Evaluation of Earthquake-Induced Liquefaction Susceptibility in the Earthquake Prone Areas of Morobe Province, Papua New Guinea

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Abstract

Earthquake-induced liquefaction is common in the areas where incidence of earthquake is high along with an amenable soil substratum. However, the extent of liquefaction is controlled by types of site and sub-surface soil-geological factors present in that particular earthquake-prone areas. The earthquake-induced liquefaction can be a major calamity that warrants appropriate investigations in infrastructure development planning. To identify susceptible areas of liquefaction in the earthquake-prone areas, the site soil-geology and earthquake data are mostly needed. There are different approaches used discipline-wise across the world to identify areas that are prone to liquefaction. The output results are used as tools for site selection and also for determining viability of funding in infrastructure development. Liquefaction is one of the main Geo-hazards related to tremor. The presence of saturated soils or unconsolidated sediments in a particular area can pose greater chance of liquefaction at certain earthquake magnitude levels. The study sought to evaluate and assess site and sub-surface soil-geology including historical data on magnitude and frequency of earthquake events that occurred within the study region to identify and demarcate areas that are more susceptible to liquefaction. The main method applied was multi-criteria evaluation using GIS and Remote sensing technologies. Several thematic layers were prepared from the database as mentioned, followed by assigning weightage to each thematic layer generated. The final outputs of liquefaction-prone areas were identified using the weighted overlay tool in ArcGIS 10.2 computer software and were reclassified to show levels of susceptibility from 'very high', 'high', 'medium', 'low' to 'very low'.

Keywords: *liquefaction, earthquake, multi-criteria evaluation, GIS, geomorphology, PNG*

1. Introduction

Earthquake is one of the most horrible disaster events that occur preferentially at certain locations around the globe. The extent of disaster happens in accordance with the shaking intensity of the tremor, the former being often aggravated by the liquefaction potential of the water-saturated, unconsolidated substratum of the specific site. Lots of people around the world have lost life including their valuable properties in the event of earthquake. According to the NEIC-U.S.G.S (2013), the death toll specifically for earthquake events alone globally estimated between year 2000 and year 2012 was 493, 736. This figure proves the disastrous danger of earthquakes. Also it is the most important task for scientists and researchers to know how the earthquake events are correlated to the extent of damage in the aftermath.

Earthquakes are mostly caused by the interaction of tectonic plates and also they might have a possible link to anthropogenic activities. The earthquake strikes due to colliding plates gliding past each other all of a sudden. As a consequence a seismic wave is generated and propagates from the earthquake focus to the surface around the epicentre. The intensity of shaking depends on magnitude of earthquake and also on particular underlying site and sub-surface soil-geology (Wilige and Wenzel, 2009). The stronger the shaking the more damage that is likely to occur. It is very important to understand that when the wave propagates it has to negotiate different site soil geology strata before arriving at the surface. Hence, in accordance with the strength generated by the tremor the output intensity of seismic wave could be either attenuated or amplified owing to stiffness / softness of site and sub-surface soil-geology. Therefore, assessment of site surface soil-geology with seismic data is very important in order to categorise earthquake risk areas.

Papua New Guinea is one of the countries in the Pacific region where occurrence of earthquake is common. PNG is caught between colliding pacific and indo-Australian plates including several micro plates that put PNG on a very active tectonic region (Stanaway, 2008). Within the country, there have been several deaths and destructions, which have occurred due to earthquake events alone. A major example, according to Devies (1998), is the earthquake of Aitape (PNG) of magnitude 7, which was triggered at 10km depth that had caused under-sea landslide resulting in a Tsunami in the year 1998 and caused deaths up to 2,202 with 50 million USD in economic losses. According to previous studies, it was found out that in parts of Momase region and the Island region of PNG, earthquakes of Magnitude levels in Richter scale from 3 up to 8.5 had slapped damages and destructions that were sometimes recorded and also sometimes went unrecorded owing to lack of financial support.

For the current study, site soil-geological parameters were assessed and integrated with seismicity data, that is: earthquake magnitude, depth and shaking intensity. The main focus of the study was to delineate and find out liquefaction susceptible areas within the study zone using the application of GIS and Remote Sensing. Liquefaction is common in many earthquake events of greater magnitude (Justin, Baldwin and Hoeft, 2005). High shaking intensity is the main cause of any liquefaction to occur. Thus liquefaction is the process in which water is combined intimately with soft and saturated sediments or soils, normally from the actions of shaking intensity and the pressure it implies, which causes the soils to behave like quicksand (CRC, 2006). This physical act leads to ground failure or subsidence resulting in demolition of existing infrastructure. According to the NBMG (1980) liquefaction may occur in fills, swamps, sloughs, or bogs, or other areas of loose, unconsolidated, poorly drained material that have a high water table.

Investigation and assessment of site and sub-surface relating to geology and geomorphological structure is of importance in terms of identifying plausible Liquefaction Potential Zones (LPZs) (Sharma and Solanki, 2013). Liquefaction susceptible zonation is a scientific and technical approach into estimating and understanding the types of soil and or sediment structures that are under earthquake excitation and hence GIS is the most preferable approach to carry out this task (Habibullah et al. 2012). In order to delineate LSZs in GIS platform, we need to identify and assess several input data in the form of geological, seismological and geomorphological factors. Each input factor is to be weighted and ranked according to how important it is in contributing to liquefaction (Sharma and Solanki, 2013). Such study here is vitally important for the governing bodies and the general public as a whole; it provides fixed tools that help in better infrastructure development planning, mitigation measures and also fosters the development of early warning preparatory systems.

2. Study Area and Method

2.1 Setting

The country PNG is made up of 22 provinces. Within these 22 provinces the area where the study focused on consisted of four (4) districts in Morobe Province, namely: Bulolo, Huon, Nawae and Lae District. The study area is located somewhere between, 8^0 0'0'' S, 6^0 10'0''S and 147^0 20'0''E, 146^0 10' 0''E. The study area has experienced several episodes of earthquake from the past up till today. It can be predicted from previous studies that the study area is prone to more earthquakes in the near future. The study region is dominated by its huge mountains and valleys created through the process of weathering, erosion and tectonic plates motion. Within the mountain range lies the flat land dominated by Ramu-Markham River flanked on all sides and guided by mountain ranges. Valleys or flat lands are basically found near rivers and are located on a poorly unconsolidated sediments deposit that are dominated by alluvial or quaternary deposits from the past weathering and erosion events/processes. The second largest industrial city (Lae City) of PNG is located within the study area. Based on the tectonic spatial organisation of the study area that was created and modified by Stanaway (2008), Koulali et al. (2015), Ghamsemi et al. (2015) and Wallance et al. (2004), it can be seen that the study area is located on two (2) major fault lines - Ramu Markham fault zone and Owen Stanley fault zone - captured between 3 plates namely: Woodlark plate, South Bismark Plate and New Guinea Highlands Deformation Zones. Within the study area, according to Geobook and PNGRIS METADATA, there exists also the geological minor fault lines that also contribute to earthquakes. This tectonic structure aptly defines the study area as a most active earthquake region. Figure 1 illustrates the locality of the study area, while Figure 2 illustrates the tectonic distribution of the area.

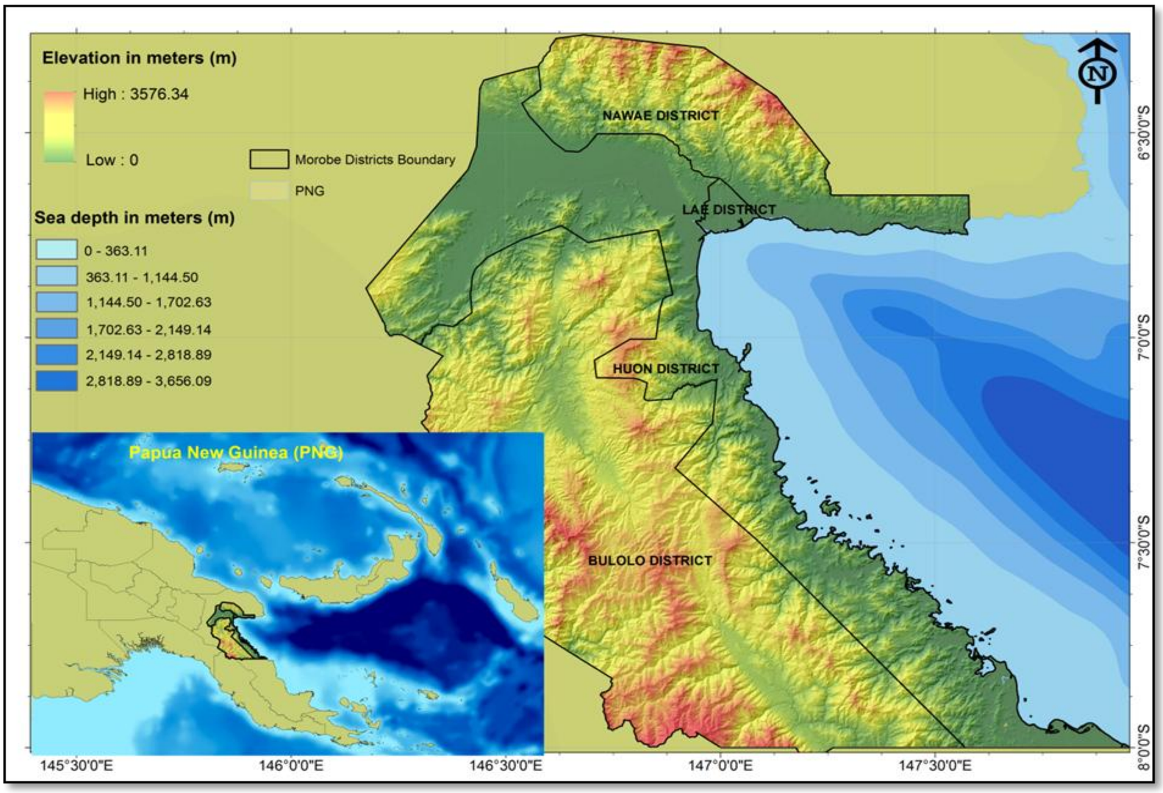

Figure 1: Study Area Locality Map

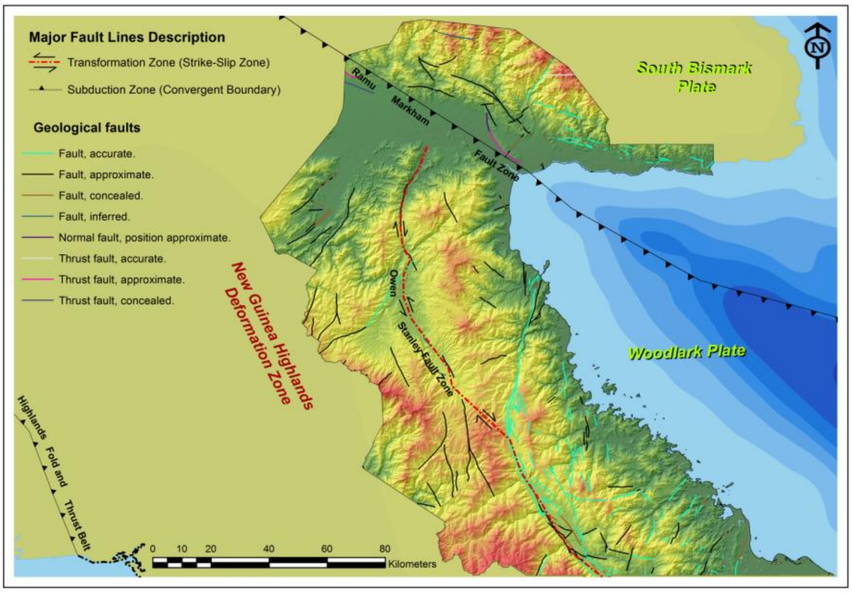

Figure 2: Tectonic Distribution within the study area

Three main sources of data that were acquired and assessed are: (i) Historical earthquake data in terms of magnitude level, levels of earthquake depth in kilometre and Peak Ground Acceleration (PGA) in %gal that is the shaking intensity (ii) Geomorphological data in terms of soil texture group and soil drainage, and finally (iii) geological data in terms of rock types in form of compactness. Soil data was further updated using Landsat 8 OLI & 7 ETM+ satellite image. The general idea of such data types is to show whenever the earthquakes occur, how strong or stiff is the particular underlying site soil-geology so that the overlying infrastructure can cope with shaking hazard leading to a certain degree of destruction. The study should answer to what kind of building code (civil construction) should be set by the district administrators to cope with the impending tremors. The seismicity data layers were acquired from USGS Earthquake catalogue and USGS earthquake archive centre. The geomorphological and geological data layers were acquired from Geobook and PNGGRIS metadata. The fault line data was collected and modified from several base maps prepared by different researchers across the country. Table 1 tabulates the types of data used for the analysis.

Table 1: Data layers needed and analysed

Data layers	**Source**
Earthquake Magnitude	USGS earthquake catalogue
Earthquake Depth	
PGA	USGS Shake map archive
Lithology (Rock Types)	PNGRIS, Geobook and PNG Geological metadata (PNG Unitech & UPNG RS Centre).
Soil Texture	Geobook (PNG Unitech & UPNG RS Centre).
Soil Drainage	
Landsat 8 OLI satellite image (30m spatial resolution, 2014) – multi-spectral image of 11 bands	Libra.com

2.2 Methods of Data Processing and Analysis

Seismicity data was collected in csv Microsoft excel format, subsequently imported to ArcGIS 10.2.2 software and converted to point features shape file format. The earthquake data collected were from year 1990 up to 2017, having magnitudes ranging from 4 up to 7.1. Figure 3 illustrates the earthquake distribution within the study region and Figure 4 illustrates magnitudes and numbers of earthquake events each year. The main focus here was to create raster surface distribution for magnitude, PGA and depth level with respect to such earthquake distribution as illustrated. Hence, interpolation technique in ArcGIS environment was applied. The interpolation tool called Inverse Distance Weighting (IDW) in ArcGIS 10.2.2 was used to create a raster surface of magnitude distribution and depth distribution followed by assigning weightage to the classes based on how influential it can be in terms of contribution to liquefaction. In the case of PGA, the shaking hazards of magnitude 5 and above were considered and those below 4 were ignored. Each point denotes levels of shaking felt from such earthquake events of magnitude 5 and above within the study area. The spatial analyst IDW tool in ArcGIS 10.2.2 was used to create a raster surface of PGA distribution in %gal and the ratings and weightage were assigned.

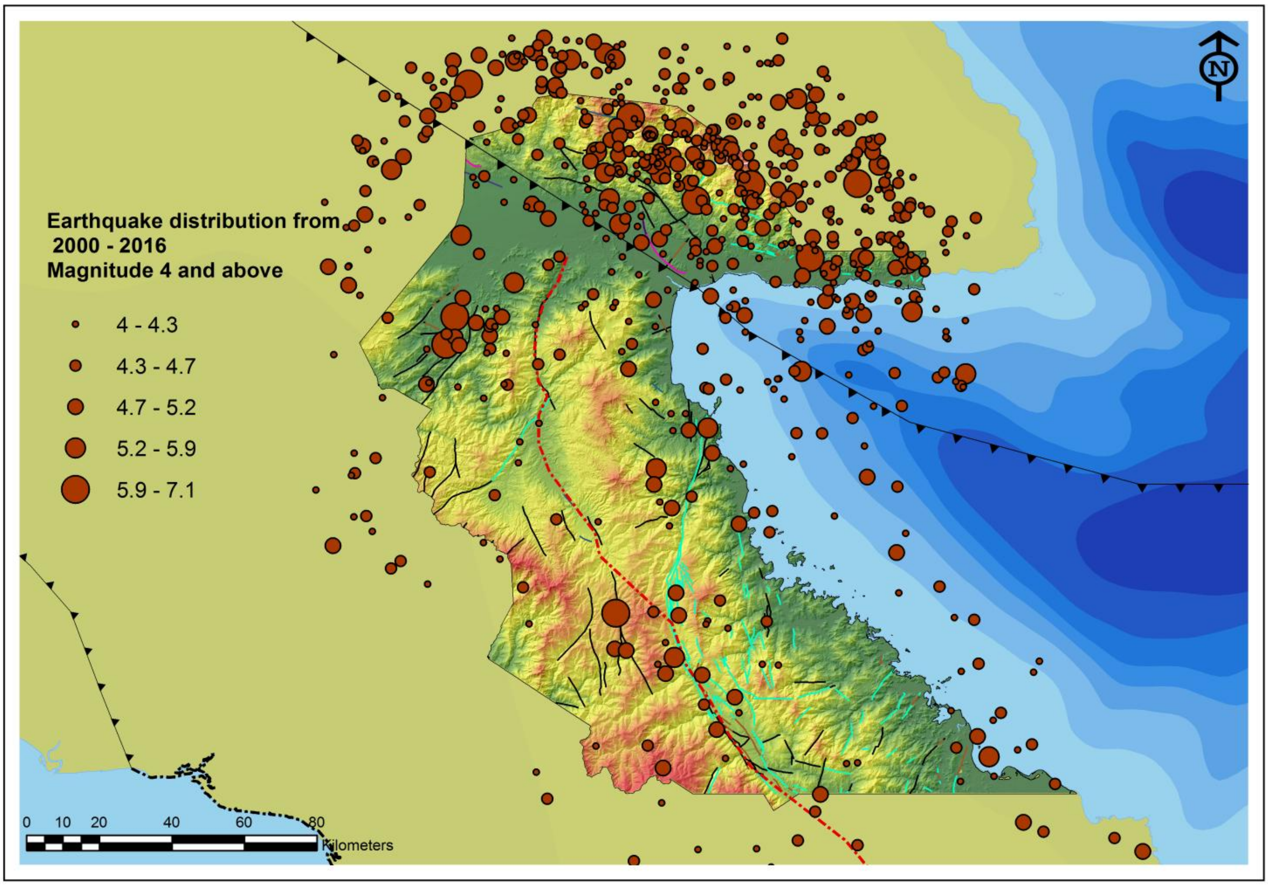

Figure 3: Seismicity Distribution –From year 1990 up to May, 2017

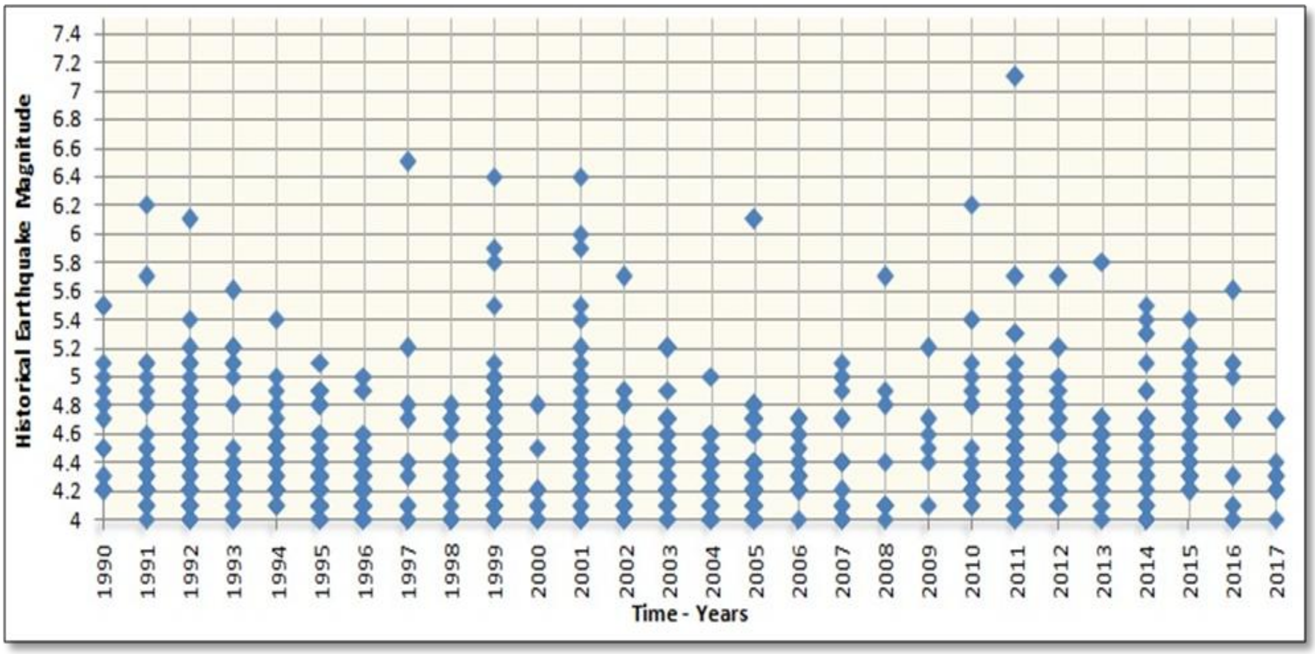

Figure 4: Year-wise Distribution of Earthquake Events (1990-2017 May)

The other data layers processed were Geological and Geomorphological data. From the PNGRIS METADATA the geological data according to rock structures were extracted. Different types of rock structures within the study area were assessed and reclassified based on their consolidation or compactness properties by taking into consideration the classification of rock types from Loffler (1974), and based on simple criteria, such as origin, composition and grain size of parent material. The rock structures were then re-classed into 3 groups of consolidation status, namely: consolidated, semi-consolidated and unconsolidated. Subsequently, each class was assigned a rating based on its capability to contribute to liquefaction during earthquake events. Figure 5 illustrates different categories of rock types that were assessed and re-classified into consolidation status. In the case of geomorphological data, it was soil attributes that were considered. The soil attributes viz. soil texture groups and soil drainage were considered and were extracted from Geobook database using ArcGIS software. The soil attributes group were then updated using Landsat images. The soil texture was assessed base on saturation capacity and was re-classed into Hydrological Soil Groups (HSG) as A, B, C and D. The soil drainage was assessed based on duration of wetness period. Both soil attributes were then assigned weightages and ratings based on the extent to which they can contribute to liquefaction during earthquake.

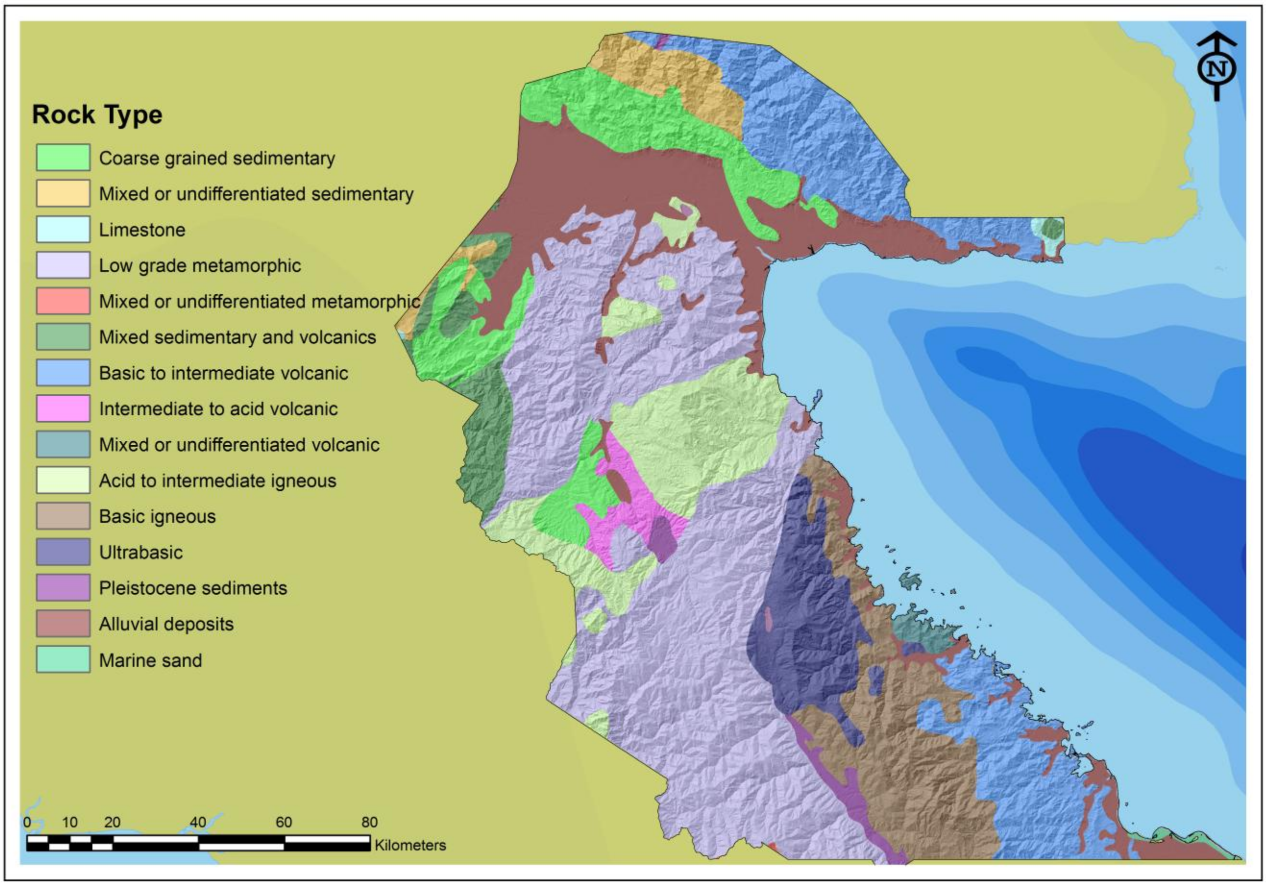

Figure 5: Rock types

2.3 Weightage Assigned and Analytical Hierarchy Process

The techniques of Multi-Criteria Evaluation (MCE) and Analytical Hierarchy Process (AHP) were used for data analysis. MCE is an approach where several thematic layers are prepared and their classes are ssigned weightage and rating based on understanding from literature, interview and questionnaires, which are designed to probe how each factor and its class may contribute to susceptibility of liquefaction. The assigned weightage and rating to each factor and their class based on different experts' opinions are to be normalized using the Saaty's AHP. The AHP was developed by Saaty (1980, 1989, 1992), specifically to assess or synthesize judgments or decisions made by the experts to achieve their set goal and to evaluate and check the consistency of judgment made. It is one of the best known and most widely used MCE approaches. It allows users to assess the relative weights of multiple criteria or multiple options against given criteria in an intuitive manner. It allows efficient group decision-making, where group members can use their experience, values and knowledge to break down a problem into a hierarchy and solve it by AHP steps. In order to be consistent about the weightage assignment the CR value should be calculated to be less than 0.10 (Saaty

1980, 1986, 1992). If the CR is greater than 0.10 then the weight assignment is to be re-evaluated to avoid inconsistency. Also the CR denotes the possibility that the matrix ratings were randomly generated. CR is calculated as follows:

$$CR = \frac{CI}{RI}$$ ....Equation 1

Where CR = Consistency Ratio, CI = Consistency Index, RI = Random Index

Consistency Index (CI) is calculated after the normalised weight is derived from pair-wise comparison matrix. The CI for assigned weights for classes or factors were calculated following the procedure adopted from Saaty (1980, 1992), as follows:

$$CI = \frac{(\lambda m - n)}{(n-1)}$$ ....Equation 2

Where CI = Consistency Index, n = order of matrix, λm = normalised weights multiplied by each column total.

The consistency random index (RI) is the average value of CI for random matrices. The average consistency of square matrices of various orders *n* was calculated by Saaty (1977) up to the matrix order of 15 and is shown in Table 2, as follows:

Table 2: Random indices for matrices of various sizes (n)

n	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0.52	0.90	1.12	1.24	1.32	1.41	1.46	1.49	1.51	1.48	1.56	1.57	1.59

Source: (Saaty, 1977)

After all the raster surfaces (thematic layers) of the factors above were created, they were re-classified and classes were assigned ratings while the factors themselves were assigned weights according to how they were (the factors and their classes) less or more influential towards contributing to liquefaction during earthquake. For example, to delineate LSZ the compactness of substratum rock or sediment structure was considered as the factor of high importance in deciding for LSZ; hence the factor was assigned a weight of 6 out of 6 factors. The classes were assigned ratings from 1 to 5, that is for the highly compact / consolidated areas, a rating of 1 was assigned because it cannot contribute much to liquefaction susceptibility, while for areas that were considered unconsolidated, a rating of 5 was assigned because these areas are more prone to liquefaction during any earthquake. Same idea and technique was applied to all other prepared factors with their classes. Table 3 indicates the factors and their classes assigned, as well as normalized weights and ratings. Figure 6 illustrates the general outline of methodology followed.

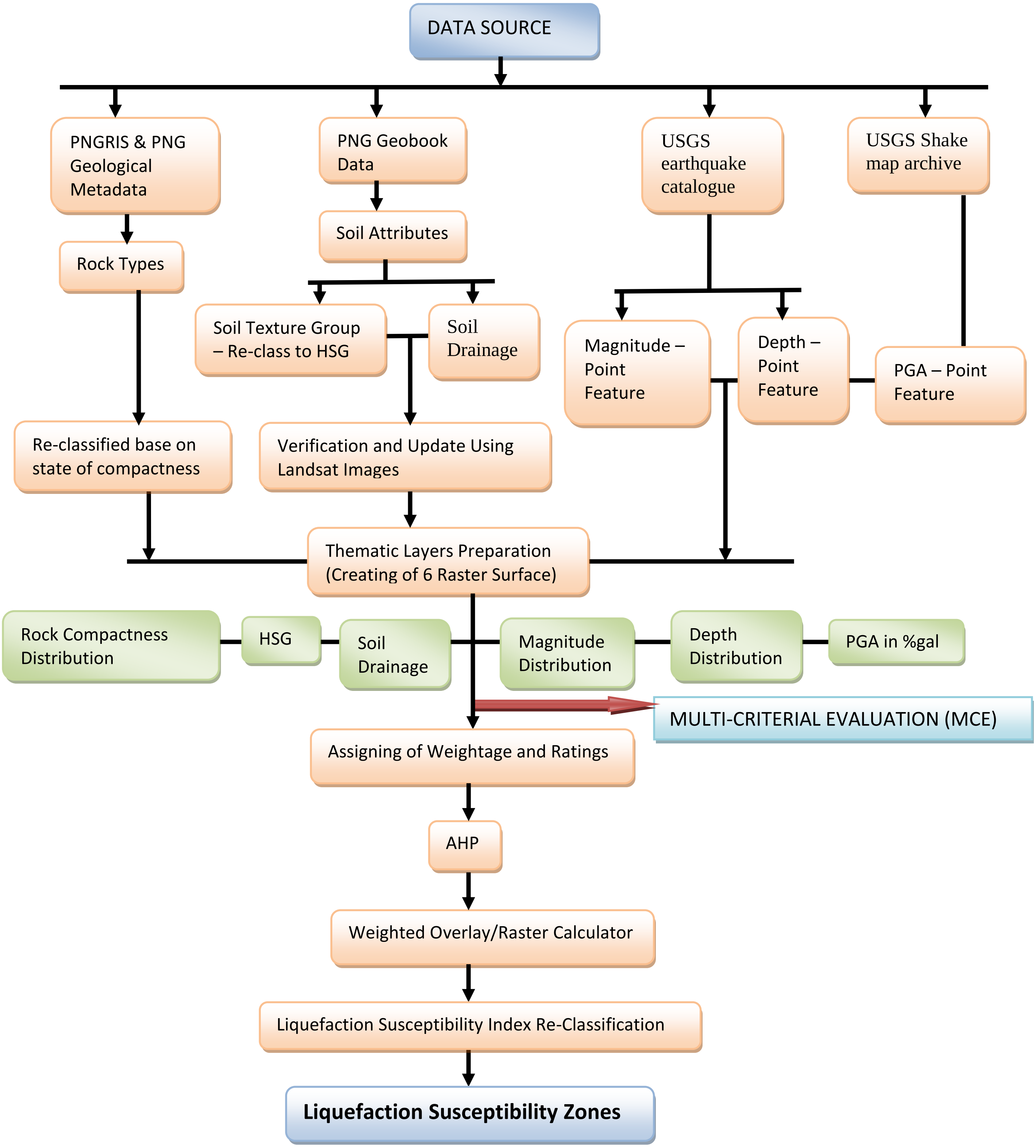

Figure 6: Research Methodological Flow Chart

3. Results and Discussion

A total of six (6) thematic layers were prepared and integrated in GIS environment to identify the potential susceptible areas of liquefaction within the study area during earthquake events. All the factors and their classes were assigned weightages and ratings based on findings from literature review, interviews and questionnaire surveys on how such factors and classes of factors can contribute to liquefaction during earthquake events. All assigned weights and ratings were normalized for consistency in accordance with their individual potentials for triggering liquefaction. The factors assessed and integrated for LSZ are explained as follows:

3.1 Compactness of Substrata Lithology

All rock types as illustrated in Figure 5 were assessed and re-reclassified based on their state of compactness, i.e., consolidated, semi-consolidated and unconsolidated. During the earthquake events and when the seismic wave is generated, it passes through sediments and bed rocks to the surface. According to Andrew (2005), when the seismic waves pass through the unconsolidated substrata, they get amplified leading to plausible liquefaction or ground failure evoking infrastructure collapse due to subsidence. When the waves pass through consolidated substrata the strength of seismic wave propagation gets attenuated minimising the chance of ground failure owing to liquefaction and subsidence in such zones. Hence, it can be concluded that areas that are highlighted as unconsolidated areas (Figure 7A) are more prone to liquefaction while areas highlighted as consolidated are less prone to liquefaction. Based on this understanding, the ratings were assigned to the classes of rock type factors. A higher weightage of value 5 was assigned to unconsolidated zones and a lower rating of value 1 was assigned to consolidated zones.

3.2. Peak Ground Acceleration (PGA %gal)

PGA was the second most important factor that was prepared and integrated with other factors to identify LSZ. PGA is the shaking intensity felt right after specific magnitude earthquake events. It is contoured in units of percentage (g = acceleration due to the force of gravity). Hence, the shaking intensity felt at each location is measured in %gal at nearby recording stations. From the earthquake focus the seismic waves are generated, which have to negotiate media of differential densities as they propagate to the surface. It is obvious that the greater the shaking felt, the greater the chance for liquefaction and possible ground failure in the aftermath. The lesser the shaking felt, the lesser the liquefaction probability. Based on this understanding, PGA intensity values were classified into 5 classes and the ratings were assigned to each class. The higher PGA values were given higher ratings, while the lower PGA values were given lower ratings. Figure 7B illustrates the levels of shaking intensity distribution within the study area.

3.3 Soil Texture

The soil texture groups were one of the third common factors considered and integrated with other factors for LSZ mapping. The soil texture group was reclassified into hydrological soil groups (HSGs) to indicate level of infiltration capacity within the study area. The HSGs are: groups A, B, C and D. Group A soils have highest infiltration rates while group D soils have lowest infiltration rates. The soil texture group reclassification to HSG was prepared based on saturation status keeping in mind that saturated and soft soils are more prone to liquefaction and also can amplify seismic waves resulting in liquefaction. The rate or capacity of infiltration of surface water into soils has the potential to cause adverse geotechnical or geohazardous conditions such as potential for liquefaction during earthquakes, expansion of clay soils, or compression of fill or alluvium under certain circumstances (CSLIDB, 2009). The common understanding here is that, if the infiltration rate is high at any particular site it can be concluded that the soil particles at that site are loose and have lots of void air spaces. Hence, the volume of water mixed with soil is high such that when any earthquake strikes, such areas have a higher chance of experiencing liquefaction and subsidence leading to collapse of infrastructure. Consequently, a higher rating of value 5 was assigned to soil group A and a lower rating of 1 assigned HSG D. Figure 7C illustrates the HSG distribution within the study area.

3.4 Soil Drainage

One of the geomorphological factors assessed for LSZs was soil drainage that was considered as the fourth most important factor considered in delineating LSZs. It was assessed based of duration of wetness period that holds how saturated the underlying soil is. The soil drainage was reclassified to identify classes from well drain soil group to poorly drained or waterlogged areas at each site. It was discovered that the poorly drained soils are more susceptible to liquefaction because they have high water table and are saturated while well drained soils are not really susceptible to liquefaction because they have a low water and are not saturated. This is the basis of the understanding whereby weightage and ratings were assigned to the factor and its classes. The higher ratings were assigned to poorly drained soils and lower ratings were assigned to well drain soil. Figure 7D illustrates the soil drainage class at each site within the study area.

3.5 Earthquake Magnitude

Earthquake magnitude distribution was one of the 5 factors considered as inputs in integration with other factors for delineation of LSZ in the study area. Earthquake magnitude ranges from 4 up to 7.1, which is the highest within the area. The thematic layer that was created through interpolation techniques was reclassified into 5 classes. It is obvious that the greater the earthquake magnitude, the greater the shaking and higher will be the chance of experiencing liquefaction and or damage. Based on this understanding, the rating for each class was assigned. The areas of higher magnitude range were assigned ratings up to 5 while lower magnitude ranges were assigned lower weightages tending to 1. Figure 7E illustrates the magnitude distribution of the study area.

3.6 Earthquake Depth

The last factor considered was the earthquake depth of the focus that was used to integrate with other factors to delineate LSZ. The thematic layer of depth distribution within the study area was reclassified into 5 classes from shallow to very deep classes. From this common understanding, it can be seen that the shallower earthquake depth is very risky and can lead to destructions and or liquefactions, however this will depend on magnitude of earthquake and shaking hazard depending on site soil-geology. On the other hand, the deeper the earthquake events, the less the risk. However, the wave propagation from such deep depth will again be mollified / aggravated by types of site and sub-surface soil-geology until it reaches the surface. If waves come to unconsolidated sediments or saturated soils, they get amplified and then while passing through consolidated sediments or unsaturated soils, the shaking intensity reduces. On the whole, the shallower earthquakes pose more threats. Therefore a higher rating of value 5 was assigned to categories of shallower earthquake depths and lower weightage was assigned to deeper earthquake depths. Figure 7F illustrates the depth distribution within the study area.

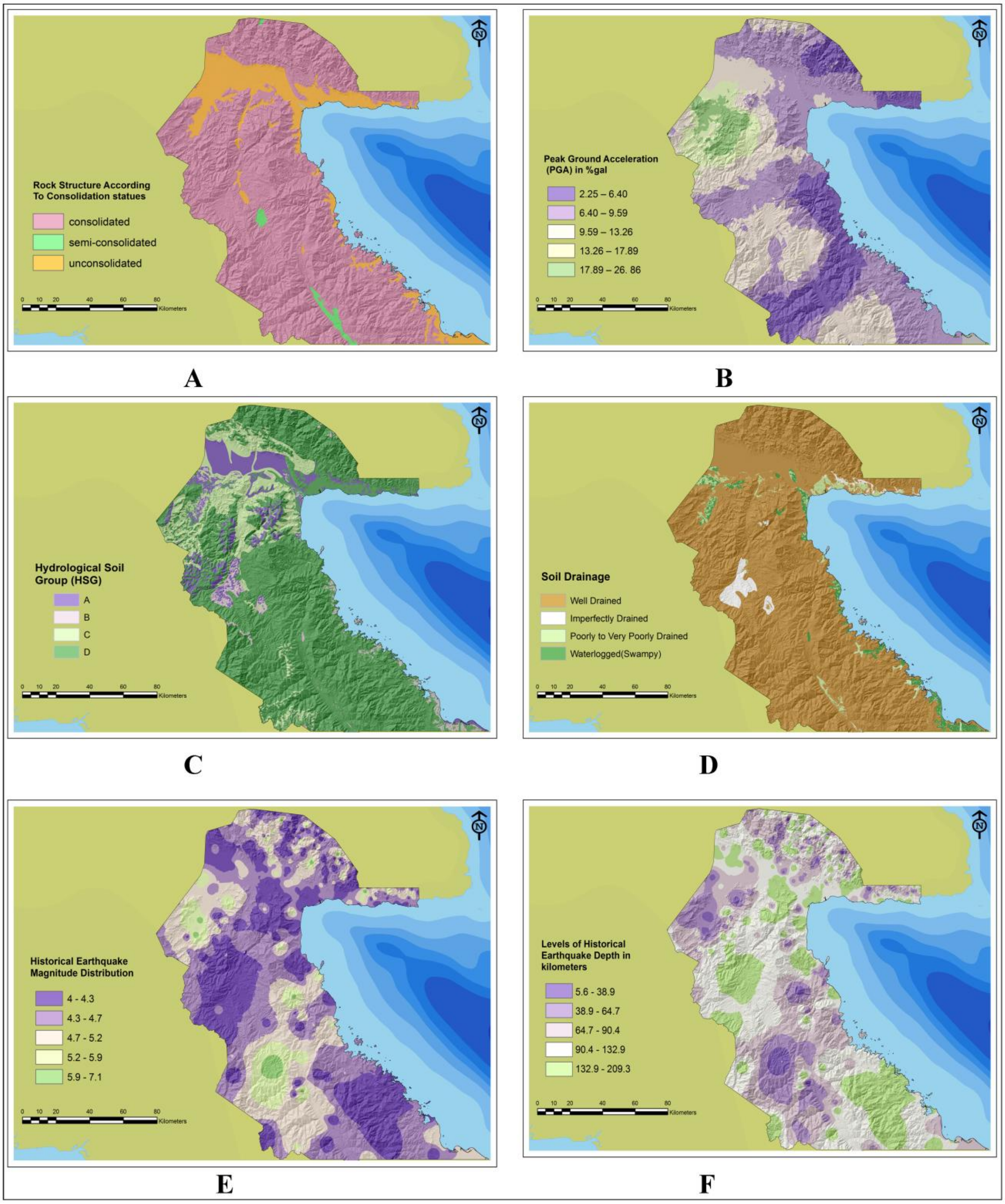

Figure 7***: A.*** Rock compactness; ***B.*** PGA in %gal; ***C.*** HSG; ***D.*** Soil Drainage; ***E.*** Earthquake Magnitude; ***F.*** Earthquake Depth.

3.7 Weightage and Ratings

The weightage and rating for each factor and their classes assigned are all shown in Table 3. All those assigned weightages and ratings are all normalized using AHP technique as discussed in the methods section and as tabulated.

Table 3: Weightages and ratings for factors and their classes

Thematic Factors	Weights	Normalized Weights	Classes	Ratings	Normalized Ratings
Rock Type (Base on compactness)	6	0.37	Consolidated	1	0.19
			Semi-Consolidated	3	0.21
			Unconsolidated	5	0.60
PGA (%gal)	5	0.23	2.25 – 6.40	1	0.03
			6.40 – 9.59	2	0.06
			9.59 – 13.26	3	0.09
			13.26 – 17.89	4	0.21
			17.89 – 26.86	5	0.61
Soil Texture	4	0.18	D	1	0.04
			C	2	0.10
			B	3	0.36
			A	5	0.50
Soil Drainage	3	0.12	Well drained	1	0.09
			Imperfectly drained	2	0.20
			Poorly to very poorly drained	4	0.30
			Water logged	5	0.51
Magnitude	2	0.07	4 – 4.3	1	0.05
			4.3 – 4.7	2	0.08
			4.7 – 5.2	3	0.14
			5.2 – 5.9	4	0.28
			5.9 – 7.1	5	0.45
Depth (km)	1	0.03	132.9 – 209.3	1	0.01
			90.4 – 132.9	2	0.10
			64.7 – 90.4	3	0.21
			38.9 – 64.7	4	0.23
			5.6 – 38.9	5	0.45

3.8 Integration of Prepared Factors for Final Result Output

In order to generate final results, that is LSZ for the study area, the prepared thematic layers or factors were integrated using the weighted-over tool in ArcGIS 10.2.2 spatial analyst. The tool calculates according to user input that is as tabulated in Table 3. From the integration and calculation and then reclassification, the LSZ was created as indicated in Figure 8. Table 4 tabulates the necessary information for results generated. It can be seen that 0.71% of the total area was categorized as Very high LSZ, 7.28% as High LSZ and 8.88% as Moderate LSZ.

Table 4: General Output Information for LSZ

Index Value	Liquefaction Susceptible Zones	Area in km^2	Area In %
0.1989	Very Low	7282.43	43.31
0.3545	Low	6697.91	39.83
0.5886	Moderate	1492.53	8.88
0.8345	High	1224.73	7.28
1.4653	Very High	118.60	0.71

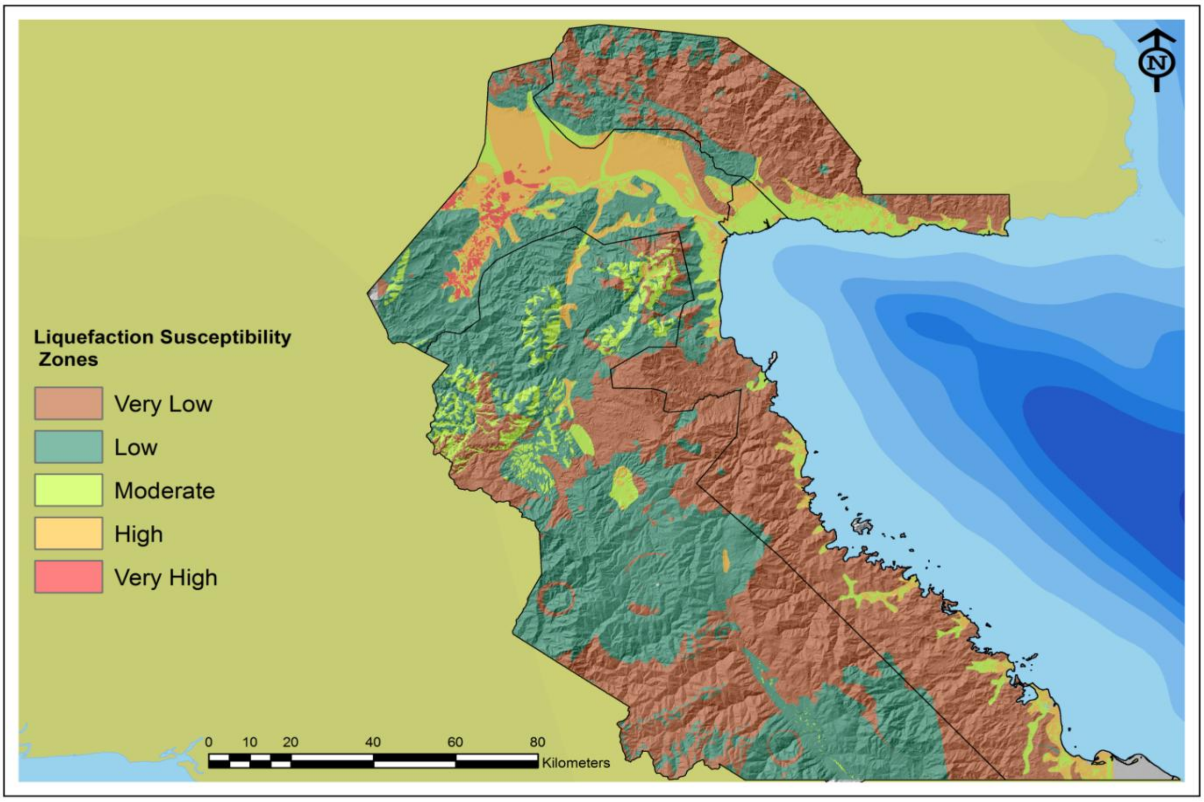

Figure 8: Liquefaction Susceptibility Zone

3.9 Assessment of Built-up Infrastructure on Liquefaction Susceptible Zones

Several existing available data for built-up infrastructure within the study area were assessed with respect to each susceptible zone; that is, the built-up infrastructure data were overlaid on LSZ within the study area and the clip tool in ArcGIS 10.2.2 was used to clip each built-up infrastructure with each LSZ. Only 3 zones (Very High, High and Moderate) were considered and used. For Low and Very Low zones, it was ignored. The overall assessment was carried out to calculate percentage of each built-up infrastructure on each LSZ. Hence, it was discovered from clipping and calculation that, for the Very High LSZ, there exist a few of built-up infrastructures while for High and Moderate there are many built-up features associated with susceptible zones. Figure 9 illustrates the LSZ with overlaid built-up infrastructure and Figure 10 illustrates the graph showing % of each infrastructure on each 3 LSZs. Table 5 tabulates overall assessments of each built-up infrastructure on each 5 zones. Such assessment is to let governing bodies and NGOs consider and make better and effective planning for better infrastructure development in the near future within four study area districts where the study was carried out.

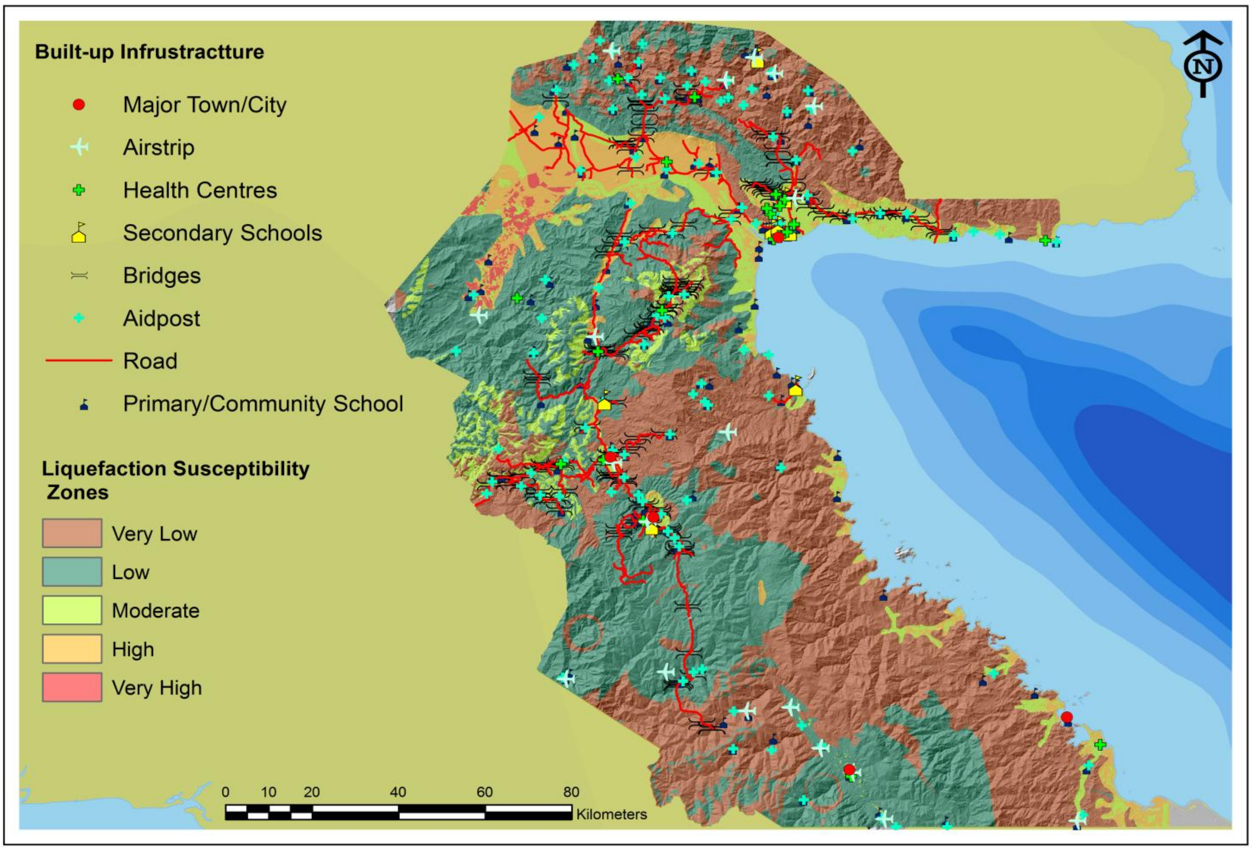

Figure 9: Built-up Infrastructures assessed under Liquefaction susceptible zones

Table 5: Number of Built-up Infrastructures on Liquefaction Susceptibility Zones

Built-up Infrastructure	**Total Nº Built-up Infrastructure Within Study Region**	**Nº Built-up Infrastructure under Very High LSZ**	**Nº Built-up Infrastructure under High LSZ**	**Nº Built-up Infrastructure under Moderate LSZ**
Health Centres (count)	22	0	5	10
Bridge (count)	151	0	22	40
Secondary Schools (count)	8	0	1	5
Primary/ Community Schools (count)	135	0	32	28
Airstrips (count)	19	0	2	3
Major Towns (count)	5	0	1	3
Road (Length in km)	1140.32	0.82	263.61	276.75
Aid post (count)	111	1	13	23

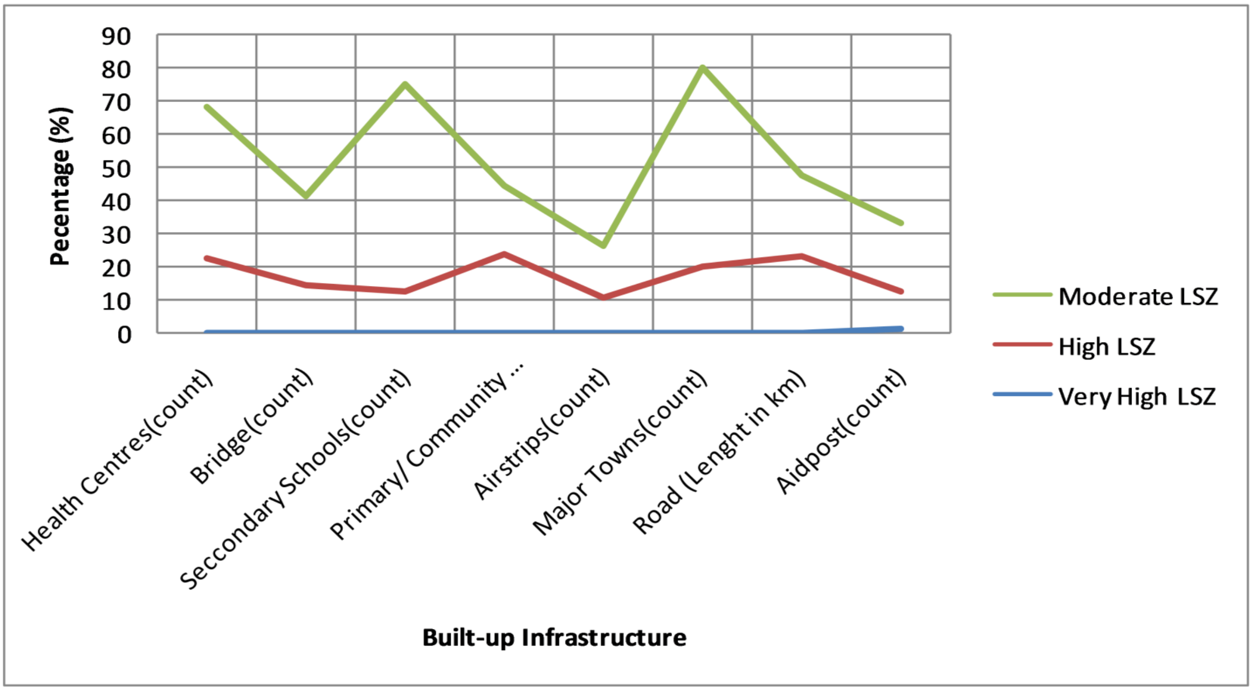

Figure 10: Percentage Evaluation of Built-up infrastructure on LSZ

4. Conclusion and Recommendations

The significance of studies like the present one in Papua New Guinea is paramount because the country is geographically located in an active seismic zone. Any time anywhere within PNG, earthquake events of varying magnitudes may occur. The most risky areas of earthquake are along the Momase and Island regions of PNG and hence the study area is based within Momase Region of PNG. The main focus of this paper is to evaluate and understand background site and sub surface soil-geology where the seismic waves pass through, and how strong and stiff it is for negotiating seismic waves of various ferocities. Historical earthquake data coupled with geological and geomorphological database were integrated and analysed in GIS environment to identify Liquefaction susceptible zones. The following are recommendations for the beneficial application of the findings in this paper:

i) The Liquefaction susceptible zones highlighted in the maps may be used as a tool for cost-effective planning of infrastructure development in the country. Accordingly, government institutions, PPPs and NGOs can make good use of such maps for better environmental planning and infrastructure development;

ii) Municipal authorities can use the maps for improved land use zoning and design of better location-specific building codes for civil constructions;

iii) Scientific utilisation of such information can assist rural and urban communities in selecting viable sites for development projects; and

iv) Finally, the results of the study may be used as an awareness tool to control urban sprawl in cities and for designing warning signals and caveats for mitigating possible damage from impending disasters.

5. References

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