International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

# Assessing the Compliance of Physical Plans using GIS and Remote Sensing: A Case of Olkalou Town

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**Abstract:** ***Compliance assessment is a component of physical planning concerned with the instigative inquiry as to whether an approved physical plan is implemented and guidelines followed as stipulated. The aim of the study is to assess the compliance of a physical plan using the Geospatial information system and remote sensing technologies and propose a framework to be used for the assessment. The study area was Olkalou Township in Nyandarua county of Kenya. Recent high resolution satellite imagery of the study area was used together with the approved physical plans as data sources to extract the information which was cross referenced with information gathered during the field study. Remote sensing was used to extract information from the satellite imagery which was later used as input into GIS system as a data source. Subsequently, GIS analysis was carried out and the compliance level was computed. From the results zones such as the transportation zone exhibited a compliance of 89.47% whereas the public utility zone showed a 0% non-compliance. Non-compliance observed in the various zones was represented by the difference in the existing land use from the proposed land use. It is evident that the responsible authorities do not emphasize the need for compliance assessment of the developments taking place and have to rely on the paper based system which is time and labour consuming and is easily marred by corruption.***

**Keywords:** Physical planning, Compliance, Land uses, Geospatial information system, Remote sensing

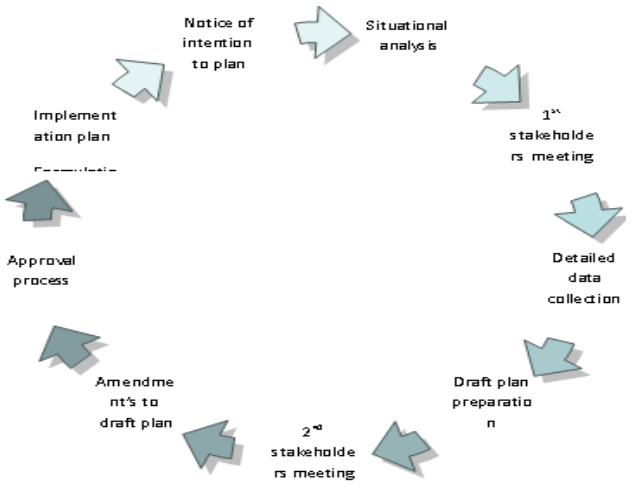
## 1. Introduction

Spatial planning, urban planning, land use planning, regional planning and physical planning are terminologies which have been used over time interchangeably to refer to the equitable allocation of resources to competing land uses whilst upholding sustainability. The role of physical planning in Kenya is currently vested on the Director of physical planning with the oversight of planning in the country being carried out by the National Land Commission [1, 2]. The planning process is procedural and varies from country to country [3] .GIS application in planning can either take the form of toolbox or database application with the extent of use of either of the applications depending on the levels and the stages of planning. Remote sensing on the other hand has been/and is still used as a prime data source for planning purposes owing to its numerous advantages. Assessment for compliance on the other hand is a collective mechanism of monitoring and evaluating the existing development in lieu of the proposed land uses as per the approved development plan which acts as a blueprint document.

### 1.1 Physical planning in Kenya

Physical planning is a discipline relating to the equitable allocation of scarce resources to various competing land uses. These land uses and their development guidelines are implied in physical plans prepared by the Office of the director of physical planning with the oversight of the National Land Commission [1, 2]. Upon their approval these plans become enforceable attracting legal implications. Land uses incorporated in the physical plans includes residential, commercial, agricultural, transportation, recreational among others. The physical planning process is a dynamic process which can be customised depending on the specific scenario. The process of planning results in different types of plans ranging from the regional development plan, local physical development plan to the action area plan. These plans vary dependent on the scope as well as the valid duration of each. The former, Regional development plan outline strategies geared towards the urban and rural development , measures relating to resource allocation and utilization, strategies and the measures relating to coordination of the various sectors including the suitable provision for transportation, public purposes, industrial, residential and recreational areas including parks and open spaces[3]. The local physical development plan on the other hand are prepared in reference to a trading or a market Centre and can either be long-term (20-30 years) or short term plans (3-5 years).

The planning process is an iterative process commencing at the notice of the intention to plan and is summarized by the Figure 1.



### 1.2 GIS, Remote Sensing and physical planning

GIS is a powerful set of tools enabling the collection, storage, integration and the subsequent analysis of both spatial and non-spatial data to arrive at various planning decisions [4]. Remote sensing technology on the other hand refers to the process of gathering information from an object without getting into contact with it. Remote sensing has over time been used as a source of data owing to its advantages ranging from synoptic viewing capabilities, temporal resolution and high spectral resolution [5]. GIS and Remote sensing applications in spatial planning are slowly gaining popularity owing to their efficiency and effectiveness though their uptake in developing countries is still low and is attributed to factors such as the lack of necessary workforce, lack of adequate data, low levels of technological adoption among other factors.

### 1.3 Development control and Compliance assessment in Kenya

The local authorities are empowered by the local Authorities Act Chapter 265, to regulate and control development in their jurisdictions in partnership with the Director and other relevant authorities [6]. This provides for the process of granting development permission through development application made to them, enforcing the preservation orders, approval and enforcement mechanism as well as monitoring to ensure that plans are adhered to minimizing chances of non-compliance, formulate by-laws to regulate zoning in respect of use and density of development, reserve and maintain all the land planned for open spaces, parks, urban forests and green belts in accordance with the approved physical development plan as well as to prohibit or control the use of and development of land and buildings in the interest of proper and orderly development of its area [7]

Assessment for compliance in an ideal situation follows the plans implementation phase, this however is not always the case and instead it is advised by the unpleasant outcomes the noncompliance brings. The Kenya law through the physical planning Act Cap 286, mandates local authorities to monitor development control in the areas within their jurisdiction. The laws guiding development control in Kenya have not critically detailed the process of assessing the existing developments .With most local authorities' facing challenges ranging from lack of technological advancement forcing them to use the manual paper based systems which have over time proofed to be inefficient and ineffective as far as speed ,accuracy and efficiency is concerned [8]. Non-compliance has been characterized by unapproved developments coming up, encroachment through settlements into restricted areas with the overall effect being the reduced quality of life of the urban dwellers. Some of the outcomes attributable to the high levels of uncontrolled development include increased instances of collapse of buildings, development of slums over time, reduction in the quality of life of the urban dwellers, high levels of environmental pollution among others [9].

### 1.4 The case of McAllen, Texas versus the Kenyan Case.

The city McAllen in Texas experienced problems as far as compliance assessment for development in the city was concerned .Some of the problems attributed to the paper based systems ranged from inefficiency in the workforce, inaccuracy of the data picked using various equipment's, lack of integration of data picked by different field personnel. The process was also expensive as field personnel required to pick this data were many [10]. The McAllen administrative authority decided to adopt the usage of GIS solutions to tackle their problems. This not only solved the problems the authority was facing but also made it possible to carry out work on a real time bases through establishing an integrated system. The integrated system meant that all persons, equipment's, processes used a common geodatabase concurrently. In Kenya the similar problems which were faced by the McAllen are commonplace. Taking the case of the capital city of Kenya, Nairobi only 40% of buildings within the county meet the required standards according to city Hall report [11]. A lot of lives are lost through collapse of buildings which experts have blamed on factors such as inaccurate construction of materials ratios, incompetent designs, and poor workmanship all of which are supposed to be monitored by the county technocrats for compliance. If similar approaches would be adopted in Kenya it would then become possible to monitor new developments coming up and hence field work involved will be more targeted on the new developments coming up.

## 2. Problem Statement

It is notable that upon physical plans approval the planning process is deemed complete [2]. This begs the question of how and who will monitor the implementation process of the approved development plans as this role is moved to a different institution (local authority) [6]. With the many challenges being faced by the local authorities ranging from inadequate manpower, inadequate resources. Noncompliance of developments to the physical plans bears many undesirable effects ranging from collapse of buildings, reduced quality of lives and growth of slum areas over time. There arises the need to have a framework that monitors the implementation of this plans to ensure that plans are implemented and one that harmonizes the transition process from the formulating to the .This research aimed at establishing a framework which would bridge the gap and facilitate the implementation of physical development plan as intended by establishing a methodology which would be implemented by any institution to enhance adherence.

## 3. Study Area

The study area is located within Nyandarua County in the central province of Kenya as shown in Fig 2. It has an average elevation of approximately 2970m above sea level. The township faces many land tenure issues which have hindered the level of the developments taking place. The dominant land use as per the approved development plan is residential land use taking 34.07%. The land uses in the township are grouped into commercial, residential, agricultural, recrea-

tional, transportation, industrial, public purpose and public utility.

## 4. Data And Methodology

The main data sources for this study was a Pleiades satellite imagery with a spatial resolution of 0.5m dated February 2014 showing the township area, an updated development plan for the township for the year 2000, a block plan showing the township boundaries and the field data that was collected in the field. The procedures used to extract and analyses the information to produce the final output is summarized in Fig 2.

**a. Georeferencing the satellite imagery and the development plan (spatial data sources)**

Bearing into consideration the difference in the coordinate systems of different datasets which could introduce serious errors as far as spatial analysis is concerned there arises the need for the harmonization of the referencing systems [9]. To eliminate this probable error ground reference points picked using an RTK GPS were used to reference all the datasets. These reference points were many and evenly distributed in the township area. The datasets referenced included the spatial plan, the block plans, and the satellite imagery. The reference points were in the projected coordinate system (UTM Arc 1960 zone 37S) and all the datasets were transformed to the same.

**b. Creating a Geo-database**

The ArcGIS 10.1 software was used for this study. A Geo-database was created using Arc Catalog into which all the referenced datasets were stored and the subsequent vector layers prepared from them.

**c. Extracting information through onscreen digitizing and keyboard entry**

Developments in the Olkalou township were extracted from the high resolution satellite imagery, parcel based information was extracted from the year 2000 development plan with information such as the stipulated land uses, area of the land parcels, the name of the preparing and approving authority.

**d. Sampling and field investigation**

Sampling was carried out to select the datasets from which field data was collected. Since the developments are few and close to each other all the developments in the entire township area were selected. Fieldwork was carried out and information on the existing uses of the buildings was obtained together with the spatial information.

**e. Performing spatial analysis**

The buildings layer was linked to the development plan layer using the spatial intersection feature in GIS making it possible for the attribute contained in the development plan to be copied to the buildings layer to create the layer A which was later to be referred to as the control dataset as shown in the Fig 3.The field data was linked to the layer A via spatial intersection to create the field dataset.

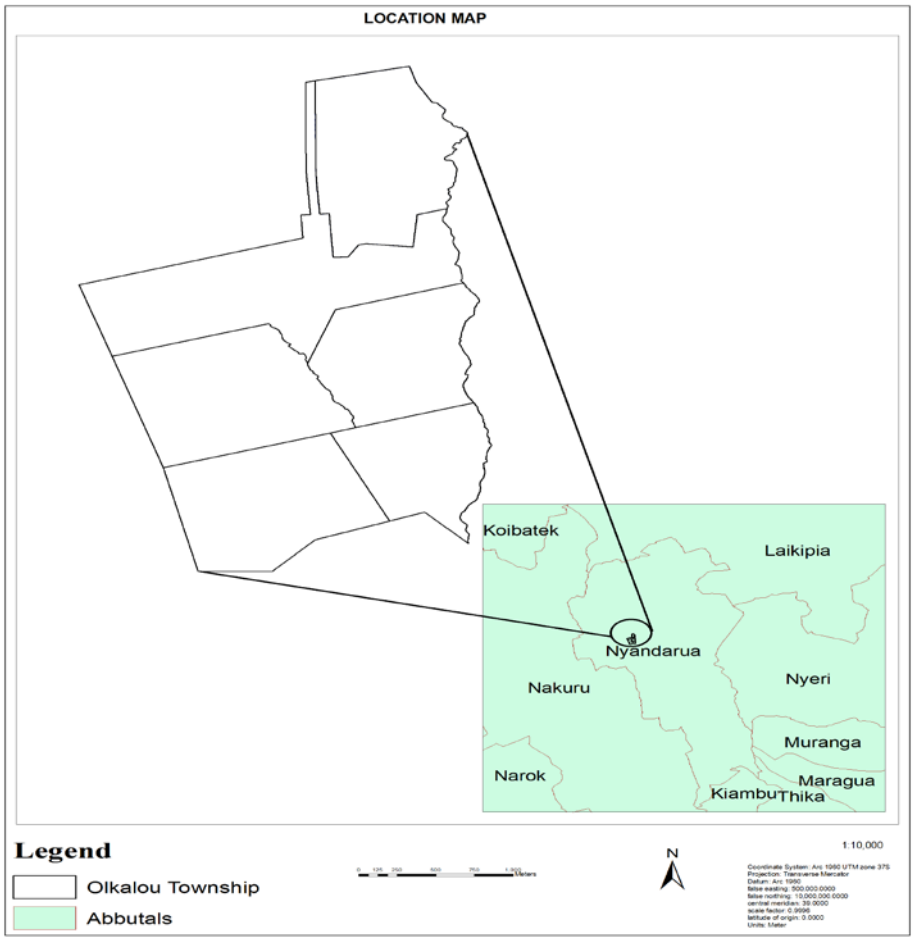



**Figure 2:** Location map showing Olkalou Township in the county context

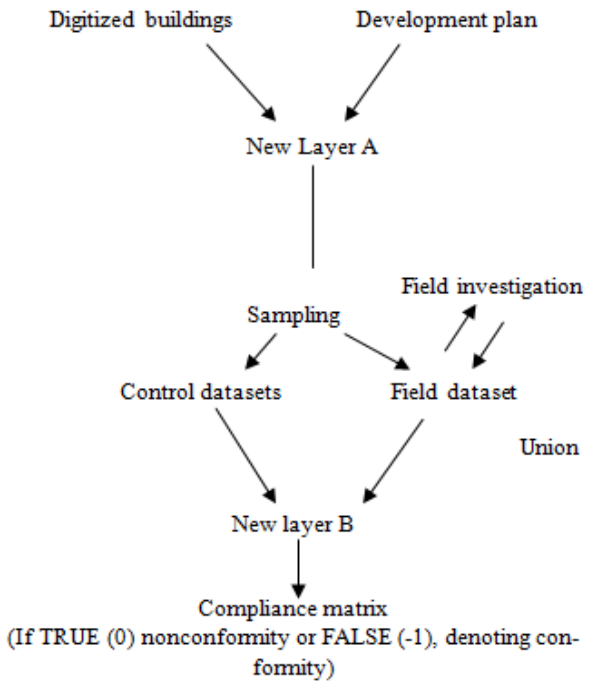



**Figure 3:** The methodology for conducting complaince assesment

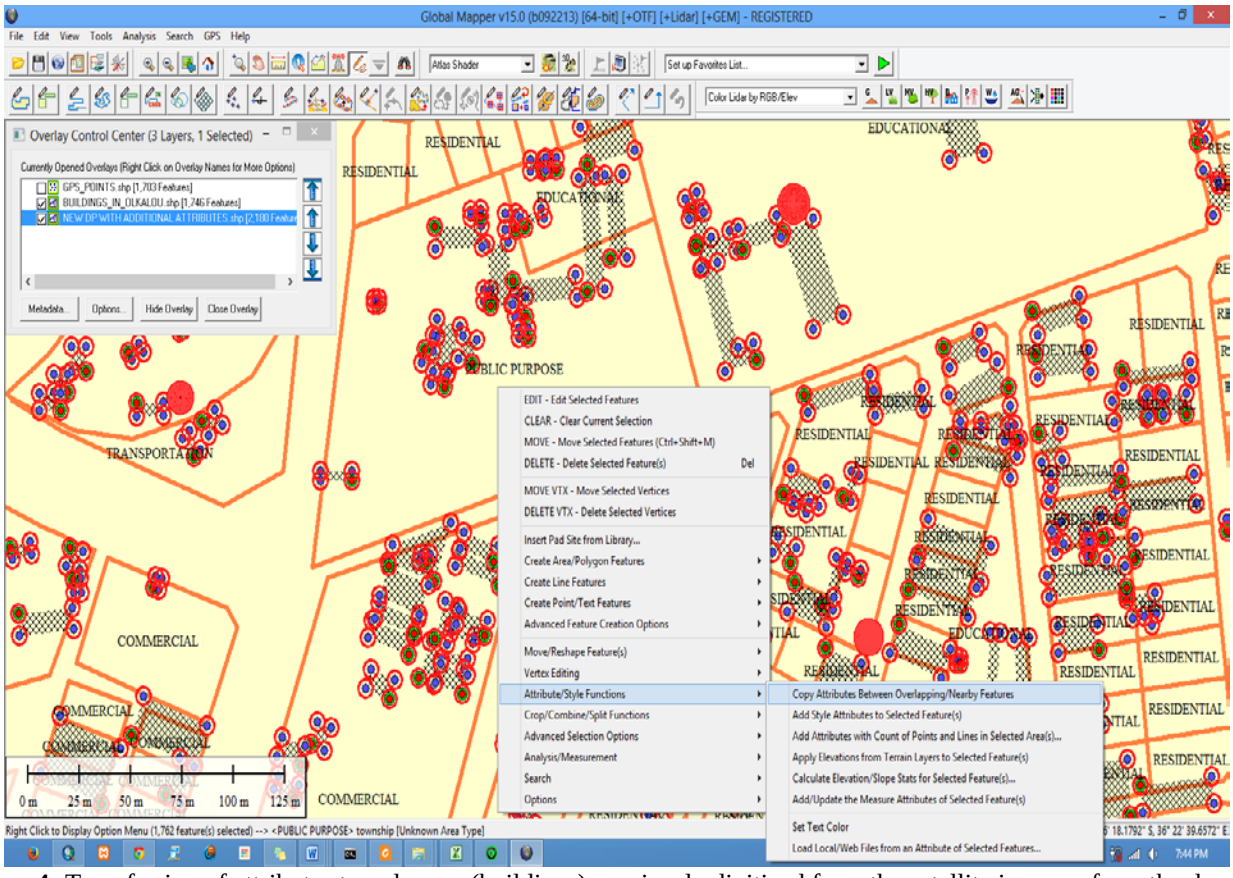



**Figure 4:** Transferring of attributes to polygons (buildings) previously digitized from the satellite imagery from the development plan attributes contained in the parcels.

The control data contained the proposed land use whereas the field data layer contained the existing land uses. Through the copying of attributes the primary key contained in the development plan was hence transferred to the control and the field dataset as a foreign key during the spatial intersection process. Using this foreign key in the control and the field dataset creating a union between the two layers was possible. A new layer B was hence created. The product of the union as illustrated in Fig 3 referred to as layer B facilitated further analysis to be possible. Based on the new layer created through the union a compliance matrix was created that checked whether the proposed land use conformed to the existing land use. The result of the query was either TRUE

(0), denoting nonconformity or FALSE (-1), denoting conformity.

## 5.5 Results and Analysis

### 5.1 The Township extents

From the onscreen digitization process of the block plan the township boundary was extracted and the result overlaid with the satellite imagery as shown in Fig 5.

### 5.2 Olkalou proposed land uses

Olkalou township land uses are grouped into 8 namely as residential, commercial, public purpose, public utility, industrial, recreational, transportation and the educational land use. The distribution of each land use is as shown by Table 1 .The residential land use has the highest percentage at 34.07% and the commercial was the lowest at 1.53%. Figure 4 show a proposed land use map for Olkalou Township.

### 5.3 Olkalou existing developments

From the satellite image information on the current developments was extracted as shown in Table 2 and displayed in Fig 7. The analysis was parcel based whereby the buildings assumed the land use of the parcel they are built on. The residential developments were the predominant with a 49.68% whereas the public utility was the lowest at 0.47%.

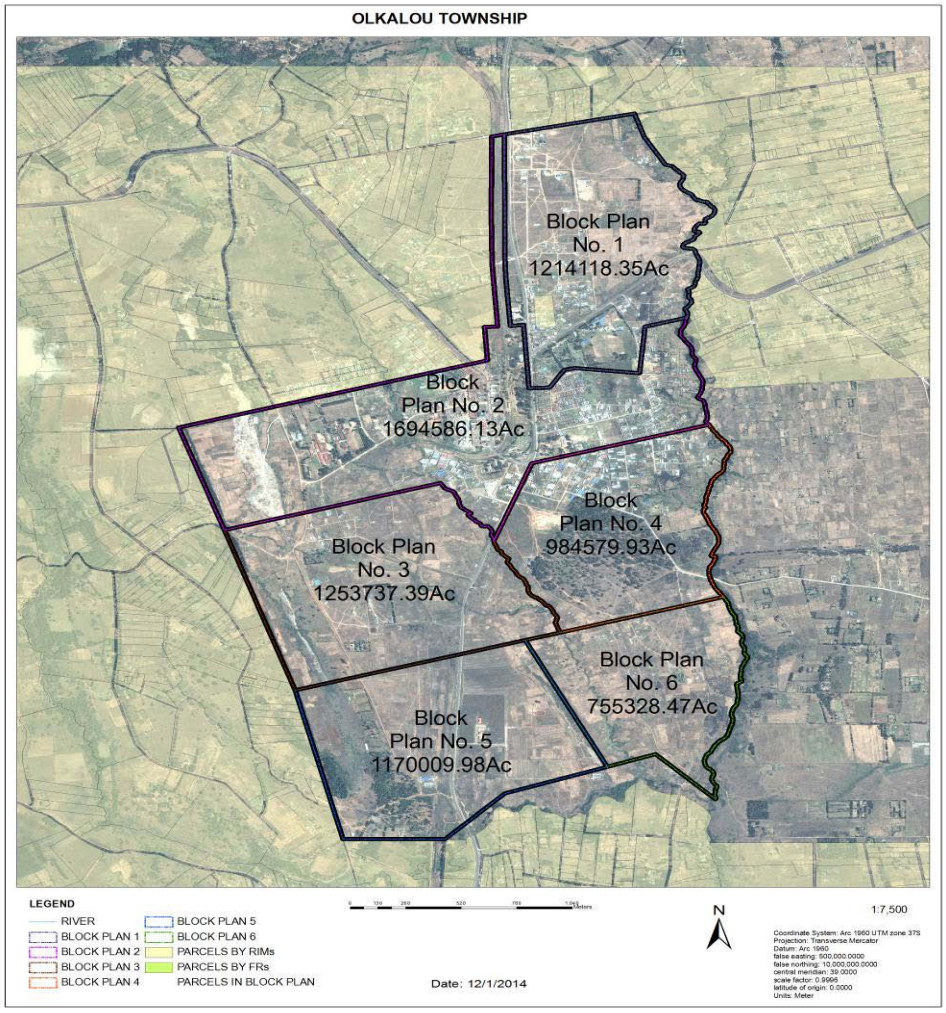



**Figure 5:** Olkalou Township block plan

**Table 1 :** proposed land uses in olkalou Township

| Zone | Area (HA) | Percentage |
|---|---|---|
| Transportation | 7.27 | 1.53% |
| Residential | 161.48 | 34.07% |
| Recreational | 55.19 | 11.65% |
| Public utility | 16.76 | 3.54% |
| Public purpose | 105.69 | 22.30% |
| Industrial | 43.09 | 9.09% |
| Educational | 70.53 | 14.88% |
| Commercial | 13.9 | 2.93% |
| **Totals** | **473.91** | **100.00%** |

**Table 2:** Olkalou Township Existing developments in the proposed zones.

| Existing developments per each zone | | |
|---|---|---|
| Zone | Count | Percentage |
| Transportation | 19 | 1.12% |
| Residential | 846 | 49.68% |
| Recreational | 28 | 1.64% |
| Public utility | 8 | 0.47% |
| Public purpose | 224 | 13.15% |
| Industrial | 201 | 11.80% |
| Educational | 155 | 9.10% |
| Commercial | 222 | 13.04% |
| **Total** | **1703** | 100.00% |

**Table 3:** Table comparing the existing (field dataset) and the proposed (control datasets) developments.

| CONTROL DATASET | | | FIELD DATA | | | COMPARISON RESULTS | |
|---|---|---|---|---|---|---|---|
| *Zone* | *Count* | *Percentage* | *Zone* | *Count* | *Percentage* | *Variation* | *Non-* |
| Transportation | 19 | 1.12% | Transportation | 2 | 0.12% | 17 | **17** |
| Residential | 846 | 49.68% | Residential | 917 | 53.85% | -71 | **71** |
| Recreational | 28 | 1.64% | Recreational | 22 | 1.29% | 6 | **6** |
| Public utility | 8 | 0.47% | Public utility | 8 | 0.47% | 0 | **0** |
| Public purpose | 224 | 13.15% | Public purpose | 174 | 10.22% | 50 | **50** |
| Industrial | 201 | 11.80% | Industrial | 160 | 9.40% | 41 | **41** |
| Educational | 155 | 9.10% | Educational | 191 | 11.22% | -36 | **36** |
| Commercial | 222 | 13.04% | Commercial | 229 | 13.45% | -7 | **7** |
| **Total** | **1703** | 100.00% | **Total** | **1703** | 100.00% | | |

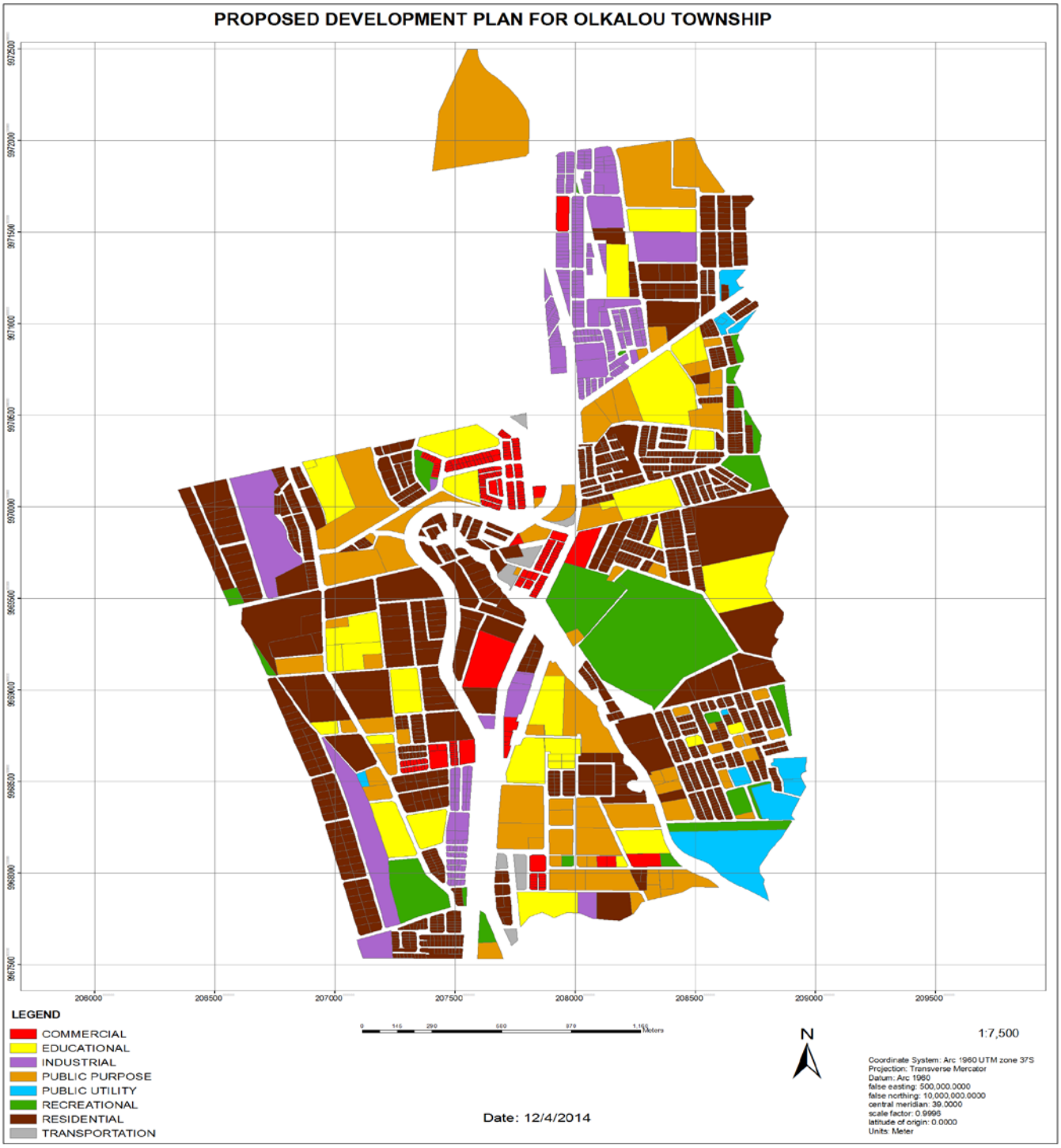



**Figure 6:** proposed land uses in Olkalou Township

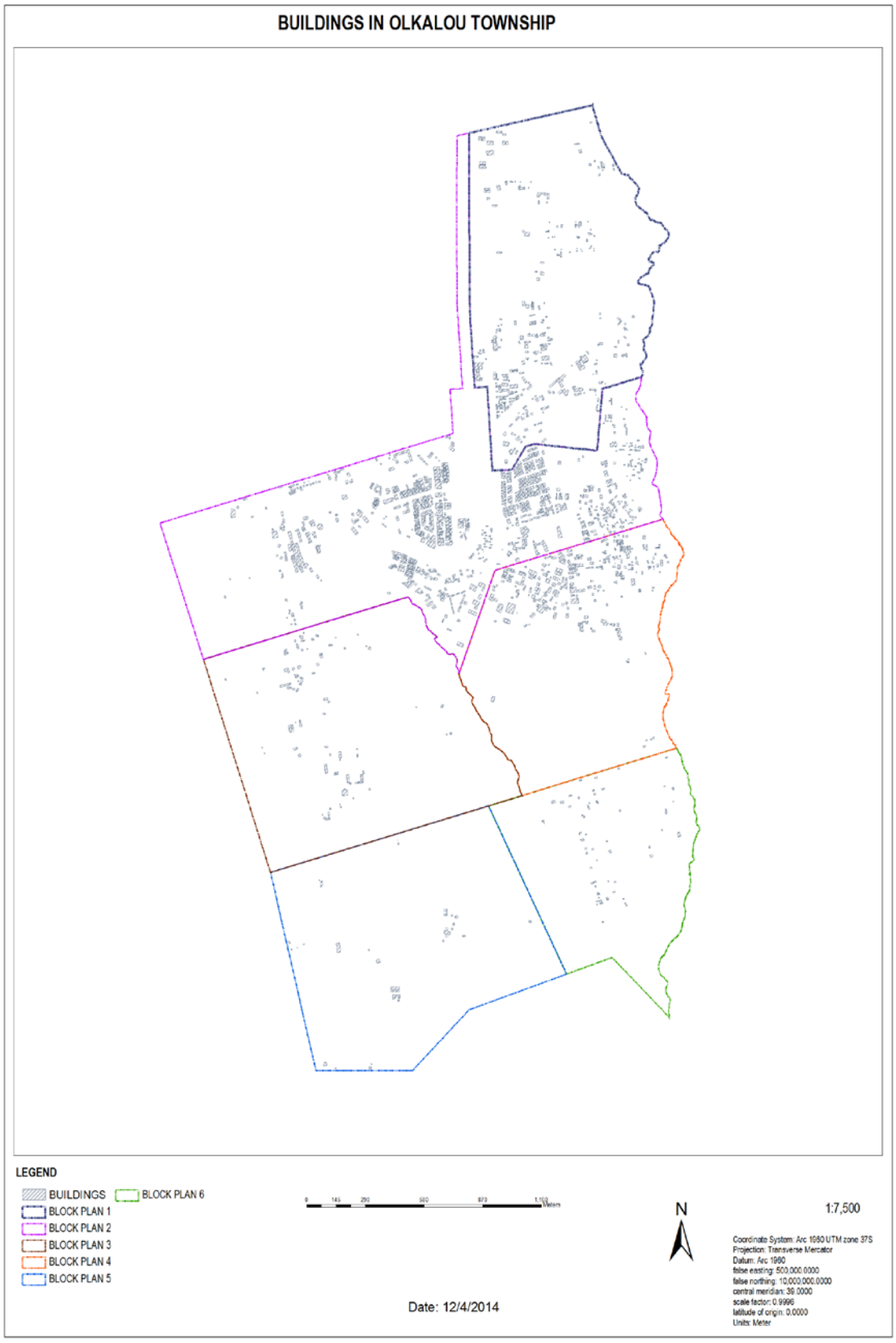



**Figure 7:** Buildings within Olkalou Township

### 5.4 Compliance summary

By comparing the field and the control data, i.e. the existing land uses and the proposed land uses as in Table 3 the resultant were the compliance results. The summary of the compliance was as shown in the Table 4 with the residential zone showing the highest compliance level at 99.29% whereas the transportation land use had the highest noncompliance at 89.47%. Non-compliance meant a difference in the existing uses versus the proposed uses. The result in the township extents when mapped are shown by the red selections in Figure 8.

**Table 4:** Summary of the compliance for each zone within the Township

| Non-Compliance | | | |
|---|---|---|---|
| Zone | Total | Non-compliant | Non-compliant |
| Transportation | 19 | 17 | 89.47% |
| Residential | 846 | 6 | 0.71% |
| Recreational | 28 | 6 | 21.43% |
| Public utility | 8 | 0 | 0.00% |
| Public purpose | 224 | 52 | 23.21% |
| Industrial | 201 | 41 | 20.40% |
| Educational | 155 | 14 | 9.03% |
| Commercial | 222 | 20 | 9.01% |
| **Total** | **1703** | 156 | |

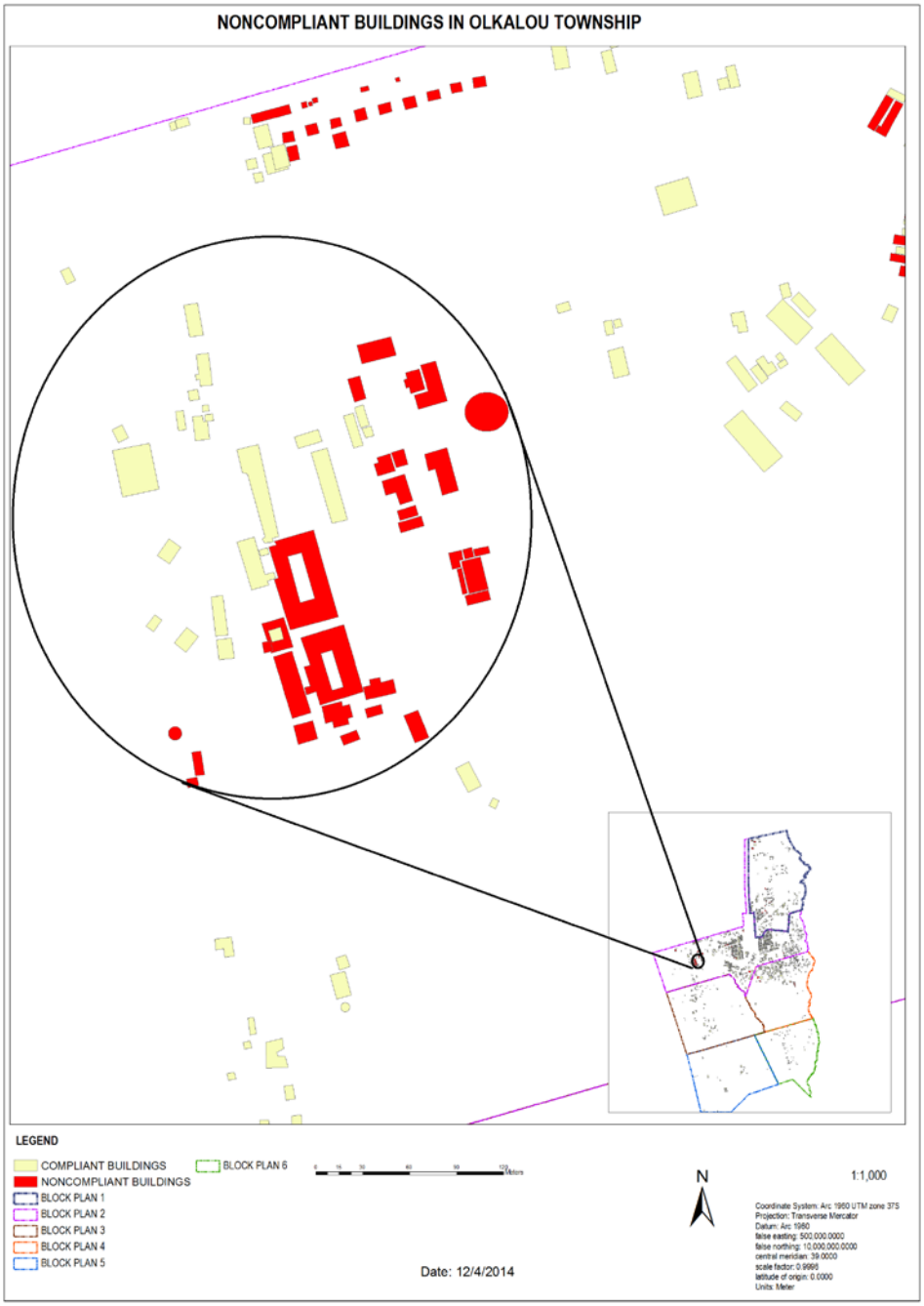



**Figure 8:** A select section showing the Non-compliant buildings in Olkalou Township.

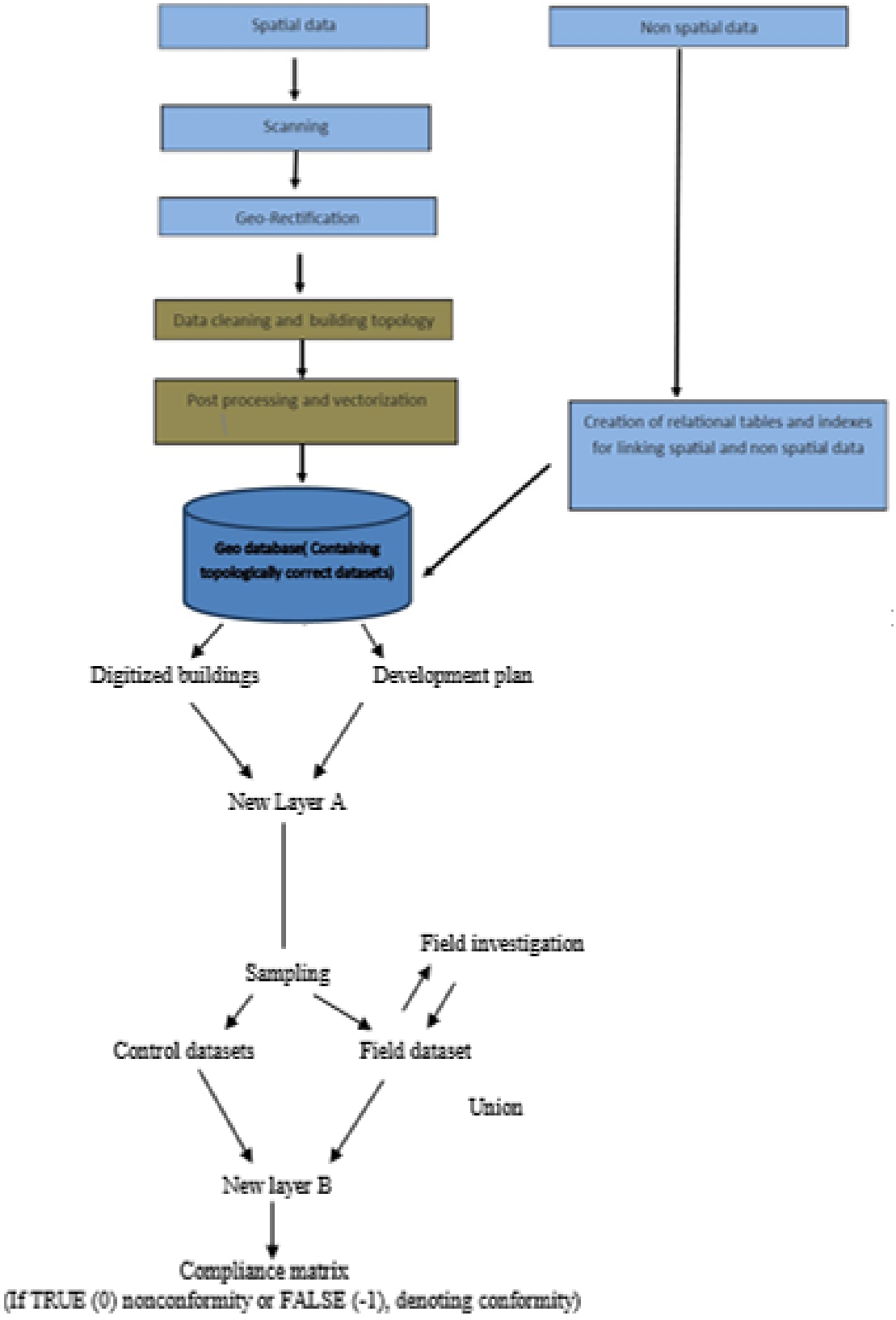



**Figure 9:** The compliance assessment framework

## 6. Conclusion

Compliance assessment is crucial to ensure that a plans vision are implemented as proposed in the approved physical plans. There currently lacks a methodology to do so hence the need to create one. The research was carried out to assess the compliance level of a development plan in a Township by making use of the GIS for data storage and spatial analysis and Remote sensing technology as a data source. It was possible to develop a compliance matrix after following the methodology that showed the compliance level. The compliance matrix can be mapped and responsible authorities can use it to file legal suits against the defaulters to ensure that compliance is adhered to.

## 7. Recommendations

Assessment for compliance should be carried out as a method of identifying new developments. This necessitates its integration with other methods used during field visit such as use of observation, questionnaires and interviews to gather other data relevant for a successful assessment activity.

It is necessary to perform compliance assessment time after time to ensure that the physical plans are implemented as intended in the development plans. The frequency of Compliance assessment to be performed in each locality should be advised by the developmental rates of the specific area, with a direct relationship i.e. an increase in either translates to an increase in the other.

Compliance assessment should be anchored on the law to become part of the development control tools as there currently exists none. This inexistence of an assessment framework has resulted in the continued usage of the manual system which is not only time consuming but also inaccurate and inefficient. From the study the proposed framework to perform assessment is as summarized in the Figure 9.

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## Author Profile

**Racheal N. Mugo** received a Bachelor's degree in Urban and Regional planning with IT from Maseno University in 2012 and is currently pursuing her Master's degree in Geospatial Information system and Remote sensing from Jomo Kenyatta University of agriculture and Technology .She has worked with many physical planning consultancies companies. She is currently working as an international consultancy with Regional Center of Mapping of Resources for Development.

**David N. Kuria** has wide knowledge of GIS and Remote sensing and their applications in numerous fields. He is a Lecturer at Dedan Kimathi University of Technology, Nyeri, Kenya. He holds a Bachelor's degree in surveying from Nairobi University, an MSc degree in photogrammetry and Geoinformatics from the Stuttgart University in Germany and a PhD in civil engineering from university of Tokyo, Japan. He has authored many papers and pursued numerous research related to the same .His interests are evaluation of digital image processing methods for remote sensing applications, development of data assimilation systems that utilize visible and microwave remote sensing, GIS applications that solve Geomatic engineering problems and providing platforms for data sharing and web mapping.

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