

Assessment of Impacts of Road Infrastructure Using GIS and Remote Sensing: A Case Study of Yatta Sub County

Peter Muthama¹, Kenneth Mubea², Charles N. Mundia³

Institute of Geomatics, GIS and Remote Sensing, Dedan Kimathi University of Technology P.O. Box 657-10100, Nyeri, Kenya

Abstract: Roads play an important role in infrastructure and services in rural development. This is well established in the development literature. There is a direct link which exists between productive investments and growth, social and economic infrastructure (such as roads, electricity, water and sanitation, and communications) facilitates and integrates economic activities. The purpose of this study was to assess the impact of road infrastructure in Yatta Sub County. Descriptive research design was used for the study. GIS and remote sensing were used to capture images on road infrastructure while questionnaires were used to collect data from farmers and business owners. Simple random sampling technique was used to sample respondents for the study. A total of 50 respondents were sampled for the study where all responded giving 100% response rate. Descriptive statistics such as frequencies and percentages were used to analyze the quantitative data collected through questionnaires. Qualitative data collected through open ended questions were analyzed thematically. Pre-processing of images involved: layer stacking, radiometric correction, pan-sharpening, atmospheric correction and sub setting while post-processing of images involved: Image classification, creating training sites, generating statistical tables, accurate assessment and ground survey using GPS for ground truthing. The study found that roads which cover the Sub County are not sufficient to serve the people of Yatta Sub County effectively. Most of the in-roads in this sub County are in very poor conditions whereby people need to use motor cycle to reach their destinations. The findings revealed that most of the vehicles avoid using earth surface roads as they spent more money on maintaining the vehicles. Where roads are in good conditions, growth of towns such as Matuu, Kithimani and Katangi has greatly been realized. The poor road conditions led to high costs of living and doing business with more time spent on movement from one place to another and difficulty in accessing social facilities. The study recommended that the roads in Yatta Sub-County should be upgraded to facilitate movement of people and goods and that the County Government of Machakos should embrace use of GIS in decision making and planning.

Keywords: Road infrastructure, GIS and remote sensing, image processing

1. Introduction

The provision of good quality infrastructure is often cited as the most important factor of local and regional development, through which adequate conditions for the growth of new business and attraction of firms to less developed areas are provided. At the same time, the impact of infrastructure development on local and regional development is the subject of various discussions. Despite political influences, the economic impact of infrastructure development is one of the most important considerations in infrastructure policy making. The contribution of infrastructure to the economy has received attention from both policymakers and researchers.

In that context, the removal of obstacles to the movement of goods and factors would itself cause convergence of factor returns and living standards. Underdeveloped infrastructure can be considered as important obstacle to the regional development, and its improvements should spur the economic growth in the region. This notion is well recognized in the relevant theoretical literature. Richardson and Jensen indicate that spatial differences in the European Union (EU) cannot be reduced without a fundamental improvement of transport infrastructure and services to and within the regions where lack of access to transport and communications infrastructure restricts economic development [1].

Transport infrastructures are a vital social and economic resource, and provide access to today's economic and social

opportunities (Richardson and Jensen, 2005). Investment in the construction and maintenance of transport infrastructures is vast, and its repercussions can be seen throughout all areas of society [2], [3]. This is why correct planning of transport systems is essential [2]

The increased use of transport systems has gone hand-in-hand with a growing awareness of their impacts [4], creating a need for sustainable and integrated development [5] [6]. To attain sustainability in the area of transport it is necessary to have an overall view of the decision-making process; in other words, which involves – transport planning, land use and the environment – must be considered in conjunction rather than viewed in isolation. The great challenge is to succeed in integrating these principles into decisions on transport and land use. This challenge requires tools that can identify and assess the environmental, social and economic aspects of their decisions [7], [8]. A further requirement is to be able to identify which criteria need to be assessed the importance of each one and how they can be integrated; this is a highly challenging task [8].

Although the impact of infrastructure investment on regional economic development is generally assumed to be positive, there is no clear consensus on the magnitude or scope of this effect. A summary of recent literature by Romp and De Haan has concluded that not all studies confirm that public capital has a growth enhancing effect, there is now greater consensus than in the past that public capital promotes economic growth [9]. However, the impact reported by recent studies is not as big as some earlier studies suggested.

Sustainable rural development is a function of a number of factors in which transportation is of importance. Efficient and effective rural transportation serves as one of the channels for the collection and exchange of goods and services, movement of people, dissemination of information and the promotion of rural economy. Along this line, Owen stated that “Immobility perpetrates poverty”, effective transportation eases accessibility to inherent potentials of rural areas which could be harnessed for the development of its economy [10].

In other words, rural transportation provision forms an intrinsic part of rural development strategies, serving as a mechanism and catalyst for rural transformation through the reinforcement of rural development and contributes to poverty reduction by enhancing both equity and efficiency outcomes. In Kenya road infrastructure is generally accepted as a key to economy and it is vital for economic growth and poverty reduction since it plays a key role in enhancing competitiveness. Road infrastructure opens up unconnected regions to trade and investment and improves access to goods, services and employment opportunities. It is upon this background that this study seeks to assess the impact of road infrastructure layout on livelihoods in Yatta Sub County, Machakos County.

1.2 Problem Statement

Poor condition roads have made the life very expensive. Good roads facilitate the movement of farmers output between places offering different income earning opportunities; create markets; and serve as an important vehicle for the transfer of information in the absence of telecommunication that facilities. Investments in rural infrastructure and rural services are often not under control of rural households, and are typically provided by the government as public services. Nonetheless, the quality and quantity of social and economic infrastructure and rural services make a big difference to the viability of rural livelihoods.

The roads condition in Yatta Sub County has been poor as evidenced by the drowning of the late Yatta MP Mr. James Mutiso in Mbakoni River (The daily Nation, 2 May 2003, Reporter Mburu Mwangi) which lacked a bridge. This study was therefore aimed at assessing the impact of road infrastructure layout on livelihoods in Yatta Sub County.

2. Material and Methods

2.1 Study Area

The study area is Yatta Sub County, Machakos County. Yatta Sub County has a total Population of 147,579 as per 2009 Population Census. The Sub County covers an area of 10957.3 km². It has three divisions namely: Katangi, Ikombe and Yatta with a total of twenty three sub/Locations (23) and a total of four hundred and twenty four villages (424) as per 2009 population Census. The Sub County is located between 37.343 (W) and 037.807 (E) longitude and latitude between S 0.994 and S 1.5

Data Sources

The table 1 shows the identified datasets and their sources from different Government Department, Non-Governmental Organizations and Developed Countries.

Table 1: Datasets and Sources

<i>Type of data</i>	<i>Source of data</i>
Base Map	Google Earth
Base Map and Topo sheets	Ministry Of Land, Housing and Urban Development
Roads	Ministry of Transport
Health Facilities	Ministry of Health
Sub Location maps With Enumeration Areas	KNBS
Population Data	KNBS
Schools	Ministry of Education
Points	Ground Survey
Questionnaire	Research assistants
Land Use Land Cover	Landsat Images

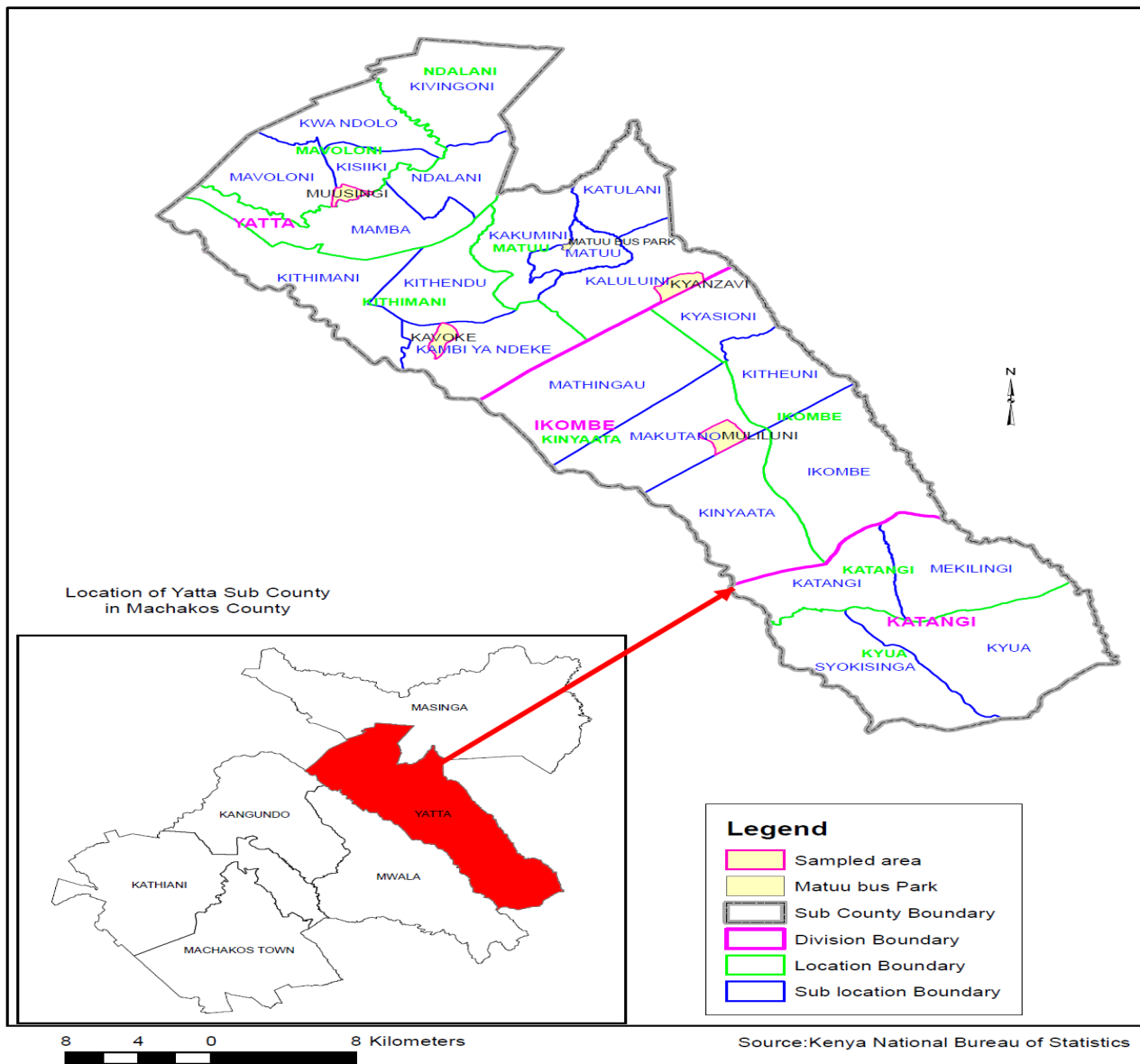


Figure 1: Study Area

2.2 Data Collection

Questionnaires were used as instruments for data collection because they are considered economical and easy to formulate and analyze the data. In addition, questionnaires elicit a lot of data and gives greater depth of response.

The questionnaire was divided into two different sections namely Household and Drivers questionnaire. These questionnaire contained questions addressing a particular objective of the study which helped to capture important data which concerns the study. For households, data was captured indicating the Conditions of roads, Pattern of population migration, Security, Social economic, healthy status, availability of water and ease of access to administration.

The drivers questionnaire captured the conditions of roads, types of roads favored for use and the amount they spend to maintain their vehicles.

Raw data from the field was edited to correct errors which might have been made by research assistance during data collection e.g. inappropriate answers given by the respondents. Coding was done to translate question responses into specific categories to reduce research data into manageable summaries. Using GIS and remote sensing the images were analyzed. The coded items were analyzed with the aid of a computer using excel package. Descriptive statistics such as frequencies and percentages were used to analyze quantitative data while qualitative data was analyzed thematically. The analyzed data is presented in form of tables, pie-charts and bar-graphs where applicable.

The handheld GPS was also used to pick geographical coordinates showing location of homestead and any other necessary information such as land marks and any other point of interest. The right parameters of the handheld GPS were set to enable the coordinates to overlay with the shape file accurately.

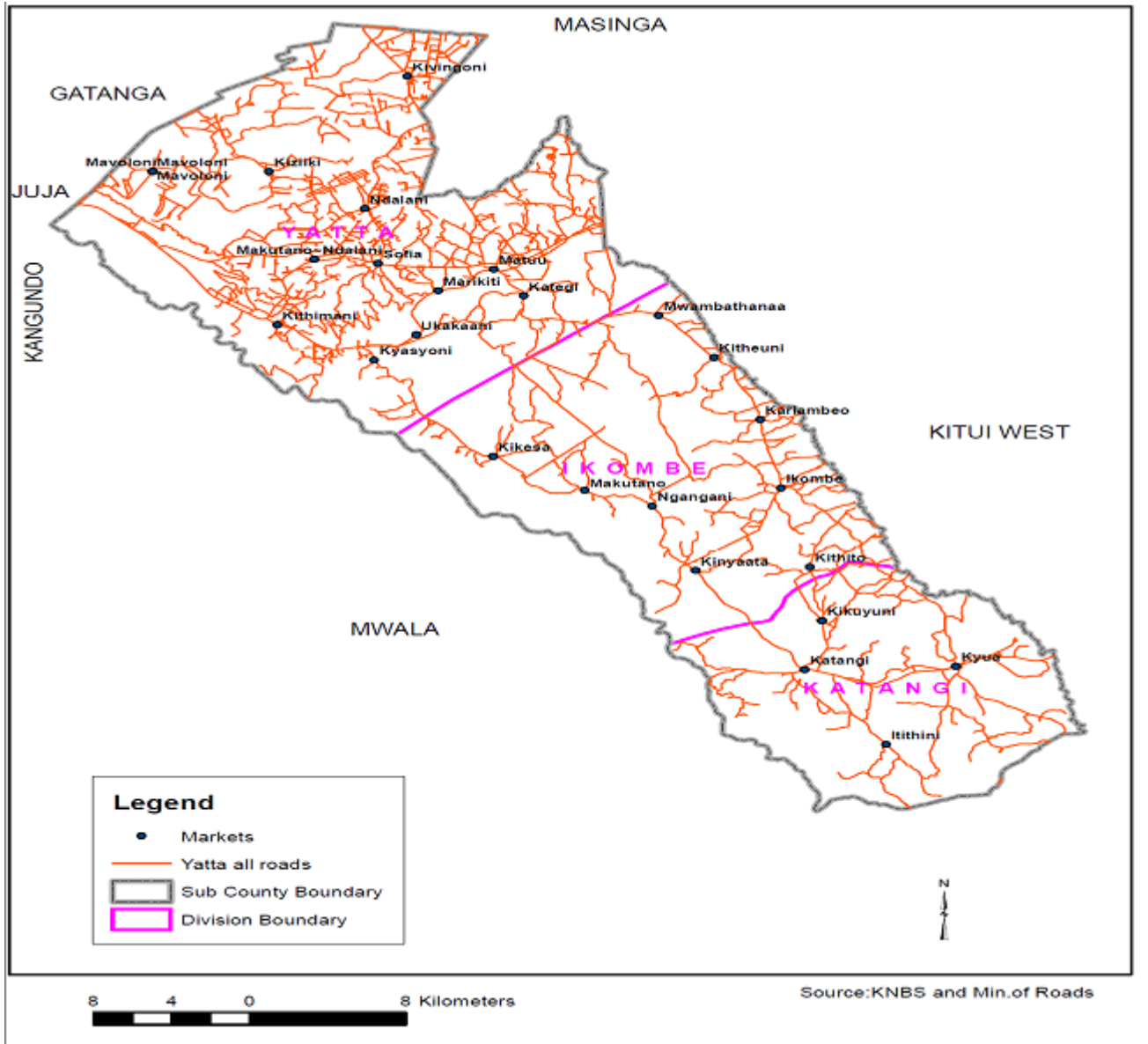


Figure 2: Road Network in Yatta Sub County before classification

2.3 Target Population

A population or universe for a study is any group of individuals or institutions which have one or more characteristics in common that are of interest to the researcher (Cooper 1996). This study target farmers (Head of Household) and business owners (Drivers of Public Vehicles) in the Sub County which is a subset of a statistical population.

2.4 Sampling Technique and Sample Size

Simple random sampling technique was used to sample respondents for the study. This sampling technique was

deemed appropriate as it gives the targeted respondents equal chances to be selected for the study. The members of the subset had equal probability of being chosen. Yatta Sub County has a total of 424 villages and four villages from the total villages were sampled. The sub County had a sample size of 40 respondents from four villages and 10 respondents from Matuu Urban who are drivers of transport sector making a total of 50 sampled respondents. After sampling various villages in the sub County household listing was carried out and the sample of at least ten household per village. Sample Size $424/4 = 106$, so the Interval was 106.

Table 2: Selected Villages after sampling

DIV NAME	LOC NAME	SL NAME	EA NAME	AREA_SQKM	Male	Female	Population	Households	Village No.
YATTA	Kithimani	Kambi Ya Ndeke	Kavote	1.88056	137	162	299	61	04
YATTA	Matuu	Kaluluini	Ngegi/Kya-Nzavi	6.025864	356	321	677	134	110
YATTA	Mavoloni	Kisiiki	Muusini	1.454005	199	260	459	88	216
IKOMBE	Ikombe	Makutano	Muliluni	2.43041	147	130	277	45	322

However, vehicles transport operators were also interviewed to establish the expenses they meet to maintain their vehicle and the time it takes them from the departure to their destination. This involve vehicle from various routes at Matuu market which is the biggest town in this sub county and located at center of the region.

Descriptive statistics such as frequencies ad percentages were used to analyze the quantitative data collected through questionnaires. Qualitative data collected through open ended questions were analyzed thematically.

2.5 Image Processing

Image processing involved preprocessing: layer staking, radiometric correction, pan-sharpening, atmospheric correction and sub setting and post processing: Image classification, creating training sites, generating statistical tables, accurate assessment and ground survey using GPS for ground truthing. Preprocessing of data is essential for successful analysis because the images are compared on a pixel basis.

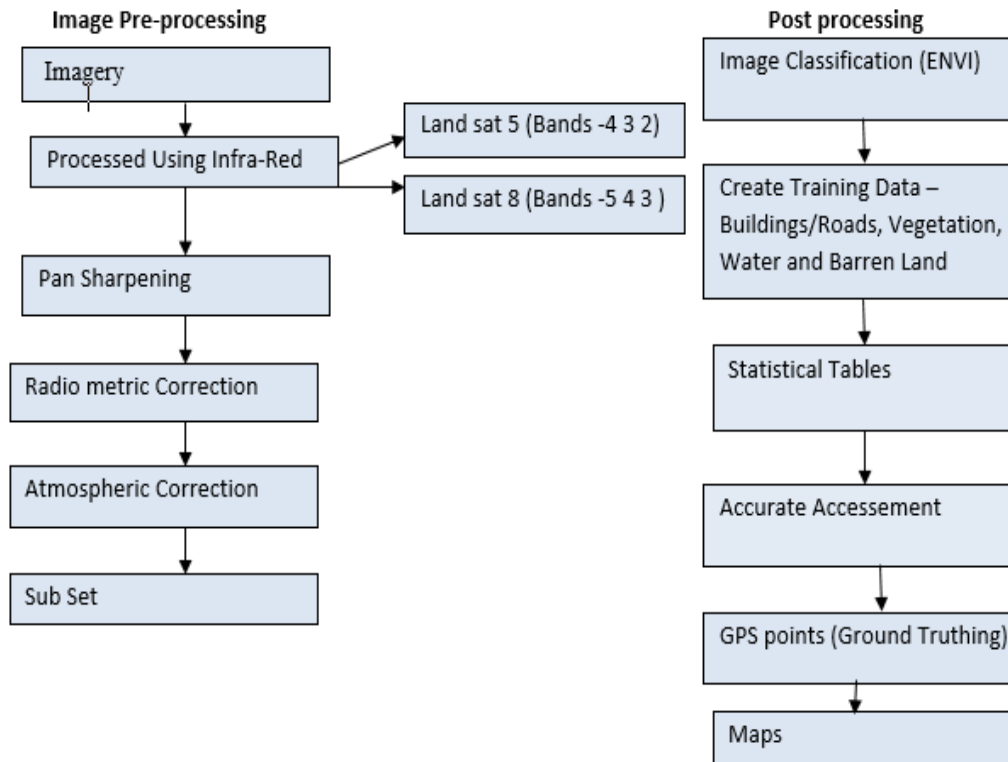


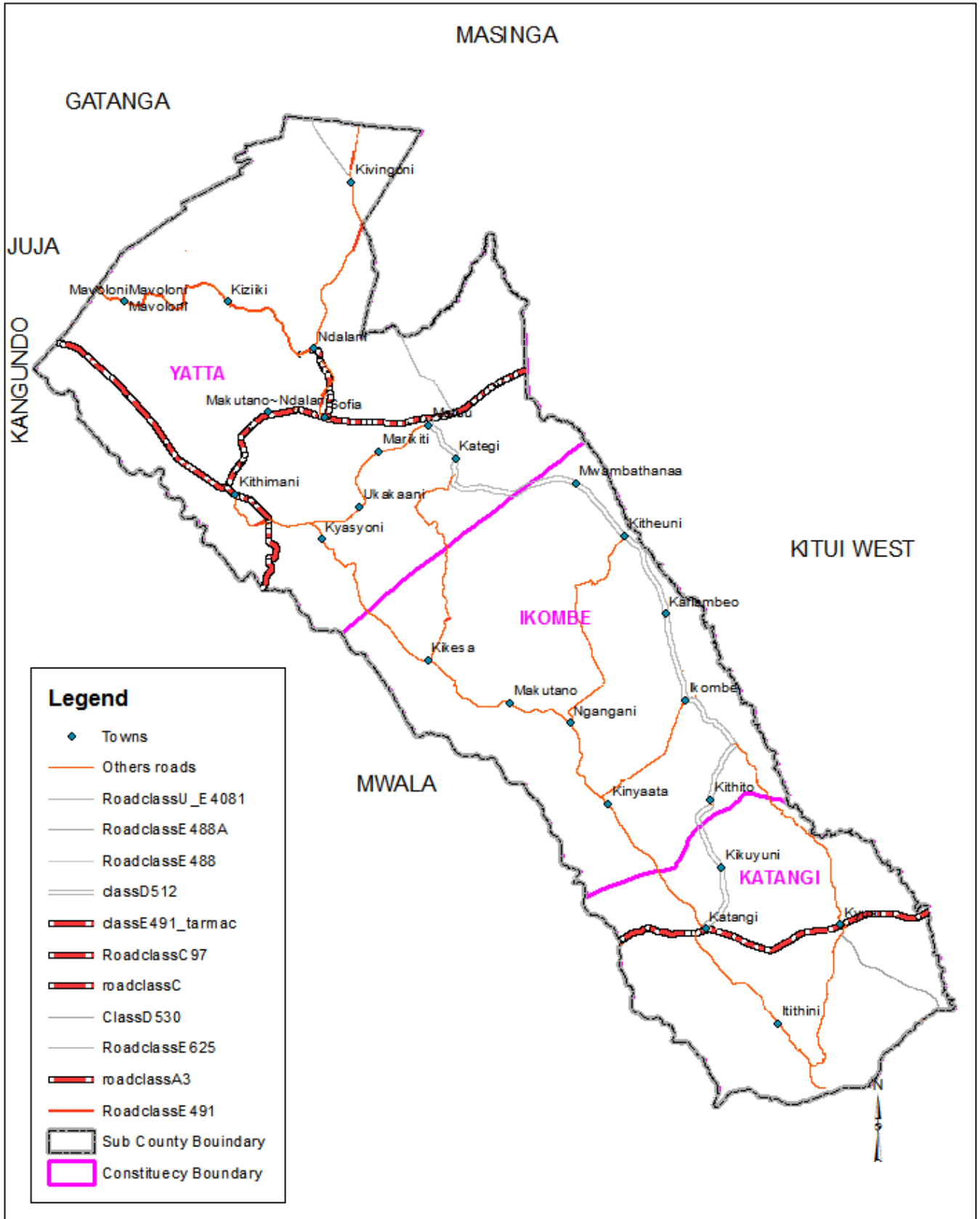
Figure 3: Diagram showing steps of image processing

3. Result, Conclusions and Recommendations

This section presents the findings of the study, conclusions and the recommendations.

3.1 Roads Classification

Figure 4 and table 3 shows all the road classifications in the Sub County. The region has twenty different types of road Classification. It has four major tarmac roads which go to different destination. The tarmac roads lead to Machakos - Kitui, Thika – Kitui, Kithimani –Makutano and Sofia-dalani.



Source: KNBS and Min. of Roads



Figure 4: Roads Classification

Table 3: Classification of roads in Yatta Sub County

RID	Surface type	Surface condition	Drainage	Road usage	Length
Tarmac Roads					
Class A	Tarmac	Good			0.197861145
C97	Tarmac	Good			0.765500000
C100	Tarmac	Fair			0.678729737
E491	Tarmac	Good			0.199229523
Motorable Murrum Roads					
C100	Gravel	Fair	None		0.410606520
D512	Earth	Fair		Used	0.167701913
Other Roads					
E491	Surface Dressing	Good			0.076964761
E488A	Earth	Very poor			0.752618112
E488	Earth	Very Poor			0.697428684
U-E4081	Earth	Poor	None	Busy	0.001851197
E716	Earth	Very Poor			1.066706152
D530	Earth	Good			2.119034739
E625A	Earth	Poor			0.118566202
E625	Earth	Poor			0.172791373
U-G210065	Earth	Very Poor			1.145967562
U-G210072	Earth	Poor	None	Used	0.237655696
U-G210066	Earth	Poor	None		0.273876971
U-G210077	Earth	Poor	None	Used	0.271886068
U-G210078	Earth	Poor	None		0.425356142
U-G44439-45236	Earth	Poor	None		0.469395208

3.2 Results

The table 4 shows there was more settlement in Kavoke village between 2002 and 2015 after the construction of Thika-Kitui Tarmac Road.

Table 5 shows settlement kyanzavi is low since the village has poor road condition.

Table 6 there was an increase in settlement in Muusini village after the construction of Sofia-Ndalani tarmac road.

The table 7 the settlement was more between 1920 and 1940 in Muliluni village.

Table 8 shows the reasons for people to settle in this sub county was for farming and for pasture.

Table 14 indicates 45 % of the respondents cover more than 2 kilometers to reach the schools. This clearly shows the areas need more schools closer to the people.

On economic impact, table 15 shows that 65% of respondents show that the cost of living is very high due to poor condition of roads as all the other infrastructure relies on road transport. This shows how poor roads have contributed to negative impact on economy of its people. The cost of leaving is high which makes it difficult for the people to meet the basic needs they require.

Table 9 indicates 50% gets water from the River while table 10 indicate that 30% walk more than one kilometer to rich the source of water.

Table 11 shows that 60 % of respondents walk more than three kilometers to reach health facilities.

The Table 12 indicates 40% spend more than ksh.200 to reach the sub county office at Kithimani.

On Security, Table 13 shows we have petty theft which stand at 82.5% due to the poor condition of the roads cannot enable the patrol of police effectively.

The price of items /commodities is high simply because it is very expensive to transport goods due to poor conditions of roads.

Table 16 indicate that 80% of public vehicles prefer operating on tarmac roads while table 17 shows vehicle operating on murrum roads spend more on maintenance.

Table 18: indicates the data which was collected from responded at the sampled villages before it was analyzed.

Table 4: Year Settled-Kavoke village

<i>Year</i>	<i>Frequency</i>	<i>Percentage</i>
1920-1940	1	10
1941-1979	2	20
1980-2001	3	30
2002-2015	4	40
<i>Total</i>	<i>10</i>	<i>100</i>

Table 5: Year Settled-Kyanzavi Village

<i>Year</i>	<i>Frequency</i>	<i>Percentage</i>
1920-1940	3	30
1941-1979	7	70
1980-2001	0	0
2002-2015	0	0
<i>Total</i>	<i>10</i>	<i>100</i>

Table 6: Year Settled-Muusini Village

Year	Frequency	Percentage
1920-1940		
1941-1979	7	70
1980-2001	3	30
2002-2015	0	0
Total	10	100

Table 7: Year Settled-Muliluni Village

Year	Frequency	Percentage
1920-1940	6	60
1941-1979	4	40
1983-2001	0	0
2002-2015	0	0
Total	10	100

Table 8: Reasons for Settlement

Response	Frequency	Percentage
Farming	26	65
Business	1	2,5
Pasture	12	30
Security	0	0
Road network	1	2,5
Total	40	100

Table 9: Source of Water

Response	Frequency	Percentage
River	20	50
Bore hole	0	0
Dam	15	37.5
Piped Water	2	5
well	3	7.5
Total	40	100

Table 10: Distance to the Source of Water

Kilometers	Frequency	Percentage
0-0.1	6	15
0.11-0.5	11	27.5
0.51-1	11	27.5
Above 1	12	30
Total	40	100

Table 11: Health facility

Kilometers	Frequency	Percentage
0-1	0	0
1.1-2	2	5
2.1-3	14	35
Above 3	24	60
Total	40	100

Table 12: Transport cost from home to the Administration Office (Sub County Office)

K/Shillings	Frequency	Percentage
0-50	2	5
51-100	8	20
101-200	14	35
Above 200	16	40
Total	40	100

Table 13: Insecurity

	Frequency	Percentage
Thurgery	7	17.5
Pet theft	33	82.5
Total	40	100

Table 14: Distance to school

Kilometers	Frequency	Percentage
0-1	14	35
1.1-2	8	20
Above 2	18	45
Total	40	100

Table 15: Economic Impact

Age	Frequency	Percentage
Low	2	5
Moderate	10	25
High	26	65
Not Sure	2	2
Total	40	100

Table 16: Commonly used Roads

	Frequency	Percentage
Tarmac	8	80
Murram	2	20
Total	10	100

Table 17: Vehicle maintenance

Road Type	K/shillings	Frequency	Percentage
Tarmac	3000-4000	3	30
Tarmac	Above 6000	5	50
Murram	9000=1000	2	20
Total		10	100

Table 18: Data By respondent

EA-NAME	HH NAME	HH	HH Size	Year home established	Reasons to settle	Distance to water (Km)	Road condition	Adequacy of Road	Bus fare	Health facility (Kms)	Source of water	Admn. Off (Min)
KYAN ZAVI	MBITHI KIOKO	10	6	1945	Farming/pasture	2	Poor	No	High	3	River	60
	MUTHUKU NDAMBUKI	16	5	1940	Farming/pasture	1	Poor	No	High	2	River	60
	NDOLO KILONZO	22	6	1940	Farming/pasture	2	Poor	No	High	2	River	60
	NZAMU MUTUA	28	6	1960	Farming/pasture	2	Poor	No	High	2	River	60
	KILU KATUMO	34	7	1970	Farming/pasture	2	Poor	No	High	3	River	60
	KYALO KISILU	40	5	1970	Farming/pasture	2	Poor	No	High	2	River	45
	MULEI KAVOI	46	12	1960	Farming/pasture	2.5	Poor	No	High	3	River	60
	KITHENGE KASENGA	52	5	1940	Farming/pasture	2	Poor	No	High	4	River	60
KAVO KE	MUTISYA KASYOKI	58	7	1960	Farming/pasture	2	Poor	No	High	5	River	30
	PETER MUTHAMA	2	5	1960	Farming/pasture	0.25		No	Moderate	4	River	60
	GEORGE	7	7	1980	Farming/pasture	1	Poor	No	Moderate	3	River	30
	JOHN NGUMBI	12	6	1995	Farming/pasture	1	Poor	No	Moderate	3	River	20
	KIMEU KILONZO	17	9	2002	Farming/pasture	1	Poor	No	Moderate	4	River	30
	WAYU MBITHI	22	2	1952	Farming/pasture	0.1	Poor	No	Moderate	3	River	30
	MUTHINI MUIINDE	27	9	1940	Farming/pasture	1	Poor	No	Moderate	2	River	30
	PIUS MWETU	32	4	1990	Farming/pasture	1	Poor	No	Moderate	4	River	30
	JOSEPHINE KINGOO	37	4	2007	Farming/pasture	0.15	Poor	No	Moderate	3	River	20
	TITUS KIOKO	42	4	2003	Farming/pasture	0.2	Poor	No	Moderate	4	River	30
MUUSI NI	JOSEPH MUOKI	47	5	2010	Farming/pasture	0.2	Poor	No	Moderate	4	River	30
	MUTISO LINDA	3	6	1972	Farming/pasture	0.1	Poor	No	Moderate	4	River	30
	BENEDETA MATHEKA	10	4	1982	Farming/pasture	0.5	Poor	No	High	4	River	60
	MICHAEL KISILU	17	3	1968	Farming/pasture	0.8	Poor	No	High	2	River	30
	JULIUS ZAKAYO	24	9	1976	Farming/pasture	0.1	Poor	No	High	3	River	45
	JOSEPH WAMBUA	31	5	1972	Farming/pasture	0.4	Poor	No	High	3	River	60
	RICHARD FORO	38	9	1970	Farming/pasture	0.4	Poor	No	High	3	River	30
	MUSAU KITONYI	45	4	1978	Farming/pasture	0.6	Poor	No	High	3	River	30
	BENEDICT KILONZO	52	5	1963	Farming/pasture	0.1	Poor	No	High	3	River	60
	JOHN MAKUMBI	59	8	1982	Farming/pasture	0.1	Poor	No	High	4	River	45
MULIL UNI	MULEI MATIVO	66	3	1980	Farming/pasture	0.3	Poor	No	High	3	River	60
	MUSAU NDUTU	2	7	1950	Farming/pasture	0.5	Poor	No	High	3	River	120
	MUTISO KING'OO	6	9	1960	Farming/pasture	1	Poor	No	High	3	River	60
	KAUNDA KING'OO	10	9	1940	Farming/pasture	0.3	Poor	No	High	4	River	60
	WAMBUA MUSEMBI	14	11	1939	Farming/pasture	2	Poor	No	High	5	River	120
	MUSYOKI MUALUKO	18	7	1939	Farming/pasture	2.5	Poor	No	High	4	River	60
	MUASA MBULI	22	7	1929	Farming/pasture	1	Poor	No	High	3	River	30
	KAUNI MWALUKO	26	14	1920	Farming/pasture	2	Poor	No	High	4	River	30
	NTHUKU MUSEMBI	30	7	1930	Farming/pasture	1	Poor	No	High	4	River	45
	MUTUNGA KIVUVA	34	8	1979	Farming/pasture	0.2	Poor	No	High	5	River	60
KAMAU MUTUA	38	8	1969	Farming/pasture	0.1	Poor	No	High	5	River	5	

3.2 Conclusions

From the findings of the study, it can be concluded that roads play an important role in infrastructure and services in any rural set up to be developed. This was also established in its importance to the Yatta Sub County as the level of capital accumulation embodied in infrastructure development, hence it is a crucial factor determining the pace and diversity of economic development in any society. Although the direct link exists between productive investments and growth, social and economic infrastructure (such as roads, electricity, water and sanitation, and communications) facilitates and integrates economic activities.

The study also concludes that roads which cover the Sub County are not sufficient to serve the people of Yatta Sub County effectively. Most of the in-roads in this sub County are in very poor conditions whereby people need to use

motor cycle to reach their destinations. Where roads are in good conditions, growth of towns search as Matuu, Kithimani and Katangi has greatly grown.

It was finally concluded that the cost of living is very high in the Sub-County. This resulted from poor conditions of roads making road users spent a lot of time while travelling from one point to another. Most of areas are served by public vehicles only once by one matatu which usually goes to Matuu in the morning and gets back in the evening.

3.3 Recommendations

In this Sub County many roads needs to be upgraded in order to improve the livelihoods of the people in Yatta. Currently, the area has four tarmacked roads which have generally improved the transport sector within the areas where it serves. However due to expansiveness of the area,

more roads need to be improved in order to improve other types of infrastructure. The road from Katangi to Matuu via Ikombe should be Tarmac in order to enable transport of quarry stones from Ikombe which is a major income generating activity to the people around the area.

Other roads which should be improved for better murrum roads are - Katangi-Kikesa-Kithimani, Mavoloni-Kisiiki, Ndalani-Kavingoni, and Kyasioni-Matikiti Matuu Roads. The County Governments should put necessary structures to enabled sustained maintenance of roads infrastructures. Most of the rivers have no bridges and even the ones which have underground bridges which are not safe during rainy season.

The County Government should embrace use of GIS to make decision making and planning. This can be very useful to Engineers to monitor any changes and can store large information and manipulate it. The use of remote sensing will help gather lots of information which is precise and cheap to acquire.

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Author Profile

Peter M.Muthama received a Bachelor's degree in Geography from University Of Nairobi 2013 and is currently pursuing his Master's degree in Geospatial Information system and Remote sensing from Dedan Kimathi University of Technology .He works with Kenya National Bureau of Statistics at GIS and Cartography Section which deals with preparing maps for Census.

Kenneth Mubea has wide knowledge of Geomatics, 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 Geomatic Engineering from Jomo Kenyatta university of Agriculture and technology (Kenya), an MSc degree in GIS and Remote Sensing from Jomo Kenyatta university of Agriculture and technology (Kenya) and a PhD in Remote Sensing & GIS from University of Bonn (Germany). He has authored many papers and attended various international conferences. His interests are urban growth modeling, remote sensing, cellular automata, GIS, Land information systems (LIS), surveying, Geodesy, web mapping among other related disciplines in Geomatics.

Prof. Charles N. Mundia has Considerable research and teaching experience in Geomatic Engineering, GIS and Remote Sensing analyses of over nine years both locally and internationally. Two year post-doctoral research experience at the school of Integrative Environmental Science, University of Tsukuba. , Served as an associate professor of GIS and Remote Sensing for two years at the Centre for Spatial Information Science, University of Tsukuba, Japan.. Served as head of department and a senior lecturer at the department of Geomatic Engineering and Geospatial Information Science of Jomo Kenyatta University. Currently an Associate Professor of Geoinformatics at Dedan Kimathi University of Agriculture and Technology, Institute of Geomatic, GIS and Remote Sensing. Authored two University level books published by Nova Science publishers (USA) and Lambert Publishing Company (Germany) and have published widely in high impact international journals on Remote sensing and GIS analyses. Appears in the 'Who is Who' in Science and Engineering', eleventh edition (2011-2012) by Marquis who is who publication board of United States.