Remote Sensing & GIS Based Spatial Data Evaluation for Rural Development Planning in Gumine District, Simbu Province, PNG

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Abstract

Decentralised planning at the district LLG level aimed at implementing directives of National Government remains the core responsibility of the District Development Authorities (DDA). This leads to the availability of up to date baseline data to service the needs of planners and administrators. A decision with regards to planning in the right location and targeting the right people requires a sophisticated computer-based georeferenced database, incorporating charts and maps to service the needs of planners and decision makers. The current research focuses on utilising Remote Sensing and GIS technologies to analyse infrastructural data for roads, bridges, health facilities and schools based on their conditions, availability, accessibility to the community (village), distribution and affordability at the local level Governments (LLGs) of Gumine District. Both village-level spatial and non-spatial data were collected and integrated into a GIS environment for information output and delivery. The output results from analysis will serve as a District information tool to help uplift the existing service delivery functions and also enhance better planning and resource mobilisation rendering in knowledgeable decision-making at micro level. The main focus is to identify gaps, inadequacy and difficulty in accessibility to built-up infrastructures. These service providers at the village level were all evaluated. The database, maps and charts were all put out for public viewing as a means of information communication for proper decision-making and efficient planning to achieve accelerated development. A GIS-based geospatial data infrastructure was generated as a micro administrative unit for sustainable development planning and execution.

Keywords: *Database, GIS, Development Planning, Rural, Buffering*

1. Introduction

Papua New Guinea (PNG) is in the midst of major government reforms. In 2013, a major reform to the organic law was Decentralised Governance, which has led the government to establish District Development Authorities (DDAs). Since then, the national Government has been pivotal in providing MPs with more powers and discretion to distribute development projects directly to their Districts. However, rural development programmes in PNG have encountered a lot of difficulties in achieving their objectives. There are many cases in PNG recently reported that development programmes in rural areas have not been delivered up to expectations and /or have never been implemented by authorities as pointed out by Care International in Papua New Guinea (CIPNG) and Community Development Agency (CDA) in their joint baseline survey of Gumine district in 2013. In combating such complex challenges, Geographic Information System (GIS) together with Remote Sensing applications are such technologies that allow us to develop a spatially connected database of any geographical area, which is very crucial in planning, monitoring and decision-making at all levels from macro to micro.

As was summarised by Adinarayana et. al. (2004), GIS and the underlying Spatial Data Infrastructures have the potential to assist in planning, monitoring and exchange of information between various agencies in Rural Development administration. Any development programmes being implemented by a local Administration require a lot of baseline data with planning to identify right areas and target people, allocation of funds, monitoring activities, assessing results, assessing the constraints, mobilising resources, etc., as pointed out by Yadav and Singh (2009). It is widely recognised that Geospatial technology at micro level plays a key role in disseminating information at local level for promoting and monitoring balanced development across rural areas. A study carried out by Yadav and Singh (2011) stated that Geospatial technology is being used to improve planning, design and delivery of initiatives, particularly to address the needs of underprivileged groups and individuals at village level. It is further stated that, GIS-based systems have been developed for mapping of infrastructure, which is very helpful in identifying the gaps in availability of basic amenities and locations where facilities are necessary to be provided.

By integrating and organising village information spatially in a GIS Data Management System, planners can quickly get a wider view of the current situation at the village level and more precisely assess future implications. Geospatial technology plays a vital role in generating timely and reliable information for planning and decision making at all levels from macro to micro for a region (Gupta, 2007, Bariar, et al., 2007)**.** Gumine District in Simbu Province is arguably one of those disadvantaged districts in the country that continue to face enormous development challenges in planning and monitoring. Recently, it was reported that Gumine District Administration is unable to effectively deliver on their mandated responsibilities. The DDA development projects in the district are known for their being in a shabby state (Wiltshire & Oppermann, 2015). Even though th**e** Government has increased its budget from thousands to millions of kina to cater for infrastructural development in rural areas, basic service delivery still remains disproportionally unimproved.

This study focuses on generating geospatial data at village ward level as a micro administrative unit. The emphasis is on identifying and mapping the distribution, conditions, availability, accessibility and affordability of infrastructure, which includes: road networks, bridges, health facilities and educational facilities in three Local level governments (LLGs) of Gumine District. The database, maps and charts provided will form the basis for micro level plans and management systems taking into consideration the local needs and limitations of a ward as a viable micro-administrative unit. The development of a geospatial information system in this study will serve as a District information tool to help uplift the existing service delivery functions to enhance better planning and resource mobilisation as well as help in making informed decisions at a micro level.

2. Study Area and Research Methodology

2.1 Study Area and Background Information

The research was carried out in Gumine district of Simbu Province, PNG (Figure 1). Gumine is one of the remotest districts in Simbu province. It comprises three LLGs namely: Mt. Digine, Kumai Bomai and Gumine. Mt. Digine LLG is approximately 3 km south of Kundiawa, Simbu provincial headquarters, while the other two LLGs are 30 and 40 km further south of Kundiawa. Gumine District is situated in a mountainous and very rugged terrain. It also contains beautiful and un-exploited natural habitat within its remotest parts. It covers a land mass of about 70,203 ha and has a total population of 56,860 excluding children below

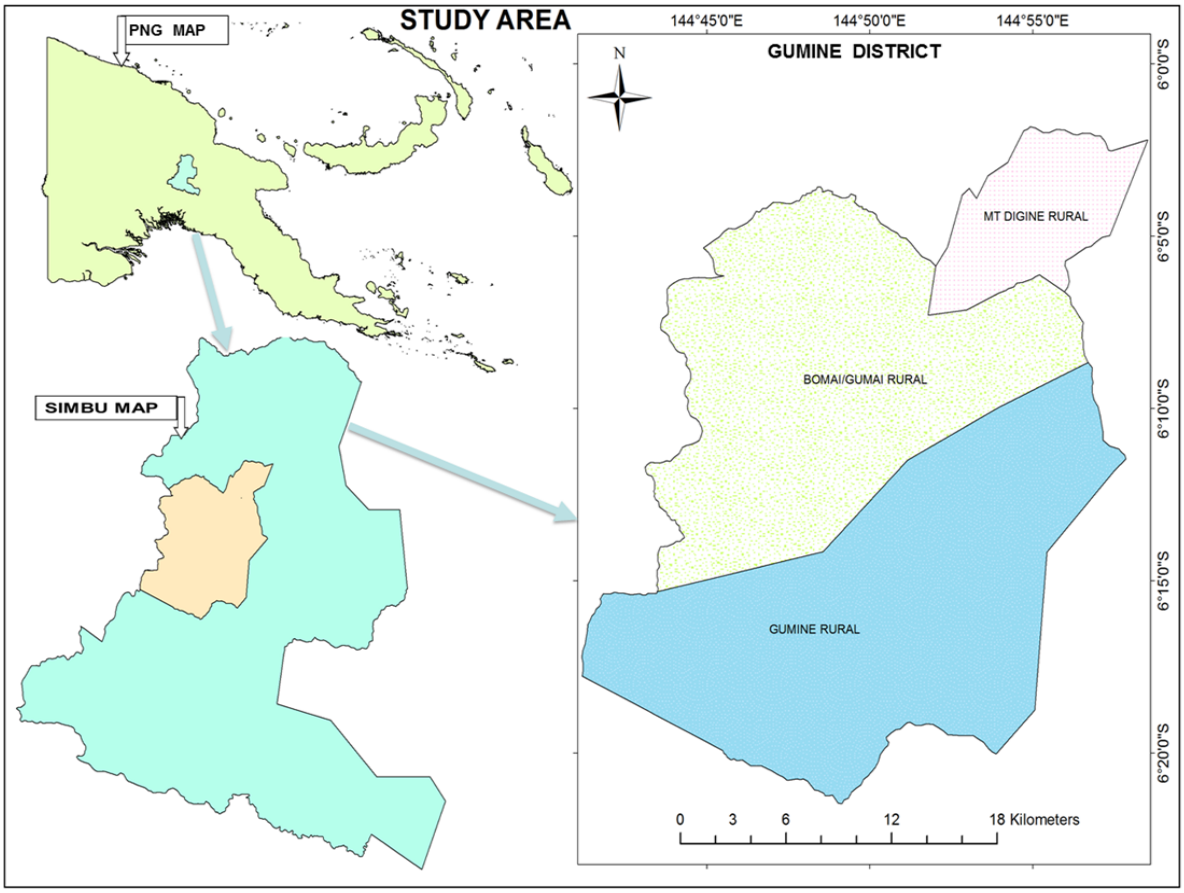

Figure 1: Map of the Study Area

eighteen years of age as recorded by the PNG Statistics Office (2011). It hosts the second highest and third highest mountain ranges in the province viz. Mt Kubour and Mt. Wikauma respectively. The Kubour Range, one of the longest ranges in the country, also runs through west of Gumine District administrative unit. It also hosts one of the biggest rivers (Wahgi) in the highlands region of PNG and a number of fast flowing rivers and streams. Thus, physical geography of Gumine is mountainous and rugged. The socio-economic conditions of the region (Gumine) are almost 95 percent subsistence farming where people cultivate land for food and shelter. This has been the means of survival for years, and will continue in the foreseeable future. It should be noted that about 80% of its landmass does not give good yield for large-scale economic crops due to the rugged terrain. As a result, the economic activities of this region remain relatively poor compared to other districts in Simbu province.

2.2 Data and Methodology

2.2.1 Data Collection and Pre-processing

For purposes of analysis, both spatial and non-spatial data were required. The spatial data was mostly the data collected using GPS (GPS data) and existing PNG geo-data. The data collected through GPS was stored in Excel spreadsheet with its attribute and X, Y information. These are point coordinates of the targeted infrastructure facilities, tracks and line segments of road networks in the study area. The X, Y data displays in the frame are temporarily saved as feature classes or shape files for retrieval and analysis. The attribute database created in the Excel spreadsheet with reference to each geographical X, Y point is automatically generated in ArcGIS for each location feature. The non-spatial data were mostly data collected through questionnaires, interviews, field visits and physical visits to government's and NGOs' offices. Census and household data, including demographic and socio-economic data, as well as existing infrastructures data were collected and recorded and later on integrated with collected spatial data with SRTM 30m spatial resolution Elevation data in the GIS environment. Spatial data is usually stored as coordinates and topology (attributes), and is data that can be mapped. When a dataset is not readily related to a location on the surface of the earth, it is referred to as non-spatial data. Examples of non-spatial data are numbers, characters or logical expressions and can be later attached to the location information. The data collected are population data and built-up infrastructures data, such as data on roads, bridges, health centres, post offices and schools. Furthermore the village point data was also collected. The infrastructures data were collected by considering and inspecting their conditions, status, distribution, community accessibility and affordability.

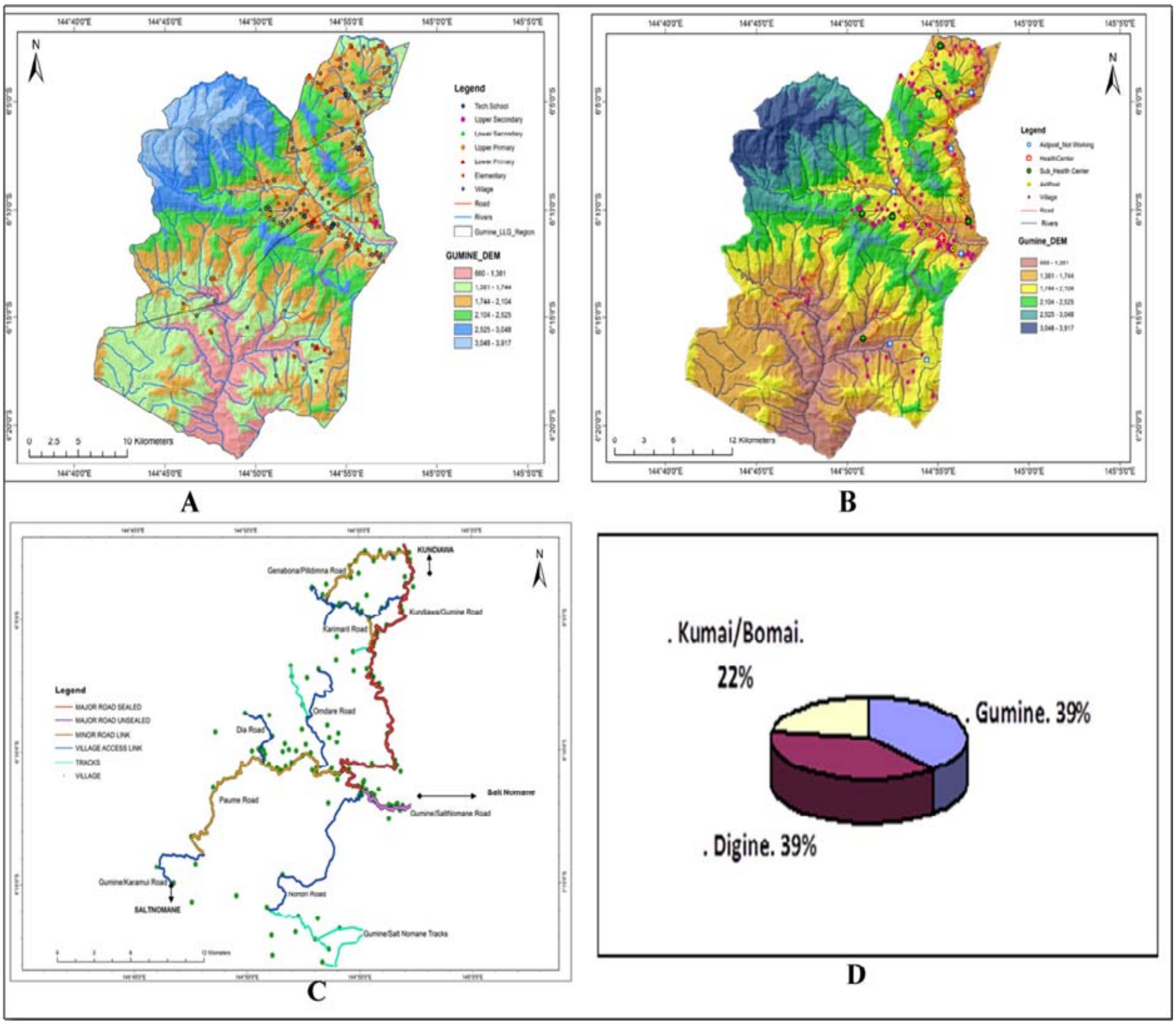

Figure 2: Distribution of infrastructure and population attributes of 3 districts in the study region. A. Education Facilities; B. Health Facilities; C. Road Network; D. Population Distribution

2.2.2 Data Analysis

Data collected and mapped as illustrated in Figures 2A, B and C were evaluated in such a way to put out information for decision makers and planners to serve the growing population of the study region as illustrated in Figure 2D. As hinted earlier, the infrastructures were analysed in terms of their conditions, distributions and accessibility based on the perceptions of surrounding villages and the growing population. The main GIS spatial analysis techniques adopted were overlay, feature digitizing and multiple ring buffer method. These GIS technical approaches were applied according to field data collected. The distribution and condition were mapped and the database was created. From the existing spatial data collected as discussed above, the infrastructure information was digitized and extracted. With regards to non-spatial data collected by field visits, analysis was done according to conditions, distributions and connectivity, while maps were prepared leading to generation of the database system.

Furthermore all the village points were digitized and extracted, attributing the population distribution of each. The overlay approach in the ArcGIS environment was performed to identify and evaluate all digitized features based on the distributions when compared with nearby villages or populations in terms of accessibility and efficient service provision concept. The overlay method is a GIS operation that combines the geometrics and attributes of the input layer (created digitized layer) to create the output layer. The multiple ring buffer technique was then executed after making all the comparisons and judgments through an understanding of overlay technique that provides visualization of interrelationship of each built-up infrastructure and the nearby surviving population within the three (3) districts of study region.

Buffering is a GIS operation that creates zones within the specific distance of select features. For example, a school might be buffered by one km radius and then we may use the buffer to select all of the students that live more than one km away from the school in order to plan for their transportation to and from school. The buffering for each infrastructure was taken in accordance with the specific distance in kilometre. The school and health infrastructures were digitized in point format and they are indicated as sources of growing population that are indicated as targets to benefit from these sources. Hence, the point feature buffering was undertaken to indicate and show how far away is each village or population from the source features. Furthermore, it is important to indicate within the buffer the obstacles or accessible limiting factor like terrain height or river to cross over to the service sites (source). For the road network, the buffering was also taken to indicate and show ease or difficulty of certain villages accessing the road. These are all necessary analyses for such a database. The idea behind the study is to show the degree of difficulty or ease of growing population within the study region in accessing government services.

3. Results and Discussion

3.1 Introduction

Better access to basic health care, education, road and other public utilities for people living in rural areas is a key issue in rural planning and development in PNG. In this study the government built infrastructure in each LLG of Gumine is considered as ‘source’ while village populations in each ward are considered as target beneficiaries. The accessibilities, availabilities and current conditions of infrastructural facilities are the main focus of discussion.

3.2 Road Infrastructure

In developing countries like PNG, road network plays a very important role in determining the level of user satisfaction with any developments. A better road link to rural settlements provides better access to markets and other basic services. Efficient and effective rural transportation serves as one of the channels for the collection and exchange of goods and services, unhindered movement of people, dissemination of information and the promotion of rural economy (Adedeji et al., 2014). The road network of Gumine district in this study is mapped and classified based on the roads' condition and usage. The study is based on four areas namely: distance, access by village wards, accessibility considering terrain factor, the general condition of the road and distribution of roads in each LLG area. The majority of rural villages are isolated by distance, physical geography, bad road conditions, lack of or broken bridges and inadequate transportation. These conditions make it difficult for people to get their goods to market and/or access public amenities.

The major and minor roads are the only serviceable roads linking habitants as village access road links are not in operation. Hence, those village wards living within 0 to 2 km are having easy access while wards further away from 2 km are continuously confronted with challenges due to difficult terrain. Those living within 5km to 8km and beyond are considered as disadvantaged groups of villagers. They continue to miss out on this service as well as other public amenities. Figure 3 illustrates the overall assessment of road distribution in Gumine in percentages and Figure 4 shows village locations and accessibility to existing road infrastructure. The most disadvantageous villages are likely to be those that are relatively isolated and have limited access to road infrastructure.

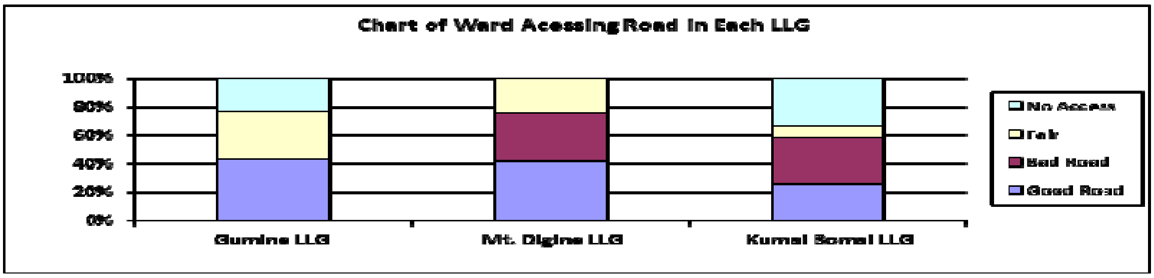

Figure 3: Road Distribution of LLG in Percentages

Terrain is one of the factors that limit the accessibility of road and other public utilities within the region. When comparing the road network and road buffer as illustrated in Figure 4 with the levels of altitude/elevation of the study area as illustrated in Figures 2 A and B, it can be seen that some villages are located on higher terrain areas and do face difficulties accessing roads. Hence those villages located in low altitudes in which the public utilities are provided, including roads, are having easy access even several kilometres away from the service. Those villages that are located close to public services but within a difficult terrain emanate challenges while those located in low attitudes have stress-free access in a reduced amount of time.

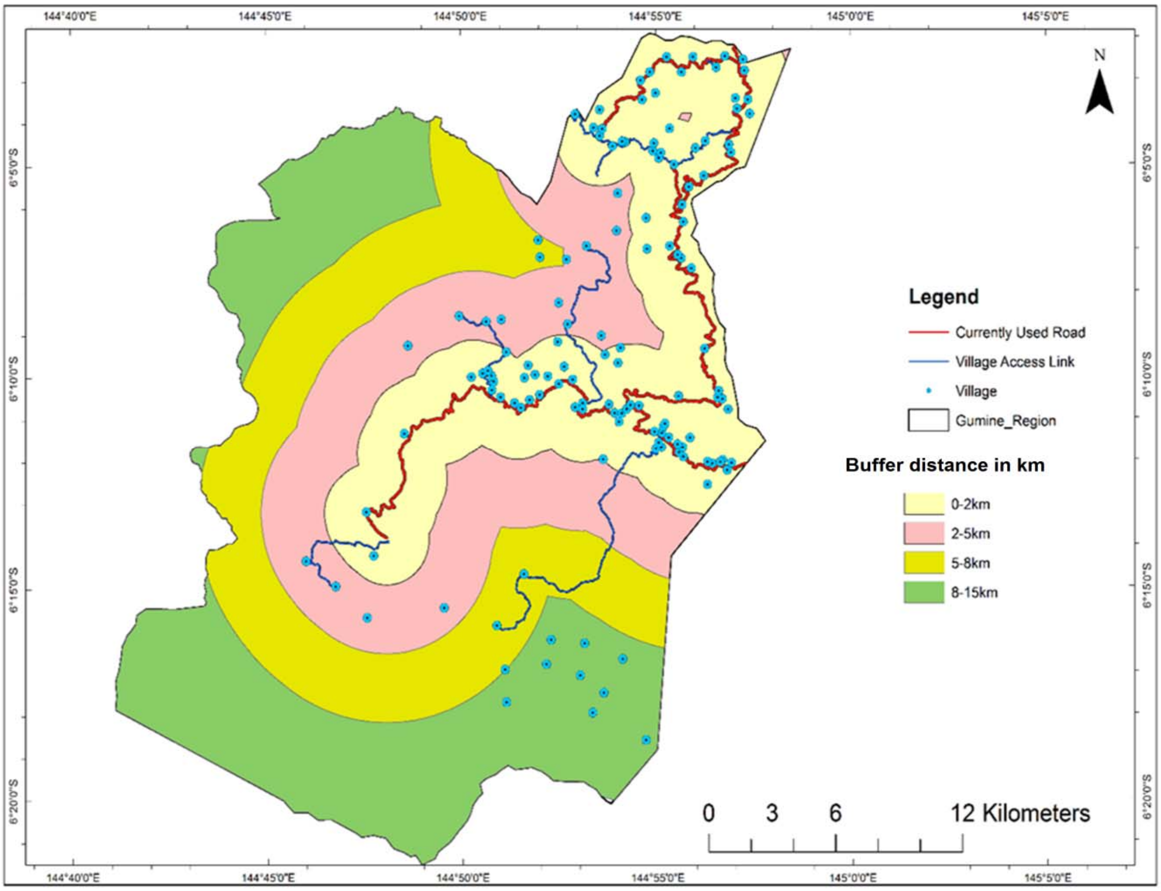

Figure 4: Difficulty / ease of villages in accessing road

3.2.1 Road Condition

The condition of the road is one of the factors that hinder the progress of economic activities as well as the accessibility to public utilities. From this study it shows that, only major road is in good condition (Figure 5). The minor road and village approach road links are in very bad and deteriorating conditions. As a result, most of the villages are disconnected from other basic services. This is a real cause of concern to the district in the future as good road is the economic life line and the only access to other services. The road is classified based on its current condition and usage. Good roads are classified as the ones with good drainage system resulting in having very good surface condition and are frequently used by the general public. Fair roads are defined as village access roads with improper drainage system and rough surface but frequently used by habitants. Bad roads are known as man-made roads, which are not up to usable standards. Many of these roads are unmanageable and their accessibility is limited. 'No access' class in this category refers to villages without any road links. Their access is through bush tracks.

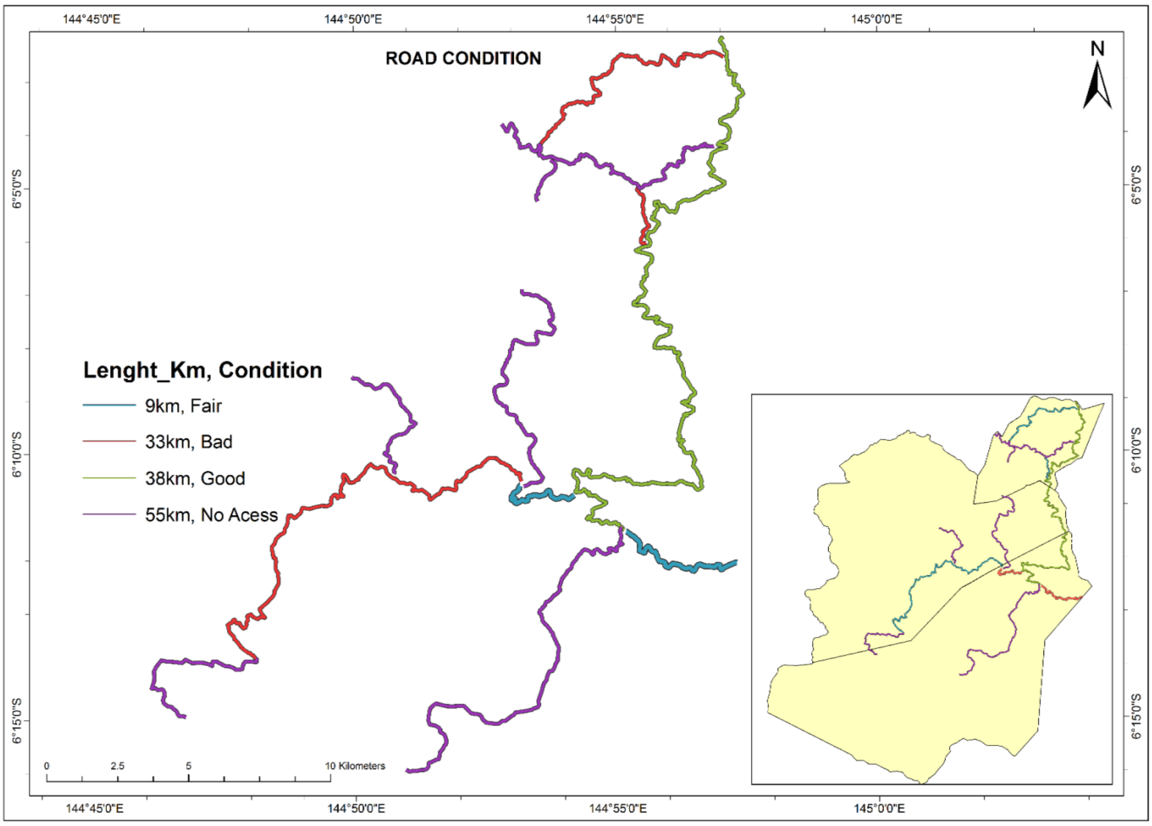

Figure 5: Road condition

3.3 Health infrastructure

Basic health care is one of the most important social services supporting humans in many ways. Also the Government of PNG is so determined to reach out to rural areas by providing primary and essential health care for everyone. As such this study intends to evaluate the availability of basic health services in the study area as well as their condition and the distance in which healthcare service is accessed by local communities. The distribution of health facilities in three LLGs of Gumine district is provided in Figure 6. The calculation is based on the total number of health facilities provided in each LLGs of Gumine district. Only one Health centre is provided at Gumine District administrative unit which is not shown as it is one of the district administrative functional requirements across the country. This study shows that the distribution of health services across the district is not adequate as per the LLG wards.

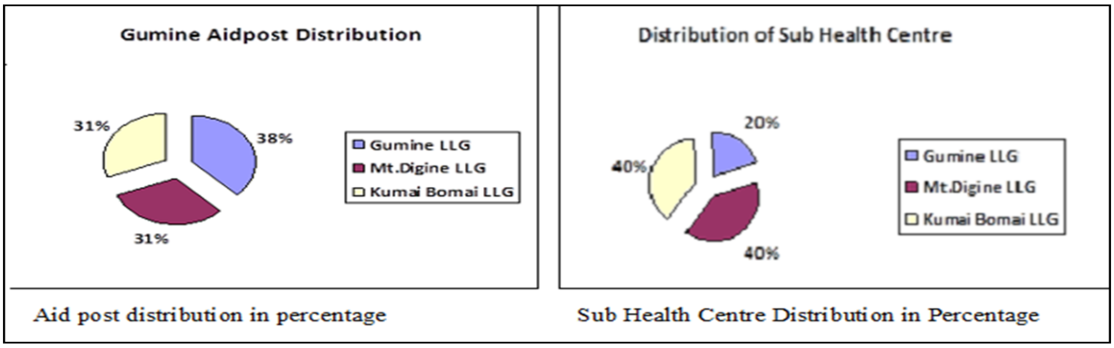

Figure 6: Health Distribution in Percentages

Healthcare is considered as one of the most important community basic services. It is captured in the top priority list of government's investment. However, the spatial map of health services available in the study area (Figure 7) shows that, more than half of the population are not having easy access to existing facilities. The only groups that have access to existing public health services are those within 2km zone. Those villages located between 2km to 3 km continue to encounter so many challenges while those living beyond are considered as most disadvantaged and unprivileged group. Their chances of having access to existing facilities are very limited due to difficult topography and the distance in which this service is provided. The terrain analysis also provides additional information on the accessibilities.

Due to difficult terrain and the location at which this service is provided, some villages are considered as privileged while others are not due to the nature of the terrain. When comparing the road network and road buffer as illustrated in Figure 7 with the levels of altitude/elevation of the study area as illustrated in Figures 2 A and B, it can be seen that some villages are located on difficult terrain areas and do face difficulties accessing health services. Hence, those villages located at very low to low attitude are having easy access through a walk while those located in high attitude are not so lucky due to difficult terrain. The sad scenario is that, those villages within close distance but are situated at high to very high altitude are also severely challenged to access. It takes good numbers of hours to reach the destination, which is extremely cumbersome; while those located at very low to low altitudes are having easy access even though they are far away from the service entities.

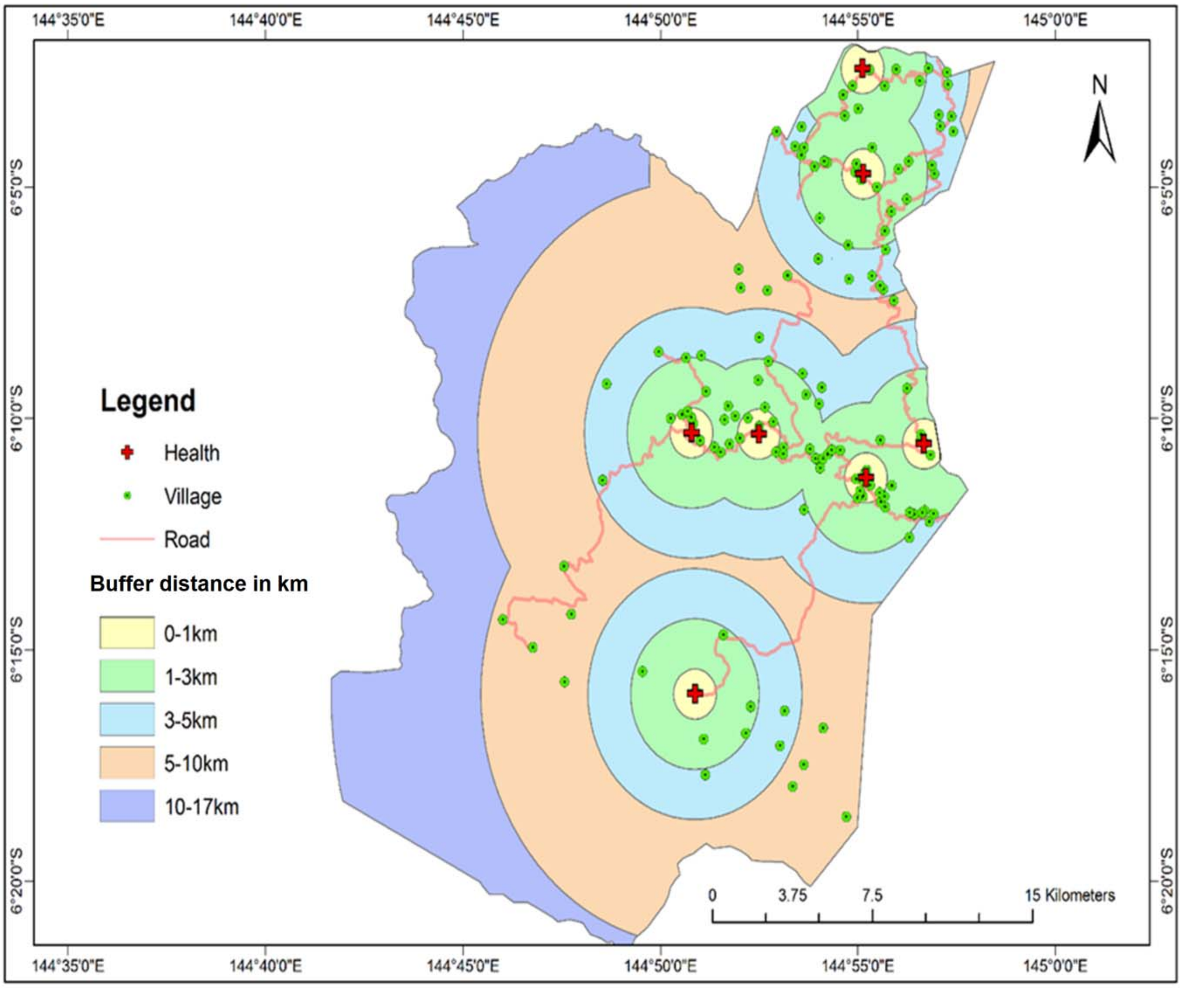

Figure 7: Village wards with easy or difficult access to health services

3.3.1 Condition of Health Facilities

The health facilities in the district are assessed and classified based on current condition, including state of staff housing, state of clinic facilities, availability of trained medical staff, availability of medicine and the capacity in which health services are provided. The map in Figure 8 shows the location of villages and operating health clinics. The bad condition refers to rundown health facilities which are not operational. The fair condition refers to very deteriorating and rundown health facilities in which services are still being provided. Good condition refers to health facilities which require immediate maintenance but are functioning well with adequate supply of medicine and staff. Very good condition is classified according to good infrastructure and utilities as well as adequate manpower and medicine supplies with effective clinical operations. Also this study shows that, most of the aid posts in the villages are not functioning while some are in dire need of maintenance.

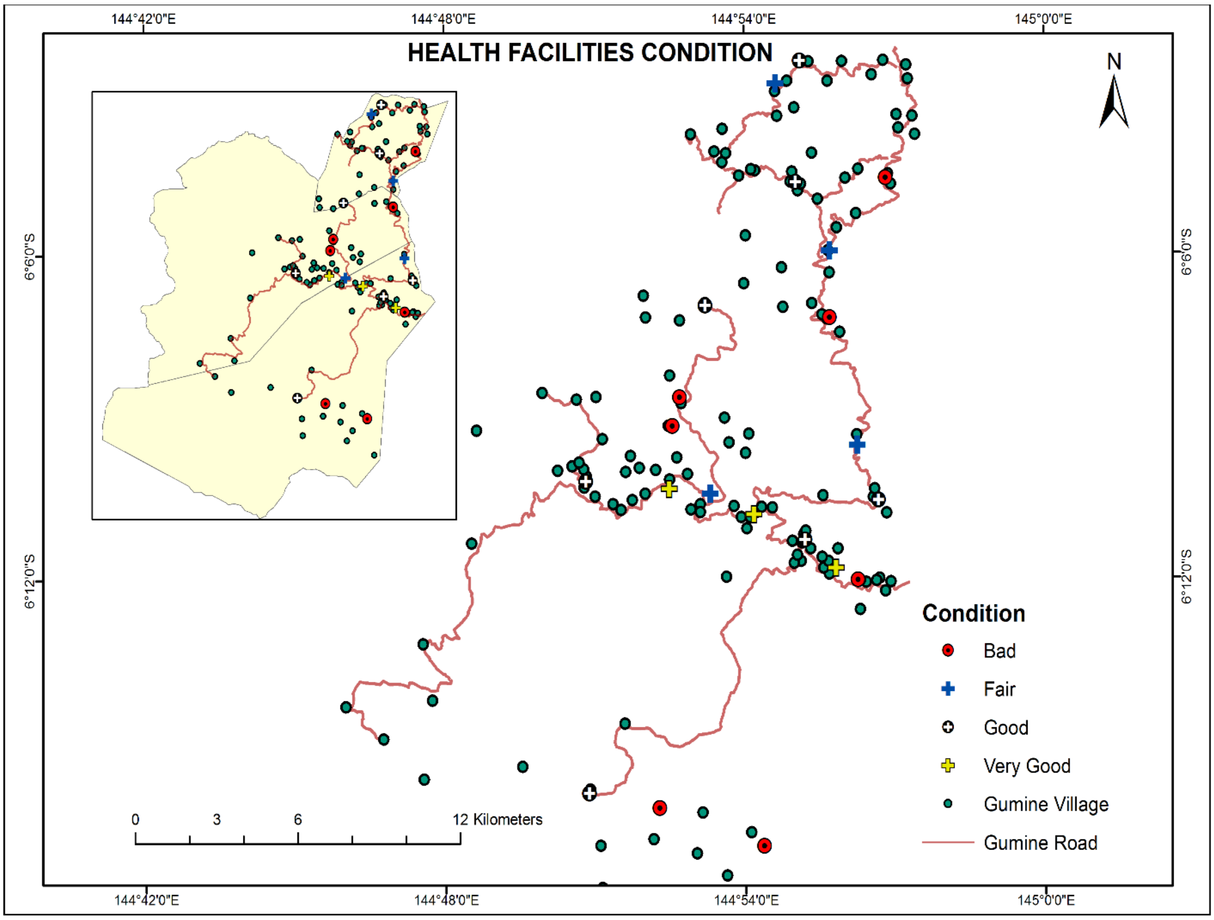

Figure 8: The condition of existing health facilities

3.4 Education Facilities

Education is considered as one of the priority investments of the current government. However, based on spatial maps (Figures 9 and 10), almost all wards have elementary schools but there is a need for more primary schools and secondary schools. Also some of the current conditions of education facilities provided in the three LLGs are in very bad state of maintenance as identified in this study. The total number of schools in each LLG is provided in Figure 9. This distribution is a summary report of all the levels of education facilities available from Elementary to Technical/Vocational schools. The study shows that elementary schools are well distributed based on the number of wards. However primary, secondary and technical schools are not sufficiently provided. From this study it shows that there are many existing elementary schools in each LLG. Every ward has its own elementary school set-up. However, the availability of primary school, the distance from surrounding village and the stage of facilities are of paramount concern as to accommodate the increased number of kids at elementary.

When compared with the map in Figure 2 A and Figure 11, it indicates that those kids graduating from elementary schools are having difficulty in accessing nearby primary schools as villages are scattered. Those villages' wards within 0 to 1 km are having easy access while those within 1 to 3 kilometres are struggling due to distance and difficult terrain. However, village wards further away from 3 km are considered disadvantaged and unprivileged group as kids cannot walk that far. As such there is a high chance of kids missing out on basic education. Also there are two secondary schools in the study areas (Figure 10). It indicates that the conditions are up to the expected standard. The distances within which these services are provided do not affect the users as the schools provide boarding facilities to accommodate students. However, there is a need for additional secondary schools to cater for increased number of enrolments. From the map in Figure 10, it can be concluded that the village wards away from school beyond 5km are more than enough to justify additional secondary schools and it is contended that government needs to make this dream possible.

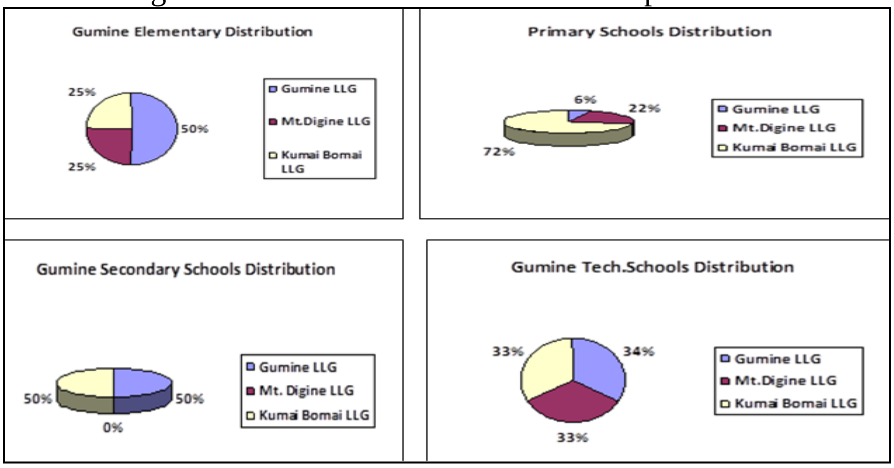

Figure 9: Distribution of schools in each LLG

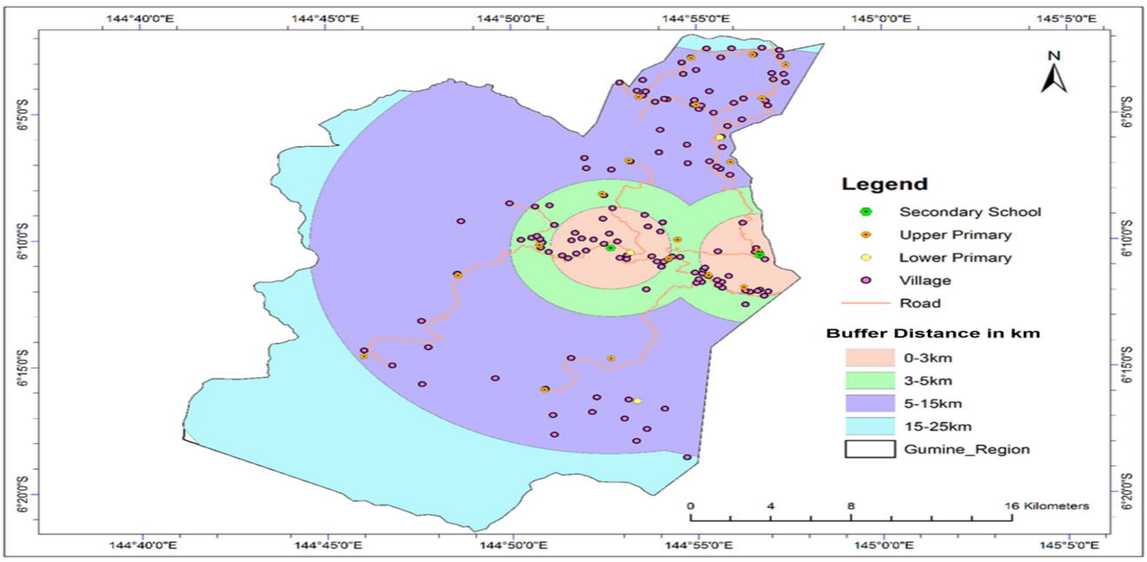

Figure 10: Distances between the villages and secondary schools

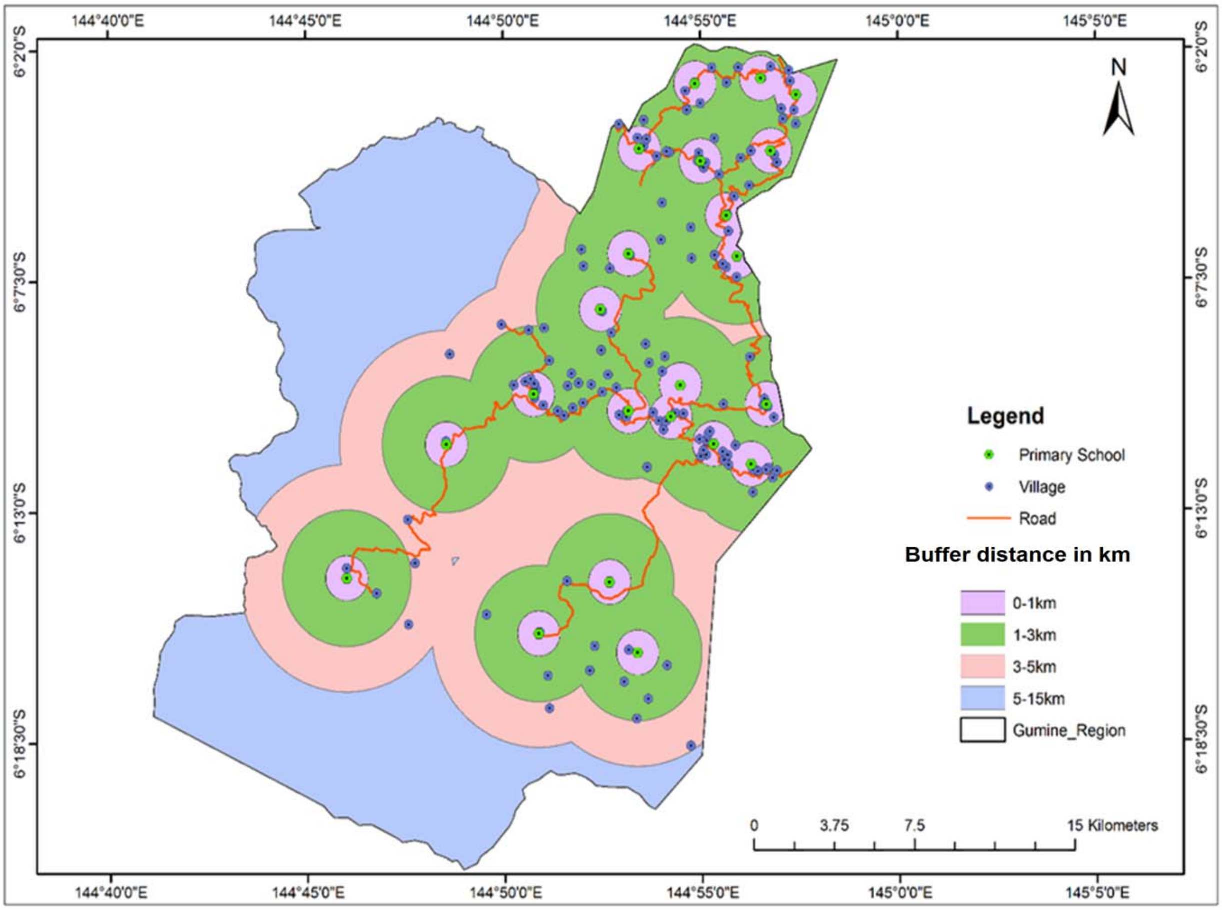

Figure 11: Distances between the villages and primary schools

There are a good number of primary and secondary schools established in three LLGs of Gumine District. The primary schools are programmed in such a way to accommodate both upper and lower primary levels. Their enrolment comes from elementary school. This comes to the core of struggles identified from this study as almost all of the elementary graduates are unable to access nearby primary schools due to distance and difficult topography. When comparing the elevation/altitude level in Figures 2 A and B with Figures 10 and 11, those villages located within 0 to 1 km buffer distance and in very low altitude have easy access, while 1 to 3 km involve much challenges. However, villages located in the low altitude from 2 to 3 km away from school still have easy commutes, while in the high altitude it is hard to hike the terrain to reach the destination. As a result, few kids continue to lower primary while many are left excluded in the villages.

3.4.1 Condition of Education Facilities

The condition of education facilities is classified based on the current state of classrooms, staff houses and their utilities (Learning material). Bad condition refers to wooden materials, which require immediate maintenance and/or rundown schools which are not in operation due to lack of maintenance, facilities and utilities. Fair condition refers to schools with semi-permanent buildings, which require major maintenance as well as utilities that are not up to standards but are nevertheless in operation. Good condition refers to schools with both permanent and semi-permanent buildings and well established amenities like toilets and rubbish disposal, learning materials, etc., with effective operations. Very good is classified based on its current condition, which requires minor maintenance; utilities and learning materials are well maintained and the general operational functions with regards to enrolment and availability of skilled staff are up to expectation. Figure 12 illustrates the conditions of schools.

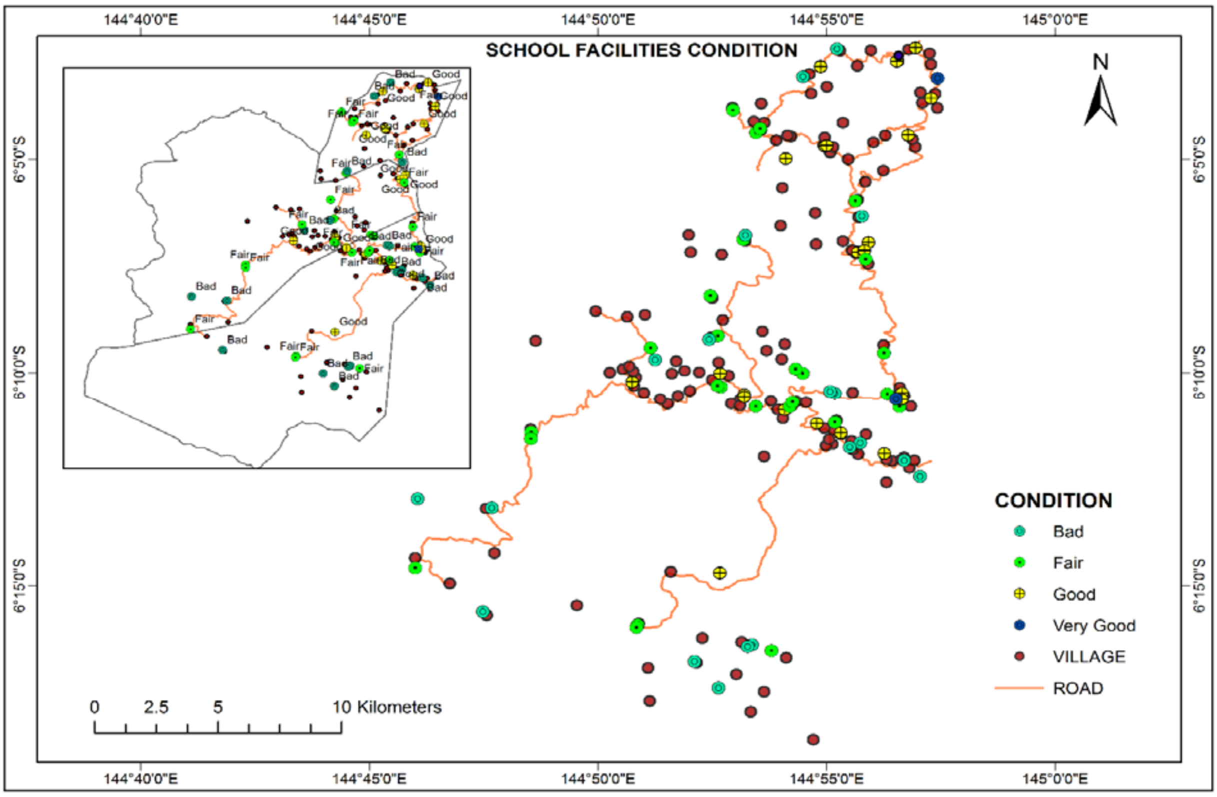

Figure 12: Map Showing General Condition of Education Facilities

4. Conclusion

This study is undertaken in the tribal-oriented and rural-based Gumine district of Simbu Province, to generate Geospatial data for assisting decision-makers with main emphasis on mapping basic rural infrastructural planning and development in the districts including road network, health facilities and education facilities. The primary focus is on demonstrating the potential of spatial data infrastructure for both District and LLG level development planning, taking into consideration the local needs and constraints. It also serves as information tool to support decision-makers in the district to generate community participation towards decision-making at the district level. This study is much like a prototype district administrative GIS tool designed to serve as a first step towards any development of Advance Geospatial Database for decentralized planning at district and LLG administration levels. The geospatial data infrastructure is modular and can be updated to accommodate additional information about the district in the form of new thematic layers to make it more comprehensive.

4.1 Future Focus and Recommendations for Geospatial Database

In a developing country like PNG with difficult topography, it gives a big challenge for the government to access current baseline data to assist in their decision-making process for developmental planning. A systematic planning and management tool for rural development planning is a paramount necessity for the PNG government. Geospatial technologies have the capabilities to assist planners and environmental managers in a number of ways in planning better service delivery and for efficient management of existing infrastructure services. Possible geospatial future development programmes to be derived from this study include the following:

i) Graphical User Interface (GUI) could be built from this database. It will provide easy access to quality and up-to-date information for non-GIS professionals. It is indeed a very fast, friendly and convenient tool to users.

ii) Advance and sophisticated Decision Support Systems (DSS) could also emerge from the application of the study findings. The availability of baseline data in a computer system is more important as data security is concerned. The data collected from this study can be customised to develop a Decision Support System for the District to use as a tool in planning and managing rural infrastructural development.

Finally, GIS systems are now becoming a very important planning tool in today's world of technology and as such further recommendations can be accessed from time to time when this country comes to realise the full potential of GIS and Geospatial Technologies.

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