processing

Image processing was done in the Agisoft Metashape environment. The procedure involved aligning photos, building dense clouds, building mesh, building DEM, Building orthomosaic. The result of this procedure was an orthophoto.

2.3.5 Georeferencing of Flight Images and Local Plan of the Study Area

Georeferencing is the name given to the process of geospatially referencing data and information objects – datasets, maps, photographs, and imagery to their proper locations on the ground. The vast majority of such objects derive from measurements and observations of phenomena that are inherent and can be georeferenced. Georeferencing can be accomplished in two main ways formally, by assigning geospatial coordinates directly to data and information objects; and informally, by relating such objects to one or more pre-existing ones for which georeferencing has already been established. (Hastings and Hill, 2019). Georeferencing was performed to orient the images and the local plan so that features on the images or the local plan will correspond to that on the ground. Ground control points were picked with south static GNSS receiver and the area was marked with surveyor's spray. The sprayed or marked areas of the points were to make them more identifiable when Georeferencing the flight images. The local plan was also georeferenced using the coordinates of identified features which can be found on both the ground and the scheme.

2.3.6 Orthophoto Production

An orthophoto is an aerial photo, which has been processed such that the features on the photo represent an orthographic projection or an aerial photograph that can be geometrically corrected such that the scale is uniform. To generate orthophotos sparse clouds and dense clouds were built around the study area. Mesh is built and the orthophoto is generated. The task of orthorectification is to produce an orthogonal projection from the originally taken images. Since the DEM is already in the target projection, a reprojection of original image pixels onto the reference plane is possible. This reprojection is normally done per DEM-mesh and to retrieve a more appealing orthoimage, some texture and colour balancing was applied.

2.3.7 Generation of Maps

A map of the digitised study area was produced in ArcGIS software. This map was digitised for more clarity. The map was digitized and the allocated plot numbers and their intended purposes were stated. To further improve the accuracy of the map, GCPs were collected for Geo-referencing and checkpoints processing. Also, individual maps from the orthophoto of the study area were generated to aid in the analysis of the results

2.3.8 Superimposition of Maps

The proposed plan scheme and the drone imagery were superimposed on each other. This was done to check whether the individual plots and sections

were used according to the Layout Scheme. This was achieved by first georeferencing the planning scheme and the orthophoto within the same coordinated space (Projected Coordinate System). Unauthorised buildings or parcels were then identified using the selection by location approach. This was complemented by field inspection to verify whether the proposed uses of the land use scheme were respected.

2.3.9 Data Validation

The methods used for validating the data were ground-truthing and setting out. With ground-truthing, coordinates of some features on the ground were picked and plotted on the georeferenced images to see whether they fall on the exact features. Vice versa, coordinates from the orthophotos were also picked and set out on the ground to see whether it falls at the same place. Validating the georeferenced local scheme, it was superimposed on the images to see whether existing features like roads and old buildings that are identifiable on both images and the local scheme will correspond to that on the image. The Tarkwa – Takoradi Highway served as a check in validating the georeferencing since almost all coordinates on the photo and the ground were in alignment.

2.3.10 Data Analysis

The primary and secondary data were analysed quantitatively. Quantitatively, Microsoft Excel was used to provide quantitative outputs such as coordinates of the boundary picked by the static GPS and the georeferenced data. Also, The Local Scheme of the study area was georeferenced and then evaluated to see whether the plan Scheme is being followed. This was done carefully to ascertain the margin of deviation from the proposed plan scheme.

3 Results and Discussions

The following subsections present the results of this study

3.1 Results

Coordinates from the photo and the Ground Control Points picked with the Static GPS were used in georeferencing. The images were mosaic and georeferenced using Agisoft Metashape with a Root Mean Square Error (RMSE) of 0.041129 m. Some roads within the community were tracked and then plotted on the imagery to verify their validity. Fig. 5 was used as a check to ascertain the validity of the georeferencing since both photo coordinates and the ground coordinates when aligned are supposed to fall almost exactly in the same region. The area used for this check is the Tarkwa-Takoradi road, a major road linking Accra, cape coast, and Takoradi to Tarkwa. Since the land used for the road does not belong to any of the inhabitants of the Akyempim township, the road was not shifted to suit the inhabitants' developments.

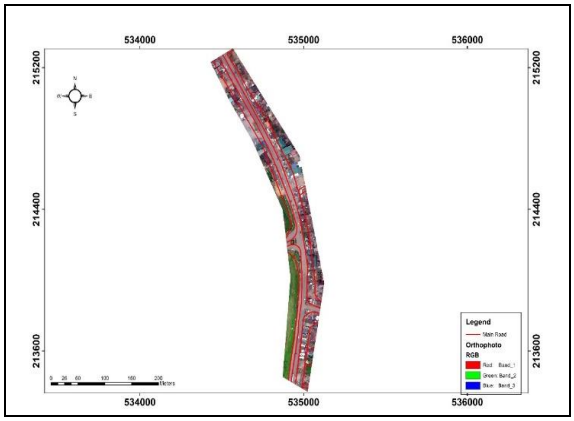

Fig. 5 The Tarkwa-Takoradi Highway

A total of 152 aerial images were captured from the study area which was processed with Agisoft Metashape software to produce orthophotos. Fig. 6 is an orthophoto generated from the study area. This orthophoto is geometrically aligned. This is a coverage of all areas falling within the study area.

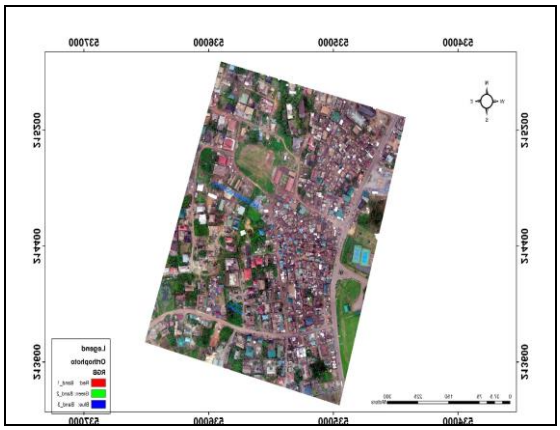

Fig. 6 Orthophoto of the Study Area

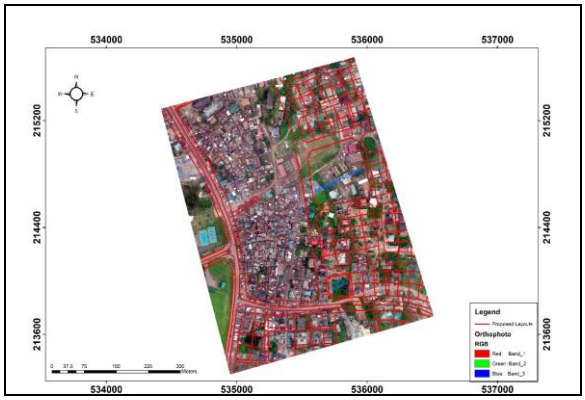

Fig. 7 Superimposition of the Orthophoto and the Planning Scheme

Transformation of both the photo coordinate and the planning scheme coordinates into the same coordinate system (WGS 84) was done to make superimposition possible. After the superimposition of the proposed planning Scheme and the orthophoto, there was a clear disparity between the orthophoto and the planning scheme. The entire settlement has deviated from the Proposed Planning Scheme from the Physical Planning Department.

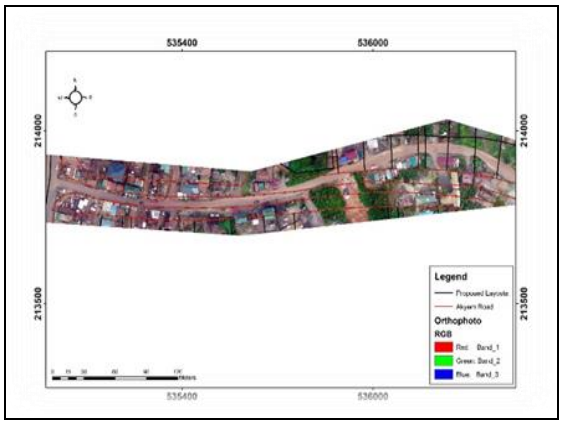

Fig. 8 The Akyem Road

From Fig. 8, the Akyem road a minor road meeting the Tarkwa – Takoradi road has diverted from its planned course. The road has been shifted by developers to suit their interests and favor their development. Developments in the area were based on a first-come, first-served basis. Developers make sure no road passes through their parcel once construction commences. The road is shifted to suit developers. Once parcels are bought individuals try as much as possible to avoid roads passing through their parcels. They immediately build walls around their parcel to avoid road construction around the parcels.

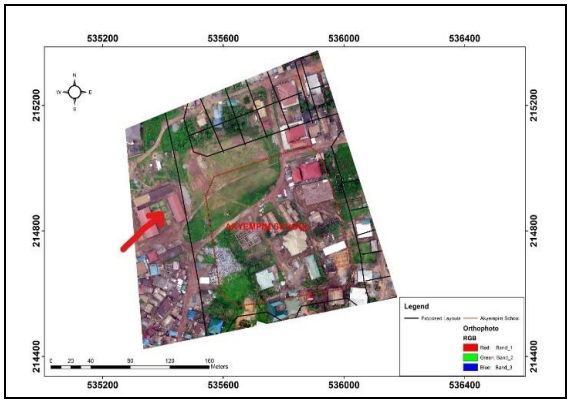

Fig. 9 Current versus Planned Location of the Akyempim School

From Fig. 9 the area demarcated for the construction of Akyempim school has been used for residential purposes which do not correspond to the original plan. The school is now built outside the delineated section shown by the red arrow.

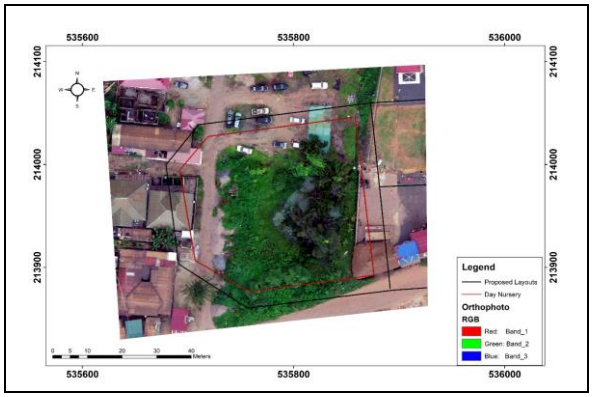

Fig. 10 Site proposed for Day Nursery

The proposed Day Nursery site has been used by a private developer for fish farming purposes. Also, the whole boundary has been encroached upon by residents as shown in Fig. 9

Discussion

All buffer zones as per the planning scheme have been encroached upon. These zones were created to serve the purpose of keeping real-world features distant from one another thus protecting the environment, residential and commercial zones from industrial accidents or natural disasters.

The Akyem road joining the Tarkwa – Takoradi highway as compared to the planning scheme has been diverted from its course and part of the road

has been heavily encroached by internal developers. All lanes as per the planning scheme have been encroached upon. Based on ground observations, there are no lanes between adjoining parcels as per the planning schemes.

A site proposed for Day Nursery is being used for a fish pond and part of the land is encroached upon by a mechanic shop. Charlekrom an area within Akyempim has no planning scheme because the area was developed before the planning. The area is a slum and has no proper road networks.

Conclusion

The planning scheme was evaluated and critically considered and it revealed that developments on the ground were not in conformity with the proposed planning scheme, some developments preceded planning. It is seen that planning is usually not regarded when developments were ongoing in the study area.

6.2 Recommendations

It is therefore recommended that:

The Physical Planning Department and the Lands Commission should work with the chiefs and local authorities to avoid the indiscriminate sale of land and to comply with the planning scheme.

Individuals should also be educated on the importance of following the planning scheme and the side effects of not doing so.

The survey department should be given access to the Planning scheme to serve as a guide in their survey works.

Before giving out building permits to developers, the physical planning department must send field agents to check whether the plan coincides with the planning scheme.

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